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1- Open Fractures Management

Images



• Summary

- Open fractures are fractures with direct communication to the external environment.
- Diagnosis is made clinically by assessing the size and nature of the external wound as well as obtaining radiographs of the bone at the location of the soft tissue injury.
- Treatment depends on location of fracture but generally requires immediate IV antibiotics and urgent irrigation and debridement followed by surgical fixation as needed.

• Epidemiology

- Incidence
 - common
 - 30.7 per 100,000 persons per year
- Demographics
 - average age is 45 years old
- Anatomic location
 - tibia and finger phalanx are most common

• Etiology

- Pathophysiology
 - mechanism of injury
 - high-energy trauma
 - "inside-out" open fractures
- Associated conditions
 - often associated with additional injuries (30%)
 - compartment syndrome
 - the presence of an open wound does not preclude the occurrence of compartment syndrome in the injured limb

• Classification

- Gustilo classification
- Tscherne classification

• Presentation

- History
 - obtain information regarding mechanism, location, and timing of injury
- Physical exam

- inspection
 - assess soft-tissue damage
 - the size and nature of the external wound may not reflect the damage to the deeper structures
- neurovascular
 - if concern for vascular insult, ankle brachial index (ABI) should be obtained
 - normal ratio is > 0.9
 - vascular surgery consult and angiogram is warranted if $ABI < 0.9$
- provocative tests
 - consider saline load test or CT scan if concern for traumatic arthrotomy
 - some studies now show CT scan more sensitive than saline load test for the knee

• Imaging

- Radiographs
 - indications
 - obtain radiographs including joint above and below fracture
- CT
 - indications
 - peri-articular injuries
 - evaluation for traumatic arthrotomy of the knee

• Treatment

- Nonoperative
 - **urgent IV antibiotics, tetanus prophylaxis, and extremity stabilization and dressing**
 - indications
 - initial treatment for all open fractures
 - a soft tissue wound in proximity to a fracture should be treated as an open fracture until proven otherwise
 - multidisciplinary training of open fracture management has been associated with decreased timing to antibiotic administration
 - antibiotic type indicated by injury pattern and location
- Operative
 - **I&D, temporary fracture stabilization, local antibiotic administration and soft tissue coverage**
 - indications
 - consider I&D as soon as possible
 - ideal time of soft tissue coverage controversial, but most centers perform within 5-7 days
 - outcomes
 - infection rates of open fracture depend on zone of injury, periosteal stripping and delay in treatment
 - incidence of fracture-related infection range from $<1\%$ in type I open fractures to 30% in type III fractures
 - **definitive reconstruction and fracture fixation**
 - indications
 - once soft tissue coverage is obtained and an adequate sterility is achieved
 - outcomes
 - definitive treatment with internal fixation leads to significantly decreased time to union, improved functional outcomes, and decreased time in the hospital compared to those definitively fixed with external fixation

• Technique

- **Urgent IV antibiotics, tetanus prophylaxis, extremity stabilization and dressings**
 - Antibiotics
 - timing
 - initiate as soon as possible
 - studies show increased infection rate when antibiotics are delayed for more than 3 hours from time of injury
 - continue for 24 hours after initial injury if wound is able to be closed primarily
 - continue for 24 hours after final closure if wound is not closed during initial surgical debridement (48 hours for type III wounds)

- types
 - Gustilo type I and II
 - 1st generation cephalosporin
 - clindamycin or vancomycin can also be used if allergies exist
 - Gustilo type III
 - 1st generation cephalosporin + aminoglycoside
 - some institutions use vancomycin + cefepime
 - farm injuries, heavy contamination, or possible bowel contamination
 - add high dose penicillin for anaerobic coverage (clostridium)
 - special considerations
 - fresh water wounds
 - fluoroquinolones or 3rd or 4th generation cephalosporin
 - saltwater wounds
 - doxycycline + ceftazidime or a fluoroquinolone
- Tetanus prophylaxis
 - timing
 - initiate in emergency room or trauma bay
 - two forms of prophylaxis
 - toxoid
 - 0.5 mL, regardless of age
 - immunoglobulin
 - < 5 years old receive 75 U
 - 5-10 years old receive 125 U
 - >10 years old receive 250 U
 - toxoid and immunoglobulin should be given intramuscularly with two different syringes in two different locations
 - guidelines for tetanus prophylaxis depend on 3 factors

Immunization History	Clean, Minor Wound (GA I)	GS II and III
Unknown History or <3 doses	• Give vaccine only	• Give vaccine • Give immune globulin
Vaccination complete (3 prior doses)	• No prophylaxis if last dose within 10 years • Give vaccine if >10 years since last dose	• No prophylaxis if last dose within 5 years • Give vaccine if >5 years since last dose

- complete or incomplete vaccination history (3 doses)
 - date of most recent vaccination
 - severity of wound
- Extremity stabilization & dressing
 - stabilization
 - splint, brace, or traction for temporary stabilization
 - decreases pain, minimizes soft tissue trauma, and prevents disruption of clots
 - dressing
 - remove gross debris from wound, do not remove any bone fragments
 - place sterile saline-soaked dressing on wound
 - little evidence to support aggressive irrigation or irrigation with antiseptic solution in the ED, as this can push debris further into wound
- **I&D, temporary fracture stabilization, local antibiotic administration and soft tissue coverage**
 - Irrigation and debridement
 - timing
 - recent meta-analysis (GOLIATH study) have recommended debridement within 24 hours to minimize risk of infection for type III fractures
 - within 12 hours for type IIIB open tibia fractures
 - staged debridement and irrigation
 - perform every 24 to 48 hours as needed
 - technique
 - incision
 - extend wound proximally and distally in line with extremity to adequately expose open fracture
 - irrigation
 - low-pressure bulb irrigation vs. high-pressure pulse lavage

- studies have shown that low pressure bulb irrigation is less expensive than high pressure pulse lavage and has no difference in infection rates or union rates
 - saline vs. saline with castile soap vs. antibiotic solution
 - studies have shown that saline with castile soap had decreased primary wound healing problems when compared to antibiotic solutions
 - on average, 3L of saline are used for each successive Gustilo type (i.e 9L for type III)
 - debridement
 - thorough debridement of devitalized tissue is critical to prevent deep infection
 - bony fragments without soft tissue attachments should be removed
 - temporary fracture stabilization
 - technique
 - performed at the time of initial debridement
 - external fixation is temporary initial treatment of choice for majority of high energy open fractures of the lower extremity
 - local antibiotic administration
 - indications
 - significantly contaminated wounds with large soft tissue defects
 - large bony defects
 - technique
 - beads made by mixing methylmethacrylate with heat-stable antibiotic powder
 - vancomycin and tobramycin most commonly used
 - soft tissue coverage
 - timing
 - early soft tissue coverage or wound closure is ideal
 - timing of flap coverage for open tibial fractures remains controversial, < 7 days is desired
 - increased risk of infection beyond 7 days
 - odds of infection increase by 16% for each day beyond day 7
 - early studies demonstrated increased infection with delay beyond 72 hours, however recent studies do not support this finding (LEAP study)
 - studies have not shown any statistical difference between rate of infection when ORIF is performed before fasciotomy closure, at fasciotomy closure, or after fasciotomy closure
 - technique
 - can proceed with bone grafting after wound is clean and closed
 - negative-pressure wound therapy may be utilized during debridement until definitive coverage can be achieved (increased risk of infection if open >7 days)
 - **Definitive reconstruction and fracture fixation**
 - no critical bone defect
 - open reduction and internal fixation or intramedullary treatment depending on fracture location and morphology
 - critical bone defect
 - technique
 - Masquelet technique ("induced-membrane" technique)
 - 2 stage technique
 - 1st stage: I&D, cement spacer and temporizing fixation
 - 2nd stage: placement of bone graft into "induced membrane" and definitive fixation
 - Studies show optimal time frame for bone grafting to be 4-6 weeks after placement of cement spacer
 - distraction osteogenesis
 - vascularized bone flap/transfer
 - **Complications**
 - Surgical site infection
 - incidence
 - fracture-related infection ranges from <1% in type I open fractures to 30% in type III fractures
 - Osteomyelitis
 - incidence

- ranges between 1.8% to 27% depending on the bone involved and fracture characteristics.
- the tibia is the most common site of post-surgical osteomyelitis following surgical treatment of open fractures
- risk factors include:
 - blast mechanism of injury
 - acute surgical amputation
 - delay in definitive soft tissue coverage greater than 7 days
 - more severe Gustillo-Anderson classification.
- Neurovascular injury
- Compartment syndrome

- Prognosis

- To minimize risk of infection, debridement recommended to be performed within 24 hours for all type III fractures and within 12 hours for type IIIB open tibia fractures
- Contamination with dirt and debris and devitalization of the soft tissues increase the risk of infection and other complications
- Infection rates higher in open injuries due to blunt trauma compared to penetrating trauma

2- Gustilo Classification

- Abridged version
 - Type I
 - wound ≤ 1 cm, minimal contamination or muscle damage
 - Type II
 - wound 1-10 cm, moderate soft tissue injury
 - Type IIIA
 - wound usually >10 cm, high energy, extensive soft-tissue damage, contaminated
 - adequate tissue for flap coverage
 - farm injuries are automatically at least Gustillo IIIA
 - Type IIIB
 - extensive periosteal stripping, wound requires soft tissue coverage (rotational or free flap)
 - Type IIIC
 - vascular injury requiring vascular repair, regardless of degree of soft tissue injury
 - Most accurate way to grade open fractures is by intra-operative examination
- Complete version

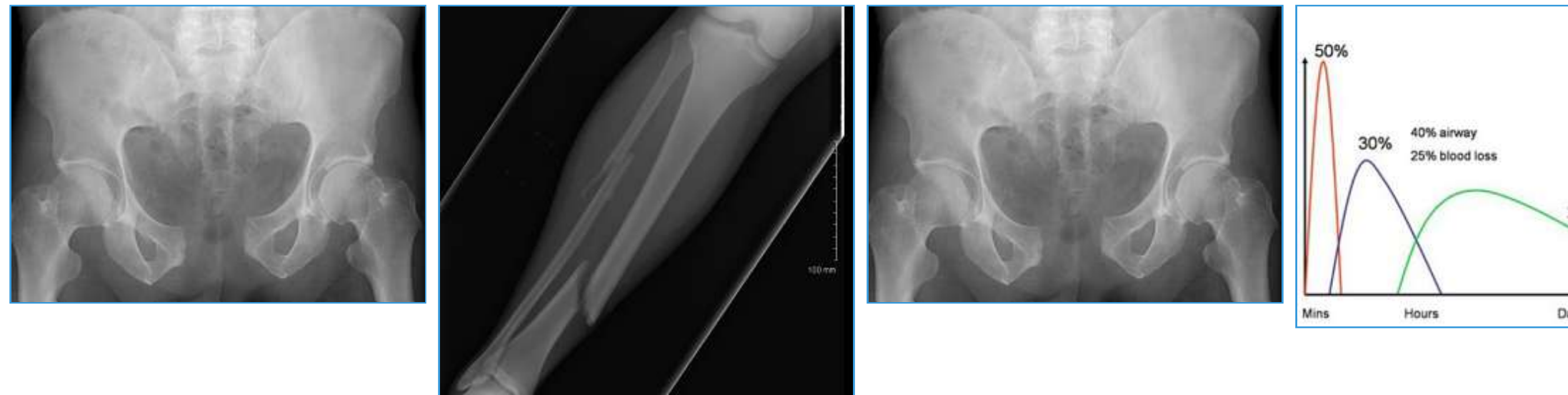
■ Gustilo Classification					
	■ I	■ II	■ IIIA	■ IIIB	■ IIIC
■ Images					
■ Energy	■ Low	■ Moderate	■ High	■ High	■ High
■ Wound size	■ ≤ 1 cm	■ 1-10 cm	■ usually >10 cm	■ usually >10 cm	■ usually >10 cm
■ Soft tissue damage	■ Minimal	■ Moderate	■ Extensive	■ Extensive	■ Extensive
■ Contamination	■ Clean	■ Moderate	■ Extensive	■ Extensive	■ Extensive
■ Fracture Comminution	■ Minimal	■ Moderate	■ Severe	■ Severe	■ Severe
■ Periosteal Stripping	■ No	■ No	■ Yes	■ Yes	■ Yes
■ Skin Coverage	■ Local coverage	■ Local coverage	■ Local coverage	■ Free tissue flap or rotational flap coverage	■ Typically requires flap coverage
■ Neurovascular Injury	■ Normal	■ Normal	■ Normal	■ Normal	■ Exposed fracture with arterial damage that requires repair
■ Antibiotics based on Gustilo Classification					
	■ Grade I and II	■ Grade IIIA, IIIB and IIIC	■ Special considerations		
■ Antibiotics	■ 1st generation cephalosporin (e.g. cefazolin)	■ 1st generation cephalosporin for gram positive coverage ■ Aminoglycoside (such as gentamicin) for gram negative coverage	■ Penicillin should be added if concern for anaerobic organism (farm injury) Flouroquinolones (e.g. ciprofloxacin) should be used for fresh water wounds or salt water wounds (can be used if allergic to cephalosporins or clindamycin) Doxycycline and 3rd or 4th-generation cephalosporin (e.g. ceftazidime) can be used for salt water wounds		

- Antibiotic Indications for Open Fractures

- Gustillo type I and II
 - 1st generation cephalosporin
- Gustillo type III
 - 1st generation cephalosporin + aminoglycoside
 - traditionally recommended, but there is controversy about this regimen
- With farm injury / bowel contamination
 - 1st generation cephalosporin + aminoglycoside + PCN
 - add PCN for clostridia
- Duration
 - initiate as soon as possible
 - increased infection rate when antibiotics are delayed > 3 hours from time of injury
 - continue for 24-72 hours after I&D
- Tetanus booster if not up to date (no booster in last 5 years)

3- Evaluation Resuscitation And Dco

Images



• Introduction

- Trauma is a major public health problem with high disability, death, and societal cost
- Three peak times of death after trauma
 - 50% within the first minutes of sustaining the injury
 - caused by massive blood loss or neurologic injury
 - 30% within hours of arrival to hospital
 - most commonly from shock, hypoxia, or neurologic injury
 - 20% within days to weeks following injury
 - multi system organ failure and infection are leading causes
- Golden Hour
 - period of time when life threatening and limb threatening injuries should be treated in order to decrease mortality
 - estimated 60% of preventable deaths can occur during this time ranging from minutes to hours
- Use of an airbag in a head-on collision significantly decreases the rate of
 - closed head injuries
 - facial fractures
 - thoracoabdominal injuries
 - need for extraction
- Psychological
 - 50% incidence of PTSD after traumatic event involving orthopedic injuries
 - females 4x more likely to develop PTSD
 - 33% incidence of depression

• Evaluation

- Primary survey
 - treat greatest threats to life first
 - pelvic fractures can be life threatening if not intervened on by orthopedic surgeons
 - brief history
 - ABCDE's
 - Airway
 - includes cervical spine control
 - Breathing and ventilation
 - Circulation
 - includes hemorrhage control and resuscitation (below)
 - pregnant women should be placed in the left lateral decubitus position to limit positional hypotension
 - Disability
 - Exposure
- Secondary survey
 - physical examination and updated history
 - obtain indicated imaging studies

- Tertiary survey
 - repeat physical examination and additional imaging as indicated when mental status has stabilized
 - formal tertiary survey decreases chances of missed orthopedic injury

- Hemorrhagic Shock Classification & Fluid Resuscitation

○	■ Hemorrhagic shock classification and fluid resuscitation							
	■ <i>Class</i>	■ <i>% Blood loss</i>	■ <i>HR</i>	■ <i>BP</i>	■ <i>Urine</i>	■ <i>pH</i>	■ <i>MS</i>	■ <i>Treatment</i>
	■ I	■ < 15% (<750ml)	■ Normal	■ Normal	■ > 30 mL/hr	■ Normal	■ Anxious	■ Fluid
	■ II	■ 15% to 30 (750-1500ml)	■ > 100 bpm	■ Normal	■ 20-30 mL/hr	■ Normal	■ Confused, ■ Irritable, ■ combative	■ Fluid
	■ III	■ 30% to 40% (1500-2000ml)	■ > 120 bpm	■ Decreased	■ 5-15 mL/hr	■ Decreased	■ Lethargic, ■ irritable	■ Fluid & blood
	■ IV	■ > 40% (life threatening) (>2000ml)	■ > 140 bpm	■ Decreased	■ negligible	■ Dereased	■ Lethargic, coma	■ Fluid & blood

- Introduction
 - average adult (70 kg male) has an estimated 4.7 - 5 L of circulating blood
 - average child (2-10 years old) has an estimated 75 - 80 ml/kg of circulating blood
- Methods of Resuscitation
 - fluids
 - crystalloid isotonic solution
 - blood options
 - O negative blood (universal donor)
 - Type specific blood
 - Cross-matched blood
 - transfuse in 1:1:1 ratio (red blood cells: platelets: plasma)
- Indicators of adequate resuscitation
 - urine output 0.5-1.0 ml/kg/hr (30 cc/hr)
 - serum lactate levels
 - normal < 2.5 mmol/L, < 45 mg/dL
 - most sensitive indicator as to whether some circulatory beds remain inadequately perfused
 - gastric mucosal ph
 - base deficit
 - normal -2 to +2
- Risk of transfusion
 - risk of viral transmission following allogenic blood transfusion
 - hepatitis B (HBV) has highest risk : 1 in 205,000 donations
 - hepatitis C (HCV): 1 in 1.8 million donations
 - human immunodeficiency virus (HIV): 1 in 1.9 million

- Non-hemorrhagic shock

- Cardiogenic shock
 - the heart is unable to generate sufficient cardiac output
- Neurogenic shock
 - hypotension and relative bradycardia from loss of sympathetic tone following spinal cord injury
- Septic shock vs. hypovolemic shock
 - the key variable to differentiate septic shock and hemorrhagic shock is that systemic vascular resistance is decreased with septic shock and increased with hypovolemic shock

○	■ Hypovolemic vs. Septic shock			
	■	■ <i>Hypovolemic shock</i>	■ Septic Shock	■
	■ Systemic Vascular Resistance	■ Increased	■ Decreased	■ Key variable to differentiate
	■ Cardiac Output	■ Decreased	■ Increased	■
	■ Pulmonary Capillary Wedge Pressure	■ Decreased	■ Decreased	■
	■ Central Venous Pressure	■ Decreased	■ Decreased	■
	■ Mixed Venous Oxygen	■ Decreased	■ Increased	■

- Imaging

- Delay of fracture diagnosis is most commonly caused by failure to image extremity
 - image any extremity with pain, crepitus, ecchymosis, deformity
- AP Chest
 - mediastinal widening
 - pneumothorax
- Lateral C-spine
 - must visualize C7 on T1
 - not commonly utilized in lieu of increased sensitivity with cervical spine CT
- AP Pelvis
 - pelvic ring
 - further CT imaging should be delayed until preliminary pelvic stabilization has been accomplished
 - acetabulum
 - proximal femur
- CT Scan
 - C-spine, chest, abdomen, pelvis
 - often used in initial evaluation of trauma patient to rule out life threatening injuries

- Damage Control Orthopaedics (DCO)

- Definition/History
 - definitive treatment delayed until physiology has improved
 - popularized in 2000
 - replaced the 1980s philosophy of Early Total Care (ETC), the concept of fixing long bone fractures as soon as possible because patients were "too sick not to operate"
 - ETC led to exacerbation of the "second-hit" in a subset of patients with hemodynamic instability, head, and/or chest injuries
- Involves staging definitive management to avoid adding trauma to patient during vulnerable period
 - the decision to operate and surgical timing on multiple injured trauma patients remains controversial
 - intra-operative hypotension increases mortality rate in patients with head injury
- Parameters that help decide who should be treated with DCO
 - ISS >40 (without thoracic trauma)
 - ISS >20 with thoracic trauma
 - GCS of 8 or below
 - multiple injuries with severe pelvic/abdominal trauma and hemorrhagic shock
 - bilateral femoral fractures
 - pulmonary contusion noted on radiographs
 - hypothermia <35 degrees C
 - head injury with AIS of 3 or greater
 - IL-6 values above 500pg/dL
- Optimal time of surgery
 - patients are at increased risk of ARDS and multisystem failure during the acute inflammatory window (period from 2 to 5 days characterized by a surge in inflammatory markers)
 - therefore only potentially life-threatening injuries should be treated in this period including
 - unstable pelvic fracture
 - compartment syndrome
 - fractures with vascular injuries
 - unreduced dislocations
 - traumatic amputations
 - unstable spine fractures
 - cauda equina syndrome
 - open fractures
- Stabilization followed by staged definitive management
 - to minimize trauma, initial stabilization should be performed and followed by staged definitive management
 - includes initial pelvic volume reduction via sheet, pelvic packing, skeletal traction, binder, or external fixation
 - if hemodynamically stable
 - proceed with further imaging including CT chest, abdomen, pelvis

- if not hemodynamically stable
 - consider exploratory laparotomy and/or pelvic angiography and embolization
 - definitive treatment delayed for
 - 7-10 days for pelvic fractures
 - within 3 weeks for femur fractures (conversion from exfix to IMN)
 - 7-10 days for tibia fractures (conversion from external fixation to IMN)
- Early Appropriate Care
 - Definition/history
 - identifies major trauma patients and definitively treats the most time-critical orthopaedic injuries while minimizing the secondary inflammatory response, guided by laboratory parameters of adequate resuscitation
 - popularized in 2013
 - Parameters
 - lactate of < 4.0 mmol/L
 - $\text{pH} \geq 7.25$
 - base excess ≥ -5.5 mmol/L
 - Optimal time of surgery
 - goal is to definitively treat spine, pelvis, femur, and acetabulum fractures within 36 hours of injury
 - Outcomes
 - decreased delay to surgery
 - decreased complication rates
 - increased hospital revenues
 - main reason for delay to treatment with implementation of this protocol was surgeon decision

4- Trauma Scoring Systems

Images

Glasgow Coma Score	Revised Trauma Score	Mangled Extremity Score	SIRS
Best Motor Response	GCS Score	Skeletal and Soft Tissue Injury	Heart Rate
Best Verbal Response	Systolic Blood Pressure	Limb Ischemia	WBC Count
Eye Opening	Respiratory Rate	Shock	Respiratory Rate
		Age	Temperature

Scoring System	Predicted mortality based on literature	Mortality in VT patients	Mortality in non-VT patients	P-value
Combined Overall	N/A	24%	11.8%	0.108
RTS > 5	< 19%	26%	2.2%	0.007
ISS > 24	> 25%	61%	28.6%	0.04
APACHE II < 14	< 19%	18.2%	0%	0.007

Table 1: Summary of mortality based on scoring system

• Introduction

- Purpose of scoring systems
 - appropriate triage and classification of trauma patients
 - predict outcomes for patient and family counseling
 - quality assurance
 - research
 - extremely useful for the study of outcomes
 - reimbursement purposes
- Classifications

Physiologic	Anatomic	Combined
Revised Trauma Score	Abbreviated Injury Score	TRISS
APACHE	Injury Severity Score	ASCOT
SOFA	New Injury Severity Score	ICISS
SIRS	Anatomic Profile	
Emergency Trauma Score	PATI	
	ICISS	
	TMPM-ICD9	

- physiologic
 - Revised Trauma Score (RTS)
 - Acute Physiology and Chronic Health Evaluation (APACHE)
 - Sequential Organ Failure Assessment Score (SOFA)
 - Systemic Inflammatory Response Syndrome Score (SIRS)
 - Emergency Trauma Score
- anatomic
 - Abbreviated Injury Score (AIS)
 - Injury Severity Score (ISS)
 - New Injury Severity Score (NISS)
 - Anatomic Profile (AP)
 - Penetrating Abdominal Trauma Index (PATI)
 - ICD-based Injury Severity Score (ICISS)
 - Trauma Mortality Prediction Model (TMPM-ICD9)
- combined
 - Trauma Score - Injury Severity Score (TRISS)
 - A Severity Characterization of Trauma (ASCOT)
 - International Classification of Diseases Injury Severity Score (ICISS)
 - Ganga Hospital Open Injury Score (GHOIS)

• Glasgow Coma Scale

- Introduction
 - quantifies severity of head injury by measuring CNS function
 - used as
 - initial assessment tool
 - continual re-evaluation of head injured patients

Variables

Feature	Scale	Score
Eye Opening	Spontaneous	4
	To speech	3
	To pain	2
	None	1
Verbal Response	Oriented	5
	Confused Conversation	4
	Words (inappropriate)	3
	Sounds (incomprehensible)	2
	None	1
Best Motor Response	Obey commands	6
	Localize pain	5
	Flexion-Normal	4
	Flexion-Abnormal	3
	Extension	2
	None	1

- Best Motor Response
 - 6 - Obeys command
 - 5 - Localizes pain
 - 4 - Normal withdrawal (flexion)
 - 3 - Abnormal withdrawal (flexion): decorticate
 - 2 - Abnormal withdrawal (extension): decerebrate
 - 1 - None (flaccid)
- Best Verbal Response
 - 5 - Oriented
 - 4 - Confused conversation
 - 3 - Inappropriate words
 - 2 - Incomprehensible sounds
 - 1 - None
- Eye Opening
 - 4 - Spontaneous
 - 3 - To speech
 - 2 - To pain
 - 1 - None
- Calculation
 - motor response + verbal response + eye opening
- Interpretation
 - brain injury
 - severe <9
 - moderate 9-12
 - minor 13 and above
- Pros
 - reliably predicts outcomes for diffuse and focal lesions
- Cons
 - does not take into account
 - focal or lateralizing signs
 - diffuse metabolic processes
 - intoxication

Revised Trauma Score (RTS)

- Introduction
 - most widely used prehospital field triage tool
- Variables

Glasgow Coma Score	Systolic Blood Pressure	Respiratory Rate	Coded Value
13-15	>90	10-29	4
9-12	76-89	>30	3
6-8	50-75	6-9	2
4-5	1-49	1-5	1
3	0	0	0

- Glasgow Coma Scale (GCS)
 - score
 - 4: 13-15
 - 3: 9-12

- 2: 6-8
 - 1: 4-5
 - 0: 3
 - systolic blood pressure
 - score
 - 4: >90
 - 3: 76-89
 - 2: 50-75
 - 1: 1-49
 - 0: 0
 - respiratory rate
 - score
 - 4: 10-29
 - 3: >30
 - 2: 6-9
 - 1: 1-5
 - 0: 0
 - Calculation
 - Glasgow coma scale score + systolic blood pressure score + respiratory rate score
 - Interpretation
 - lower score indicates higher severity
 - RTS <4 proposed for transfer to trauma center
 - Pros
 - useful during triage to determine which patients need to be transported to a trauma center
 - Cons
 - can underestimate injury severity in patients injured in one system
- Injury Severity Scale (ISS)
 - Introduction
 - first scoring system to be based on anatomic criteria
 - defines injury severity for comparative purposes
 - Variables
 - based on scores of 9 anatomic regions
 1. head
 2. face
 3. neck
 4. thorax
 5. abdominal and pelvic contents
 6. spine
 7. upper extremity
 8. lower extremity
 9. external
 - Calculation
 - Abbreviated Injury Scale (AIS) grades
 - 0 - no injury
 - 1 - minor
 - 2 - moderate
 - 3 - severe (not life-threatening)
 - 4 - severe (life-threatening, survival probable)
 - 5 - severe (critical, survival uncertain)
 - 6 - maximal, possibly fatal
 - ISS
 - ISS = sum of squares for the highest AIS grades in the three most severely injured ISS body regions
 - $ISS = A^2 + B^2 + C^2$
 - where A, B, C are the AIS scores of the three most severely injured ISS body regions
 - scores range from 1 to 75

- single score of 6 on any AIS region results in automatic score of 75

- Interpretation

- ISS > 15 associated with mortality of 10%

- Pros

- integrates anatomic areas of injury in formulating a prediction of outcomes

- Cons

- difficult to calculate during initial evaluation and resuscitation in emergency room
- difficult to predict outcomes for patients with severe single body area injury
 - New Injury Severity Score (NISS) overcomes this deficit

- Modifications

- Modified Injury Severity Score (MISS)
 - similar to ISS but for pediatric trauma
 - categorizes body into 5 areas, instead of 9
 - sum of the squares for the highest injury score grades in the three most severely injured body regions
- New Injury Severity Score (NISS)
 - takes three highest scores regardless of anatomic area
 - more predictive of complications and mortality than ISS

- Mangled Extremity Severity Score (MESS)

- Introduction

- used to predict necessity of amputation after lower extremity trauma

- Variables

- skeletal and soft tissue injury (graded 1-4)
- limb ischemia (graded 1-3)
- shock (graded 0-2)
- age (graded 0-2)

- Calculation

- score determined by adding scores of components in four categories

- Interpretation

- score of >7 is predictive of amputation

- Pros

- high specificity for predicting amputation

- Cons

- low sensitivity for predicting amputation

- Sickness Impact Profile

- Introduction

- evaluates the impact of disease on physical and emotional functioning

- Variables

- 12 categories
 - sleep
 - eating
 - work
 - home management
 - recreation
 - physical dimension
 - ambulation
 - body care
 - movement
 - psychosocial dimension
 - social interaction
 - alertness behavior
 - emotional behavior
 - communication

- Relevance to trauma

- lower extremity injuries

- psychosocial subscale does not improve with time
- polytrauma
 - at 10 year follow-up after a major polytrauma, females have
 - decreased quality-of-life scores
 - increased PTSD rates
 - increased absentee sick days when compared to males

- Systemic Inflammatory Response Syndrome (SIRS)

- Introduction

- a generalized response to trauma characterized by
 - an increase in cytokines
 - an increase in complement
 - an increase in hormones
 - a marker for an individual's generalized response to trauma that likely has a genetic predisposition
 - associated with conditions such as
 - disseminated intravascular coagulopathy (DIC)
 - acute respiratory distress syndrome (ARDS)
 - renal failure
 - multisystem organ failure
 - shock

- Variables

- heart rate > 90 beats/min
 - WBC count < 4000cells/mm³ OR >12,000 cells/mm³
 - respiratory rate > 20 or PaCO₂ < 32mm (4.3kPa)
 - temperature less than 36 degrees or greater than 38 degrees

- Calculation

- each component (heart rate, WBC count, respiratory rate, temperature) is given 1 point if it meets the above criteria

- Interpretation

- score of 2 or more meets criteria for SIRS

5- Domestic And Elder Abuse

Images



- Elder abuse

- Introduction

- can be in the form of mental or physical abuse, neglect, financial wrongdoings or abandonment

- Epidemiology

- affects around 2 million Americans per year
 - approximately 1 in 25 individuals over 65 y/o experiences abuse or neglect
 - risk factors of victims for elder abuse
 - increasing age
 - functional disability
 - child abuse within the regional population
 - cognitive impairment
 - gender is NOT a risk factor
 - caretaker risk factors for elder abuse
 - financial dependence on the elder person
 - substance abuse
 - perceiving the caretaking duty as burdensome

- Etiology

- associated injuries
 - long bone fractures
 - rib fractures
 - bruises caused from abuse are
 - commonly over 5cm in size
 - located on the face, neck or back

- Clinical signs of elder abuse

- unexplained injuries
 - delays in seeking care
 - repeated fractures, burns, lacerations, etc
 - change in behavior
 - poor hygiene

- Treatment

- duty to report**

- physicians are mandated reporters of abuse on elders in almost all states
 - elder abuse is very commonly under reported

- admit to hospital**

- if the patient is in immediate danger, the patient should be admitted to the hospital

- Domestic, spousal or intimate partner abuse

- Epidemiology

- as many as 35% of women presenting to the ER with injuries are a result of domestic violence
- approximately 25% of women experience domestic violence
- 15% of males are victims of domestic violence
- over 8.5% reported prior history of abuse
- children abused in close to 50% of homes where domestic violence occurs
- Risks for domestic abuse
 - female
 - 19-29 years
 - pregnant
 - short-term relationship
 - cohabitation
 - low-income families/low socioeconomic status
- Etiology
 - characteristic injuries or patterns
 - injuries inconsistent with history
 - long delay between injury and treatment
 - repeat injuries
 - characteristics of abused patient
 - change in affect
 - constantly seeking partner approval
 - finding excuses to stay in treatment facility for prolonged period of time
 - repeated visits to the emergency department
 - significant time missed at work or decreased productivity at work
 - characteristics of the abuser
 - refuses to leave patient alone
 - overly attentive
 - aggressive or hostile
 - refuses to let the patient answer their own questions
 - barrier to reporting
 - fear of retaliation
 - shame
 - difficulty reporting to male physicians
 - fear of custody conflicts
- Treatment
 - **duty to act**
 - health care workers should inquire into the safety environment at home in cases of suspected abuse
 - emotional abuse is more difficult to discern than physical violence
 - reporting requirements for adult abuse is not standardized among states
 - a physician does not have authority to provide protection to abused spouses in most states
 - should encourage victim to seek protection and report case to law enforcement
 - physician should document encounter completely and be familiar with their state laws

6- Gun Shot Wounds

Images



- Introduction

- Gun shot wounds are high energy injuries that contribute to extensive soft tissue damage and comminuted bony fractures.

- Epidemiology

- Incidence
 - gun shot wounds represent the second-leading cause of death for youth in United States.

- Etiology

- Pathoanatomy
 - wounding capability of a bullet directly related to its kinetic energy
 - damage caused by
 - passage of missile
 - secondary shock wave
 - cavitation
 - exponential increase in injury with increasing velocity and efficient energy transfer
 - fractures may be caused even without direct impact
- Associated conditions
 - lead intoxication (plumbism)

 - may be caused by intra-articular missile
 - systemic effects include
 - neurotoxicity
 - anemia
 - emesis
 - abdominal colic
 - GSW to hip and acetabulum are most commonly associated with bowel perforation > vascular injury > urogenital injuries

- Classification

- Low velocity
 - muzzle velocity < 350 meters per second or < 1,200 feet per second
 - most handguns except for magnums
 - wounds comparable to Gustillo-Anderson Type I or II
- Intermediate velocity
 - muzzle velocity 350-650 meters per second or 1,200-2,000 feet per second
 - shotgun blasts
 - highly variable depending on distance from target
 - can reflect wounding potential of high velocity firearms from close range (less than 21 feet) or multiple low velocity weapons
 - wound contamination/infection with close range injuries due to shotgun wadding
 - wounding potential depends on 3 factors
 - shot pattern
 - load (size of individual pellet)
 - distance from target
- High velocity
 - muzzle velocity > 600 meters per second or >2,000 feet per second
 - military (assault) and hunting rifles

- wounds comparable to Gustillo-Anderson Type III regardless of size
- high risk of infection
 - secondary to wide zone of injury and devitalized tissue

• Presentation

- Symptoms
 - pain, deformity
- Physical exam
 - perform careful neurovascular exam
 - clinical suspicion for compartment syndrome
 - secondary to increased muscle edema from higher velocity wounds
 - examine and document all associated wounds
 - massive bone and soft tissue injuries occur even with low velocity weapons



• Imaging

- Radiographs
 - obtain to identify bone involvement and/or fracture pattern
- CT scan
 - identify potential intra-articular missile



- detect hollow viscus injury that may communicate with fracture
 - high index of suspicion for pelvis or spine fractures given increased risk of associated bowel injury

• Treatment General

- Nonoperative
 - **local wound care**
 - indications
 - low velocity GSW with no bone involvement and clean wound edges
 - **local wound care, tetanus +/- short course of oral antibiotics**
 - indications
 - low-velocity injury with no bone involvement or non-operative fractures
 - technique
 - primary closure contraindicated
 - antibiotic use controversial but currently recommended if wound appears contaminated

- Operative

- **treatment of other non-orthopedic injuries**

- for trans-abdominal trajectories, laparotomy takes precedence over arthrotomy

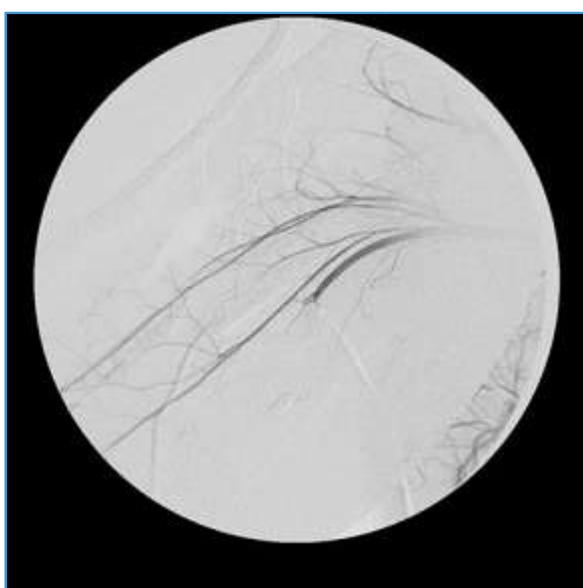
- **ORIF/external fixation**

- indications

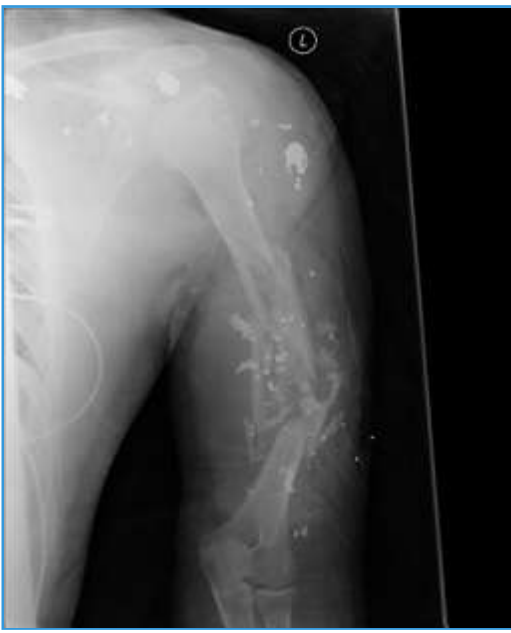
- unstable/operative fracture pattern in low-velocity gunshot injury

- technique

- treatment dictated by fracture characteristics similar to closed fracture without gunshot wound
 - stabilize extremity with associated vascular or nerve injuries



- stabilize soft tissues in high velocity/high energy gunshot injuries



- grossly contaminated/devitalized wounds managed with aggressive debridement per open fracture protocol

- **arthrotomy**

- indications
 - intra-articular missile
 - may lead to local inflammation, arthritis and lead intoxication (plumbism)
 - transabdominal GSW

- GSW to Hand/Foot

- Nonoperative

- **antibiotics**

- indications
 - gross contamination
 - joint penetration
 - extent of contamination unclear

- Operative

- **surgical debridement +/- ORIF/external fixation**

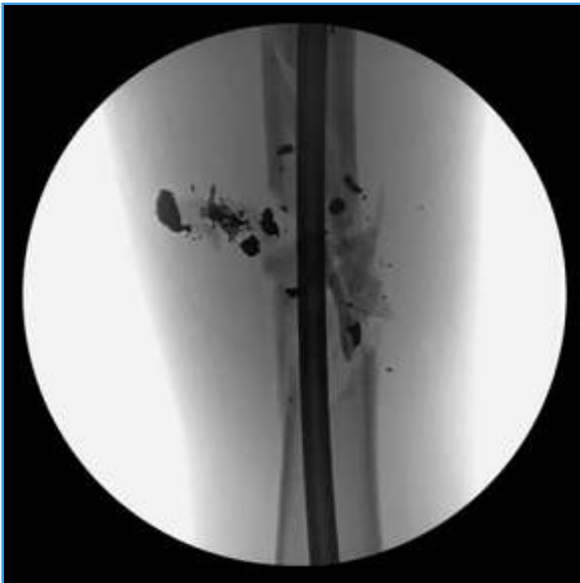
- indications
 - articular involvement
 - unstable fractures
 - tendon involvement
 - superficial fragments in the palm or sole

- GSW to Femur

- Operative

- **intramedullary nailing**

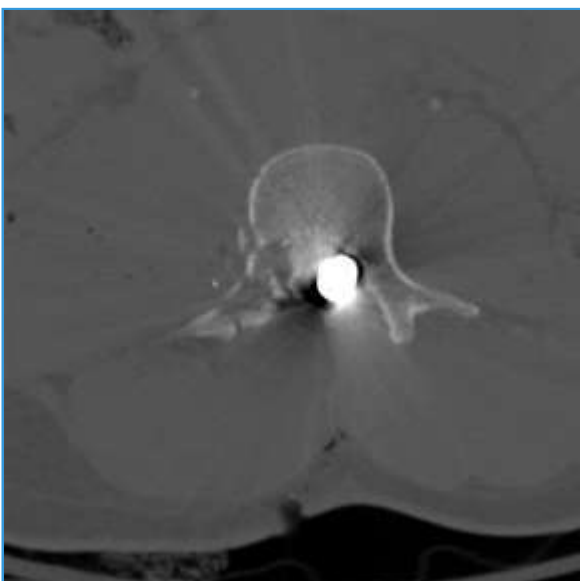
- indications
 - diaphyseal femur fracture secondary to low-velocity gunshot wound



- technique
 - superficial wound debridement and immediate reamed nailing
- outcomes
 - similar union and infection rates to closed injuries
- **external fixation**
 - indications
 - high-velocity gunshot wounds or close range shotgun blasts
 - associated vascular injury
 - temporize extremity until amenable to intramedullary nailing

• GSW to Spine

- Nonoperative
 - **broad spectrum IV antibiotics for 7-14 days**
 - indications
 - gunshot wounds to the spine with associated perforated viscus
 - bullets which pass through the alimentary canal and cause spinal cord injuries do not require surgical removal of the bullet
- Operative
 - **surgical decompression and bullet fragment removal**
 - indications
 - when a neurologic deficit is present that correlates with radiographic findings of neurologic compression



- a retained bullet fragment within the spinal canal in patients with incomplete motor deficits is a relative indication for surgical excision of the fragment

7- Amputations

Images



• overview

○ Overview

- amputations are done urgently and electively to reduce pain, provide independence, and restore function
- the goals of amputation are
 - preserve functional length
 - preservation of useful sensibility
 - prevention of symptomatic neuromas
 - prevention of adjacent joint contractures
 - early prosthetic fitting
 - early return of patient to work and recreation

• Epidemiology

○ Incidence

- 1.7 million individuals in the United States with an amputation

○ Risk factors

- 80% of amputations are performed for vascular insufficiency

• Etiology

○ Pathophysiology

- Amputations may be indicated in the following
 - trauma
 - most common reason for an upper extremity amputation
 - infection
 - tumor
 - vascular disease
 - most common reason for a lower extremity amputation
 - congenital anomalies

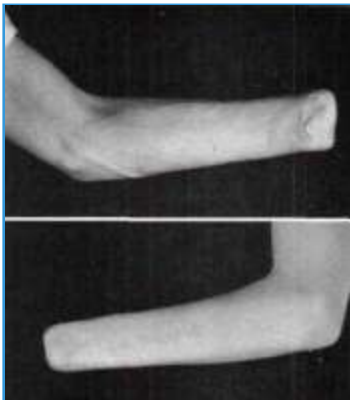
• Metabolic Demand

○ Metabolic cost of walking

- increases with more proximal amputations

- perform amputations at lowest possible level to preserve function
 - exception
 - Syme amputation is more efficient than midfoot amputation
 - inversely proportional to length of remaining limb
- Ranking of metabolic demand (% represents amount of increase compared to baseline)
 - Syme - 15%
 - transtibial
 - traumatic - 25% average
 - short BKA - 40%
 - long BKA - 10%
 - vascular - 40%
 - transfemoral
 - traumatic - 68%
 - vascular - 100%
 - thru-knee amputation
 - varies based on patient habitus but is somewhere between transtibial and transfemoral
 - most proximal amputation level available in children to maintain walking speeds without increased energy expenditure compared to normal children
 - bilateral amputations
 - BKA + BKA - 40%
 - AKA + BKA - 118%
 - AKA + AKA - >200%
- Wound Healing
 - Dependent on
 - vascular supply
 - nutritional status
 - immune status
 - Improved with
 - albumin > 3.0 g/dL
 - ischemic index > .5
 - measurement of doppler pressure at level being tested compared to brachial systolic pressure
 - transcutaneous oxygen tension > 30 mm Hg (ideally 45 mm Hg)
 - toe pressure > 40 mm Hg (will not heal if < 20 mm Hg)
 - ankle-brachial index (ABI) > 0.45
 - total lymphocyte count (TLC) > 1500/mm³
 - Hyperbaric oxygen therapy
 - contraindications include
 - chemo or radiation therapy
 - pressure-sensitive implanted medical device (automatic implantable cardiac defibrillator, pacemaker, dorsal column stimulator, insulin pump)
 - undrained pneumothorax
- Upper Extremity Amputation
 - Indications
 - irreparable loss of blood supply
 - severe soft tissue compromise
 - malignant tumors
 - smoldering infection
 - congenital anomalies
 - Amputation versus limb salvage and replantation
 - mangled upper extremity has a far greater impact on overall function than does a lower extremity amputation
 - upper extremity prostheses have much more difficulty replicating native dexterity and sensory feedback provided by the native limb
 - results of nerve repair and reconstruction are more successful in upper extremity than lower extremity
 - superior functional outcomes can be expected in replanted limbs compared with upper extremity amputations

- diminishing outcomes from replantation are expected the more proximal the level, especially about the elbow
- Levels of amputation
 - wrist disarticulation or transcarpal versus transradial amputation
 - wrist disarticulation advantages
 - improved pronation and supination
 - recommended in children for preservation of distal radial and ulnar physes
 - longer lever arm
 - disadvantage
 - can be difficult to use with highly functional prosthesis compared to transradial
 - Although, this may be changing with advancing technology
 - transradial advantages
 - more aesthetically pleasing
 - easier to fit prosthesis (myoelectric prostheses)
 - transhumeral versus elbow disarticulation
 - elbow disarticulation advantages
 - indicated in children to prevent bony overgrowth seen in transhumeral amputations
- Techniques
 - general
 - All named motor and sensory branches within operative field should be identified and preserved
 - can result in improved muscle mass and preserve the ability to create myoelectric signal for targeted reinnervation
 - myodesis, the process of attaching the muscle-tendon unit directly to bone is recommended
 - transcarpal
 - transect finger flexor/extensor tendons
 - anchor wrist flexor/extensor tendons to carpus
 - wrist disarticulation



- preserve radial styloid flare to improve prosthetic suspension
- requires healthy and intact DRUJ
- transradial amputation



- middle third of forearm amputation maintains length and is ideal
- residual 5cm of ulna is required for elbow motion, but at this level will have limited pronation/supination
- transhumeral amputation
 - maintain as much length as possible
 - ideal level is 4-5cm proximal to elbow joint
 - if more proximal amputation is required:
 - At least 5-7cm of residual length is needed for glenohumeral mechanics
- shoulder disarticulation



- retain humeral head to maintain shoulder contour

- Targeted Muscle Reinnervation

- designed to improve control of myoelectric prostheses used for amputation
- general
 - transfer amputated large peripheral nerves to reinnervated functionally expendable remaining muscles to create a new discrete muscle signal for the myoelectric prosthesis control
 - secondary benefit of alleviating symptomatic neuroma pain

- Transfemoral Amputation

- Maintain as much length as possible

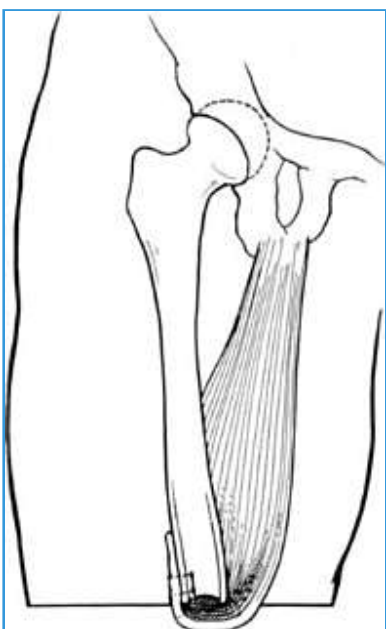
- however, ideal cut is 12 cm (10-15cm) above knee joint to allow for prosthetic fitting

- Technique

- 5-10 degrees of adduction is ideal for improved prosthesis function



- adductor myodesis



- improves clinical outcomes
- creates dynamic muscle balance (otherwise have unopposed abductors)
- provides soft tissue envelope that enhances prosthetic fitting

- Gritti-Stokes amputation

- amputation through the femur near level of adductor tubercle
- synovium is excised to prevent postoperative effusion
- patella is arthrodesed to the end of femur for improved end bearing
- prepatellar soft tissue is maintained without iatrogenic injury
- improved outcomes as compared to transfemoral amputation

- Through-Knee-Amputation

- Indications
 - ambulatory patients who cannot have a transtibial amputation
 - non-ambulatory patients
 - Technique
 - suture patellar tendon to cruciate ligaments in notch
 - use gastrocnemius muscles for padding at end of amputation
 - Outcomes (based on LEAP data)
 - slower self-selected walking speeds than BKA
 - similar amounts of pain compared to AKA and BKA
 - worse performance on the Sickness Impact Profile (SIP) than BKA and AKA
 - physicians were less satisfied with the clinical, cosmetic, and functional recovery
 - Consequence of poor soft tissue envelope from loss of gastrocnemius padding
 - require more dependence with patient transfers than BKA
- Below-Knee-Amputation (BKA)
- Long posterior flap

 - 12-15 cm below knee joint is ideal (10-16cm of residual tibia bone)
 - ensures adequate lever arm
 - longer than this gets into the achilles tendon which has a suboptimal blood supply and ability for soft tissue cushioning
 - need approximately 8-12 cm from ground to fit most modern high-impact prostheses
 - "dog ears"
 - preventable with well-designed incision lines
 - if present, left in place to preserve blood supply to the posterior flap
 - Modified Ertl



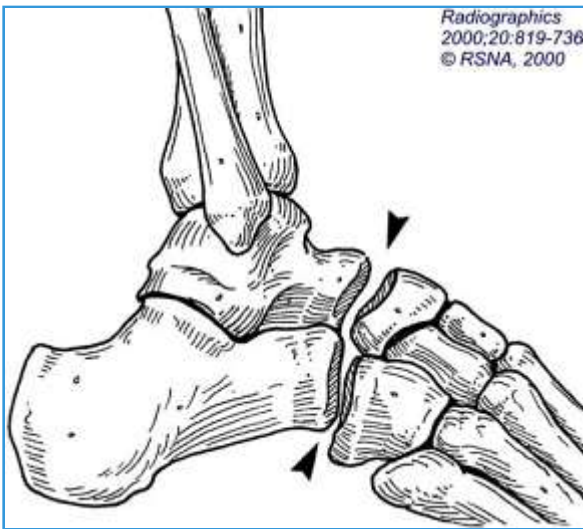
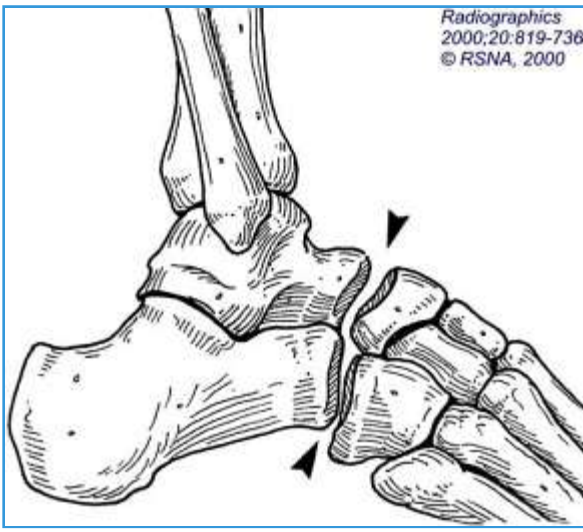
- designed to enhance prosthetic end-bearing
 - argument is that the bone bridge will enhance weight bearing through the fibula and increase total surface area for load transfer
- increased reoperation rates have been reported
- technique
 - the original Ertl amputation required a corticoperiosteal flap bridge
 - the modified Ertl uses a fibular strut graft
 - requires longer operative and tourniquet times than standard BKA transtibial amputation
 - fibula is fixed in place with cortical screws, fiberwire suture with end buttons, or heavy nonabsorbable sutures

• Ankle/Foot Amputation

- Syme amputation (ankle disarticulation)



- patent tibialis posterior artery is required
- more energy efficient than midfoot even though it is more proximal
- stable heel pad is most important factor
- used successfully to treat forefoot gangrene in diabetics
- technique
 - medial and lateral malleoli are removed flush with distal tibia articular surface
 - the medial and lateral flares of the tibia and fibula are beveled to enhance heel pad adherence
 - heel pad is secured to anterior tibia
- Pirogoff amputation (hindfoot amputation)
 - removal of the forefoot and talus followed by calcaneotibial arthrodesis
 - calcaneus is osteotomized and rotated 50-90 degrees to keep posterior aspect of calcaneus distal
 - allows patient to mobilize independently without use of prosthetic
- Chopart or Boyd amputation (hindfoot amputation)



- a partial foot amputation through the talonavicular and calcaneocuboid joints
- primary complication is equinus deformity
 - avoid by lengthening of the Achilles tendon and transfer of the tibialis anterior to the talar neck
 - leads to a propulsive gait pattern because the amputation is unable to support modern dynamic elastic response prosthetic feet
- Lisfranc amputation (midfoot amputation)



- equinovarus deformity is common
 - caused by unopposed pull of tibialis posterior and gastroc/soleus
 - prevent by maintaining insertion of peroneus brevis and performing achilles lengthening
 - a walking cast is generally used for 4 week to prevent late equinus contracture
- Energy cost of walking similar to that of BKA
- Transmetatarsal amputation



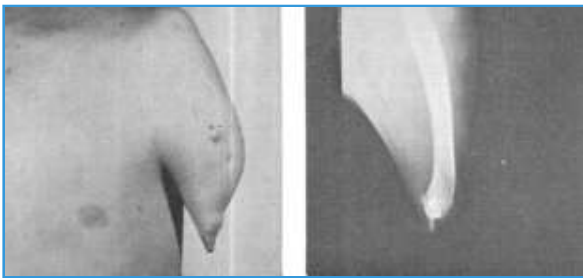
- more appealing to patients who refuse transtibial amputations
- almost all require achilles lengthening to prevent equinus
- Great toe amputations
 - preserve 1cm at base of proximal phalanx
 - preserves insertion of plantar fascia, sesamoids, and flexor hallucis brevis
 - reduces amount of weight transfer to remaining toes
 - lessens risk of ulceration

• Complications

- Wound healing
- Contractures
 - adjacent joint contractures are common
 - prevent with early aggressive mobilization and position changes
- Heterotopic ossification
 - more common in trauma-related setting
- Infection
 - trauma-related amputation have an infection rate of around 34%
- Postamputation Neuroma



- occurs in 20-30% of amputees
 - prevent with proper nerve handling at the time of procedure
 - treatment
 - targeted muscle reinnervation
 - a method of guiding neuronal regeneration to prevent or treat post-amputation neuroma pain and improve patient use of myoelectric prostheses
- Phantom limb pain
 - occurs in 53-100% of traumatic amputations
 - mirror therapy is a noninvasive treatment modality
- Bone overgrowth
 - most common complication with pediatric amputations



- treatment
 - prevent by performing disarticulation or using epiphyseal cap to cover medullary canal

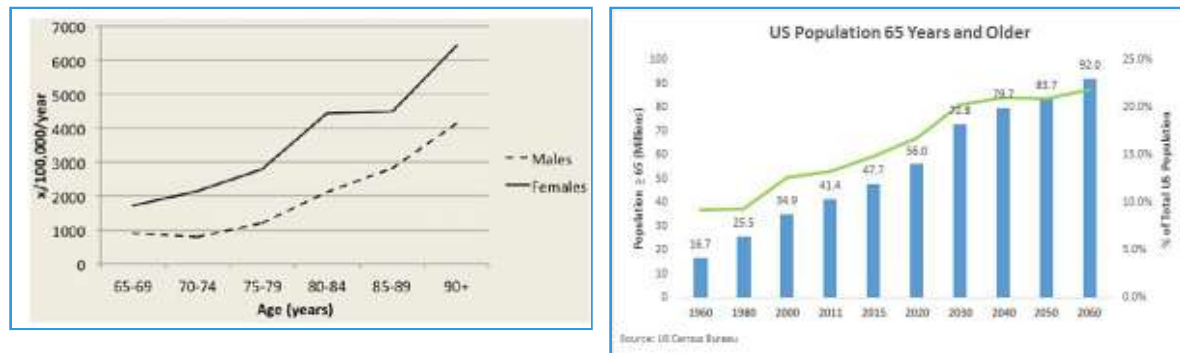
• Prognosis

- Outcomes are improved with the involvement of psychological counseling for coping mechanisms
 - Involves a close working relationship between rehab physicians, prosthetists, physical therapists, as well as psychiatrists and social workers
- High rate of late amputation in patients with high-energy foot trauma
 - 1st metatarsal fracture
 - fracture involving all five metatarsals
- Amputation vs. reconstruction
 - LEAP study
 - impact on decision to amputate limb
 - severe soft tissue injury
 - highest impact on decision-making process
 - absence of plantar sensation
 - 2nd highest impact on surgeon's decision making process
 - not an absolute contraindication to reconstruction
 - plantar sensation can recover by long-term follow-up
 - outcome measure
 - SIP (sickness impact profile) and return to work not significantly different between amputation and reconstruction at 2 years in limb-threatening injuries
 - 25% infection rate
 - mangled foot and ankle injuries requiring free tissue transfer have a worse SIP than BKA

- most important factor to determine patient-reported outcome is the ability to return to work
 - About 50% of patients are able to return to work
- METALS study
 - study focused on military population in response to LEAP study
 - slightly better results in regard to patient-reported outcomes for the amputation group with a lower risk of PTSD
 - more severe limbs were going into salvage pathway
 - military population with better access to prostheses
 - higher rates of return to vigorous activity in the amputation group

8- Geriatric Patient Trauma

Images



Definition

Definition

- management of the orthopedic problems of aging and diseases of the elderly
- commonly defined as age >65
- defining elderly based on physiologic age or frailty may be more clinically relevant

Epidemiology

Incidence

- elderly population is growing in the US
- >85 year old group had fastest growth (30%) between 2000-2010

Etiology

Pathophysiology

- musculoskeletal related conditions of the elderly are common
 - osteoarthritis
 - osteoporosis
 - 2.1 million fragility fractures annually
 - falls
 - 30% of persons >65 years old sustain at least 1 fall per year

Presentation

History

- mechanism of injury
 - mechanical
 - syncope
 - elder abuse
- medication
 - must obtain accurate medication list
 - polypharmacy common
 - anticoagulation medications important for surgical planning
- baseline
 - ambulatory status
 - mental status

Imaging

Radiographs

- radiographs of joint above and below fracture
 - may have other injuries or adjacent arthroplasty/implants

Studies

Preoperative evaluation

- admission
 - improved outcomes and decreased cost with comanagement by geriatric or hospitalist service
- emergency room
 - EKG
 - CXR
 - U/A
 - labs
- optimization on floor
 - optimization
 - coagulopathy
 - heart failure
 - sepsis
 - prevention
 - avoid overly sedating medications
 - avoid anticholinergics
 - ulcer prophylaxis
- Cardiac work-up
 - risk of major adverse cardiac events assessed with revised cardiac risk index or NSQIP risk calculator
 - guides pre-operative work-up and timing of operative procedures

• Treatment

- Nonoperative
 - indications
 - medical comorbidities
 - low functioning patients
 - family desires
 - goals
 - pain control
 - ease of transfer
- Operative
 - indications
 - similar to fractures in other age groups with some exceptions
 - acute arthroplasty may be indicated for certain fractures in the elderly
 - comminuted distal humerus fracture



- proximal humerus



- femoral neck fracture



- acetabulum
- intra-articular distal femur
- adjunct or alternative fixation may be necessary
 - allograft (fibular strut for proximal humerus)
 - multiple implants
 - locking technology
- goals
 - early mobilization
 - return to preoperative functional status
 - pain control

• Complications

- Mortality
 - hip fracture
 - mortality rate in hospital and at one year: 6% and 30% respectively
 - decreased postoperative complications, pain, length of stay, and mortality if treated within 48 hours
 - spinal cord injury
 - higher mortality rate compared to younger patients
 - increased mortality associated with
 - need for mechanical ventilation at admission
 - higher injury severity scores
 - head injury
- Delirium
 - incidence
 - 13%-50% postoperatively in elderly orthopedic patients
 - risk factors
 - dementia
 - polypharmacy
 - narcotics
 - Pre-operative fascia iliaca block and decrease overall narcotic use
 - dehydration
 - restraints
 - foley catheters
 - frequent awakenings
 - treatment
 - comanagement with geriatric or hospitalist team
 - reorientation
 - minimize narcotics
 - early mobilization
 - timely removal of catheters
- Medical complications
 - pneumonia
 - pulmonary embolism
 - deep venous thrombosis
 - pressure ulcers
 - myocardial infarction
 - stroke

- Reducing complications with co-management service
 - orthopedic geriatric co-management of trauma patients has been demonstrated to yield
 - decreased mortality, postoperative complications, time to surgery, and length of stay (though conflicting results on the length of stay)
 - improved post-operative mobility at 4 months

9- Leg Compartment Syndrome

Images



- summary

- Leg Compartment Syndrome is a devastating lower extremity condition where the osseofascial compartment pressure rises to a level that decreases perfusion to the leg and may lead to irreversible muscle and neurovascular damage.
- Diagnosis is made with the presence of severe and progressive leg pain that worsens with passive ankle motion. Firmness and decreased compressibility of the compartments is often present. Needle compartment pressures are diagnostic in cases of inconclusive physical exam findings and in sedated patients.
- Treatment is usually emergent fasciotomies of all 4 compartments.

- Epidemiology

- Anatomic location
 - compartment syndrome may occur anywhere that skeletal muscle is surrounded by fascia, but most commonly
 - leg (details below)
 - forearm
 - hand
 - foot
 - thigh
 - buttock
 - shoulder
 - paraspinous muscles

- Etiology

- Pathophysiology
 - etiology
 - trauma
 - fractures (69% of cases)
 - crush injuries
 - contusions
 - gunshot wounds
 - tight casts, dressings, or external wrappings
 - extravasation of IV infusion
 - burns
 - postischemic swelling
 - bleeding disorders
 - arterial injury
 - pathoanatomy
 - cascade of events includes
 - local trauma and soft tissue destruction
 - bleeding and edema
 - increased interstitial pressure
 - vascular occlusion (decreased venous outflow relative to arterial inflow)

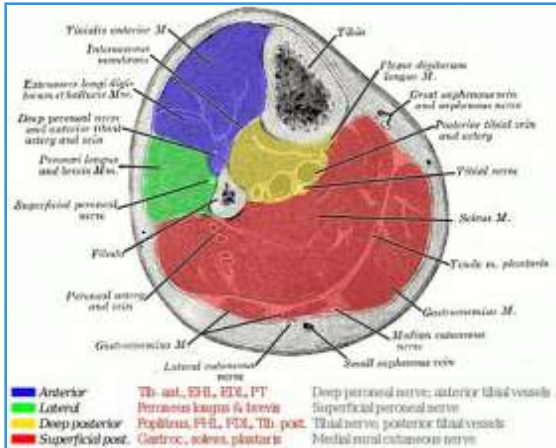
- myoneural ischemia

- Risk factors

- diaphyseal fractures
- young age (highest prevalence in 12-19 year olds)

- Anatomy

- 4 compartments of the leg



- anterior compartment

- function

- dorsiflexion of foot and ankle

- muscles

- tibialis anterior
- extensor hallucis longus
- extensor digitorum longus
- peroneus tertius

- lateral compartment

- function

- plantarflexion and eversion of foot

- muscles

- peroneus longus
- peroneus brevis

- isolated lateral compartment syndrome would only affect superficial peroneal nerve

- deep posterior compartment

- function

- plantarflexion and inversion of foot

- muscles

- tibialis posterior
- flexor digitorum longus
- flexor hallucis longus

- superficial posterior compartment

- function

- mainly plantarflexion of foot and ankle

- muscles

- gastrocnemius
- soleus
- plantaris

- Presentation

- Symptoms

- pain out of proportion to the clinical situation is usually the first symptom
 - may be absent in cases of nerve damage
 - pain is difficult to assess in a polytrauma patient and impossible to assess in a sedated patient
 - difficult to assess in children (unable to verbalize)

- Physical exam

- pain w/ passive stretch
 - is most sensitive finding prior to onset of ischemia
- paresthesia and hypoesthesia

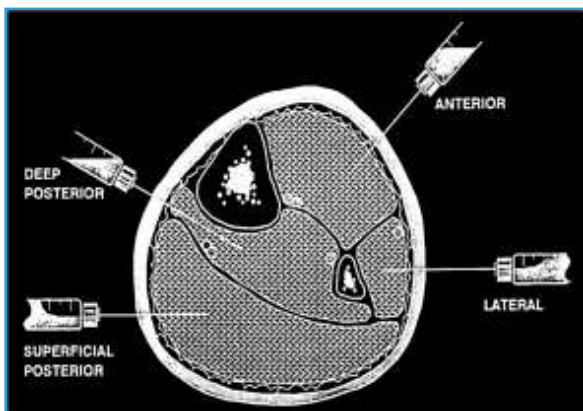
- indicative of nerve ischemia in affected compartment
- paralysis
 - late finding
 - full recovery is rare in this case
- palpable swelling
- peripheral pulses absent
 - late finding
 - amputation usually inevitable in this case

• Imaging

- Radiographs
 - obtain to rule-out fracture

• Studies

- Compartment pressure measurements
 - indications
 - polytrauma patients
 - patient not alert/unreliable
 - inconclusive physical exam findings
 - relative contraindication
 - unequivocally positive clinical findings should prompt emergent operative intervention without need for compartment measurements
 - technique



- should be performed within 5cm of fracture site
- low rates of interobserver reliability have been noted with measurements
- anterior compartment
 - entry point
 - 1cm lateral to anterior border of tibia within 5cm of fracture site if possible
 - needle should be perpendicular to skin
- deep posterior compartment
 - entry point
 - just posterior to the medial border of tibia
 - advance needle perpendicular to skin towards fibula
- lateral compartment
 - entry point
 - just anterior to the posterior border of fibula
- superficial posterior
 - entry point
 - middle of calf within 5 cm of fracture site if possible

• Diagnosis

- Clinical
 - based primarily on physical exam in patient with intact mental status

• Treatment

- Nonoperative
 - **observation**
 - indications

- diastolic differential pressure (delta p) is > 30
- presentation not consistent with compartment syndrome
- **bi-valving the cast and loosening circumferential dressings**
 - indications
 - initial treatment for swelling or pain that is NOT compartment syndrome
 - splinting the ankle between neutral and resting plantar flexion (37 deg) can also decrease intracompartmental pressures
- **hyperbaric oxygen therapy**
 - works by increasing the oxygen diffusion gradient

○ Operative

- **emergent fasciotomy of all four compartments**
 - indications
 - clinical presentation consistent with compartment syndrome
 - compartment pressures within 30 mm Hg of diastolic blood pressure (delta p)
 - intraoperatively, diastolic blood pressure may be decreased from anesthesia
 - must compare intra-operative measurement to pre-operative diastolic pressure
 - attempt to restore systemic blood pressure prior to measurement
 - contraindications
 - missed compartment syndrome

○ Special considerations

- pediatrics
 - children are unable to verbalize feelings
 - if suspicion, then perform compartment pressure measurement under sedation
- hemophiliacs
 - give Factor VIII replacement before measuring compartment pressures

• Techniques

○ Emergent fasciotomy of all four compartments

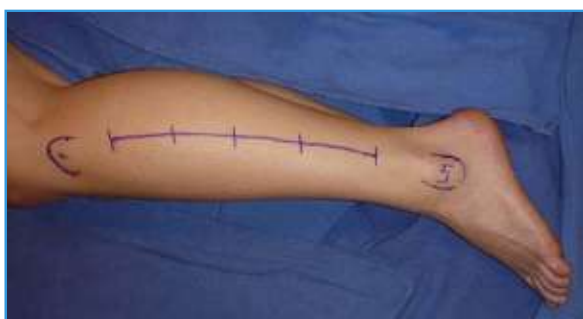
- dual medial-lateral incision
 - approach



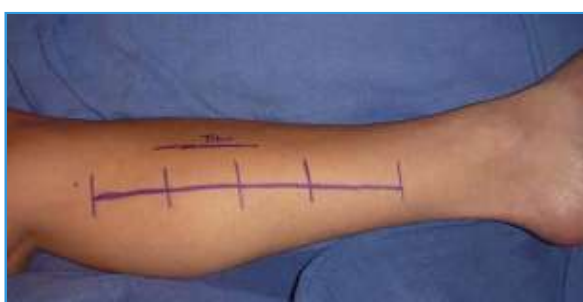
- two 15-18cm vertical incisions separated by 8cm skin bridge
 - anterolateral incision
 - posteromedial incision

▪ technique

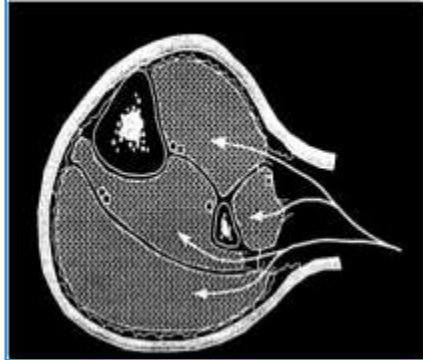
- anterolateral incision



- identify and protect the superficial peroneal nerve
- fasciotomy of anterior compartment performed 1cm in front of intermuscular septum
- fasciotomy of lateral compartment performed 1cm behind intermuscular septum
- posteromedial incision



- protect saphenous vein and nerve
 - incise superficial posterior compartment
 - detach soleal bridge from back of tibia to adequately decompress deep posterior compartment
- post-operative
 - dressing changes followed by delayed primary closure or skin grafting at 3-7 days post decompression
- pros
 - easy to perform
 - excellent exposure
- cons
 - requires two incisions
- single lateral incision
 - approach



- single lateral incision from head of fibula to ankle along line of fibula
- technique
 - identify superficial peroneal nerve
 - perform anterior compartment fasciotomy 1cm anterior to the intermuscular septum
 - perform lateral compartment fasciotomy 1cm posterior to the intermuscular septum
 - identify and perform fasciotomy on superficial posterior compartment
 - enter interval between superficial posterior and lateral compartment
 - reach deep posterior compartment by following interosseous membrane from the posterior aspect of fibula and releasing compartment from this membrane
 - common peroneal nerve at risk with proximal dissection
- pros
 - single incision
- cons
 - decreased exposure

10- Septic Arthritis Adult

Images



- summary

- Septic Arthritis is the inflammation of the joints secondary to an infectious etiology, most commonly affecting the knee, hip, and shoulder.
- Diagnosis is made with an aspiration of joint fluid with a WBC count $> 50,000$ being considered diagnostic for septic arthritis. Lower counts may still indicate infection in the presence of positive gram stains or cultures results.
- Treatment is usually urgent surgical irrigation and debridement followed by culture directed IV antibiotics.

- Epidemiology

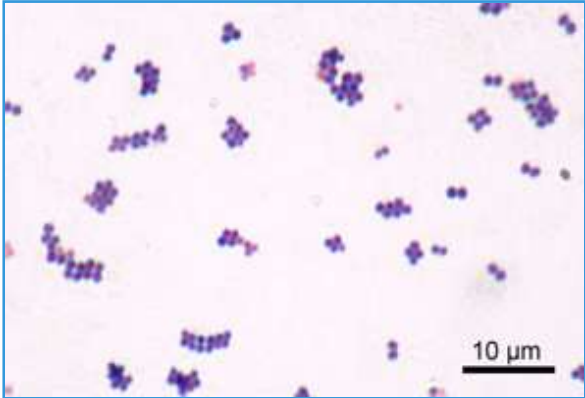
- Anatomic location
 - most commonly affected joints in descending order
 - knee (~ 50% of cases) >
 - hip >
 - shoulder >
 - elbow >
 - ankle >
 - sternoclavicular joint
 - found in IV drug users
 - pseudomonas aeruginosa was most common pathogen in 1980's
 - staphylococcus aureus is now the most common pathogen in all patients, including IV drug users
 - advanced imaging (CT/MRI) should be obtained preoperatively to rule out retrosternal abscess or chest wall phlegmon
- Risk factors
 - age > 80 years
 - medical conditions
 - diabetes
 - rheumatoid arthritis
 - cirrhosis
 - HIV
 - history of crystal arthropathy
 - endocarditis or recent bacteremia
 - IV drug user
 - recent joint surgery

- Etiology

- Pathophysiology
 - pathoanatomy
 - 3 etiologies of bacterial seeding of joint
 - bacteremia
 - direct inoculation
 - from trauma or surgery

- contiguous spread
 - from adjacent osteomyelitis
- cellular biology
 - septic arthritis causes irreversible cartilage destruction in an involved joint
 - cartilage injury can occur by 8 hours
 - caused by release of proteolytic enzymes from inflammatory cells (PMNs)
- microbiology
 - most common pathogens is staphylococcus aureus (accounts for >50% of cases)
 - see Classification below
- Associated conditions
 - prosthetic implant infection

• Classification

- By organism
 - staphylococcus species
 - staphylococcus aureus
- 
- most common and accounts for >50% of cases
 - MRSA
 - staphylococcus epidermis
 - neisseria gonorrhea
 - account for ~20% of cases
 - most common organism in otherwise healthy sexually active adolescents and young adults
 - manifests as a bacteremic infection
 - arthritis-dermatitis syndrome in ~60% of cases
 - localized septic arthritis in ~40% cases
 - gram-negative bacilli
 - account for 10-20% of cases
 - pathogens include
 - E coli, proteus
 - klebsiella
 - enterobacter
 - risk factors
 - neonates
 - IV drug users
 - elderly
 - immunocompromised patients with diabetes
 - streptococcus
 - streptococcus pyogenes (Group A)
 - most common
 - Group B streptococcus (e.g., agalactiae)
 - predilection for infants, elderly and diabetic patients
 - propionibacterium acnes
 - associated with shoulder surgery
 - salmonella or streptococcus pneumoniae
 - seen in patients with sickle cell disease
 - bartonella henselae
 - seen in patients with HIV
 - pseudomonas aeruginosa
 - seen in patients with history of IV drug abuse

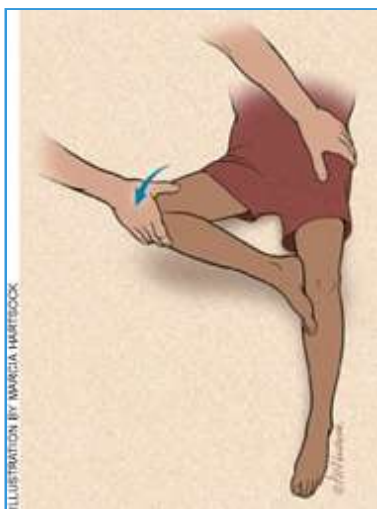
- *pasteurella multocida*
 - seen in patients after dog or cat bite
- *eikenella corrodens*
 - seen in patients after human bite
- fungal/*candida*
 - found in immunocompromised host

• Presentation

- Symptoms
 - pain in affected joint
 - fevers (only present in 60% of cases)
 - may appear toxic
- Physical exam
 - inspection
 - erythema



- effusion
- extremity tends to be in position of maximum joint volume
 - hip would be in FABER position (flexed, abducted, externally rotated)



- palpation
 - warmth
 - tender
- motion
 - inability to bear weight
 - inability to tolerate PROM

• Imaging

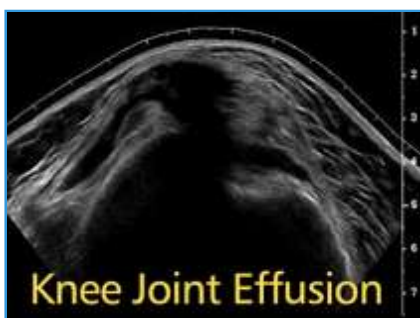
- Radiographs
 - recommended views
 - AP and lateral of the joint in question
 - findings
 - may show joint space widening or effusion



- periarticular osteopenia

- Ultrasound

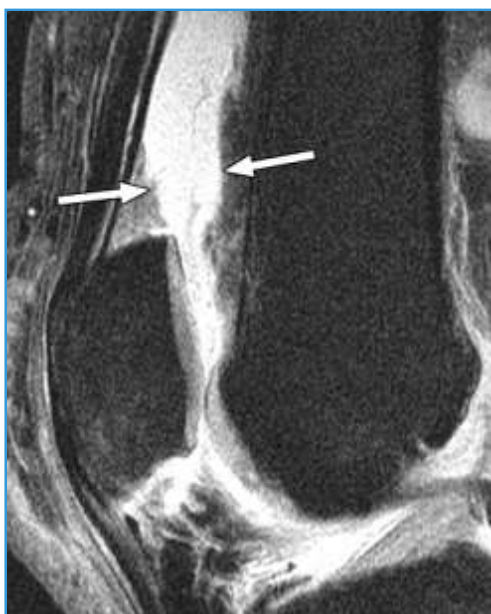
- indications
 - may help in confirming joint effusion in large joint such as hip



- can be used in guiding aspirations

- MRI

- indications
 - detects joint effusion, and may detect adjacent bone involvement such as osteomyelitis



- Studies

- Serum labs

- WBC >10K cells/mL with left shift
- ESR >30 mm/hr
 - ESR is often elevated but may be normal early in process
 - rises within 2 days of infection and can rise 3-5 days after initiation of appropriate antibiotics, and returns to normal 3-4 weeks
- CRP >1 mg/dL
 - most helpful
 - best way to judge efficacy of treatment, as CRP rises within few hours of infection, and may normalize within 1 week of treatment

- Joint fluid aspirate

- gold standard for treatment and allows directed antibiotic treatment
- should be analyzed for
 - cell count with differential
 - gram stain
 - culture
 - glucose level

- crystal analysis
 - septic arthritis occurs concurrently with gout or pseudogout in < 5% of cases
- characteristic findings
 - joint fluid appears cloudy or purulent
 - cell count with WBC > 50,000 is considered diagnostic for septic arthritis, however lower counts may still indicate infection
 - antibiotics administered within 24 hours of arthrocentesis can lower synovial WBC count and lead to false negative results
 - gram stains only identifies infective organism 1/3 of time
 - glucose less than 60% of serum level
 - negative "string" sign
 - septic synovial fluid has low viscosity compared to normal synovial fluid (high viscosity)



- Saline load test
 - utilized to determine if wound near a joint communicates with the joint
 - for the knee
 - 155 mL of saline is needed to reach 95% sensitivity
 - 175 mL of saline is needed to reach 99% sensitivity

• Differential

- Crystal arthropathy
 - gout
 - pseudogout
- Cellulitis
- Bursitis
 - prepatellar bursitis

• Treatment

- Operative
 - **IV abx, operative irrigation and drainage of the joint**
 - indications
 - considered an orthopaedic surgical emergency
 - IV antibiotic therapy
 - initiate empiric therapy prior to definitive cultures based on patient age and or risk factors
 - young, healthy adults
 - staphylococcus aureus and neisseria gonorrhea
 - immunocompromised patients
 - staphylococcus aureus and pseudomonas aeruginosa
 - transition to organism-specific antibiotic therapy based once obtain culture sensitivities
 - outcomes
 - treatment can be monitored by following serum WBC, ESR, and CRP levels during treatment

• Technique

- **Operative irrigation and drainage of the joint**
 - approach
 - can be performed open or arthroscopically (depending on joint)
 - irrigation
 - remove all purulent fluid and irrigate joint

- debridement
 - synovectomy can be performed as needed
- cultures
 - obtain joint fluid and tissue for culture

- Complications

- Arthritis
- Fibrous ankylosis
- Osteomyelitis

- Prognosis

- Delayed diagnosis can lead to profound, extensive cartilage damage within 8 hours

11- Necrotizing Fasciitis

Images



- summary

- Necrotizing Fasciitis is a life-threatening bacterial soft tissue infection that spreads along soft tissue planes rapidly.
- Diagnosis is made clinically with the presence of skin discoloration, bullae, palpable crepitus and calculation of the LRINEC score. Emergent frozen section can help confirm diagnosis in early cases.
- Treatment is emergent radical debridement of all devitalized tissues with broad-spectrum IV antibiotics.

- Epidemiology

- Risk factors
 - immune suppression
 - diabetes
 - AIDS
 - cancer
 - obesity
 - bacterial introduction
 - IV drug use
 - hypodermic therapeutic injections
 - insect bites
 - skin abrasions
 - abdominal and perineal surgery

- Etiology

- Associated conditions
 - cellulitis
 - overlying cellulitis may or may not be present

- Classification



■ Necrotizing Fasciitis Classification		
■ <i>Type</i>	■ <i>Organism</i>	■ <i>Characteristics</i>
■ Type 1	■ Polymicrobial ■ Typically 4-5 aerobic and anaerobics pecies cultured: ■ Non-Group A Strep ■ Anaerobes including Clostridia ■ Facultative anaerobes ■ Enterobacteria ■ Synergistic virulence between organisms	■ Most common (80-90%) ■ Seen in immunosuppressed (diabetics and cancer patients) ■ Postop abdominal and perineal infections
■ Type 2	■ Monomicrobial ■ Group A ð²-hemolytic Streptococci is most common organism isolated	■ 5% of cases ■ Seen in healthy patients ■ Extremities
■ Type 3	■ Marine Vibrio vulnificus ■ (gram negative rods)	■ Marine exposure
■ Type 4	■ Fungal	

- Presentation



- Symptoms

- early
 - localized abscess or cellulitis with rapid progression
 - minimal swelling
 - no trauma or discoloration
- late findings
 - severe pain
 - high fever, chills and rigors
 - tachycardia



- Physical exam



- skin bullae
- discoloration
 - ischemic patches
 - cutaneous gangrene
- swelling, edema
- dermal induration and erythema
- subcutaneous emphysema (gas producing organisms)

• Imaging

- Radiographs
 - not required for diagnosis or treatment

• Studies

- Biopsy
 - indications
 - emergent frozen section can confirm diagnosis in early cases
 - technique

- take 1x1x1cm tissue sample
 - can be performed at bedside or in operating room
 - surgical intervention should not be delayed to obtain
- histological findings
 - necrosis of fascial layer
 - microorganisms within fascial layer
 - PMN infiltration
 - fibrinous thrombi in arteries and veins and necrosis of arterial and venous walls
- LRINEC Scoring system
 - score > 6 has PPV of 92% of having necrotizing fasciitis
 - CRP (mg/L)
 - ≥150: 4 points
 - WBC count ($\times 10^3 / \text{mm}^3$)
 - <15: 0 points
 - 15-25: 1 point
 - >25: 2 points
 - Hemoglobin (g/dL)
 - >13.5: 0 points
 - 11-13.5: 1 point
 - <11: 2 points
 - Sodium (mmol/L)
 - <135: 2 points
 - Creatinine (umol/L)
 - >141: 2 points
 - Glucose (mmol/L)
 - >10: 1 point
- Differentials
 - Gas gangrene
- Treatment
 - Operative
 - **emergency radical debridement with broad-spectrum IV antibiotics**
 - indications
 - whenever suspicion for necrotizing fasciitis
 - operative findings
 - liquefied subcutaneous fat
 - dishwater pus
 - muscle necrosis
 - venous thrombosis
 - technique
 - hemodynamic monitoring with systemic resuscitation is critical
 - hyperbaric oxygen chamber if anaerobic organism identified
 - antibiotics
 - initial antibiotics
 - start empirically with penicillin, clindamycin, metronidazole, and an aminoglycoside
 - definitive antibiotics
 - penicillin G
 - for strep or clostridium
 - imipenem or doripenem or meropenem
 - for polymicrobial
 - add vancomycin or daptomycin
 - if MRSA suspected
 - **amputation**
 - indications
 - low threshold for amputation when life threatening

- Prognosis

- Life threatening infection
 - mortality rate of 32%
 - mortality correlates with time to surgical intervention

12- Osteomyelitis Adult

Images



• Summary

- Osteomyelitis is the infection of bone characterized by progressive inflammatory destruction and apposition of new bone.
- Diagnosis requires careful assessment of radiographs, MRI and determining the organism via biopsy and cultures.
- Treatment is often a combination of culture-directed antibiotics and surgical debridement of nonviable tissue.

• Epidemiology

- Incidence
 - the exact incidence is unknown
- Location
 - spine and ribs in dialysis patients
 - medial or lateral clavicle in IV drug abusers
 - foot and decubitus ulcers in diabetics
- Risk factors
 - recent trauma or surgery
 - immunocompromised patients
 - illicit IV drug use
 - poor vascular supply
 - systemic conditions such as diabetes and sickle cell
 - peripheral neuropathy

• Etiology

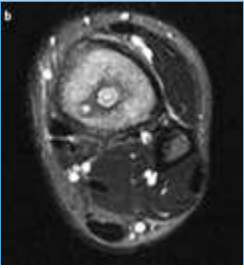
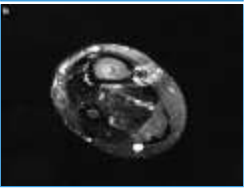
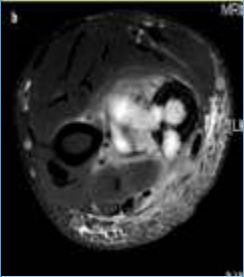
- Pathophysiology
 - mechanism of spread
 - hematogenous
 - originated or transported by blood
 - may be due to bacterial or viral systemic illness
 - most common etiology in children
 - vertebrae are the most common hematogenous site in adults
 - *S. aureus* is the most common organism
 - contiguous-spread
 - associated with previous surgery, trauma, wounds, or poor vascularity
 - can be bacterial (most common), mycobacterial, or fungal in nature
 - direct-inoculation
 - penetrating injuries
 - open fractures
 - surgical contamination
- pathobiology
 - planktonic stage
 - bacteria attach to an inert substrate and undergo apoptosis to create a matrix for biofilm

- biofilm formation
 - biofilm is characterized by bacteria entering a no-growth, or sessile, phase, which makes them even more resistant to antibiotics that depend on replication to carry out their effect
 - biofilm is then made of an extracellular polymeric substance or exopolysaccharide
 - antibiotics are less effective due to difficulty penetrating the biofilm and bacteria lowering their metabolic rate
- Associated conditions
 - orthopaedic manifestations
 - septic arthritis
 - abscess
 - medical conditions
 - immunosuppression
 - dialysis
 - IV drug use
 - diabetes
 - poor nutrition
 - vascular disease
- Organism (see table below)
 - organism varies by age of the patient
 - S. aureus is most common in adults

○	■ Osteomyelitis Organism Table	
	■ Newborns ■ (younger than 4 mo)	■ S. aureus, Enterobacter species, group A and B Streptococcus species
	■ Children ■ (aged 4 mo to 4 y)	■ S. aureus, group A Streptococcus species, Kingella kingae, and Enterobacter species
	■ Children, adolescents ■ (aged 4 y to adult)	■ S. aureus (80%), group A Streptococcus species, H. influenzae, and Enterobacter species
	■ Adult	■ S. aureus and occasionally Enterobacter or Streptococcus species
○	■ Unusual Osteomyelitis Organism Table	
	■ Salmonella	■ Sickle cell anemia patients (S. aureus is still most common)
	■ Pseudomonas	■ IV drug use with AC or SC joint infection or puncture wound through rubber soled shoes
	■ Bartonella	■ HIV/AIDS patient following cat scratch or bite
	■ Fungal osteomyelitis	■ Immunosuppressed, long-term IV medications, or parenteral nutrition
	■ Tuberculosis	■ Manifestations include Potts disease

- Classification

- Timing classification
 - acute
 - within 2 weeks
 - subacute
 - within one to several months
 - chronic
 - after several months
- Cierny-Mader classification

■ Cierny-Mader Classification of Osteomyelitis ■ (describes anatomic involvement, host, treatment, prognosis)		
	■ <i>Anatomic Location</i>	
■ Stage 1	■ Medullary	■  Medullary ■ 
■ Stage 2	■ Superficial	■  Superficial ■ 
■ Stage 3	■ Localized	■  Localized ■ 
■ Stage 4	■ Diffuse	■  Diffuse ■ 
	■ <i>Host type</i>	
■ Type A	■ Normal	
■ Type BL	■ Locally compromised	
■ Type BS	■ Systemically compromised	
■ Type C	■ Treatment is worse to the patient than infection	

- Presentation
 - History
 - duration
 - prior treatments

- characterize host
 - immunocompromised
- Symptoms
 - pain
 - fever
 - more common in acute osteomyelitis
- Physical exam
 - vital signs
 - fever, tachycardia, and hypotension suggest sepsis
 - inspection
 - erythema, tenderness, and edema are commonly seen
 - draining sinus tract



- more common in chronic osteomyelitis
 - if able to probe bone through sinus, chronic osteomyelitis is present
- motion
 - limp and/or pain inhibition with weight-bearing or motion may be present
 - assess the joints above and below the area of concern
- neurovascular
 - assessment of vascular insufficiency locally or systemically

• Imaging

- Radiographs
 - recommended views
 - orthogonal plain radiographs of the affected extremity
 - findings
 - acute
 - imaging findings lag behind by 2 weeks
 - bone loss must be 50% before evident on plain films
 - chronic
 - bone lucency, sclerotic rim, osteopenia, periosteal reaction, and lysis around hardware
 - sequestrum : devitalized bone that serves as a nidus for infection



- involucrum : formation of new bone around an area of bony necrosis



- sensitivity and specificity is variable

- CT

- indications
 - assist in diagnosis and surgical planning by identifying necrotic bone
 - sensitivity and specificity may be affected by hardware artifact and scatter

- MRI

- indications
 - assists in the diagnosis and surgical planning
 - best test for diagnosing early osteomyelitis and localizing infection
- views
 - T2 sequences will show bone and soft tissue edema
- findings
 - penumbra sign



- T1 - dark central abscess with bright internal wall and dark external sclerotic rim

- sensitivity and specificity
 - if negative rules out osteomyelitis
 - if positive may overestimate the extent of osteomyelitis

- Nuclear medicine

- technetium bone scan
 - indications
 - when radiographs are normal and MRI is not an option
 - sensitivity and specificity
 - highly sensitive but not specific
 - if negative rules out osteomyelitis
- gallium scan
 - indications
 - diabetic foot or if MRI is not an option
 - sensitivity and specificity
 - cellulitis may cause false positive
 - if negative rules out osteomyelitis

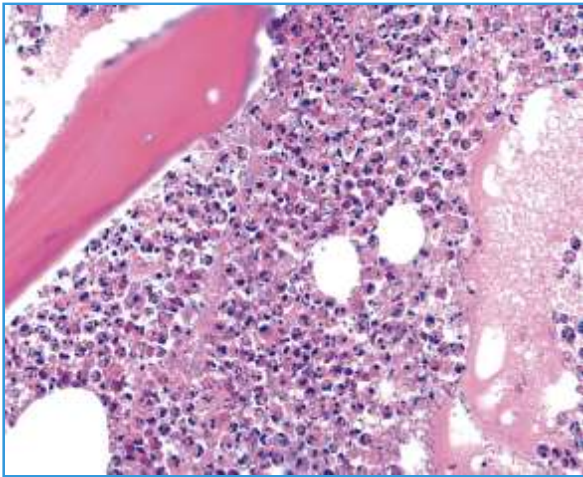
- Studies

- Laboratory analysis

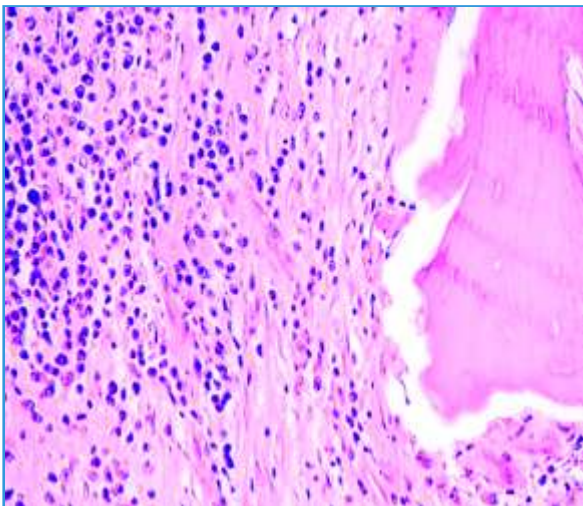
- leukocyte count (WBC)
 - only elevated in 1/3 of acute osteomyelitis
- erythrocyte sedimentation rate (ESR)
 - usually elevated in both acute and chronic osteomyelitis (90%)
 - a decrease in ESR after treatment is a favorable prognostic indicator
- C-reactive protein
 - most sensitive test with elevation in 97% of cases
 - decreases faster than ESR in successfully treated patients
- blood cultures
 - often negative, but may be used to guide therapy for hematogenous osteomyelitis
- Microbiology
 - sinus tract cultures
 - not reliable for guiding antibiotic therapy
 - culture of bone
 - gold-standard for guiding antibiotic therapy

- Histology

- acute osteomyelitis



- live osteocytes with numerous acute inflammatory cells (neutrophils)
- chronic osteomyelitis



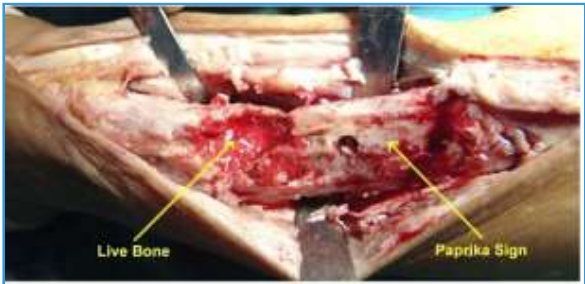
- no nuclei in osteocytes with fibrosis of marrow and chronic inflammatory cells (lymphocytes)

- Differential

- Key differential
 - benign tumor
 - biopsy all infection, cultures all tumors
 - malignant tumor
 - biopsy all infection, cultures all tumors
 - healing fracture

- Treatment

- Goals
 - success in the treatment is dependent on various factors
 - patient factors
 - immunocompetence of patient
 - nutritional status
 - injury factors
 - the severity of the injury as demonstrated by segmental bone loss

- infection location
 - metaphyseal infections heal better than mid-diaphyseal infections
 - other factors affecting prognosis and treatment include:
 - residual foreign materials and/or ischemic and necrotic tissues
 - inappropriate antibiotic coverage
 - lack of patient cooperation or desire
 - Nonoperative Treatment
 - **suppressive antibiotics**
 - indications
 - when operative intervention is not feasible
 - **hyperbaric oxygen therapy**
 - indications
 - can be used as adjunct in refractory osteomyelitis
 - Operative treatment
 - **irrigation and debridement followed by organism specific antibiotics**
 - indications
 - acute osteomyelitis that fails to improve on IV antibiotics
 - subacute osteomyelitis
 - abscess formation
 - chronic osteomyelitis
 - draining sinus
 - **amputation**
 - indications
 - chronic infection with pervasive wound or bone damage that is unable to be salvaged
- Techniques
- **Antibiotic therapy**
 - technique
 - antibiotics should be tailored to a specific organism , preferably after a bone biopsy is obtained
 - chronic suppressive antibiotics may be useful in patients who are immunocompromised or in whom surgery is not feasible
 - high rates of recurrence if suppressive antibiotics are discontinued
 - **Irrigation & debridement**
 - soft tissue
 - all devitalized and necrotic tissue should be removed
 - extensive debridement is essential to eradicate the infection
 - bone work
 - sequestrum must be eliminated from the body, or infection is likely to recur
 - debride bone until punctate bleeding is seen - "paprika sign"
- 
- hardware removal
 - any non-essential hardware should be removed
 - dead space management
 - goal is to replace dead bone and scar tissue with vascularized tissue
 - options include
 - vascularized bone grafts
 - local tissue flaps or free flaps
 - antibiotic-impregnated acrylic beads (PMMA)



- vacuum-assisted closure
 - improves wound healing and dead space closure in multiple ways
 - remove interstitial fluids
 - eliminate superficial purulence or slime
 - allow arterioles to dilate, which allows granulation tissue to proliferate
 - decrease in capillary afterload to promote inflow of blood
 - mechanical force on wound edges draws them in
- instrumentation
 - bony stability is required for successful eradication of infection
 - external fixation preferred to internal fixation
 - surgical fixation techniques
 - antibiotic-impregnated acrylic (PMMA) Intramedullary nail
 - peak antibiotic elution is 24 hours after placement
 - duration of antibiotics elution is generally up to 4 months
 - Ilizarov technique
 - intramedullary nail with or without external fixation
 - Masquelet technique
 - in situ reconstruction
 - mechanism is thought to be related to improved angiogenesis
- outcomes
 - often requires staged approach with multiple debridements and delayed soft tissue coverage
 - when combined with postoperative antibiotics tailored to a specific organism, treatment is often successful
- **Amputation**
 - technique
 - amputation at the level that will eradicate infected tissue to healing tissue with capacity to heal

• Complications

- Persistence or extension of infection
- Amputation
- Sepsis
- Malignant transformation
 - incidence
 - 1% in chronic osteomyelitis
 - most commonly squamous cell carcinoma (Marjolin's ulcer)
 - risk factors
 - chronic draining sinus
 - treatment
 - wide surgical resection

• Prognosis

- Despite surgical debridement and long-term antibiotics, recurrence rate of chronic osteomyelitis in adults is 30%
- Poor prognosis in patients with major nutritional or systemic disorders

13- Wound And Hardware Infection

Images



• summary

- Wound & Hardware Infection is the most common complication following orthopedic trauma surgery and is a significant source of patient morbidity.
- Diagnosis can be made clinically with the presence of incisional erythema, dehiscence, purulent drainage and/or persistent fracture nonunion or hardware loosening on radiographs. Intraoperative deep cultures are the most reliable method to isolate causative organisms
- Treatment is usually surgical irrigation and debridement followed by culture-directed antibiotics. Hardware removal may be performed acutely or in a delayed fashion depending on fracture healing.

• Epidemiology

- Incidence
 - up to 16% infection rate following traumatic fracture
- Risk factors
 - host immunodeficiency
 - extremes of age
 - diabetes
 - obesity
 - alcohol or tobacco abuse
 - steroid use
 - malnutrition
 - medications
 - previous radiation
 - vascular insufficiency

• Etiology

- Pathophysiology
 - mechanisms
 - seeding
 - disruption of soft tissue envelope, blood vessels, and periosteum allow bacteria to avoid host defenses
 - direct seeding of implant and/or anatomical structure
 - hematogenous seeding
 - biofilm formation
 - dependent on exopolysaccharide glycocalyx

• Presentation

- History
 - history of trauma must be detailed

- extent of soft tissue injury
- extent of bony injury
- previous or current hardware
- previous or current surgery at the same site
- history of previous skin or deep infections
- Symptoms
 - pain at previous fracture site
 - may indicate infected non-union
 - fevers, chills, and night sweats may be present
- Physical exam
 - inspection
 - erythema, drainage, or purulence
 - tenderness
 - motion
 - gross motion at fracture site is suggestive of non-union
- Imaging
- Radiographs
 - recommended views
 - biplanar images of afflicted area
 - 45 degree orthogonal views can also be obtained to evaluate for union
 - findings
 - acute infection
 - radiographs may be normal
 - sub-acute and chronic infections
 - peri-implant lucency can be seen
 - involucrum



- reactive bone surrounding active infection
- sequestrum



- retained nidus of infected necrotic bone

- CT
 - indications
 - pre-operative planning
- MRI
 - indications
 - useful adjunct for diagnosis and delineating extent of disease
 - to assess soft-tissue masses and fluid collections
 - sensitivity and specificity
 - 98% sensitive
 - 78% specific
- WBC-labeled scans
 - can help determine infection from other similar appearing etiologies
 - helpful to detect bony infection in the setting of hardware
 - hardware can cause metal artifact in an MRI making it difficult to assess for infection

• Studies

- Labs
 - WBC
 - may be normal in chronic or indolent infections
 - erythrocyte sedimentation rate (ESR)
 - may remain elevated for months following initial injury or surgery in absence of infection
 - C-reactive protein (CRP)
 - most predictive for postoperative infection in the first week after fracture fixation
 - should decrease from a plateau after postoperative day 2 (after fixation of fractures)
 - will increase further or fail to decrease if a hematoma or infection is present
- Cultures
 - in-office cultures swabs or aspirations of wounds or sinus tracts are unreliable
 - intraoperative deep cultures are most reliable method of isolated causative organisms
 - multiple specimens from varying locations should be obtained

• Treatment

- Nonoperative
 - **chronic suppression with antibiotics**
 - indications
 - risk of surgical treatment outweighs the benefit to the host
 - immunosuppressed, elderly, etc.
 - presence of an infected but incompletely healed fracture following internal fixation
 - technique
 - ESR and CRP levels used to assess adequacy of treatment
 - outcomes
 - 32% rate of chronic infected nonunion persisting or worsening despite suppression
- Operative
 - **surgical debridement**
 - indications

- any active infection
- technique
 - hardware should be maintained if stability at risk with removal
 - low-pressure irrigation with normal saline may be superior to other methods of irrigation
 - thorough identification and debridement of infection key to success
 - deep bony specimens should be obtained for culture as well as biopsy
- outcomes
 - 71% success seen with debridement and antibiotics for early acute postoperative infection
 - Risk factors for failure include intramedullary nail and open fracture

14- Brachial Plexus Injuries

Images



• summary

- Brachial plexus injuries (BPIs) can involve any degree of injury at any level of the plexus and range from obstetric injuries to traumatic avulsions.
- Diagnosis requires focused physical examination with EMG/NCS and MRI studies used for confirmation as needed.
- Treatment can be conservative versus operative depending on the age of patient, chronicity of injury, degree of injury and nerve root involvement.

• Epidemiology

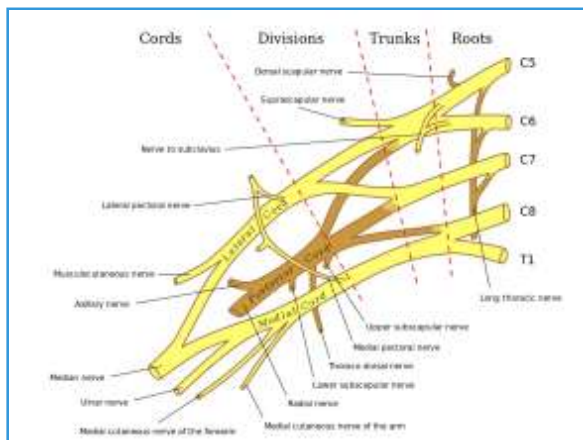
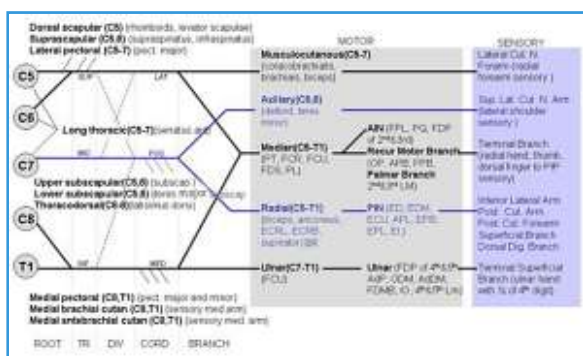
- Anatomic location
 - supraclavicular injuries
 - complete involvement of all roots is most common
 - 75%-80% of traumatic BPIs
 - C5 and C6 upper trunk (Erb palsy)
 - 20%-25% of traumatic BPIs
 - C8, T1 or lower (Klumpke palsy)
 - 0.6%-3.0% of traumatic BPIs

• Etiology

- Mechanism
 - high speed vehicle accidents (mostly motorcycle)
 - 83% of traumatic BPIs
 - caudally forced shoulder
 - predominantly affect upper brachial plexus
 - with high enough energy all roots can be affected
 - forced arm abduction (as in grabbing onto something while falling)
 - predominantly affects lower roots
- Brachial Plexus injuries include
 - traumatic injury (this topic)
 - obstetric brachial plexus injury
 - Erb's palsy
 - Klumpke palsy
 - burners and stingers
 - Parsonage-Turner Syndrome

• Anatomy

- Anatomy
 - brachial plexus motor and sensory innervation



• Classification

◦ Preganglionic vs. postganglionic

■ preganglionic

■ avulsion proximal to dorsal root ganglion

- involves CNS which does not regenerate - little potential recovery of motor function (poor prognosis)

■ lesions suggesting preganglionic injury:

■ Horner's syndrome

- disruption of sympathetic chain

■ winged scapula medially

- loss of serratus anterior (long thoracic nerve) leads to medial winging (inferior border goes medial)
- loss of rhomboids (dorsal scapular nerve) leads to lateral winging (superior medial border drops downward and protrudes laterally and posteriorly)

■ presents with motor deficits (flail arm)

- both pre- and postganglionic lesions can present with flail arm

■ sensory absent

■ absence of a Tinel sign or tenderness to percussion in the neck

■ normal histamine test (C8-T1 sympathetic ganglion)

- intact triple response (redness, wheal, flare)

■ elevated hemidiaphragm (phrenic nerve)

■ rhomboid paralysis (dorsal scapular nerve)

■ serratus anterior (long thoracic nerve)

■ normal sensory nerve action potential (SNAP)

■ evaluation

- EMG may show loss of innervation to cervical paraspinals

■ postganglionic

■ involve PNS, capable of regeneration (better prognosis)

■ presentation

- presents with motor deficit (flail arm)

■ sensory deficits

■ evaluation

- EMG shows maintained innervation to cervical paraspinals

■ abnormal histamine test

- only redness and wheal, but NO flare

◦ Classification based on location

■ Upper Lesion: Erb's Palsy (C5,6)		
■ Introduction Most common obstetric brachial plexopathy ■ Results from an excessive displacement of head to opposite side and depression of shoulder on the same side producing traction on plexus. Occurs during a difficult delivery in infants or fall onto shoulder in adults Best prognosis		■ Physical Exam Clinically, the arm will be adducted, internally rotated, at shoulder; pronated, extended at elbow (â€œwaiterâ€™s tipâ€) ■ C5 deficiency -axillary nerve deficiency (weakness in deltoid, teres minor) -suprascapular nerve deficiency (weakness in supraspinatus, infraspinatus) -musculocutaneous nerve deficiency (weakness to biceps) C6 deficiency -radial nerve deficiency (weakness in brachioradialis, supinator)
■ Lower Lesion: Klumpke Palsy (C8,T1)		
■ Introduction ■ Rare in obstetric palsy Usually avulsion injuries caused by excessive abduction (person falling from height clutching on an object to save himself) Other causes may include cervical rib, or lung mets in lower deep cervical lymph nodes Frequently associated with a preganglion injury and Horner's Syndrome Poor prognosis ■		■ Physical Exam ■ Deficit of all of the small muscles of the hand (ulnar and median nerves) Clinically, presents as â€œclaw handâ€ -wrist held in extreme extension because of the unopposed wrist extensors -hyperextension of MCP due to loss of hand intrinsics -flexion of IP joints due to loss of hand intrinsics
■ Total Palsy (C5-T1)		■
■ Introduction A form of brachial plexopathy Worst prognosis	■ Physical Exam Leads to a flaccid arm ■ Involves both motor and sensory	
■	■	

• Presentation

- History
 - high energy injury
- Physical exam
 - Horner's syndrome
 - features include
 - drooping of the eyelid
 - pupillary constriction
 - anhidrosis
 - usually show up three days after injury
 - represents disruption of sympathetic chain via C8 and/or T1 root avulsions
 - severe pain in anesthetized limb
 - correlates with root avulsion
 - important muscles to test
 - serratus anterior (long thoracic nerve) and rhomboids (dorsal scapular nerve)
 - if they are functioning then it is more likely the C5 injury is postganglionic
 - pulses
 - check radial, ulnar and brachial pulses
 - arterial injuries common with complete BPIs

• Imaging

- Radiographs
 - chest radiograph
 - recommended views

- PA and lateral
 - fractures to the first or second ribs suggest damage to the overlying brachial plexus
 - evidence of old rib fractures can be important if an intercostal nerve is needed for nerve transfer
 - inspiration and expiration can demonstrate a paralyzed diaphragm (indicates upper nerve root injury)
- cervical spine series
 - recommended views
 - AP and lateral
 - transverse process fracture likely indicates a root avulsion
- scapular and shoulder series
 - recommended views
 - at least AP and axillary (or equivalent)
 - scapulothoracic dissociation is associated with root avulsion and major vascular injury
- clavicle
 - recommended views
 - orthogonal views
 - fracture may indicate brachial plexus injury
- CT myelography
 - indications
 - gold standard for defining level of nerve root injury
 - avulsion of cervical root causes dural sheath to heal with meningocele
 - scan should be done 3-4 weeks after injury
 - allows blood clot in the injured area to dissipate and meningocele to form
- MRI
 - indications
 - suspect injury is distal to nerve roots
 - can visualize much of the brachial plexus
 - CT/myelogram demonstrates only nerve root injury
 - findings
 - traumatic neuromas and edema
 - mass lesions in nontraumatic neuropathy of brachial plexus and its branches
 - consistent with injury include
 - pseudomeningocele (T2 highlights water content present in a pseudomeningocele)
 - empty nerve root sleeves (T1 images highlight fat content nerve roots and empty sleeves)
 - cord shift away from midline (T1 highlights fat of cord)
- Studies
 - Electromyography (EMG)
 - tests muscles at rest and during activity
 - fibrillation potentials (denervation changes)
 - as early as 10-14 days following injury in proximal muscles
 - as late as 3-6 weeks in distal muscles
 - can help distinguish preganglionic from postganglionic
 - examine proximally innervated muscles that are innervated by root level motor branches
 - rhomboids
 - serratus anterior
 - cervical paraspinals
 - Nerve conduction velocity (NCV)
 - performed along with EMG
 - measures sensory nerve action potentials (SNAPs)
 - distinguishes preganglionic from postganglionic
 - SNAPs preserved in lesions proximal to dorsal root ganglia
 - cell body found in dorsal root ganglia
 - if SNAP normal and patient insensate in ulnar nerve distribution
 - preganglionic injury to C8 and T1
 - if SNAP normal and patient insensate in median nerve distribution
 - preganglionic injury to C5 and C6

- Nerve action potential (NAPs)
 - often intraoperative
 - tests a nerve across a lesion
 - if NAP positive across a lesion
 - preserved axons
 - or significant regeneration
 - can detect reinnervation months before EMG
 - NAP negative- neuropraxic lesion
 - NAP positive- axonotmetic lesion
- Sensory and Motor Evoked Potential
 - more sensitive than EMG and NCV at identifying continuity of roots with spinal cord (positive finding)
 - a negative finding can not differentiate location of discontinuity (root avulsion vs. axonotmesis)
 - perform 4-6 weeks after injury to allow for Wallerian degeneration to occur
 - stimulation done at Erb's point and recording done over cortex with scalp electrodes (transcranial)

• Treatment

- Nonoperative
 - **observation alone waiting for recovery**
 - indications
 - most managed with closed observation
 - guns shot wounds (in absence of major vascular damage can observe for three months)
 - signs of neurologic recovery
 - advancing Tinel sign is best clinical sign of effective nerve regeneration
- Operative
 - **immediate surgical exploration** (< 1 week)
 - indications
 - sharp penetrating trauma (excluding GSWs)
 - iatrogenic injuries
 - open injuries
 - progressive neurologic deficits
 - expanding hematoma or vascular injury
 - techniques
 - nerve repair
 - nerve grafting
 - neurotization
 - **early surgical intervention** (3-6 weeks)
 - indicated for near total plexus involvement and with high mechanism of energy
 - **delayed surgical intervention** (3-6 months)
 - indications
 - partial upper plexus involvement and low energy mechanism
 - plateau in neurologic recovery
 - best not to delay surgery beyond 6 months
 - techniques
 - usually involves tendon/muscle transfers to restore function

• Techniques

- **Direct nerve repair**
 - rarely possible due to traction and usually only possible for acute and sharp penetration injuries
- **Nerve graft**
 - commonly used due to traction injuries (postganglionic)
 - preferable to graft lesions of upper and middle trunk
 - allows better chance of reinnervation of proximal muscles before irreversible changes at motor end plate
 - donor sites include sural nerve, medial brachial nerve, medial antebrachial cutaneous nerve
 - vascularized nerve graft includes ulnar nerve when there is a proven C8 and T1 avulsion (mobilized on superior ulnar collateral artery)
- **Neurotization (nerve transfer)**

- transfer working but less important motor nerve to a nonfunctioning more important denervated muscle
- use extraplexal source of axons
 - spinal accessory nerve (CN XI)
 - intercostal nerves
 - contralateral C7
 - hypoglossal nerve (CN XII)
- intraplexal nerves
 - phrenic nerve
 - portion of median or ulnar nerves
 - pectoral nerve
 - Oberlin transfer
 - ulnar nerve used for upper trunk injury for biceps function
- **Muscle or tendon transfer**
 - indications
 - isolated C8-T1 injury in adult (reinnervation unlikely due to distance between injury site and hand intrinsic muscles)
 - priorities of repair/reconstruction
 - elbow flexion (musculocutaneous nerve)
 - shoulder stability (suprascapular nerve)
 - brachial-thoracic pinch (pectoral nerve)
 - C6-C7 sensory (lateral cord)
 - wrist extension / finger flexion (lateral and posterior cords)
 - wrist flexion / finger extension
 - intrinsic function
 - technique
 - gracilis most common free muscle transfer
- **Prognosis**
 - Recovery of reconstructed plexus can take up to 3 years
 - nerve regeneration occurs at speed of 1mm/day
 - Good prognostic variables
 - infraclavicular plexus injuries have better prognosis than supraclavicular injuries
 - upper plexus injuries have improved prognosis
 - preservation of hand function
 - Poor prognostic variables
 - root avulsion (preganglionic injuries) have worst prognosis
 - not repairable
 - other surgeries such as arthrodesis and tendon transfers may be needed

15- Sternoclavicular Dislocation

- summary

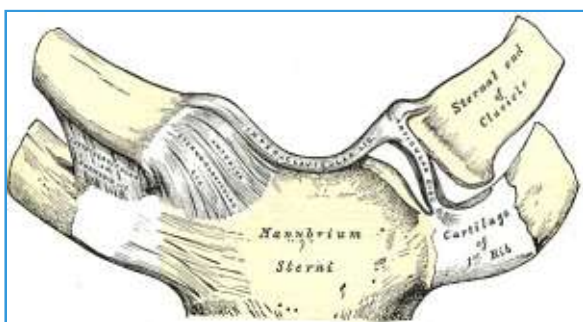
- Sternoclavicular Dislocations are uncommon injuries to the chest that consist of traumatic or atraumatic dislocations of the sternoclavicular joint.
- Diagnosis can be made with plain serendipity radiographic views. CT studies are generally required to assess for direction of displacement.
- Treatment is generally observation of atraumatic or chronic anterior dislocations. Closed versus open reduction is indicated for acute dislocations.

- Etiology

- Pathophysiology
 - traumatic dislocation
 - direction
 - anterior (more common)
 - posterior (mediastinal structures at risk)
 - important to distinguish from medial clavicle physeal fracture (physis doesn't fuse until age 20-25)
 - mechanism
 - usually high energy injury (MVA, contact sports)
 - atraumatic subluxation
 - occurs with overhead elevation of the arm
 - affected patients are younger
 - many demonstrate signs of generalized ligamentous laxity
 - subluxation usually reduces with lowering the arm
 - treatment is reassurance and local symptomatic treatment

- Anatomy

- Medial clavicle
 - first bone to ossify and last physis to close (age 20-25)
- Sternoclavicular joint
 - osteology
 - diarthrodial saddle joint
 - incongruous (~50% contact)
 - fibrocartilage
 - stability
 - stability depends on ligamentous structures



- posterior capsular ligament
 - most important structure for anterior-posterior stability
- anterior sternoclavicular ligament
 - primary restraint to superior displacement of medial clavicle
- costoclavicular (rhomboid) ligament
 - anterior fasciculus resists superior rotation and lateral displacement
 - posterior fasciculus resists inferior rotation and medial displacement
- intra-articular disk ligament
 - prevents medial displacement of clavicle
 - secondary restraint to superior clavicle displacement

- Presentation

- Symptoms

- anterior dislocation
 - deformity with palpable bump
 - posterior dislocations
 - dyspnea or dysphagia
 - tachypnea and stridor worse when supine

- Physical exam

- palpation
 - prominence that increases with arm abduction and elevation

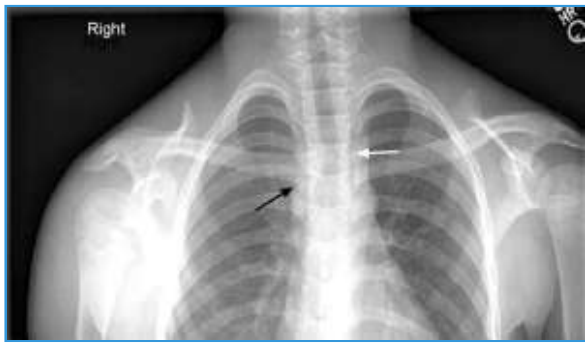
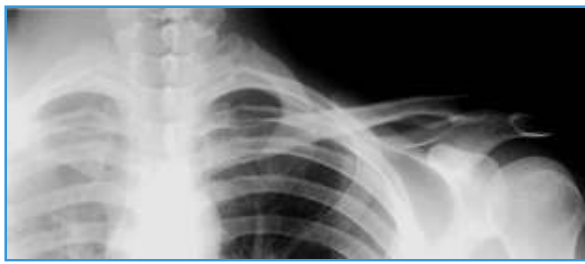


- ROM and instability
 - decreased arm ROM
 - neurovascular
 - parasthesias in affected upper extremity
 - venous congestion or diminished pulse when compared with contralateral side
 - provocative maneuvers
 - turning head to affected side may relieve pain

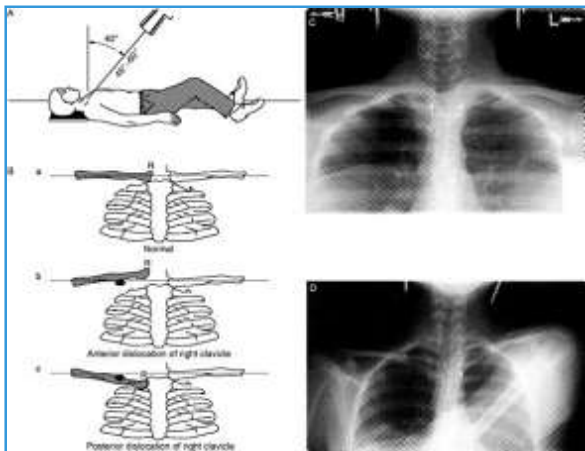
- Imaging

- Radiographs

- recommended views
 - AP and serendipity views
 - findings
 - difficult to visualize on AP



- serendipity views (beam at 40 cephalic tilt)



- anterior dislocation
 - affected clavicle above contralateral clavicle
- posterior dislocation
 - affected clavicle below contralateral clavicle

○ CT scan

- study of choice
- axial views can visualize mediastinal structures and injuries



- can differentiate from physeal fractures

• Treatment

○ Nonoperative

- **reassurance and local symptomatic treatment**
 - indications
 - atraumatic subluxation
 - chronic anterior dislocation that is minimally symptomatic (> 3 weeks old)
 - technique
 - sling for comfort
 - return to unrestricted activity by 3 months

○ Operative

- **closed reduction under general anesthesia +/- thoracic surgery back-up**
 - indications
 - acute anterior dislocations (< 3weeks old)
 - acute posterior dislocations (< 3weeks old)
 - if reduction stable
 - velpeau bandage for 6 weeks
 - may need plaster jacket or figure of eight bandage to distract shoulder
 - elbow exercises at 3 weeks
 - return to sports at 3 months
 - if reduction unstable
 - accept deformity or open reduction and soft-tissue reconstruction
- **open reduction and soft-tissue reconstruction +/- thoracic surgery back-up**



- indications
 - acute posterior dislocation with failed closed reduction
 - dysphagia
 - shortness of breath
 - decreased peripheral pulses
 - chronic anterior or posterior dislocation that remains persistently symptomatic
- presense of cardiothoracic (CT) surgery is controversial
 - recent studies state that the recommendation for routine involvement of thoracic surgeons in all casesÂ may not be necessary
- **medial clavicle excision**
 - indications
 - outdated procedure
 - rarely performed

• Techniques

○ **Closed reduction under general anesthesia**

- reduction technique
 - place patient supine with arm at edge of table and prep entire chest
 - abduct and extend arm while applying axial traction and direct pressure
 - simultaneously apply direct posterior pressure over medial clavicle
 - manipulate medial clavicle with towel clip or fingers

○ **Open reduction and soft-tissue reconstruction**

- approach
 - curvilinear incision overlying medial 1/4th of clavicle, SC joint and top of manubrium
 - care to not disrupt the SCM tendon sheath
 - clean incision through the SCJ capsule to allow for repair at the end
- technique

- figure of 8 tendon reconstruction using 2 drill holes in the manibrium and 2 in the medial distal clavicle
- holes should be 1 cm apart to avoid cortical fracture
- gracilis or semitendinosus allograft/autograft most commonly used

- **Medial clavicle excision**

- approach
 - incision made over medial clavicle



- resection
 - costoclavicular ligaments must be preserved
 - preserve by resecting < 15mm of medial clavicle
 - repair if injured

- **Complications**

- Cosmetic deformity

16- Clavicle Fractures Midshaft

Images



• Summary

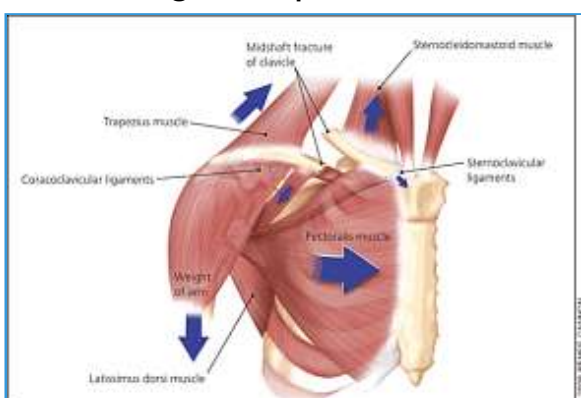
- Midshaft Clavicle fractures are common traumatic injuries caused by a direct impact to the shoulder girdle and is most commonly seen in young, active adults.
- Diagnosis can be made radiographically with AP and cephalic tilt clavicle x-rays.
- Treatment is nonoperative or operative based on patient activity and demands, along with degree of displacement, shortening, and comminution.

• Epidemiology

- Incidence
 - common
 - incidence
 - 1 in 1000 people per year
 - prevalence
 - clavicle fractures account for 2.6-4% of all adult fractures
- Demographics
 - often seen in young, active patients
 - most common in males < 30 years old
- Location
 - 75-80% of all clavicle fractures will occur in the middle third segment

• Etiology

- Pathophysiology
 - mechanism of injury
 - fall onto lateral aspect of shoulder (85%)
 - direct impact to clavicle
 - pathoanatomy
 - junction of the outer and middle third is the thinnest part of the bone
 - prone to fracture with axial loading
 - only area not protected by or reinforced with muscle and ligamentous attachments
 - displaced fractures
 - medial fragment pulled posterosuperiorly by sternocleidomastoid muscle
 - lateral fragment pulled inferomedially by pectoralis major and weight of arm

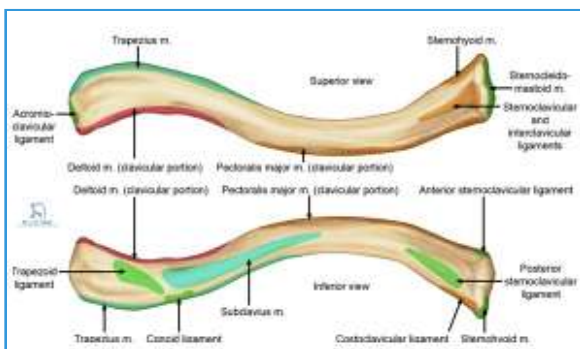


- open fractures usually result from medial fragment "buttonholing" through platysma

- Associated conditions
 - medical
 - pneumothorax
 - closed head injury
 - orthopedic
 - ipsilateral scapular fracture (floating shoulder)
 - scapulothoracic dissociation
 - traction injury
 - significantly distracted/widened fracture fragments
 - widened interval between scapula and spine
 - brachial plexus or vascular injury
 - rib fracture
 - neurovascular injury

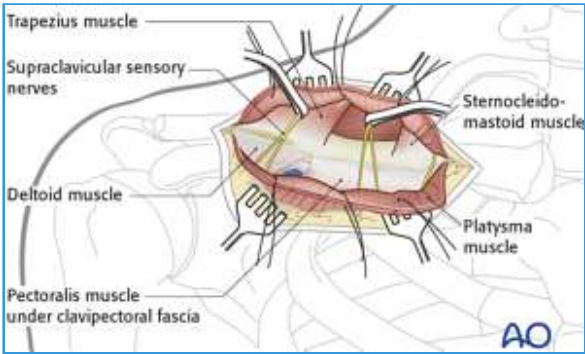
• ANATOMY

- Osteology
 - Shape
 - S-shaped bone
 - flat laterally, tubular centrally, and prismatic medially
- Articulations
 - sternoclavicular joint
 - four primary stabilizers
 - posterior capsular ligament
 - anterior sternoclavicular ligament
 - costoclavicular ligament
 - intra-articular disc
 - acromioclavicular joint
 - two primary stabilizers
 - coracoclavicular ligament
 - acromioclavicular ligament
- Ligaments
 - coracoclavicular (CC) ligaments
 - provide superior/inferior stability to AC joint
 - two components
 - trapezoid (lateral)
 - inserts 3 cm medial to distal clavicle
 - conoid (medial)
 - inserts 4.5 cm medial to distal clavicle
- Muscles



- sternocleidomastoid
 - pulls medial segment proximally
 - clavicular head originates superiorly on medial third
 - inserts on mastoid process
- deltoid
 - stabilizes distal clavicle and assists with shoulder abduction
 - shortening of clavicle decreases lever arm of deltoid
 - originates from anterior lateral third clavicle, acromion, and scapular spine
 - inserts on deltoid tuberosity
- trapezius
 - originates from occiput and C-T spine spinous process

- inserts on lateral posterosuperior third of clavicle, acromion, and scapular spine
- pectoralis major
 - pulls medially causing shortening
 - clavicular head originates from anteroinferior surface of medial half of clavicle
 - inserts on crest of greater tubercle of humerus, lateral to bicipital groove
- subclavius
 - protects NV structures which pass deep to muscle and displace clavicle inferiorly
 - originates from 1st rib and costal cartilage
 - inserts on undersurface of clavicle
- sternohyoid
 - originates on sternal end of clavicle
 - inserts on hyoid bone
- platysma
 - violated with skin tenting
 - originates from pectoral fascia
 - inserts mandible
- Neurovascular structures
 - supraclavicular nerves



- cutaneous nerves that run vertically over clavicle and supply superior chest wall
- subclavian vessel
 - passes posterior and underneath clavicle near junction of medial and middle third
 - subclavian vein closest to clavicle and anterior to artery and plexus
- brachial plexus
- Biomechanics
 - middle third is weakest portion of clavicle
 - thinnest and narrowest
 - transitional of the bone in both curvature and in cross-sectional anatomy
 - only area not supported by ligamentous or muscular attachments

• Classification

■ Neer Classification (simple)			
■ Nondisplaced	■ < 100% displacement	■ Nonoperative	■ 
■ Displaced	■ > 100% displacement	■ Operative	■ 

AO classification			
Type A = Simple	- A1 = spiral - A2 = oblique - A3 = transverse	Nonoperative vs. operative	
Type B = Wedge	- B1 = spiral wedge - B2 = bending wedge - B3 = fragmented wedge	Nonoperative vs. operative	
Type C = Complex	- C1 = complex spiral - C2 = segmental - C3 = irregular	Operative	

• Presentation

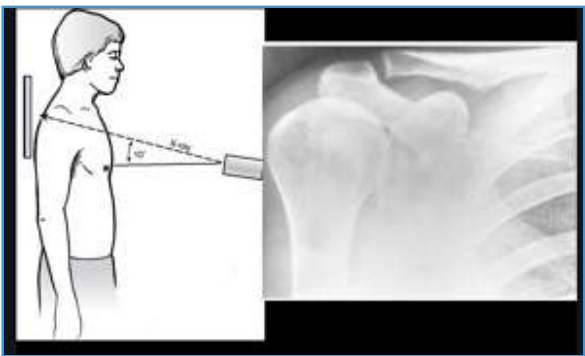
- History
 - popping or cracking sound near shoulder after fall
- Symptoms
 - acute onset of anterior shoulder pain or directly over clavicle
- Physical exam
 - inspection
 - tender, swelling, crepitus and deformity over clavicle
 - skin tenting (impending open fracture)



- neurovascular exam
 - assess subclavian vessels and brachial plexus

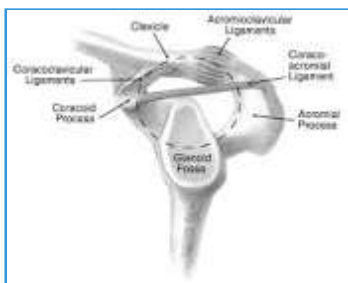
• Imaging

- Radiographs
 - recommended views
 - clavicle series
 - upright AP clavicle
 - supine may underappreciate displacement with gravity eliminated
 - 15° cephalic tilt (zanca view)



- eliminates overlapping scapula
 - shoulder series
 - evaluate for other injuries (ie proximal humerus, scapula)
 - optional views
 - upright chest x-ray
 - compare shortening with contralateral side
 - evaluate for pneumothorax

- findings
 - superior displacement of medial fragment
 - inferior displacement of lateral fragment
 - shortening
 - measurements
 - shortening
 - two methods
 - AP clavicle - distance between the corresponding ends of the medial and lateral fragments
 - AP chest - direct comparison of length of clavicle to the contralateral side
 - shortening >2cm associated with decrease shoulder strength and endurance
 - displacement
 - displacement relative to width of clavicle (percent)
 - >100% displacement is a risk factor for nonunion
 - CT
 - indications
 - assess fracture pattern for preop planning
 - comminution, shortening, articular extension, nonunion
 - vascular injury
 - medial clavicle fracture
 - SC joint dislocation
 - views
 - axial, coronal and 3D reconstruction most useful
 - with contrast if concern for vascular injury
- Differential
 - Adult distal third clavicle fx
 - older, osteoporotic patient
 - x-ray may show increased CC distance
 - Sternoclavicular dislocation
 - high energy mechanism
 - may present with dysphagia, stridor, asymmetric pulses, paresthesias due to compression of surrounding structures
 - serendipity view or CT best demonstrate displacement
 - Acromioclavicular Joint Injury
 - pain and prominence more lateral over AC joint
 - zanca or axillary views shows displaced distal clavicle relative to acromion
 - Treatment
 - Nonoperative
 - indications
 - < 2cm shortening and displacement
 - < 1cm displacement of the superior shoulder suspensory complex



- closed and no neurovascular injury
- low demand patient
- modalities
 - sling
 - figure-of-8 strap
 - elevate and extend shoulder to bring distal fragment to the proximal fragment
- outcomes
 - figure-of-8 associated with more pain, shortening, and lower compliance than sling
 - no difference in functional or cosmetic outcomes between sling and figure-of-eight braces

- Operative
 - indications
 - absolute
 - open fractures
 - displaced fracture with skin tenting



- subclavian artery or vein injury
 - floating shoulder (clavicle and scapular neck fracture)
 - relative and controversial indications
 - displaced with > 2cm shortening
 - bilateral displaced clavicle fractures
 - brachial plexus injury (questionable because 66% have spontaneous return)
 - closed head injury
 - seizure disorder
 - polytrauma patient
 - techniques
 - intramedullary fixation
 - open reduction internal fixation with plate and screws
 - outcomes
 - operative fixation has higher union rate (>94%)
 - similar or better functional outcomes than nonoperative
 - faster time to union - operative (16.4 weeks) vs. non-operative (28 .4 weeks)

• Techniques

○ Sling Immobilization

- technique
 - immobilize using sling or figure-of-eight brace
 - no attempt at reduction should be made
 - rehab
 - gentle passive ROM exercises at 2 weeks
 - strengthening exercises begin at 6 weeks
 - return to sports at 4-6 months
- advantage
 - overall good outcomes
 - avoid surgical/hardware complications
- disadvantage
 - higher nonunion rate compared to operative management
 - slower time to union
- complications
 - nonunion (10-15%)
 - malunion
 - poor cosmesis
 - decreased shoulder strength and endurance
 - displaced midshaft clavicle fractures healed with > 2cm of shortening

○ Open Reduction Internal Fixation with Plate

- approach
 - beach chair vs. supine
 - direct superior vs. anterior incision
- technique
 - plate configuration
 - anterior plating

- superior plating (compared to anterior plating)
 - higher load to failure
 - increased plate strength with inferior bone comminution
 - increased risk of neuromuscular injury
 - decreased removal of deltoid attachment
- dual plating
 - low rate of symptomatic hardware removal (0-3.7%)
 - biomechanically equivalent or superior to single 3.5mm plate
- plate options
 - limited contact, pre-contoured, 3.5mm dynamic compression plate
 - 3.5mm reconstruction plate
 - 2.0mm, 2.4mm and 2.7mm plates can be used and combined for dual plating
- advantages
 - improved results with ORIF for clavicle fractures with > 2cm shortening and > 100% displacement
 - improved functional outcomes/less pain with overhead activity
 - faster time to union
 - decreased symptomatic nonunion and malunion rate
 - improved cosmetic satisfaction
 - improved overall shoulder satisfaction
 - increased shoulder strength and endurance
- disadvantage
 - increased risk of need for future procedures
 - implant removal
 - debridement for infection
- complications
 - hardware irritation
 - infection
 - neurovascular injury
 - supraclavicular nerve injury
 - hardware failure
 - pneumothorax
- postoperative Rehabilitation
 - early
 - sling for 7-10 days followed by active motion
 - late
 - strengthening at ~6 weeks when pain-free motion and radiographic evidence of union
 - full activity including sports at ~3 months

○ Intramedullary Fixation



- technique
 - positioning
 - beach chair or supine
 - approach
 - percutaneous or mini-open
 - implant choices
 - intramedullary nail

- goal size of intramedullary nail is 30-40% of midshaft diameter
 - cannulated screws
 - titanium elastic nail
 - Hagle pin
- advantages
 - smaller incision
 - less soft-tissue disruption
 - avoids supraclavicular nerves that are commonly injured with plating
 - best for simple patterns
- disadvantages
 - higher complication rate
 - hardware migration, implant irritation, secondary procedures
 - biomechanically inferior to plating
 - unable to lock and control rotation
 - typically requires hardware removal at 6 months
- contraindications
 - substantial comminution
 - segmental fractures
- complications
 - hardware migration
 - loss of reduction

• Complications

- Nonoperative treatment
 - nonunion (~15%)
 - risk factors
 - fracture comminution (Z deformity)
 - fracture displacement
 - female gender
 - advanced age
 - smoker
 - predictors at 6 week
 - motion at fracture site, no callus on x-ray, DASH >40
 - 0 - 3% nonunion
 - 2 or 3 - 60% nonunion
 - treatment
 - if asymptomatic, no treatment necessary
 - if symptomatic, ORIF with plate and bone graft (particularly atrophic nonunion)



- malunion (~20%)
 - definition
 - shortening > 3cm
 - angulation > 30°
 - translation > 1cm
 - presentation
 - pain and increased fatigue with overhead activities
 - thoracic outlet syndrome
 - dissatisfaction with appearance
 - difficulty with shoulder straps and backpacks
 - treatment
 - clavicle osteotomy with bone grafting, if symptomatic

- Operative treatment
 - hardware prominence
 - 8-30% of patient request plate removal
 - superior plates associated with increased irritation
 - neurovascular injury
 - superior plates associated with increased risk of subclavian artery or vein penetration
 - subclavian thrombosis
 - supraclavicular nerve injury
 - most common complication
 - 83% incidence of numbness noted at 2 weeks postop
 - can improve over time with ~50% having persistent numbness at 1 year
 - nonunion (1-5%)
 - infection (~4.8%)
 - risk factors
 - illicit drug use
 - diabetes
 - previous shoulder surgery
 - mechanical failure (~1.4%)
 - pneumothorax
 - adhesive capsulitis
 - 4% in surgical group develop adhesive capsulitis requiring surgical intervention

17- Clavicle Fractures Distal

- Summary

- Distal clavicle fractures are traumatic injuries usually caused by direct trauma to the shoulder from a fall in adults.
- Diagnosis is confirmed with standard shoulder radiographs and a 15° cephalic tilt view (zanca view).
- Treatment is immobilization or surgery, depending on the displacement and stability of the distal clavicle, as determined by whether coracoclavicular (CC) ligaments (trapezoid and conoid) are intact.

- Epidemiology

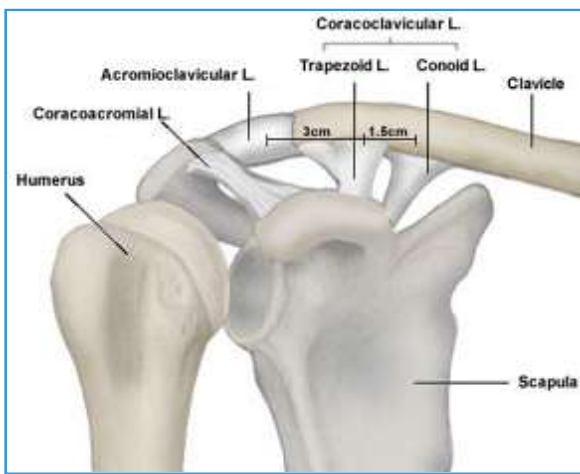
- Incidence
 - common
 - clavicle fractures account for 2.6-4% of all adult fractures
- Demographics
 - more commonly in older or osteoporotic patients
 - less common in pediatric patients
- Anatomic location
 - 10-25% of all clavicle fractures occur in the distal third segment

- Etiology

- Pathophysiology
 - mechanism
 - similar mechanism to midshaft clavicle fractures
 - usually occurs after a direct compressive force is applied to the shoulder, i.e. after a fall or trauma
 - pathoanatomy
 - fracture displacement corresponds to
 - fracture location (e.g. extra-articular vs. intra-articular)
 - fracture pattern (e.g. simple vs. comminuted)
 - integrity of the coracoclavicular ligaments
 - conoid (medial) and trapezoid (lateral) provide primary resistance to superior displacement of the lateral clavicle
 - age (e.g. pediatric patients usually have an intact periosteal sleeve)
 - deforming forces include
- Associated conditions
 - rare but may include
 - floating shoulder
 - scapulothoracic dissociation
 - should be considered with significantly distracted or widened fractures
 - rib fracture
 - pneumothorax
 - neurovascular injury

- Anatomy

- Acromioclavicular joint anatomy
- AC joint stability



- static stabilizers
 - acromioclavicular (AC) ligament
 - provides anterior/posterior stability
 - inserts 6 mm from distal end of clavicle
 - components
 - superior
 - inferior
 - anterior
 - posterior
 - superior ligament is strongest, followed by posterior
 - coracoclavicular (CC) ligaments (trapezoid and conoid)
 - provides superior/inferior stability
 - components
 - trapezoid ligament (lateral)
 - inserts 2 cm from distal end of clavicle
 - conoid ligament (medial)
 - inserts 4 cm from distal end of clavicle in the posterior border
 - conoid ligament is strongest
 - capsule
- dynamic stabilizers
 - deltoid
 - trapezius

- Classification

○

○

○

■ Type A = nondisplaced + intact CC ligaments	■ A1 = extra-articular ■ A2 = intra-articular	■ Nonoperative	■
■ Type B = displaced + intact CC ligaments	■ B1 = extra-articular ■ B2 = comminuted	■ Nonoperative vs. Operative	■
■ Type C = displaced + torn CC ligaments	■ C1 = extra-articular ■ C2 = intra-articular	■ Operative	■

- Presentation
 - Symptoms
 - anterior shoulder pain
 - Physical exam
 - swelling, ecchymosis, tenderness to palpation
 - AC joint deformity
 - may have tenting of skin (impending open fracture)
 - perform careful neurovascular exam
 - suprascapular nerve is at risk of injury
 - can see weakness of external rotation with the arm in adduction
- Imaging
 - Radiographs
 - recommended views
 - upright AP of bilateral shoulders
 - axillary lateral
 - 15° cephalic tilt (zanca view)
 - helps to determine superior/inferior displacement
 - may consider having the patient hold 5-10 lbs of weight in the affected hand
 - CT
 - views
 - coronal, sagittal, axial
 - 3D reconstruction views
 - findings
 - may help evaluate displacement, shortening, comminution, articular extension, and nonunion
- Differential
 - Clavicle shaft fractures
 - Pediatric medial clavicle physeal injury
 - Pediatric distal clavicle physeal injury
 - Acromioclavicular separation
- Treatment
 - Nonoperative
 - **sling immobilization with gentle ROM exercises at 2-4 weeks and strengthening at 6-10 weeks**
 - indications
 - stable fractures (Neer Type I, III, IV)
 - pediatric distal clavicle fractures (skeletally immature)
 - Operative
 - **open reduction internal fixation**
 - indications
 - absolute
 - open or impending open fractures
 - subclavian artery or vein injury
 - floating shoulder (distal clavicle and scapula neck fractures with > 10mm of displacement)
 - symptomatic nonunion
 - relative
 - unstable fracture patterns (Neer Type IIA, IIB, V)
 - brachial plexus injury (questionable because 66% have spontaneous return)
 - closed head injury
 - seizure disorder
 - polytrauma patient
- Techniques
 - **Sling Immobilization**

- technique
 - immobilize using sling or figure-of-eight brace
 - prospective studies have not shown a difference in functional or cosmetic outcomes between sling and figure-of-eight braces
 - no attempt at reduction should be made
 - begin gentle range of motion exercises after 2-4 weeks
 - strengthening exercises begin at 6-10 weeks

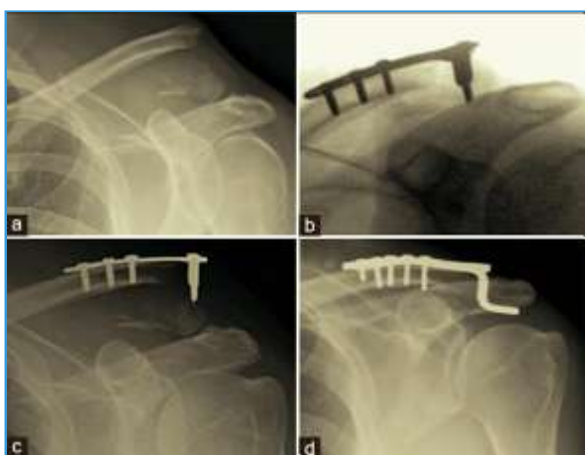
- outcomes
 - nonunion (~15%)
 - risk factors
 - Neer group II (up to 56%)
 - disrupted CC ligaments
 - advanced age
 - female gender
 - poorer cosmesis

○ **Open Reduction Internal Fixation**

- techniques
 - limited contact dynamic compression plate



- position
 - beach chair vs. supine
- approach
 - superior approach to AC joint
 - temporary fixation with k wires
- instrumentation
 - locking plates
 - precontoured anatomic plates
- technique
 - need larger distal fragment for multiple locking screws
 - > 3-4 bicortical screws into medial fragment to reduce the risk of screw pull-out



- hook plate



- position
 - beach chair vs. supine
- approach
 - superior approach to AC joint

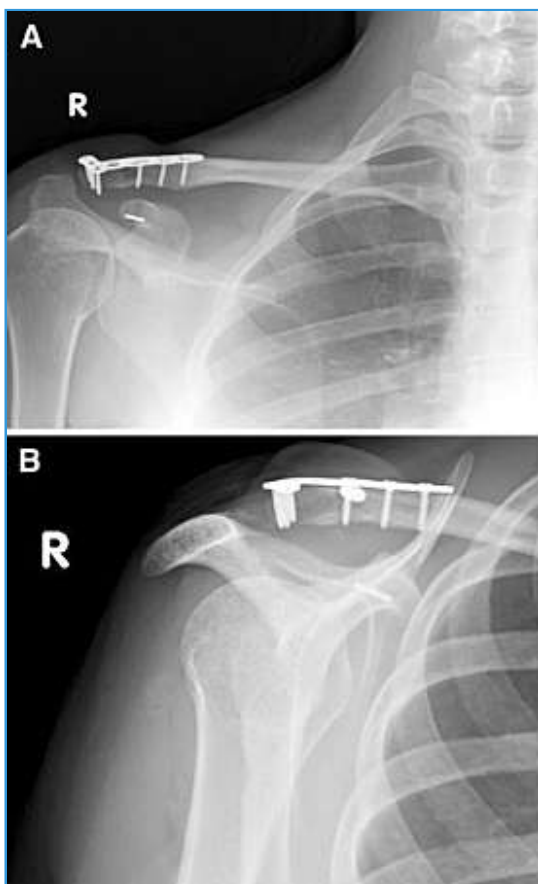
- temporary fixation with k wires
- instrumentation
 - hook plates vary in hook depth and number of holes
 - proper hook depth ensures the AC joint is not over- or under-reduced
- technique
 - hook plates are generally used when there is insufficient bone in the distal fragment for conventional clavicle plate fixation
 - hook should be placed posterior to AC joint and positioned as far lateral as possible to avoid hook escape



- > 3-4 bicortical screws should be placed into the proximal (medial) fragment to reduce the risk of screw pull-out
 - requires a second procedure for hook plate removal
- other options
 - AC joint spanning fixation
 - usually used as an alternative to hook plates
 - transacromial fixation
 - tension band wire
 - intramedullary screw fixation



- coracoclavicular ligament repair/reconstruction



- modified Weaver-Dunn procedure
 - primarily used for AC dislocations
 - can also be used for distal clavicle fractures with an easily excisable fragment and transferable CA ligament
- advantages
 - higher union rates
 - faster time to union

- improved functional outcome/less pain with overhead activity
- decreased symptomatic malunion rate
- improved cosmetic satisfaction
- disadvantages
 - increased risk of need for future procedures (e.g, removal of hook plate)
 - symptomatic hardware
 - infection
- postoperative rehabilitation
 - early
 - sling for 7-10 days followed by active motion
 - late
 - strengthening at ~6 weeks when pain-free motion and radiographic evidence of union
 - full activity including sports at ~3 months
 - hardware removal considered usually after 3 months

• Complications

- Nonoperative treatment
 - nonunion (~15%)
 - risk factors
 - comminution
 - displacement
 - Z deformity
 - female
 - older
 - smoker
 - distal third clavicle > middle third clavicle
 - treatment
 - if asymptomatic, no treatment necessary
 - if symptomatic, ORIF with plate and bone graft (particularly atrophic nonunion)
 - AC joint arthritis
 - risk factors
 - Neer Type I and III
 - treatment
 - distal clavicle resection
- Operative treatment
 - hardware prominence
 - ~30% of patient request plate removal
 - superior plates associated with increased irritation
 - hardware removal
 - most common with hook plates
 - neurovascular injury (3%)
 - superior plates associated with increased risk of subclavian artery or vein penetration
 - subclavian thrombosis
 - nonunion (1-5%)
 - infection (~4.8%)
 - mechanical failure (~1.4%)
 - pneumothorax
 - adhesive capsulitis
 - 4% in surgical group develop adhesive capsulitis requiring surgical intervention

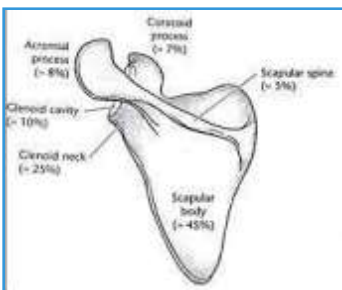
18- Scapula Fractures

- summary

- Scapula Fractures are uncommon fractures to the shoulder girdle caused by high energy trauma and associated with pulmonary injury, head injury, and increased injury severity scores.
- Diagnosis can be made with plain radiographs and CT studies are helpful for fracture characterization and surgical planning.
- Treatment is usually nonoperative with a sling. Surgical management is indicated for intra-articular fractures, displaced scapular body/neck fractures, open fractures, and those associated with glenohumeral instability.

- Epidemiology

- Incidence
 - rare
 - <1% of all fractures
 - 3-5% of shoulder girdle fractures
- Demographics
 - age
 - commonly between 25-50
 - males > females
- Location

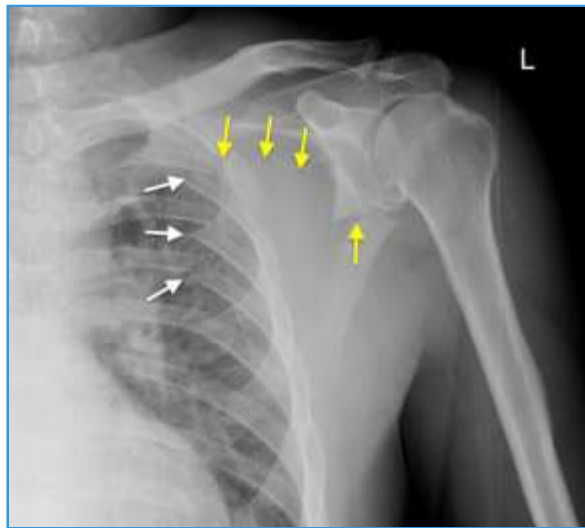


- scapular body/spine = 45-50%
- glenoid = 35%
 - glenoid neck = 25%
 - glenoid fossa/rim = 10%
 - often associated with impaction of humeral head into glenoid
- acromion = 8%
- coracoid = 7%

- Etiology

- Pathophysiology
 - mechanism of injury
 - high-energy trauma (80-90%)
 - motor vehicle collisions
 - account for >70% of scapula fractures
 - indirect trauma through fall on outstretched hand
 - glenohumeral dislocation
 - anterior dislocation leads to anterior rim fracture
 - posterior dislocation leads to posterior rim fracture
 - seizure
 - electric shock
- Associated injuries (in 80-95%)
 - medical
 - thoracic injury (80%)
 - hemothorax/pneumothorax (>30%)
 - pulmonary contusion (>40%)
 - head injury (35-50%)

- orthopaedic
 - rib fractures (53%)

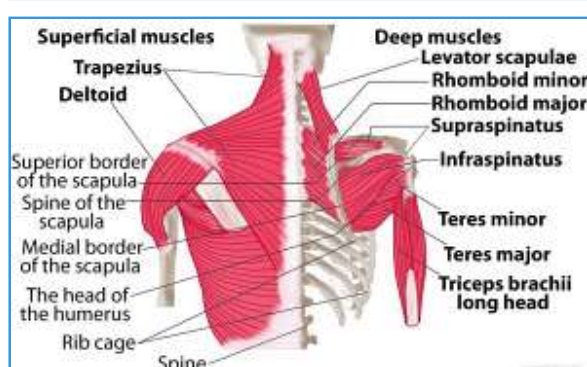
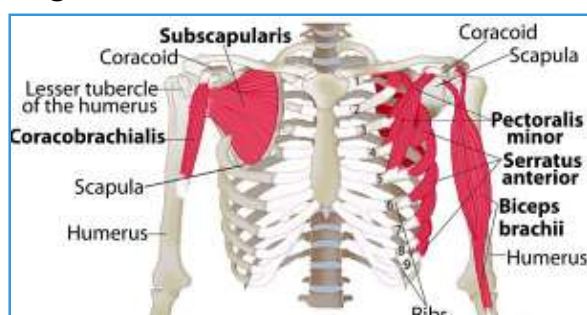


- ipsilateral extremity injury (50%)
 - ipsilateral clavicle fractures (25%)
- spine fracture (26-30%)
- pelvic ring/acetabular fractures (15%)
 - scapula fracture is important predictor
- upper extremity vascular injury (11%)
 - subclavian and axillary arteries at risk
 - higher risk with scapulothoracic dissociation
- brachial plexus injury (5-13%)
 - 75% of brachial plexus injuries resolve
 - complete brachial plexus injuries less likely to resolve

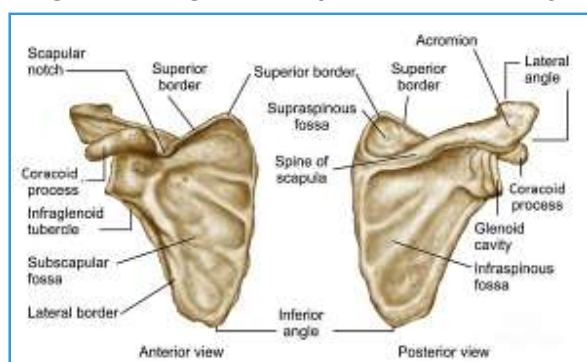
• Anatomy

○ Osteology

- scapular body
 - origin or insertion of 18 muscles

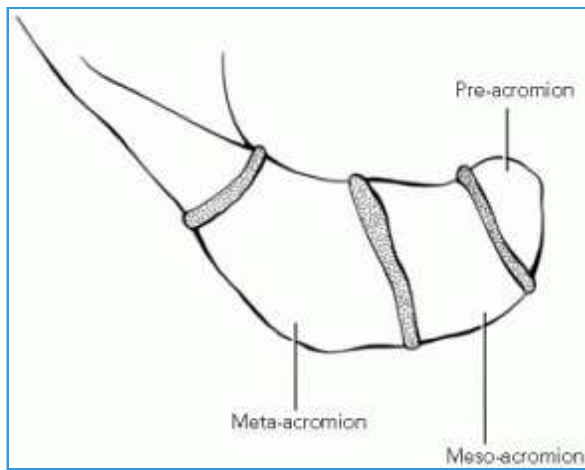


- function to connect scapula to thorax, spine and upper extremity
- large triangle shape with 4 major processes



- scapular spine
 - osseous bridge separating supraspinatus and infraspinatus
 - spinoglenoid notch represents possible site of compression for suprascapular nerve
- glenoid
 - represents articulating process on lateral scapula serving as socket for glenohumeral joint
 - pear-shaped and wider inferiorly from anterior to posterior

- average 1-5° of retroversion and 15° superior tilt from scapular plane
- fibrocartilaginous labrum deepens glenoid fossa by 50% to increase stability
- acromion
 - articulates with clavicle to form acromioclavicular joint
 - formed by 3 ossification centers



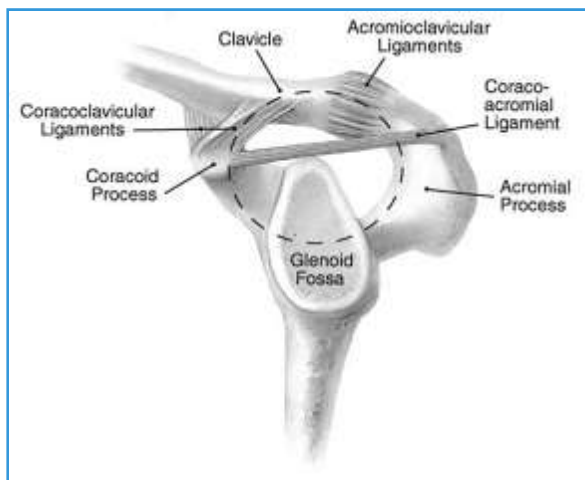
- pre acromion - tip
 - meso acromion - mid
 - meta acromion - base
- coracoid process



- has two secondary ossification centers that are open until around age 25 and should not be interpreted as fracture
 - angle of coracoid
 - tip of coracoid
- muscular attachments
 - conjoint tendon
 - coracobrachialis
 - short head biceps
 - pectoralis minor
- ligament attachments
 - coracoclavicular (CC) ligaments
 - most anterior CC ligament attachment is 25mm from tip of coracoid
 - coracoacromial ligament

○ Arthrology

- glenohumeral joint
 - glenoid & labrum support humeral head to produce high degree of motion
 - stability provided by static and dynamic stabilizers
- scapulothoracic joint
 - not a true joint but does represent an articulation between scapula and thorax
 - involved primarily in elevation and depression of shoulder as well as rotation and pro-/retraction
- acromioclavicular (AC) joint
 - articulation of acromion and distal clavicle
 - supported by acromioclavicular ligaments (horizontal stability) and coracoclavicular ligaments (vertical stability)
 - 8° of rotation occurs through acromioclavicular joint
- superior shoulder suspensory complex



- bone & soft tissue ring which provides connection of glenoid/scapula to axial skeleton
- composed of 4 bony landmarks
 - distal clavicle
 - acromion
 - coracoid
 - glenoid
- also composed of ligamentous complexes of acromioclavicular and coracoclavicular joints
- Blood supply
 - contributions from anterior and posterior circumflex, scapular circumflex and suprascapular arteries
 - watershed area present in anterosuperior glenoid
- Nervous system
 - scapula is intimately associated with brachial plexus
 - axillary nerve is at risk inferior to the glenoid as it runs from anterior to posterior
 - compression of suprascapular nerve at scapular notch leads to supraspinatus/infraspinatus weakness, with compression at the spinoglenoid notch leading only to infraspinatus weakness
- Biomechanics
 - scapula contributes to glenohumeral rotation and abduction
 - 1/3 of shoulder motion is scapulothoracic, 2/3 is glenohumeral

• Classification

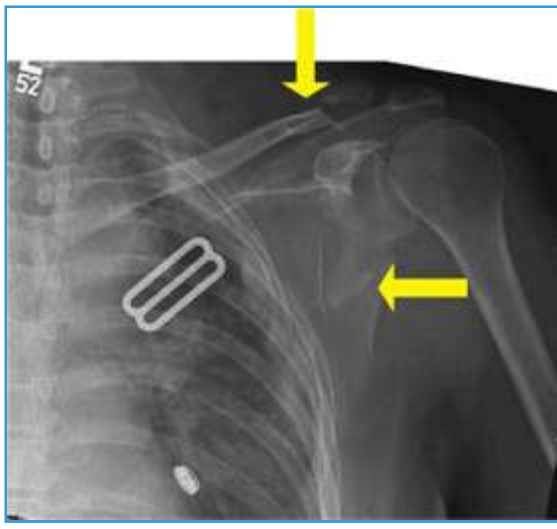
- Classification is based on the location of the fracture and includes
 - scapular body fractures



- usually described based on anatomic location
- scapular neck fractures



- look for associated AC joint separation or clavicle fracture
 - if occurring together, known as "floating shoulder"

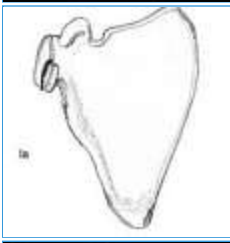
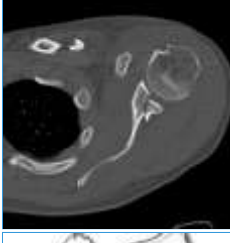
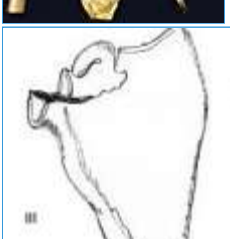
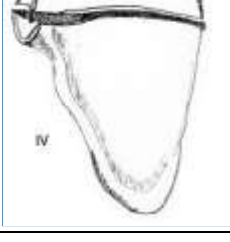


- glenoid fractures
 - Ideberg classification with Goss modification (below)
 - low inter- and intra-observer reliability and questionable association with management
 - AO-OTA classification
 - more reliable in diagnosis than Ideberg classification
- acromial fractures
 - Kuhn classification
- coracoid fractures
 - Ogawa classification - based on fracture proximity to CC ligaments
 - Eyres classification
- scapulothoracic dissociation

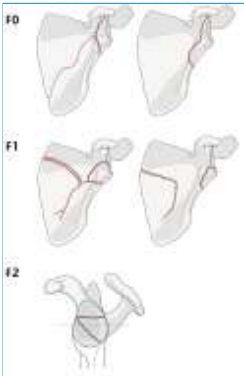
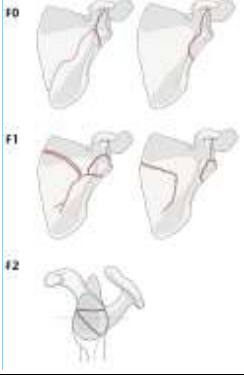
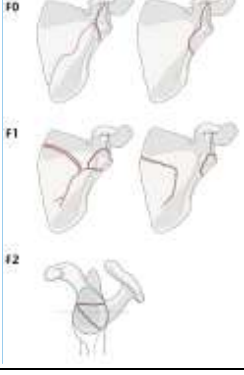
○ ■ Ogawa Coracoid Fracture Classification		
■ Type I	■ Fracture occurs proximal to the coracoclavicular ligament	■
■ Type II	■ Fracture occurs towards the tip of the coracoid	■
○ ■ Kuhn Acromial Fracture Classification		
■ Type I	■ Nondisplaced or minimally displaced	■
■ Type II	■ Displaced but does not compromise the subacromial space	■
■ Type III	■ Displaced and compromises the subacromial space	■

- Ideberg Classification of Glenoid Fracture



Type Ia	Anterior rim fracture	   
Type Ib	Posterior rim fracture	 
Type II	Fracture line through glenoid fossa exiting scapula inferiorly	 
Type III	Fracture line through glenoid fossa exiting scapula superiorly	 
Type IV	Fracture line through glenoid fossa exiting scapula medially through body	 
Type Va	Combination of types II and IV	

		
■ Type Vb	■ Combination of types III and IV	■ 
■ Type Vc	■ Combination of types II, III, and IV	■ 
■ Type VI	■ Severe comminution	■ 

○ ■ AO Classification for Glenoid Fractures			
■ Fracture type	■ Subtype	■ Qualification	
■ 14F0: Extra-articular	■ Glenoid neck	■	■ F0 F1 F2 
■ 14F1: Simple, intra-articular	■ 1.1: anterior glenoid rim ■ 1.2: posterior glenoid rim ■ 1.3: transverse/short oblique	■ f: infraequitorial, single quadrant ■ r: supraequatorial, 2 quadrants ■ t: infraequitorial, 2 quadrants ■ i: infraequitorial ■ e: equitorial ■ p: supraequitorial	■ F0 F1 F2 
■ 14F2: Multifragmentary	■ 2.1: >= 3 articular fragments ■ 2.2: central fracture-dislocation	■	■ F0 F1 F2 
■ 14B: Extension into body	■ 1: exits body at <=2 points ■ 2: exits body at >=3 points	■	■

- presentation
 - History
 - traumatic direct blow to shoulder or fall on outstretched arm
 - scapula fracture may be missed or diagnosed late in presence of other distracting, traumatic injuries
 - Symptoms
 - diffuse, severe shoulder pain
 - systemic symptoms
 - shortness of breath
 - chest wall pain
 - Physical exam
 - inspection
 - tenderness to palpation
 - shoulder diffusely

- inaccurate in determining specific location of fracture
 - clavicle
 - spine
 - rib cage
 - evaluate for abnormal shoulder contour compared to contralateral site
 - look for open wounds or abrasions
 - soft tissue swelling may be significant
- motion
 - acute active range of motion testing not recommended
 - likely to cause unnecessary pain
 - gentle passive range of motion can be useful in noting any blocks to motion
- neurovascular
 - check motor and sensory function of nerves at risk
 - axillary
 - radial
 - median
 - ulnar
 - confirm symmetry of extremity pulses to contralateral side

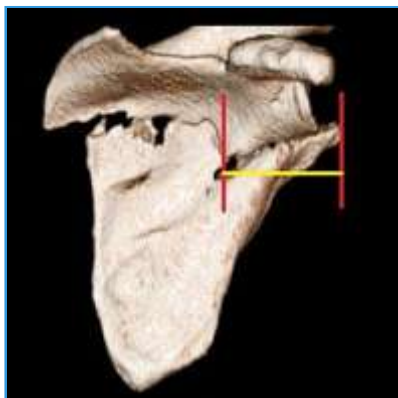
• Imaging

◦ Radiographs

- recommended views
 - true AP, grashey AP, scapular Y and axillary lateral view



- AP chest radiograph
 - evaluate for pneumothorax
 - evaluate for widening of space between medial scapular border and spine
 - >1 cm indicates possible scapulothoracic dissociation
- measurements
 - intra-articular step-off
 - lateral border offset (medialization)

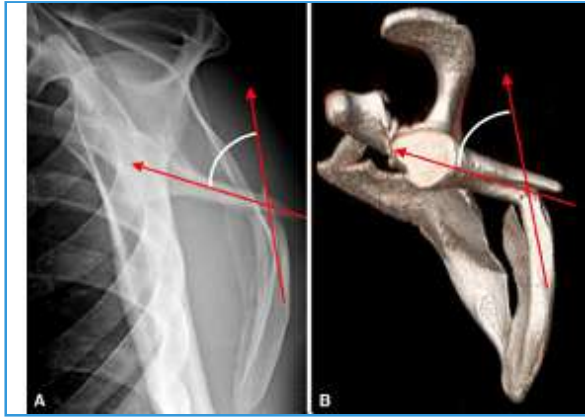


- glenopolar angle (measured on grashey AP)



- angle connecting superior/inferior scapula and lateral border of scapula

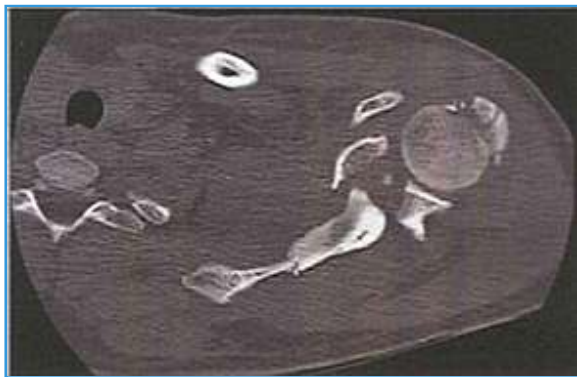
- normal considered 30-45°
- scapular angulation



- best seen on scapular Y radiograph

○ CT

- indications
 - intra-articular fracture



- significant displacement >1cm
- may also help detect other thoracic/spine injuries

▪ views

- three-dimensional reconstruction better demonstrates fracture patterns



- coronal and axial views useful to evaluate displacement, intra-articular step-off and medialization of glenoid
- sagittal view useful to evaluate anterior-posterior displacement and angulation

○ MRI

- indications
 - not regularly obtained but may be useful in some cases to evaluate the superior shoulder suspensory complex for ligamentous injury

• differential

○ Os Acromiale



- unfused secondary ossification centers (meso- and meta-acromion)

- associated with impingement and rotator cuff symptoms and may be detected incidentally with trauma

- Treatment

- Nonoperative

- **sling for 2-3 weeks, followed by early motion**

- scapular body fractures
 - indications
 - indicated for vast majority of scapula fractures
 - 90% are minimally displaced and acceptably aligned



- outcomes
 - progressive deformity/displacement is possible during first 3 weeks
 - recommend serial weekly radiographs during this time
 - those associated with multiple underlying rib fractures or superior shoulder suspensory complex disruptions are more likely to displace
 - union at 6-8 weeks in most cases
 - most recover near-normal function
 - attributed to shoulder's capability for compensatory motion
 - poorer outcomes noted in patients with glenopolar angle $<20^{\circ}$
- scapular neck fractures
 - indications
 - translation <1 cm
 - angulation $<40^{\circ}$
 - glenopolar angle $>20^{\circ}$
 - no additional injury to superior shoulder suspensory complex
 - outcomes
 - true outcomes not well established
 - some reports of unsatisfactory results in $\sim 30\%$ of cases treated nonoperatively, while others note equivalent outcomes to surgical fixation
- intra-articular glenoid fractures
 - indications
 - <4 mm step-off and less than 25% glenoid involvement
 - outcomes
 - with small fractures and minimal intra-articular step-off, nonoperative management results in excellent functional outcomes
 - risk of instability exists in rim fractures with larger degree of articular surface involvement
- acromion fractures
 - indications
 - displacement <1 cm and no additional injury to superior shoulder suspensory complex
 - outcomes
 - good outcomes with Kuhn type I and II fractures which do not compromise subacromial space
- coracoid fractures
 - indications
 - displacement <1 cm and no additional injury to superior shoulder suspensory complex
 - coracoid tip fractures distal to insertion of coracoclavicular (CC) ligaments, even if displacement is >1 cm (Ogawa II)
 - outcomes
 - good results and motion with both type I and II fractures meeting indications

- Operative

- **open reduction internal fixation**

- indications (most are relative)
 - open fracture
 - scapular body fractures
 - medialization of lateral border > 20 mm
 - glenopolar angle < 20-22°
 - angulation > 40°
 - combination of medialization >15 mm and angulation >35°
 - scapular neck fracture
 - angulation > 40°
 - translation > 1 cm
 - glenopolar angle < 20-22°
 - "double disruption" of the superior shoulder suspensory complex (floating shoulder)
 - indicates unstable nature of bony/ligamentous ring
 - intra-articular glenoid fracture
 - > 20-25% anterior or posterior glenoid involvement with subluxation of humerus
 - can cause persistent glenohumeral instability
 - articular step-off > 4 mm
 - acromion fracture
 - displacement > 1cm
 - painful nonunion
 - subacromial impingement
 - double disruption of superior shoulder suspensory complex
 - coracoid fracture
 - displacement > 1 cm
 - painful nonunion
 - ipsilateral scapula fracture requiring fixation
 - Ogawa type I coracoid fracture extending into scapular body
 - double disruption of superior shoulder suspensory complex
- techniques
 - screw(s)
 - percutaneous vs. open
 - plate(s) + screws(s)
 - arthroscopic-assisted
 - suture anchor repair vs. percutaneous screw fixation
 - useful in anterior/posterior glenoid rim fractures
- outcomes
 - scapular body fractures
 - most return to having near-normal strength and symmetric range of motion
 - scapular neck fractures
 - good shoulder function and high union rates
 - complication rates up to 15%
 - intra-articular glenoid fractures
 - good to excellent subjective outcomes (pain, strength, and motion) in 80-95% of patients
 - higher rate of poor outcomes with concomitant chest and neurologic trauma
 - coracoid/acromion fractures
 - good outcomes in >85% of cases
 - high rates of union and full range of motion
 - some risk exists for requiring hardware removal

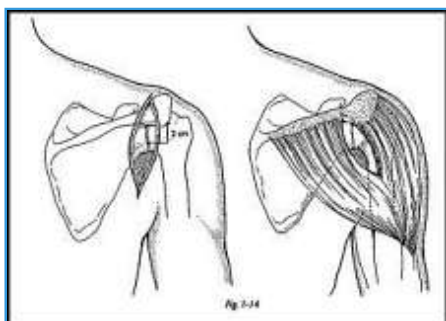
- Techniques

- **Nonoperative (immobilization)**

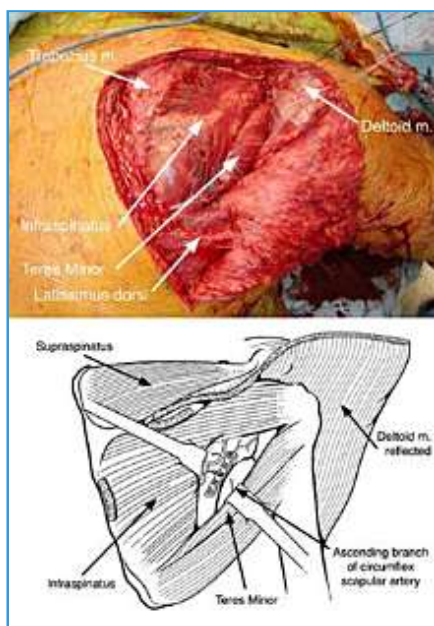
- noninvasive but can lead to stiffness
- technique
 - sling immobilization for 2-3 weeks

- **Open Reduction Internal Fixation (ORIF)**

- scapular body/neck fractures
 - approaches
 - straight posterior overlying glenohumeral joint



- indicated in isolated displaced fractures
 - scapular neck
 - lateral scapular border
 - less extensile than Judet approach
- Judet approach



- indicated if multiple scapular borders need to be accessed
 - incision courses along spine of scapula and angles down vertebral scapula border in "L" shape
 - utilizes internervous plane between infraspinatus (suprascapular nerve) and teres minor (axillary nerve)

- technique
 - can use 2.7 mm or 3.5 mm plates
 - locking plate technology may be advantageous given thin scapular bone, especially along vertebral border
 - reconstruction plates can be contoured around scapular spine and superomedial angle of scapula

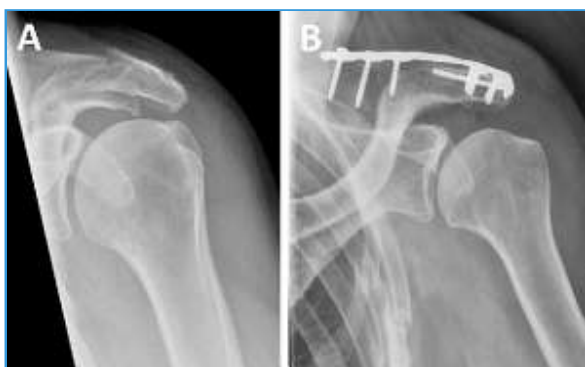


- complications
 - neurovascular injury
 - malunion
 - hardware failure
- intra-articular glenoid fractures
 - approaches
 - deltopectoral approach
 - utilizes intermuscular plane between deltoid (axillary n.) and pectoralis major (medial/lateral pectoral n.)
 - indicated in fractures involving anterior glenoid with inferior extension (Ideberg II)
 - in cases of medial/inferior fracture extension into scapular body, posterior approach may be necessary
 - can be extended proximally to clavicle in cases where superior glenoid fracture extends to coracoid
 - posterior approach (detailed above)
 - displaced posterior glenoid rim fractures with intra-articular involvement

- intra-articular glenoid fractures with inferior or medial extension into body not accessible anteriorly
- lateral midaxial approach
 - incision just caudal to axilla in order to access inferior glenoid fractures
 - easier ability to instrument along inferior scapular neck
- techniques
 - percutaneous fixation
 - if hardware is inserted percutaneously, arthroscopic assistance may be beneficial to ensure articular reduction
 - suture anchors can be used to advance labrum in cases of small bony defects
 - screw fixation can be used to fixate larger bony rim fragments



- minifragment fixation recommended in most cases
- open fixation
 - inferior glenoid fractures may be fixed with plate/screw(s) in buttress fashion
- complications
 - post-traumatic arthritis
 - subscapularis failure
 - if anterior approach requires subscapularis take-down
 - recurrent glenohumeral instability
- acromion fractures
 - approach
 - vertically based posterior incision centered over the scapular spine and posterior acromion
 - dissection taken down to deltoid and trapezius muscles and reflected off the scapular spine and posterior acromion
 - technique
 - proximal acromial fracture
 - 2.7 or 3.5 mm lag screws placed perpendicular to fracture site if possible
 - 2.4 or 2.7 mm reconstruction plate placed to neutralize fracture



- distal acromial fracture
 - bone is very thin in this area
 - plate fixation may be difficult to obtain, although 2.0mm mini-fragment plate can function well
 - tension band technique can be considered
- complications
 - hardware irritation/failure
- coracoid fractures
 - approach

- deltopectoral approach (detailed above)
 - retractor placed at base of coracoid to visualize fracture
- technique
 - can carefully remove portion of the coracoacromial ligament and pectoralis minor attachment to better visualize the fracture bed
 - provisionally pin the coracoid with 1-2 Kirschner wires
 - fixation achieved with 1-2 bicortical 2.7 or 3.5 mm screws +/- washers



- may also place quarter tubular buttress plate if needed
 - increased risk of requiring hardware removal
- rarely, in Ogawa type II fractures requiring intervention, suture anchor can be placed in fracture bed and tip can be captured using a suture lasso technique
- complications
 - neurovascular injury
 - hardware irritation

• complications

- Post-traumatic glenohumeral arthritis
 - risk factors
 - intra-articular glenoid fracture with residual step-off/displacement
 - treatment
 - conservative management
 - NSAIDs, therapy, injections
 - shoulder arthroplasty (total vs. reverse)
- Malunion
 - risk factors
 - higher degree of angulation, translation or medialization
 - more likely with nonoperative management
 - questionable effect on shoulder function
 - treatment
 - typically nonoperative depending on location of fracture and degree of deformity
 - If deformity involves glenoid, may be correctable with reverse total shoulder arthroplasty
- Recurrent glenohumeral instability
 - risk factors
 - younger patients
 - larger degree of bone loss (anterior or posterior)
 - treatment
 - bony fixation (open or percutaneous)
 - arthroscopic vs. open suture anchor repair with labral advancement
 - more useful for smaller bony fragments which are not able to be fixated otherwise
- Neurovascular injury
 - risk factors
 - scapulothoracic dissociation
 - iatrogenic injury during surgical dissection
 - deltopectoral approach
 - musculocutaneous n.
 - axillary n.
 - posterior/judet approach
 - axillary n.
 - suprascapular n.
 - circumflex scapular v.

- posterior humeral circumflex v.
- treatment
 - nerve injury after scapulothoracic dissociation
 - EMG 3-6 weeks after injury to assess extent of injury and degree of recovery
 - iatrogenic neurovascular injury
 - direct repair if possible

19- Scapulothoracic Dissociation

Images



- summary

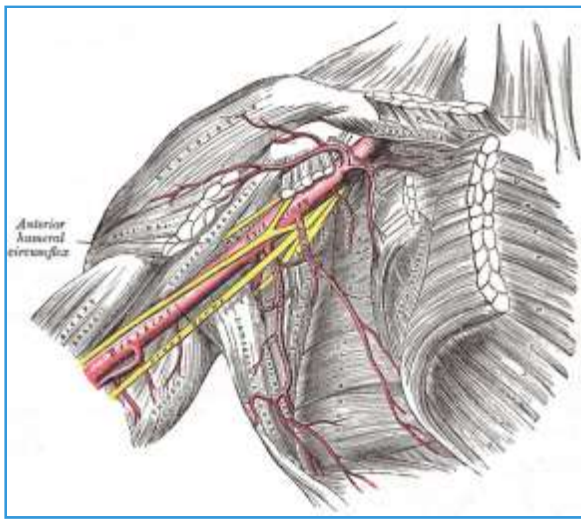
- Scapulothoracic Dissociation is a high-energy traumatic disruption of the scapulothoracic articulation often associated with severe neurovascular injuries, scapula fractures, and clavicular fractures.
- Diagnosis can be made with the edge of the scapula being displaced > 1 cm from the spinous process as compared to the contralateral side. CT scan of the chest will show an asymmetric distance from the spinous process to the medial edge of the scapular body.
- Treatment is generally open reduction and internal fixation of associated fractures and urgent exploration in the setting of vascular injuries. Functional outcome is dependent on the level of neurologic injury.

- Etiology

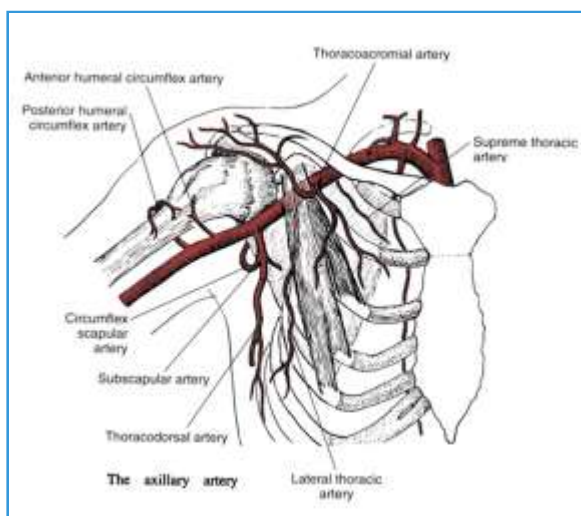
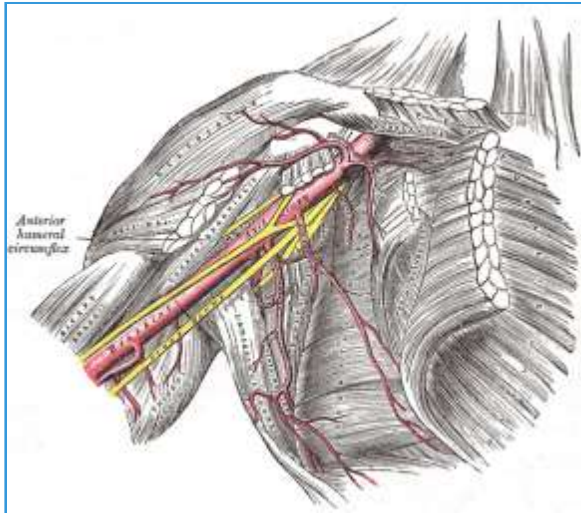
- Mechanism
 - usually caused by a lateral traction injury to the shoulder girdle
 - involves significant trauma to heart, chest wall and lungs
- Associated conditions
 - orthopaedic
 - scapula fractures
 - clavicle fractures
 - AC dislocation/separation
 - sternoclavicular dislocation
 - flail extremity (52%)
 - complete loss of motor and sensory function rendering the extremity non-functional
 - vascular injury
 - subclavian artery most commonly injured
 - axillary artery
 - neurologic injury (up to 90%)
 - ipsilateral brachial plexus injury (often complete)
 - neurologic injuries more common than vascular injuries

- Anatomy

- Scapulothoracic joint
 - a sliding joint
 - articulates with ribs 2-7
 - moves into abduction at 2:1 ratio
 - GH joint 120°
 - ST joint 60°
- Neurovascular anatomy
 - brachial plexus
 - subclavian artery



■ axillary artery



• Presentation

- History
 - history of high energy trauma
- Symptoms
 - pain in involved upper extremity (UE)
 - numbness/tingling in involved UE
- Physical exam
 - inspection
 - significant swelling in shoulder region
 - bruising around shoulder
 - vascular exam
 - decreased or absent pulses in involved UE
 - neurological exam
 - neurologic deficits in UE
 - neurological status critical part of exam

• Imaging

- Radiographs
 - required views
 - AP chest
 - recommended view
 - AP and lateral of shoulder as tolerated
 - appropriate images of suspected fracture sites
 - findings

- laterally displaced scapula



- edge of scapula displaced > 1 cm from spinous process as compared to contralateral side
- widely displaced clavicle fx
- AC separation
- sternoclavicular dislocation

- CT scan

- recommended views
 - chest CT
 - axial views
- findings
 - asymmetric distance from spinous process to medial edge of scapular body

- Angiogram

- indicated to detect injury to subclavian and axillary artery

- Treatment

- Nonoperative

- **immobilization/supportive care**
 - indications
 - patients without significant vascular injury who are hemodynamically stable
 - patients may have adequate collateral flow to UE even with injury

- Operative

- **high lateral thoracotomy with vascular repair**
 - indications
 - axillary artery injury in hemodynamically unstable patient
- **median sternotomy with vascular repair**
 - indications
 - more proximal arterial injury (i.e., subclavian artery) in a hemodynamically unstable patient
- **ORIF of the clavicle or AC joint**
 - indications
 - associated clavicle and AC injuries
- **forequarter amputation**
 - indications
 - complete brachial plexus injury

- Prognosis

- Mortality rate of 10%
- Functional outcome is dependent on neurologic injury
 - if return of neurological function is unlikely, early amputation is recommended

20- Coronoid Fractures

Images



- summary

- Coronoid Fractures are traumatic elbow fractures that are generally pathognomonic for an episode of elbow instability.
- Diagnosis can be made using plain radiographs of the elbow. CT studies may be helpful for surgical planning.
- Treatment may be nonoperative for nondisplaced coronoid tip fractures with a stable elbow. Surgical management is indicated for anteromedial facet fractures or fractures associated with elbow instability.

- Epidemiology

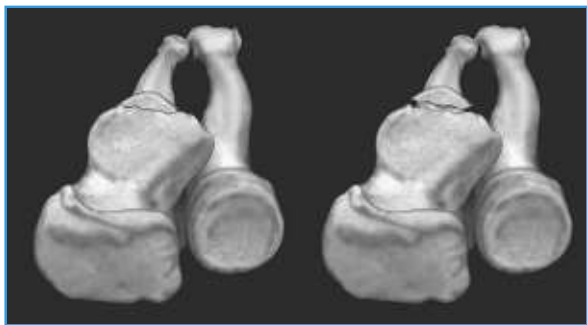
- Incidence
 - 10-15% of elbow injuries

- Etiology

- Types
 - isolated coronoid fracture
 - less common than previously thought
 - coronoid fracture + associated injuries
 - commonly occur with elbow dislocation
 - associated with recurrent instability after dislocation
- Mechanism
 - traumatic shear injury
 - typically occurs as distal humerus is driven against coronoid with an episode of severe varus stress or posterior subluxation
 - not an avulsion injury as nothing inserts on tip
- Pathoanatomy
 - fractures at the coronoid base can amplify elbow instability given that
 - anterior bundle of the medial ulnar collateral ligament attaches to the sublime tubercle 18 mm distal to tip
 - anterior capsule attaches 6 mm distal to the tip of the coronoid
- Associated conditions
 - posteromedial rotatory instability
 - coronoid anteromedial facet fracture and LCL disruption



- results from a varus deforming force
- posterolateral rotatory instability
 - coronoid tip fracture, radial head fracture, and LCL injury



- olecranon fracture-dislocation
 - usually associated with a large coronoid fracture
- terrible triad of elbow
 - coronoid fracture (transverse fracture pattern), radial head fracture, and elbow dislocation

Anatomy

- Osteology
 - coronoid tip
 - is an intraarticular structure
 - can be visualized during elbow arthroscopy
 - medial facet
 - important for varus stability
 - provides insertion for the medial ulnar collateral ligament
- Biomechanics
 - coronoid functions as an anterior buttress of the olecranon greater sigmoid notch
 - important in preventing recurrent posterior subluxation
 - primary resistor of elbow subluxation or dislocation

Classification

Regan and Morrey Classification		
Type I	Coronoid process tip fracture	
Type II	Fracture of 50% or less of height	
Type III	Fracture of more than 50% of height	
O'Driscoll Classification		
- Subdivides coronoid injuries based on location and number of coronoid fragments -Recognizes anteromedial facet fractures caused by varus posteromedial rotatory force		

Presentation

- Symptoms
 - elbow deformity & swelling
 - elbow pain
 - forearm or wrist pain may be a sign of associated injuries
- Physical exam
 - inspection & palpation
 - varus or valgus deformity
 - ecchymosis & swelling

- diffuse tenderness
- range of motion & instability
 - document flexion-extension and pronation-supination
 - crepitus should be noted
 - varus/valgus instability stress test
 - challenging but important for an accurate diagnosis
- neurovascular exam

• Imaging

- Radiographs
 - recommended views
 - AP and lateral elbow views



- findings
 - interpretation may be difficult due to overlapping structures
- CT scan
 - useful for high grade injuries and comminuted fractures

• Treatment

- Nonoperative
 - **brief period of immobilization, followed by early range of motion**
 - indications
 - Type I, II, and III that are minimally displaced with stable elbow
- Operative
 - **ORIF with medial approach**
 - indications
 - Type I, II, and III with persistent elbow instability
 - posteromedial rotatory instability
 - **ORIF with posterior approach**
 - indications
 - olecranon fracture dislocation
 - terrible triad of elbow
 - **hinged external fixation**
 - indications
 - large fragments
 - poor bone quality
 - difficult revision cases to help maintain stability

• Techniques

- **ORIF with medial approach**
 - approach
 - medial exposure through an interval between two heads of FCU
 - exposure more anteriorly through a split in flexor pronator mass
 - technique
 - cerclage wire or No. 5 suture through ulna drill holes for Type I injuries

- ORIF with retrograde cannulated screws or plate for Type II or III injuries
- ORIF with buttress plate fixation or pins and lateral ligament repair for posteromedial rotatory instability



- postoperative rehabilitation
 - depends on intraoperative exam following the procedure
 - thermoplastic resting splint
 - applied with elbow at 90° and forearm in neutral
 - restrict terminal 30 ° extension for 2-4 weeks
 - avoid shoulder abduction for 4-6 weeks
 - to prevent varus moment on arm
 - early active motion
 - dynamic muscle contraction may improve gapping of the ulnohumeral joint after surgical repair
- **ORIF with posterior approach**
 - approach
 - posterior
 - technique
 - mobilize olecranon fracture to access coronoid fracture for associated olecranon fracture-dislocations
 - repair coronoid fragment first prior to reducing main ulnar fracture
 - olecranon ORIF with dorsal plate and screws
- Complications
 - Recurrent elbow instability
 - especially medial-sided
 - Elbow stiffness
 - Posttraumatic arthritis
 - Heterotopic ossification
 - Early failure
 - associated with failure to recognize and repair underlying elbow instability
- Prognosis
 - Complications and reoperation rates are high

21- Humeral Shaft Nonunion

- summary

- Humeral Shaft Nonunion is characterized by the arrest of the fracture repair process of a humeral shaft fracture which may occur following nonoperative or operative management.
- Diagnosis can be made with plain radiographs. CT studies are helpful to assess the extent of bridging callous and for preoperative planning.
- Treatment is generally open reduction with compression plating with or without bone grafting.

- Epidemiology

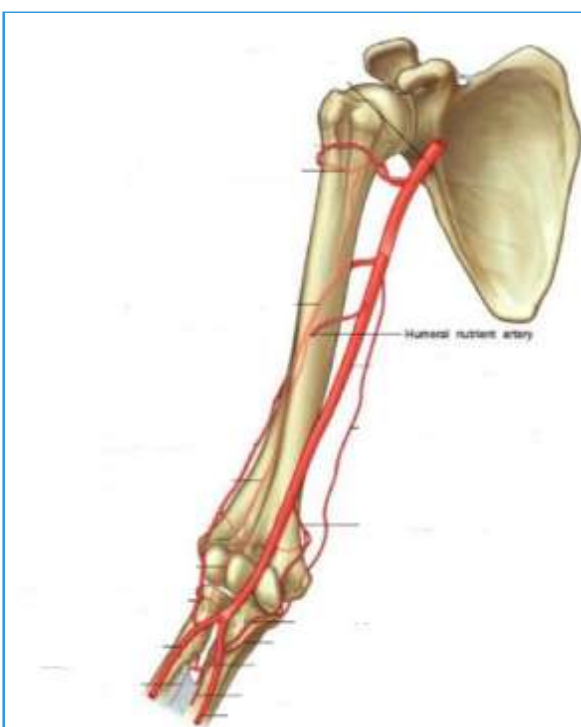
- Incidence of primary nonunion
 - 2 to 33% with nonoperative management
 - 5 to 10% with surgical management
- Anatomic location
 - proximal third humeral shaft fractures are felt to have higher rates of nonunion
- Risk factors
 - biologic
 - metabolic/endocrine abnormalities (osteoporosis, Vitamin D deficiency most common)
 - infection
 - patient factors (smoking, obesity, malnutrition, noncompliance)
 - open fracture
 - mechanical
 - unstable fracture patterns with inadequate stability
 - shoulder or elbow stiffness (motion directed to fracture site)

- Etiology

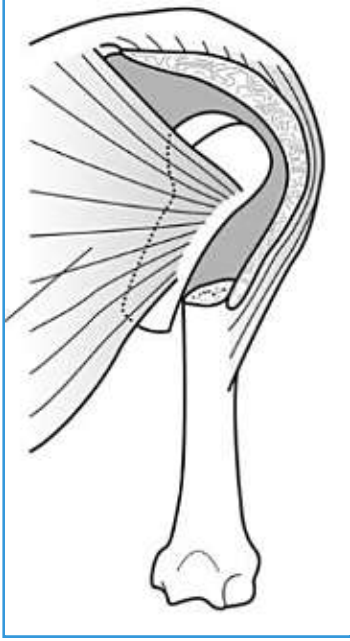
- Pathophysiology
 - pathophysiology
 - inadequate stability at fracture site with operative or nonoperative treatment
 - pathobiology
 - inadequate biology as a result of metabolic/endocrine abnormalities, infection, smaller bone surface area for healing
- Associated conditions
 - radial nerve palsy

- Anatomy

- Blood Supply
 - nutrient vessel of humerus courses along the medial aspect of the mid to distal third of the diaphysis



- Muscles
 - pectoralis major and deltoid create strong deforming forces on proximal diaphyseal fractures



- Tendon
 - biceps tendon interposition in proximal diaphyseal fractures may lead nonunion

- Presentation

- Symptoms
 - pain with use of the extremity
- Physical exam
 - inspection
 - assess the fit of functional brace and skin irritation
 - atrophy
 - angulation
 - motion
 - gross motion at the fracture site
 - neurovascular
 - assess radial nerve function

- Imaging

- Radiographs
 - recommended views
 - AP and lateral of the humerus, shoulder, and elbow
 - findings
 - lack of fracture consolidation



- hypertrophic callous formation
- pseudarthrosis



- CT
 - indications
 - to evaluate for the extent of bridging callous and preoperative planning

• Studies

- Serum Labs
 - CRP, ESR, CBC
 - must rule out infection
 - total protein and serum albumin
 - vitamin D, TSH, PTH

• Treatment

- Nonoperative
 - **functional bracing +/- bone stimulation**
 - indications
 - rarely indicated unless low demand, high-risk surgical candidate, and asymptomatic nonunion
 - modalities
 - continued functional brace
 - bone stimulators

- nonunion over a period greater than 9 months or no progressive healing 3 months from injury
- contraindicated if pseudarthrosis, fracture gap >5mm, or poor blood supply

- Operative

- **compression plating with bone grafting (gold standard)**

- indications
 - symptomatic nonunion
- outcomes
 - shown to be superior to IM nailing

- **dual plating**



- indications
 - very proximal or distal fracture nonunion
 - poor metaphyseal bone quality
 - micromotion noted at fracture site following single plate fixation
- outcomes
 - 92-100% union at 16 weeks
- **cortical strut allograft/autograft**
 - indications
 - severe osteopenia from disuse, age, or prior surgery
 - severe bone loss
 - recalcitrant nonunion
 - outcomes
 - 95-100% union rate
- **bone morphogenic proteins (BMP's)**
 - indications
 - limited role as no studies show improved outcomes

- Techniques

- **Compression plating with or without bone grafting**

- approach
 - anterior
 - anterolateral
 - posterior
 - radial nerve exploration and neurolysis or release of nerve entrapment
- soft tissue
 - radial nerve protection and neurolysis
- bone work
 - debridement of fibrous tissue and bone ends to stimulate healing
 - fracture reduction with maximal cortical contact and stability
 - autologous bone grafting from ICBG if atrophic nonunion
 - DBM, RIA, or local callous autograft as alternative grafts
- instrumentation
 - 4.5mm compression plate placed anterior, lateral, or posterior
- complications specific to this treatment
 - radial nerve neuropraxia or injury

- ICBG donor site morbidity
- outcomes
 - nearly 100% union rate reported
 - 44% rate of ICBG donor site morbidity
- **Dual plating**
 - instrumentation
 - place additional plate orthogonal to the first plate
- **Cortical strut allograft/autograft**
 - bone work
 - place strut intramedullary and then place the plate



- place strut medially and place laterally based compression plate



• Complications

- Nerve injury
 - radial nerve most common
- Persistent nonunion
 - treatment
 - **free fibular grafting**
 - indications
 - recalcitrant atrophic nonunions

• Prognosis

- With operative treatment of nonunion, 83-100% of patients go on to union

22- Distal Humerus Fractures

Images



- summary

- Distal Humerus Fractures are traumatic injuries to the elbow that comprise of supracondylar fractures, single column fractures, column fractures or coronal shear fractures.
- Diagnosis is made with plain radiographs of the humerus and elbow. CT scan is helpful for intra-articular assessment and operative planning.
- Treatment is usually open reduction and internal fixation.

- Epidemiology

- Incidence
 - accounts for 0.5-7% of all fractures
 - accounts for 30% of elbow fractures
- Demographics
 - most common in young males and older females
- Anatomic location
 - distal intercondylar fractures are the most common fracture pattern

- Etiology

- Forms
 - distal humerus fractures are traumatic injuries that include
 - supracondylar fractures
 - single column (condyle) fractures
 - bicolumn fractures
 - coronal shear fractures
- Pathophysiology
 - mechanism
 - low energy falls in elderly
 - high energy impact in younger population
 - pathoanatomy
 - elbow position affects fracture type
 - elbow flexed $< 90^\circ$
 - axial load leads to transcolumar fracture
 - direct posterior blow leads to olecranon fracture with or without distal humerus involvement
 - elbow flexed $> 90^\circ$
 - may lead to intercondylar fracture
- Associated injuries
 - elbow dislocation

- terrible triad injury
- floating elbow
- Volkmann contracture
 - results from missed forearm compartment syndrome

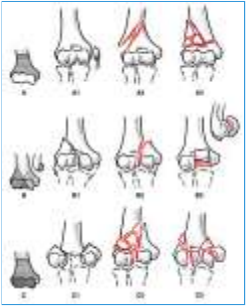
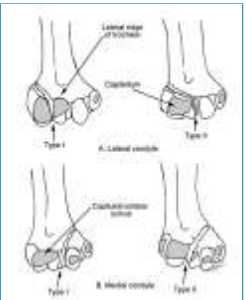
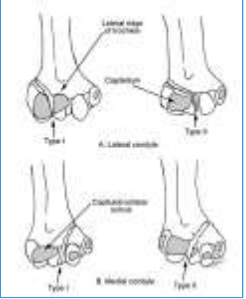
• Anatomy

- Osteology
 - elbow is a hinged joint
 - trochlea
 - articulates with sigmoid notch
 - allows for flexion and extension
 - capitellum
 - articulates with proximal radius
 - allows for forearm rotation
- Muscles
 - common flexors (originate from medial epicondyle)
 - pronator teres
 - flexor carpi radialis
 - palmaris longus
 - FDS
 - FCU
 - common extensors (originate from lateral epicondyle)
 - anconeus
 - ECRL
 - ECRB
 - extensor digitorum communis
 - EDM
 - ECU
- Ligaments
 - medial collateral ligament
 - anterior bundle originates from distal medial epicondyle
 - inserts on sublime tubercle
 - primary restraint to valgus stress at the elbow from 30-120°
 - tight in pronation
 - lateral collateral ligament
 - originates from distal lateral epicondyle
 - inserts on crista supinatoris
 - stabilizer against posterolateral rotational instability
 - tight in supination
- Nerves
 - ulnar nerve
 - resides in the cubital tunnel in a subcutaneous position below the medial condyle
 - radial nerve
 - resides in the spiral groove 15cm proximal to distal humeral articular surface
 - also can be reliably found 3.9 cm (two finger-breadths) proximal to the triceps aponeurosis.
 - runs between brachioradialis and brachialis proximal to elbow
 - divides into PIN and superficial radial nerve at the level of the radial head

• Classification

- Can be classified as
 - supracondylar fractures
 - distal single column fractures
 - subclassified using Milch classification system (see table)
 - lateral condyle more common than medial
 - distal bicolunar fractures
 - classified using Jupiter classification system (see table)

- 5 major articular fragments have been identified
 - capitellum/lateral trochlea
 - lateral epicondyle
 - posterolateral epicondyle
 - posterior trochlea
 - medial trochlea/epicondyle

■ AO/OTA Classification of Distal Humerus Fractures		
■ Type A	■ Extra-articular (supracondylar fracture), 80% are extension type; epicondyle	■ 
■ Type B	■ Intraarticular- Single column (partial articular-isolated condylar, coronal shear, epicondyle with articular extension)	■
■ Type C	■ Intraarticular- Both columns fractured and no portion of the joint contiguous with the shaft (complete articular)	■
	■ Each type further divided by degree and location of fracture comminution	■
■ Milch Classification of Single Column Condyle Fractures		
■ Milch Type I	■ Lateral trochlear ridge intact	■ 
■ Milch Type II	■ Fracture through lateral trochlear ridge	■ 

■ Jupiter Classification of Two-Column Distal Humerus Fractures		
■ High-T	■ Transverse fx proximal to or at upper olecranon fossa	■ 
■ Low-T	■ Transverse fx just proximal to trochlea (common)	■ 
■ Y	■ Oblique fx line through both columns with distal vertical fx line	■ 
■ H	■ Trochlea is a free fragment (risk of AVN)	■ 
■ Medial lambda	■ Proximal fx line exists medially	■ 
■ Lateral lambda	■ Proximal fx line exists laterally	■ 
■ Multiplane T (not pictured)	■ T type with an additional fracture in coronal plane	■ 

• Presentation

- Symptoms
 - elbow pain and swelling
- Physical exam
 - gross instability often present
 - avoid ROM due to risk of neurovascular damage
 - neurovascular exam
 - check function of radial, ulnar, and median nerves
 - check distal pulses
 - brachial artery may be injured

- if pulse decreased, obtain noninvasive vascular studies and consult vascular surgery if abnormal
- monitor carefully for forearm compartment syndrome

• Imaging

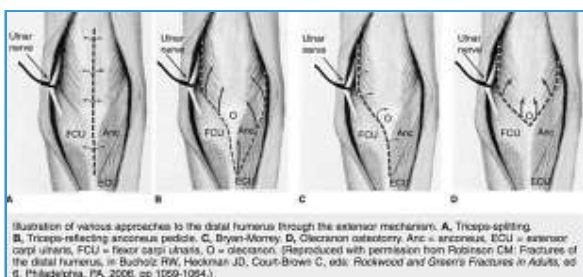
- Radiographs
 - recommended views
 - AP
 - lateral
 - additional views
 - obtain wrist radiographs if elbow injury present or distal tenderness on exam
 - oblique and traction radiographs may assist with surgical planning
 - specifically used to evaluate if there is continuity of the trochlear fragment with the medial epicondylar fragment, this can influence hardware choice
- CT
 - often obtained for surgical planning
 - especially helpful when shear fractures of the capitellum and trochlea are suspected
- MRI
 - usually not indicated in acute injury

• Treatment

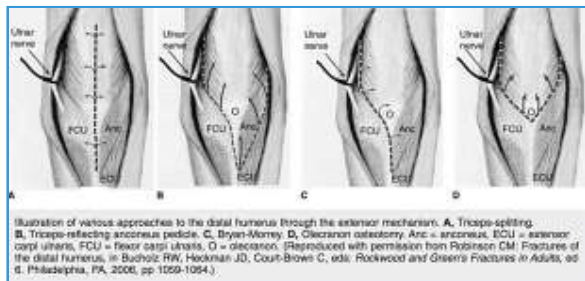
- Nonoperative
 - **cast immobilization**
 - indications
 - nondisplaced Milch Type I fractures
- Operative
 - **closed reduction and percutaneous pinning (CRPP)**
 - indications
 - displaced Milch Type I fractures
 - **ORIF**
 - indications
 - supracondylar fractures
 - intercondylar / bicolunar fractures
 - Milch Type II fractures
 - **total elbow arthroplasty**
 - indications
 - distal bicolunar fractures in elderly patients

• Techniques

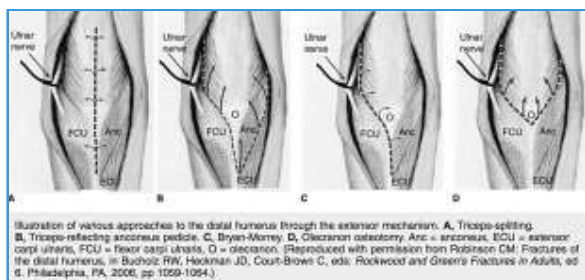
- **Cast Immobilization**
 - technique
 - immobilize in supination for lateral condyle fractures
 - immobilize in pronation for medial condyle fractures
- **ORIF**
 - approach
 - posterior superficial approach
 - exposures
 - triceps-splitting (Campbell)



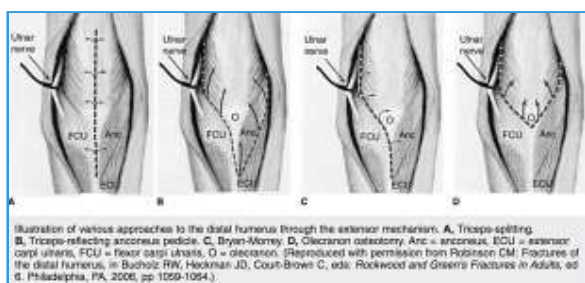
- technique
 - split triceps tendon in midline down to olecranon
- triceps-sparing (paratricipital, Alonso-Llames, medial and lateral windows)



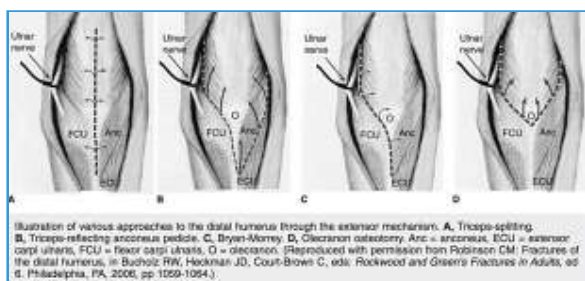
- indications
 - extra-articular fractures
 - fractures with a simple articular split
- technique
 - elevate triceps from the humerus using medial and lateral windows
 - can be converted to olecranon osteotomy if needed
- olecranon osteotomy



- indications
 - complex intra-articular fractures
 - fractures with a coronal split
- contraindications
 - total elbow arthroplasty is planned/may be required
- technique
 - perform chevron (apex distal) osteotomy
 - fixation of osteotomy performed using a combination of screws, K wires, tension band or plate
- complications
 - AIN nerve injury
 - check ability to flex thumb interphalangeal joint in recovery
 - symptomatic hardware
- triceps-reflecting (Bryan-Morrey)



- technique
 - reflect triceps tendon, forearm fascia, and periosteum off the olecranon from medial to lateral
 - repair through transosseous drill holes
 - immobilize to protect triceps repair for 4-6 weeks postoperatively
- triceps-reflecting anconeus pedicle (O'Driscoll)



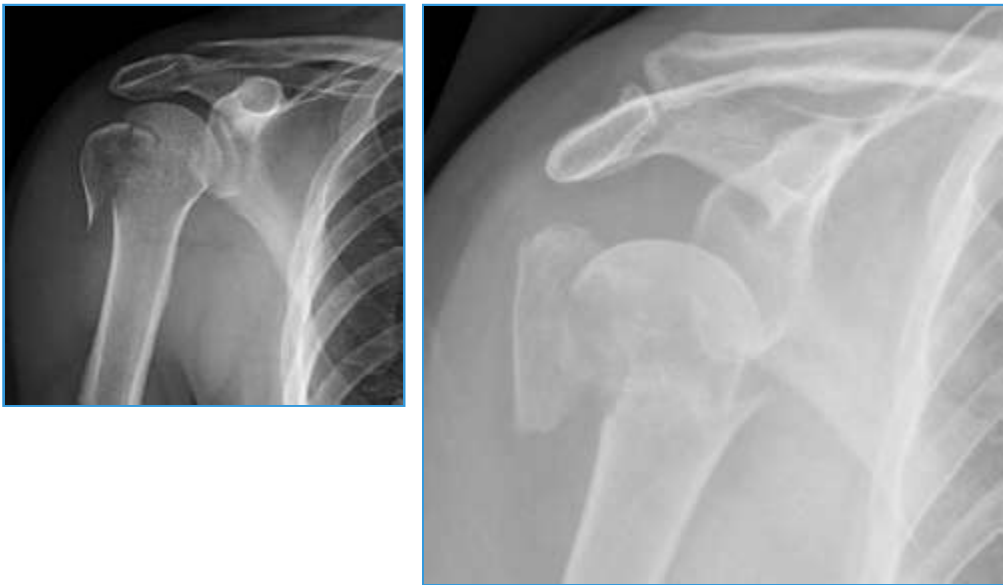
- technique
 - elevate anconeus subperiosteally from proximal ulna
- lateral muscles interval
 - technique
 - elevate the ECRB and part of the ECRL off of the supracondylar ridge
- fixation
 - perform provisional reduction with k-wires
 - if metaphyseal injury is not comminuted, reducing one column to the metaphysis first may be beneficial
 - perform fixation of articular fragments with countersunk/headless screws
 - consider using positional screws when reducing trochlea to avoid narrowing it with compression

- perform fixation of condyles and epitrochlear ridge
 - fix the lateral epicondyle using a tension band wire or plate
 - fix the articular segment to the shaft using two plates in orthogonal planes
 - new literature supports parallel plates
 - if the ulnar nerve contacts medial hardware during flexion/extension, can perform an ulnar nerve transposition
 - no difference between rates of post-operative ulnar neuritis with in situ release compared to transposition
 - no difference in patient-reported outcomes between transposition and in-situ release
 - postoperative
 - splint elbow in 70° of flexion
 - remove splint at 48 hours post-operatively and initiate ROM exercises
 - if osteotomy performed
 - active and active-assisted flexion and extension for 6 weeks
 - no active extension against gravity or resistance
 - no restrictions to rotation
 - if osteotomy not performed
 - active motion against gravity without restrictions
 - no restrictions to rotation
 - start gentle strengthening program at 6 weeks and full strengthening program at 3 months
 - **Total Elbow Arthroplasty**
 - indications
 - communitied articular fractures in osteoporotic bone
 - inflammatory conditions (e.g. RA)
 - complications specific to this treatment
 - activity restrictions (e.g. can not lift more than 5 pounds)
 - implant loosening
 - polyethylene wear
 - periprosthetic fracture
 - functional outcomes similar with salvage arthroplasty following failed ORIF
- Complications
 - Elbow stiffness
 - most common
 - Heterotopic ossification
 - seen in 8%
 - routine prophylaxis is not warranted due to increased rate of nonunion in patients treated with indomethacin
 - Nonunion
 - low incidence
 - avoid excessive soft-tissue stripping
 - Malunion
 - avoided by proper surgical technique
 - cubitus valgus (lateral column fractures)
 - cubitus varus (medial column fractures)
 - AIN injury
 - can be seen with olecranon osteotomy
 - Ulnar nerve injury
 - Postoperative ulnar nerve palsies are most often secondary due to traction during open reduction and internal fixation
 - DJD
-
- Prognosis
 - Majority of patients regain 75% of elbow motion and strength
 - goal is to restore elbow ROM 30-130° of flexion
 - Total elbow arthroplasty has rates of implant survival >75% at 10 years if used with appropriate indications

- Unsatisfactory outcomes in up to 25%
 - treatment of these fractures is complex due to
 - low fracture line of one or both columns
 - metaphyseal fragmentation of one or both columns
 - articular comminution
 - poor bone quality

23- Proximal Humerus Fractures

Images



• Summary

- Proximal humerus fractures are common fractures often seen in older patients with osteoporotic bone following a ground-level fall on an outstretched arm.
- Diagnosis is made with orthogonal radiographs of the shoulder.
- Treatment with sling immobilization is indicated for minimally displaced fractures with surgical fixation versus arthroplasty indicated in more complex and displaced fractures.

• Epidemiology

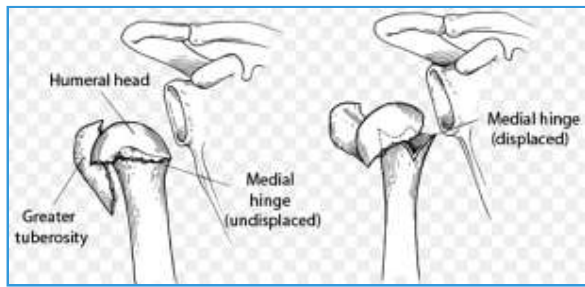
- Incidence
 - common
 - 4-6% of all fractures
 - third most common non-vertebral fracture pattern seen in the elderly (>65 years old)
 - two-part surgical neck fractures are most common
- Demographics
 - 2:1 female to male ratio
 - increasing age associated with more complex fracture types
- Anatomic location
 - may occur at the surgical neck, anatomic neck, greater tuberosity, and lesser tuberosity
 - two-part surgical neck fractures are most common
- Risk factors
 - osteoporosis
 - diabetes
 - epilepsy
 - female gender

• Etiology

- Pathophysiology
 - mechanism
 - low-energy falls
 - elderly with osteoporotic bone
 - high-energy trauma
 - young individuals
 - concomitant soft tissue and neurovascular injuries
 - pathoanatomy
 - vascularity of articular segment is more likely to be preserved if ≥ 8 mm of calcar is attached to articular segment



- predictors of humeral head ischemia (Hertel criteria)
 - <8 mm of calcar length attached to articular segment
 - disrupted medial hinge



- increasing fracture complexity
- displacement >10mm
- angulation >45°
- predictors of humeral head ischemia does not necessarily predict subsequent avascular necrosis

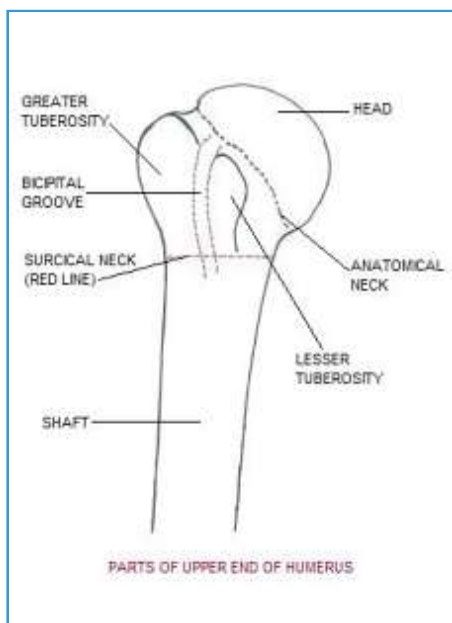
○ Associated conditions

- nerve injury
 - axillary nerve injury most common
- arterial injury
 - uncommon (incidence 5-6%), higher likelihood in older patients
 - most often occur at level of surgical neck or with subcoracoid dislocation of the head

• Anatomy

○ Osteology

- anatomic neck

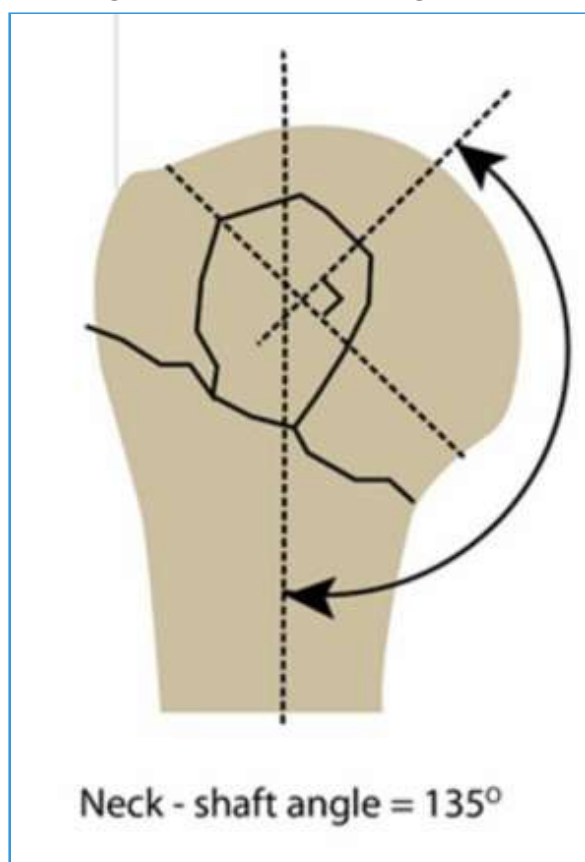


- represents the old epiphyseal plate
- surgical neck



- represents the weakened area below head
- more often involved in fractures than anatomic neck

- average neck-shaft angle is 135 degrees



- Muscles

- pectoralis major displaces shaft anteriorly and medially
- supraspinatus, infraspinatus, and teres minor externally rotate greater tuberosity
- subscapularis internally rotates articular segment or lesser tuberosity

- Ligaments

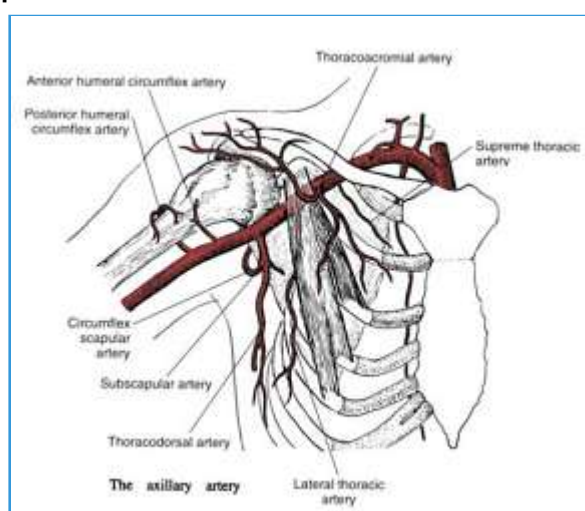
- Coracohumeral ligament
 - attaches to coracoid and greater tuberosity and strengthens the rotator interval
- SGHL
 - restraint to inferior translation at 0° degrees of abduction (neutral rotation)
- MGHL
 - resists AP translation in the midrange (~45°) of abduction
- IGHL
 - restraint to AP translation at 90° degrees of abduction

- Blood Supply

- anterior humeral circumflex artery



- large number of anastomosis with other vessels in the proximal humerus
- branches
 - anterolateral ascending branch
 - arcuate artery is the terminal branch and main supply to greater tuberosity
- posterior humeral circumflex artery



- recent studies suggest it is the main blood supply to humeral head

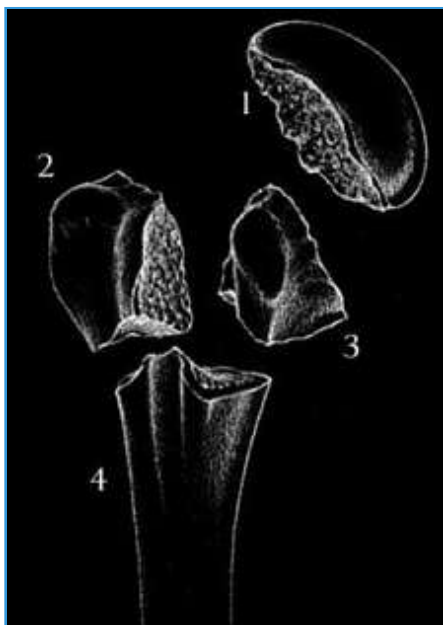
- Classification

- AO/OTA

A: Unifocal Extra-articular 2-Part Fracture Intact Blood Supply				
B: Bifocal Extra-articular Possible injury to blood supply				
C: Articular fracture involving the anatomic neck high likelihood of necrosis				

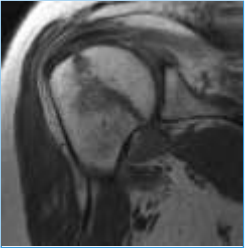
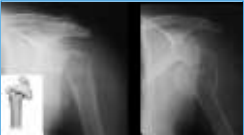
- organizes fractures into 3 main groups and additional subgroups based on
 - fracture location
 - status of the surgical neck
 - presence/absence of dislocation

- Neer classification



Minimal displacement	Displaced fractures			
	2 Part	3 Part	4 Part	
II Anatomical neck				
III Surgical neck				
IV Greater tuberosity				
V Lesser tuberosity				
VI Fracture dislocation Anterior-posterior				Articular surface

- based on anatomic relationship of 4 segments
 - greater tuberosity
 - lesser tuberosity
 - articular surface
 - shaft
 - considered a separate part if
 - displacement of > 1 cm
 - 45° angulation

Neer Classification				
	Minimally displaced	Two-part	Three-part	Four-part
Anatomical neck				
Surgical Neck				
Greater Tuberosity				
Lesser Tuberosity				
Fracture-Dislocation				
Head Split				

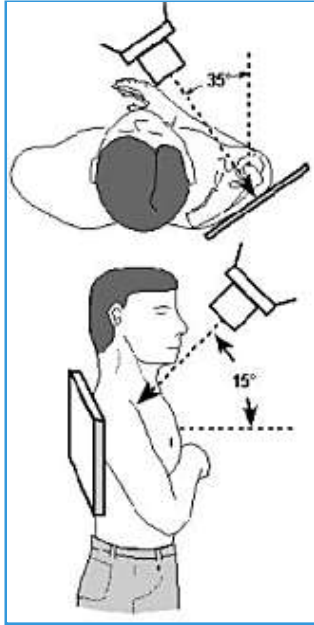
• Presentation

- Symptoms
 - pain and swelling
 - decreased motion
- Physical exam
 - inspection
 - extensive ecchymosis of chest, arm, and forearm
 - neurovascular exam
 - axillary nerve injury most common
 - determine function of deltoid muscle and lateral shoulder sensation
 - arterial injury may be masked by extensive collateral circulation preserving distal pulses
 - examine for concomitant chest wall injuries

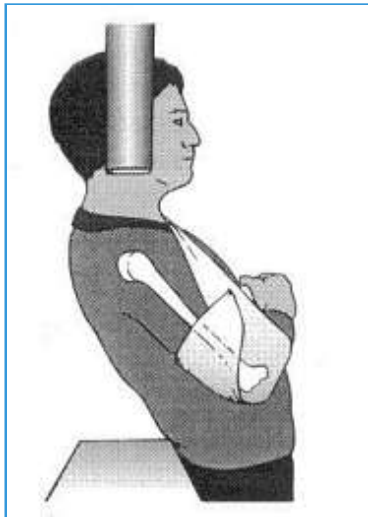
• Imaging

- Radiographs
 - recommended views
 - complete trauma series
 - true AP (Grashey)

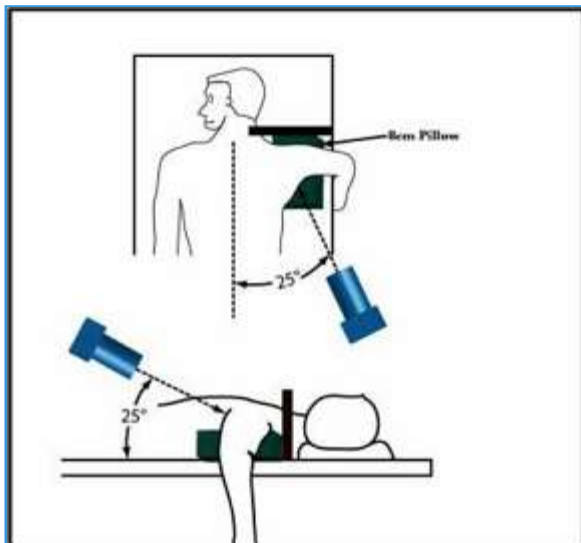
- scapular Y
- axillary
- additional views
 - apical oblique



- Velpeau



- West Point axillary



- findings
 - combined cortical thickness (medial + lateral thickness >4 mm)
 - studies suggest correlation with increased lateral plate pullout strength
 - pseudosubluxation (inferior humeral head subluxation) caused by blood in the capsule and muscular atony



- CT scan
 - indications
 - preoperative planning
 - humeral head or greater tuberosity position uncertain
 - intra-articular comminution
 - concern for head-split fracture
- MRI
 - indications
 - rarely indicated
 - useful to identify associated rotator cuff injury
- Treatment
 - Nonoperative
 - **sling immobilization followed by progressive rehabilitation**
 - indications
 - most proximal humerus fractures can be treated nonoperatively including
 - minimally displaced surgical and anatomic neck fractures
 - greater tuberosity fracture displaced < 5mm
 - >5mm displacement will result in impingement with loss of abduction and external rotation
 - fractures in patients who are not surgical candidates
 - additional variables to consider
 - age
 - fracture type
 - fracture displacement
 - bone quality
 - dominance
 - general medical condition
 - concurrent injuries
 - outcomes
 - immediate physical therapy results in faster recover
 - Operative
 - **CRPP (closed reduction percutaneous pinning)**
 - indications
 - 2-part surgical neck fractures
 - 3-part and valgus-impacted 4-part fractures in patients with good bone quality, minimal metaphyseal comminution, and intact medial calcar
 - outcomes
 - considerably higher complication rate compared to ORIF, HA, and RSA
 - axillary nerve at risk with lateral pins
 - musculocutaneous nerve, cephalic vein, and bicep tendon at risk with anterior pins
 - **ORIF**
 - indications
 - greater tuberosity displaced > 5mm
 - displaced 2-part fractures
 - 3-, and 4-part fractures in younger patients
 - head-splitting fractures in younger patients
 - outcomes
 - medial support necessary for fractures with posteromedial comminution
 - consider use of a fibula strut if concerned about medial support or bone quality
 - calcar screw placement critical to decrease varus collapse of head
 - **Intramedullary nailing**
 - indications
 - surgical neck fractures or 3-part greater tuberosity fractures in younger patients
 - combined proximal humerus and humeral shaft fractures
 - outcomes
 - biomechanically inferior with torsional stress compared to plates

- retroversion of humeral component $> 40^\circ$

- ORIF v. hemiarthroplasty v. reverse total shoulder arthroplasty in elderly

- Rare

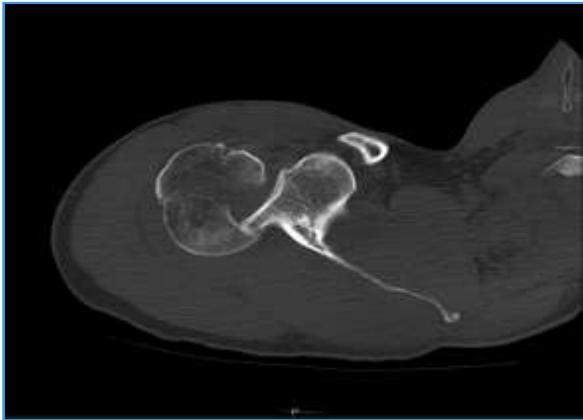
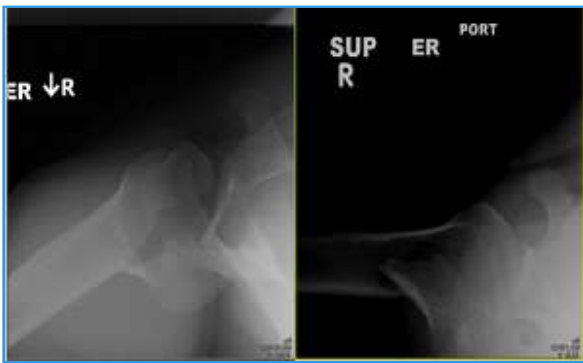
■ Three-part fracture			
■ Surgical neck and GT ■	■ Subscap will internally rotate articular segment ■ Often associated with longitudinal RCT	■ Nonoperative if: ■ Minimally displaced (GT<5 mm; articular segment <1 cm and <45 degrees) ■ Poor surgical candidate ■ Operative: ■ Young patient ■ - percutaneous pinning (good results, protect axillary nerve) ■ - IM fixation (violates cuff) ■ - locking plate (poor results with high rate of AVN, impingement, infection, and malunion) ■ Elderly patient ■ - hemiarthroplasty with RCR or tuberosity repair vs. reverse total shoulder arthroplasty	■
■ Surgical neck and LT 	■ Unopposed pull of posterior cuff musculature leads articular surface to point anterior ■ Often associated with longitudinal RCT	■ Trend towards nonoperative management given high complications with ORIF ■ Young patient ■ - percutaneous pinning (good results, protect axillary nerve) ■ - IM fixation (violates cuff) ■ - locking plate (poor results with high rate of AVN, impingement, infection, and malunion) ■ Elderly patient ■ - hemiarthroplasty with RCR or tuberosity repair vs. reverse total shoulder arthroplasty	■
■ Four-Part Fracture			
■ Valgus impacted fracture 	■ Radiographically will see alignment between medial shaft and head segments	■ Low rate of AVN if posteromedial component intact thus preserving intraosseous blood supply ■ Surgical technique ■ 1. raise articular surface and fill defects ■ 2. repair tuberosities	■
■ 4-part with head-splitting fracture	■ Characterized by high risk of AVN (21-75%) ■ Deforming forces: 1) shaft pulled medially by pectoralis	■ Young patient ■ - ORIF vs. hemiarthroplasty (hemiarthroplasty favored for non-reconstructible articular surface, severe head split, extruded anatomic neck fracture) ■ Elderly patient ■ - hemiarthroplasty v. reverse total shoulder arthroplasty	■

Techniques

- **Sling immobilization followed by progressive rehabilitation**
 - technique
 - sling for comfort x2-3wks, immediate physical therapy for early ROM
- **CRPP (closed reduction percutaneous pinning)**



- approach
 - percutaneous
- technique
 - use threaded pins but do not cross cartilage
 - externally rotate shoulder during pin placement
 - engage cortex 2 cm inferior to inferior border of humeral head
- complications
 - with lateral pins
 - risk of injury to axillary nerve
 - with anterior pins
 - risk of injury to biceps tendon, musculocutaneous n., cephalic vein
 - possible pin migration
- **ORIF**



- approach
 - anterior (deltopectoral)
 - lateral (deltoid-splitting)
 - increased risk of axillary nerve injury



- technique
 - heavy nonabsorbable sutures
 - figure-of-8 technique should be used for isolated greater tuberosity fx reduction and fixation (avoid hardware due to impingement)
 - isolated screw



- may be used for greater tuberosity fx reduction and fixation in young patients with good bone stock
- locking plate
 - screw cut-out (up to 14%) is the most common complication following ORIF with a periarticular locking plates

- more elastic than blade plate making it a better option in osteoporotic bone
- place plate lateral to the bicipital groove and pectoralis major tendon to avoid injury to the ascending branch of anterior humeral circumflex artery
- placement of an inferomedial calcar screw(s) can prevent postoperative varus collapse, especially in osteoporotic bone
- postoperative Rehabilitation
 - important part of management
 - best results with guided protocols (3-phase programs)
 - early passive ROM
 - active ROM and progressive resistance
 - advanced stretching and strengthening program
 - prolonged immobilization leads to stiffness

○ **Intramedullary nailing**



- approach
 - superior deltoid-splitting approach
- technique
 - lock nail with trauma or pathologic fractures
 - straight nails are placed through the superior articular cartilage (more central entry point)
 - nails with proximal bend are placed through an entry point just medial to rotator cuff insertion
- complications
 - rod migration in older patients with osteoporotic bone is a concern
 - shoulder pain from violating rotator cuff
 - nerve injury with interlocking screw placement
 - radial nerve at risk with lateral to medial distal screw
 - musculocutaneous nerve at risk with anterior to posterior distal screw

○ **Hemiarthroplasty**



- approach

- anterior (deltopectoral)
- technique for fractures
 - cerclage wire or suture passed through hole in prosthesis and tuberosities improves fracture stability
 - place greater tuberosity ~8 mm below articular surface of humeral head (HTD = head to tuberosity distance)
 - nonanatomic placement of tuberosities results in impairment in external rotation kinematics with an 8-fold increase in torque requirements
 - height of the prosthesis best determined off the superior edge of the pectoralis major tendon
 - 5.6cm between top of humeral head and superior edge of tendon
 - post-operative passive external rotation places the most stress on the lesser tuberosity fragment

○ **Reverse shoulder arthroplasty**



- approach
 - anterior (deltopectoral)
 - anterolateral deltoid split
- technique for fractures
 - ensure adequate glenoid bone stock
 - ensure functioning deltoid muscle
 - repair of tuberosities recommended despite ability of RSA design to compensate for non-functioning tuberosities/rotator cuff
 - improves range of motion

• **Complications**

- Screw cut-out
 - incidence
 - most common complication following periarticular locking plating fixation (up to 14%)
- Avascular necrosis



- risk factors
 - risk factors for humeral head ischemia are not the same for developing subsequent avascular necrosis
 - better tolerated than in lower extremity
 - no relationship to type of fixation (plate or cerclage wires)
- Nerve injury
 - incidence
 - axillary nerve injury most common (up to 58% with studies using EMG)
 - increased risk with lateral (deltoid-splitting) approach
 - axillary nerve is usually found ~5-7cm distal to the tip of the acromion
 - at risk with lateral pins in CRPP
 - suprascapular nerve (up to 48%)
 - musculocutaneous nerve
 - at risk with anterior pins in CRPP
- Malunion
 - usually varus apex-anterior or malunion of GT
 - results inferior if converting from varus malunited fracture to TSA
 - use reverse shoulder arthroplasty instead
- Nonunion
 - most common after two-part surgical neck fracture
 - treatment of chronic nonunion/malunion in the elderly should include arthroplasty
 - lesser tuberosity nonunion leads to weakness with lift-off testing
 - greater tuberosity nonunion after arthroplasty leads to lack of active shoulder elevation
 - greatest risk factors for nonunion are age and smoking
- Rotator cuff injuries and dysfunction
- Long head of biceps tendon injuries
 - also at risk with anterior pin in CRPP
- Missed posterior dislocation
 - consider in all patients with lesser tuberosity fracture
- Adhesive capsulitis and scar tissue
- Posttraumatic arthritis
- Infection

24- Humeral Shaft Fractures

Images



• Summary

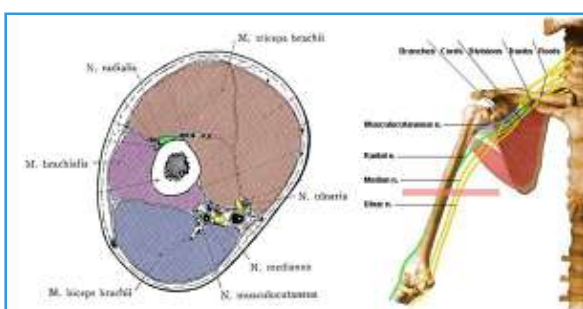
- Humeral shaft fractures are common fractures of the diaphysis of the humerus, which may be associated with radial nerve injury.
- Diagnosis is made with orthogonal radiographs of the humerus.
- Treatment can be nonoperative or operative depending on location of fracture, fracture morphology, and association with other ipsilateral injuries.

• Epidemiology

- Incidence
 - 3-5% of all fractures
- Demographics
 - bimodal age distribution
 - young patients with high-energy trauma
 - elderly, osteopenic patients with low-energy injuries

• Anatomy

- Osteology
 - humeral shaft is cylindrical
 - distally humerus becomes triangular
 - intramedullary canal terminates 2 to 3 cm proximal to the olecranon fossa
- Muscles
 - insertion for
 - pectoralis major
 - deltoid
 - coracobrachialis
 - origin for
 - brachialis
 - triceps
 - brachioradialis
- Nerve
 - radial nerve



- courses along spiral groove
- 14cm proximal to the lateral epicondyle
- 20cm proximal to the medial epicondyle

• Classification

- OTA
 - bone number: 1
 - fracture location: 2
 - fracture pattern: simple:A, wedge:B, complex:C
- Descriptive
 - fracture location: proximal, middle or distal third
 - fracture pattern: spiral, transverse, comminuted
- Holstein-Lewis fracture



- a spiral fracture of the distal one-third of the humeral shaft commonly associated with neuropraxia of the radial nerve (22% incidence)

• Presentation

- Symptoms
 - pain
 - extremity weakness
- Physical exam
 - examine overall limb alignment
 - will often present with shortening and in varus
 - preoperative or pre-reduction neurovascular exam is critical
 - examine and document status of radial nerve pre and post-reduction

• Imaging

- Radiographs
 - views
 - AP and lateral
 - be sure to include joint above and below the site of injury



- transthoracic lateral

- may give better appreciation of sagittal plane deformity



- rotating the patient prevents rotation of the distal fragment avoiding further nerve or soft tissue injury
- traction views
 - may be necessary for fractures with significant shortening, proximal or distal extension but not routinely indicated

• Treatment

◦ Nonoperative

▪ **cast/splint followed by functional brace**

- indications
 - indicated in vast majority of humeral shaft fractures
 - criteria for acceptable alignment include:
 - $< 20^\circ$ anterior angulation
 - $< 30^\circ$ varus/valgus angulation
 - < 3 cm shortening
- absolute contraindications
 - severe soft tissue injury or bone loss
 - vascular injury requiring repair
 - brachial plexus injury
- relative contraindications
 - see relative operative indications section
 - radial nerve palsy is NOT a contraindication to functional bracing
- outcomes
 - 90% union rate
 - increased risk with proximal third oblique or spiral fracture



- varus angulation is common but rarely has functional or cosmetic sequelae

▪ **damage control orthopaedics (DCO)**

- closed humerus fractures, including low velocity GSW, should be initially managed with a splint or sling
- type of fixation after trauma should be directed by acceptable fracture alignment parameters, fracture pattern and associated injuries

◦ Operative

▪ **open reduction and internal fixation (ORIF)**

- absolute indications
 - open fracture
 - vascular injury requiring repair
 - brachial plexus injury
 - ipsilateral forearm fracture (floating elbow)
 - compartment syndrome
 - periprosthetic humeral shaft fractures at the tip of the stem
- relative indications
 - bilateral humerus fracture
 - polytrauma or associated lower extremity fracture
 - allows early weight bearing through humerus
 - pathologic fractures
 - burns or soft tissue injury that precludes bracing
 - fracture characteristics
 - distraction at fracture site
 - short oblique or transverse fracture pattern
 - intraarticular extension

▪ intramedullary nailing (IMN)



- relative indications
 - pathologic fractures
 - segmental fractures
 - severe osteoporotic bone
 - overlying skin compromise limits open approach
 - polytrauma

• Techniques

◦ Coaptation Splint & Functional Bracing

- coaptation splint
 - applied until swelling resolves
 - adequately applied splint will extend up to axilla and over shoulder
 - common deformities include varus and extension
 - valgus mold to counter varus displacement
- functional bracing



- extends from 2.5 cm distal to axilla to 2.5 cm proximal to humeral condyles
- sling should not be used to allow for gravity-assisted fracture reduction
- shoulder extension used for more proximal fractures
- weekly radiographs for first 3 weeks to ensure maintenance of reduction

- every 3-4 weeks after that

○ Open Reduction and Internal Fixation (ORIF)

- approaches
 - anterior (brachialis split) approach to humerus
 - used for middle third shaft fractures
 - deep dissection through internervous plane of brachialis muscle
 - lateral fibers (radial n.) and medial fibers (musculocutaneous n.) in majority of patients (~80%)
 - anterolateral approach to humerus
 - used for proximal third to middle third shaft fractures



- distal extension of the deltopectoral approach
 - radial nerve identified between the brachialis and brachioradialis distally
- posterior approach to humerus
 - used for distal to middle third shaft fractures although can be extensile
 - triceps may either be split or elevated with a lateral paratricipital exposure
 - radial nerve is found medial to the long and lateral heads and 2cm proximal to the deep head of the triceps



- radial nerve exits the posterior compartment through lateral intramuscular septum 10 cm proximal to radiocapitellar joint
- lateral brachial cutaneous/posterior antebrachial cutaneous nerve serves as an anatomic landmark leading to the radial nerve during a paratricipital approach
- techniques
 - plate osteosynthesis commonly with 4.5mm plate (narrow or broad)
 - 3.5mm plates may function adequately
 - absolute stability with lag screw or compression plating in simple patterns



- apply plate in bridging mode in the presence of significant comminution



- postoperative
 - full crutch weight bearing shown to have no effect on union
- **Intramedullary Nailing (IMN)**
 - techniques
 - can be done antegrade or retrograde
 - complication
 - nonunion
 - nonunion rates not shown to be different between IMN and plating in recent meta-analyses
 - IM nailing associated with higher total complication rates
 - shoulder pain
 - increased rate when compared to plating (16-37%)
 - functional shoulder outcome scores (ASES scores) not shown to be different between IMN and ORIF
 - nerve injury
 - while controversial, a recent meta-analysis showed no difference between the incidence of radial nerve palsy between IMN and plating
 - radial nerve is at risk with a lateral to medial distal locking screw
 - musculocutaneous nerve is at risk with an anterior-posterior locking screw
 - postoperative
 - full weight bearing allowed and had no effect on union
- **Complications**
 - Humeral shaft fx nonunion
 - no callous on radiograph and gross motion at the fracture site at 6 weeks from injury has a 90-100% PPV of going on to nonunion in closed humeral shaft fractures
 - Malunion
 - varus angulation is common but rarely has functional or cosmetic sequelae
 - risk factors
 - transverse fracture patterns
 - Radial nerve palsy
 - incidence
 - seen in 8-15% of closed fractures
 - increased incidence distal one-third fractures (22%)
 - neuropraxia most common injury in closed fractures and neurotomesis in open fractures
 - iatrogenic radial nerve palsy is most common following ORIF via a lateral approach (20%) or posterior approach (11%)
 - 85-90% of improve with observation over 3 months
 - spontaneous recovery found at an average of 7 weeks, with full recovery at an average of 6 months
 - treatment
 - **observation**
 - indicated as initial treatment in closed humerus fractures
 - obtain NCS/EMG at ~2 months
 - useful to determine extent of nerve damage, baseline of function, and to monitor recovery
 - wrist extension in radial deviation is expected to be regained first
 - brachioradialis first to recover, extensor indicis is the last
 - **surgical exploration**

- indications
 - open fracture with radial nerve palsy (likely neurotomesis injury to the radial nerve)
 - closed fracture that fails to improve over ~4-6 months
 - fibrillations (denervation) seen on EMG
- **tendon transfers**
 - indications
 - persistent radial nerve palsy - optimal timing debated
 - wrist extension: PT to ECRB
 - finger extension: FCR/FCU to EDC
 - thumb extension: PL to EPL

3

3

Rockwood

And

Green's™:

Fractures in

Adults

Rockwood and Green's Fractures in Adults. Chapter 36: HUMERAL SHAFT FRACTURES

Christos Garnavos

- Trauma
- - Humeral Shaft Fractures

Christos Garnavos,

25- Proximal Humerus Fracture Nonunion And Malunion

Images



• Summary

- Proximal Humerus Fracture Nonunion and Malunion are common complications associated with proximal humerus fractures which can lead to persistent shoulder pain, instability, and restricted motion.
- Diagnosis is made radiographically with shoulder radiographs demonstrating malposition of the humeral tuberosities, varus/vaglus head-shaft angulation, articular incongruities, or absence of bony union.
- Treatment ranges from nonoperative to revision ORIF to shoulder arthroplasty depending on severity of malunion, available bone stock, patient age and activity demands.

• Epidemiology

- Incidence
 - common
 - proximal humerus fractures account for 4% to 5% of all fractures
- Risk factors for nonunion
 - fracture characteristics
 - 2-part (surgical neck) fracture patterns
 - humeral head split
 - displaced tuberosity fractures



- patient factors
 - osteoporosis
 - chronic renal disease
 - chronic alcohol or steroid use
 - smoking

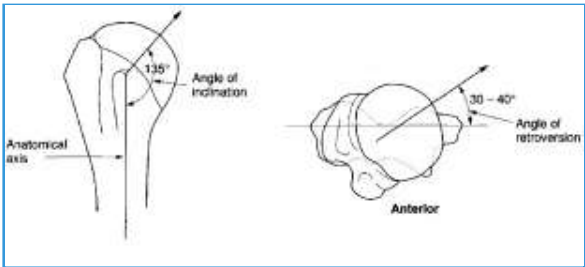
• Etiology

- Pathophysiology
 - origin of malunion
 - initial fracture displacement

- secondary displacement after loss of reduction
 - failure of internal fixation
- humeral head malunion
 - varus/valgus
 - impacted (>1cm displacement)
 - articular surface incongruity (e.g. head split)
- greater tuberosity malunion
 - usually displaced posterior, superior and externally rotated
- lesser tuberosity malunion
 - usually displaced medial
- Associated conditions
 - rotator cuff tearing
 - osteonecrosis of humeral head
 - glenohumeral joint issues
 - stiffness
 - post-traumatic arthritis
 - subluxation or dislocation
 - subacromial impingement

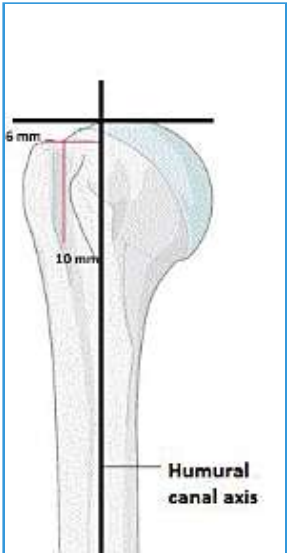
• Anatomy

- Humeral head
 - shape
 - spheroidal in 90% of individuals
 - size
 - average diameter is 43 mm
 - orientation



- retroverted 30° from transepicondylar axis of the distal humerus
 - neck-shaft angle usually 1 30° to 140°

- Greater tuberosity
 - position important for rotator cuff muscle fuction



- horizontal position
 - medial edge of tuberosity is 10mm lateral to humeral canal axis
 - vertical position
 - superior edge of tuberosity is 6mm inferior to upper edge of humeral head

• Classification

○	▪ Beredjiklian Classification		
	▪ Type I	▪ Malposition of the greater or lesser tuberosity(e.g. >1 cm from native anatomical position)	▪
	▪ Type II	▪ Articular incongruity (e.g.intra-articular fracture extension, osteoarthritis)	▪
	▪ Type III	▪ Articular surface malalignment (e.g. >45°of deformity with respect to the humeral shaft in the coronal, sagittal, or axial planes	

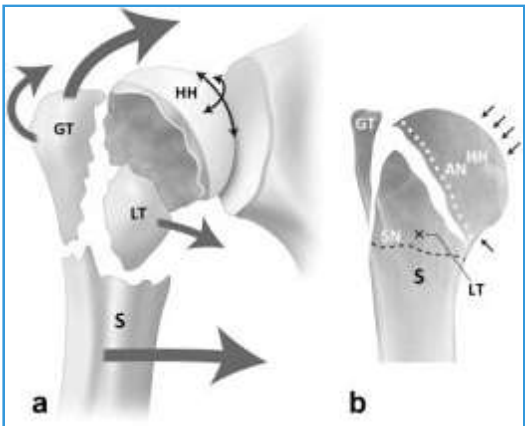
Boileau Classification		
Type I	Humeral head necrosis or impaction	
Type II	Chronic dislocations or fracture-dislocations	
Type III	Nonunion of the surgical neck	
Type IV	Severe malunion of the tuberosity	

• Presentation

- History
 - initial evaluation
 - date and mechanism of injury
 - current and prior function
 - handedness
 - treatment to date
 - specific goals of treatment
- Symptoms
 - pain and weakness
 - limitations
- Physical exam
 - inspection
 - features of systemic disease
 - muscle atrophy
 - diffuse tenderness
 - motion
 - active and passive shoulder range-of-motion
 - blocks or crepitus should be noted
 - rotator cuff
 - greater tuberosity malunion = weakness with abduction, external rotation
 - lesser tuberosity malunion = weakness with internal rotation
 - instability
 - humeral head malunion = apprehension test
 - neurovascular
 - check axillary nerve function

• Imaging

- Radiographs
 - recommended views
 - true AP, scapular Y, axillary
 - optional views
 - apical oblique
 - Velpeau
 - West Point axillary
 - findings
 - neck-shaft angle = varus or valgus
 - greater tuberosity = superiorly and posteriorly displaced, externally rotated
 - lesser tuberosity = medialized
 - measurements



- humeral head

- > 45° of deformity in any plane
 - symptomatic articular incongruity
 - neck-shaft angle <120° or >150°
 - greater or lesser tuberosity
 - >1 cm from native anatomical position
- CT scan
 - indications
 - preoperative planning
 - assess bone stock, orientation and articular surface
 - findings
 - humeral head and greater tuberosity displacement
 - glenoid version and glenoid bone stock
 - articular injury
- MRI
 - indications
 - preoperative planning
 - soft-tissue structures
 - findings
 - rotator cuff or labral injury
 - deltoid atrophy secondary to axillary nerve injury
 - long-head biceps injury
 - osteonecrosis
- Studies
 - Labs
 - CBC, ESR, CRP, blood cultures to rule out infection
 - Electrodiagnostics
 - concern for nerve dysfunction
- Treatment
 - Nonoperative
 - **NSAIDS, physical therapy, occasional corticosteroid injection**
 - indications
 - low-demand patient
 - painless shoulder limitations
 - unable to comply with the rehabilitation protocol
 - modalities
 - physical therapy
 - maximize ROM and strengthening program
 - outcomes
 - impacted varus and valgus fractures show good-to-excellent results
 - return to 90% of normal function
 - Operative
 - **ORIF +/- osteotomy, subacromial decompression, and soft tissue technique**
 - indications
 - symptomatic malunion following
 - nonoperative treatment
 - failed internal fixation
 - anatomical requirements
 - adequate bone stock for fixation
 - preserved articular surface
 - intact blood supply to humeral head
 - outcomes
 - complication rates associated with surgical management of malunions are higher than those associated with acute fractures
 - **shoulder arthroplasty**

- indications
 - symptomatic malunion following
 - nonoperative treatment
 - failed internal fixation
 - anatomical requirements
 - inadequate bone stock for fixation techniques
 - articular incongruity, destruction or collapse (e.g. osteonecrosis or head-split)
 - compromised blood supply
 - chronic dislocation
- techniques
 - hemiarthroplasty
 - total shoulder arthroplasty
 - reverse total shoulder arthroplasty
 - greater improvement in functional outcome scores than hemiarthroplasty
 - lower complication rates than hemiarthroplasty

- techniques

- **ORIF +/- osteotomy, subacromial decompression, and soft tissue technique**

- technique
 - humeral head deformities
 - minor deformity techniques
 - open/arthroscopic tuberoasty
 - +/- acromioplasty
 - +/- capsular release
 - +/- bursectomy
 - severe deformity techniques
 - varus/valgus osteotomy
 - +/- rotational osteotomy and lateral plate fixation
 - treated with corrective osteotomy/fixation if patient is young or active
 - may be augmented with strut allograft for poor bone stock
 - greater tuberosity deformities
 - <1.5 cm displacement
 - arthroscopic subacromial decompression +/- rotator cuff repair
 - >1.5 cm displacement
 - open/arthroscopic tuberosity osteotomy +/- subacromial decompression

- **Shoulder arthroplasty**

- technique
 - hemiarthroplasty
 - anatomic total shoulder arthroplasty
 - reverse total shoulder arthroplasty

- Complications

- Persistent pain and weakness
 - Stiffness
 - Loss of fixation
 - Infection
 - Bleeding

26- Olecranon Fractures

Images



- summary

- Olecranon Fractures are common fractures of the elbow that lead to loss of extensor mechanism.
- Diagnosis can be made with plain radiographs of the elbow.
- Treatment may be nonoperative for nondisplaced fractures with an intact extensor mechanism. Surgical management is indicated for displaced fractures or fractures associated with loss of extensor mechanism.

- Epidemiology

- Incidence
 - 12 per 100,000 per year
 - account for approximately 10% of upper extremity fractures
- Age
 - mean age is ~57 years
 - Bimodal distribution
 - high energy injuries in the young
 - low energy falls in the elderly

- Etiology

- Pathophysiology
 - mechanism
 - direct blow
 - usually results in comminuted fracture
 - indirect blow
 - fall onto outstretched upper extremity
 - usually results in transverse or oblique fracture
- Associated conditions
 - Transolecranon fracture/dislocation

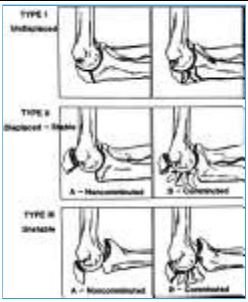


- severe axial load leading to potential instability of the ulnohumeral joint due to severe intra-articular comminution of the olecranon fracture
- considered an anterior dislocation of the elbow (distal humerus is driven through the olecranon)
- there is no disruption of the proximal radioulnar joint

- Anatomy

- Osteology
 - together with coronoid process, forms the greater sigmoid (semilunar) notch
 - greater sigmoid notch articulates with trochlea
 - provides flexion-extension movement
 - adds to stability of elbow joint
- Muscles
 - triceps
 - inserts onto posterior, proximal ulna
 - blends with periosteum
 - innervated by radial nerve (C7)
 - anconeus
 - inserts on lateral aspect of olecranon
 - innervate by radial nerve (C7)

- Classification

◦	▪ Mayo Classification	
	▪ Based on comminution, displacement, fracture-dislocation	▪ 
◦	▪ Colton Classification	
	▪ Nondisplaced - Displacement does not increase with elbow flexion	▪ 
	▪ Avulsion (displaced)	▪ 
	▪ Oblique and Transverse (displaced)	▪ 
	▪ Comminuted (displaced)	▪ 
	▪ Fracture-dislocation (Transolecranon)	▪ 

■ Schatzker Classification		
■ Type A	■ Simple transverse fracture	■ 
■ Type B	■ Transverse impacted fracture	■ 
■ Type C	■ Oblique fracture	■ 
■ Type D	■ Comminuted fracture	■ 
■ Type E	■ More distal fracture, extra-articular	■ 
■ Type F	■ Fracture-dislocation	■ 
■ AO Classification		
■ Type A	■ Extra-articular	■ 
■ Type B	■ Intra-articular	■ 
■ Type C	■ Intra-articular fractures of both the radial head and olecranon	■ 

- Presentation

- Symptoms
 - pain well localized to posterior elbow
- Physical exam
 - palpable defect

- indicates displaced fracture or severe comminution
- inability to extend elbow
 - indicates discontinuity of triceps (extensor) mechanism

• Imaging

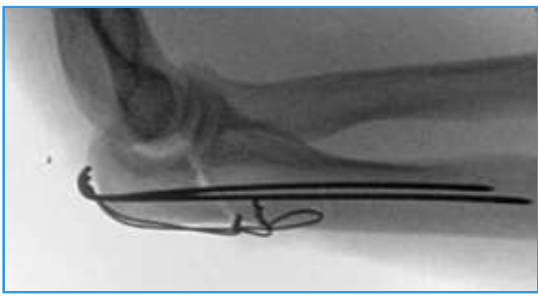
- Radiographs
 - recommended views
 - AP/lateral radiographs
 - true lateral essential for determination of fracture pattern
 - additional views
 - radiocapitellar may be helpful for
 - radial head fracture
 - capitellar shear fracture
- CT
 - may be useful for preoperative planning in comminuted fractures

• Treatment

- Nonoperative
 - **immobilization**
 - indications
 - nondisplaced fractures with intact extensor mechanism
 - displaced fracture in low demand, elderly individuals
 - technique
 - immobilization in 45-90 degrees of flexion initially
 - begin motion at 1 week
- Operative
 - **tension band technique**
 - indications
 - transverse fracture with no comminution
 - outcomes
 - excellent results with appropriate indications
 - **intramedullary fixation**
 - indications
 - transverse fracture with no comminution (same as tension band technique)
 - **plate and screw fixation**
 - indications
 - comminuted fractures
 - Monteggia fractures
 - fracture-dislocations
 - oblique fractures that extend distal to coronoid
 - **excision and triceps advancement**
 - indications
 - elderly patients with osteoporotic bone
 - fracture must involve <50% of joint surface
 - nonunions
 - outcomes
 - salvage procedure that leads to decreased extension strength
 - may result in instability if ligamentous injury is not diagnosed before operation

• Techniques

- **Tension band technique**



- technique
 - converts distraction force of triceps into a compressive force
 - engaging anterior cortex of ulna with Kirschner wires may prevent wire migration
 - avoid overpenetration of wires through anterior cortex
 - may injury anterior interosseous nerve (AIN)
 - may lead to decreased forearm rotation
 - use 18-gauge wire or non-absorbable thick suture in figure-of-eight fashion through drill holes in ulna
- cons
 - high % of second surgeries for hardware removal (40-80%)
 - does not provide axial stability in comminuted fractures

○ Intramedullary fixation



- technique
 - can be combined with tension banding
 - intramedullary screw must engage distal intramedullary canal

○ Plate and screw fixation



- technique
 - place plate on dorsal (tension) side
 - oblique fractures benefit from lag screws in addition to plate fixation
 - one-third tubular plates may not provide sufficient strength in comminuted fractures
 - may advance distal triceps tendon over plate to avoid hardware prominence
- pros
 - more stable than tension band technique
- cons
 - 20% need second surgery for plate removal

○ Excision and triceps advancement



- technique
 - triceps tendon reattached with nonabsorbable sutures passed through drill holes in proximal ulna

- Complications

- Symptomatic hardware
 - most frequent reported complication
- Stiffness
 - occurs in ~50% of patients
 - usually doesn't alter functional capabilities
- Heterotopic ossification
 - more common with associated head injury
- Posttraumatic arthritis
- Nonunion
 - rare
- Ulnar nerve symptoms
- Anterior interosseous nerve injury
- Loss of extension strength

27- Radial Head Fractures

- summary

- Radial Head Fractures are common intra-articular elbow fractures that can be associated with an episode of elbow instability, a mechanical block to elbow motion, an injury to the distal radioulnar joint and/or to the interosseous membrane (Essex-Lopresti).
- Diagnosis can be made with plain radiographs of the elbow. CT studies can be helpful for surgical planning.
- Treatment may be nonoperative for non-displaced fractures without a mechanical block to motion butÂ operative management is indicated for displaced fractures, or fractures associated with mechanical block to motion or elbow/forearm instability.

- Epidemiology

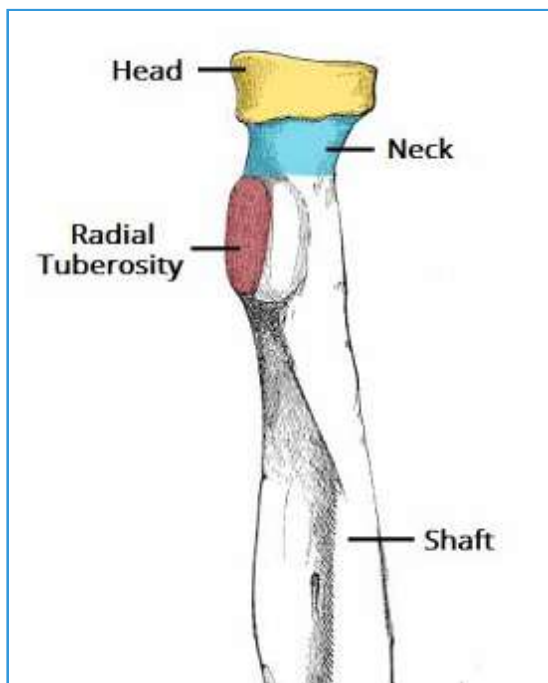
- Incidence
 - very common fracture
 - makes up 1-4% of all fractures in adults
 - makes up 20-30% of all elbow fractures
- Demographics
 - 85% occur between the ages of 30-60
 - mean age is ~ 45 years

- Etiology

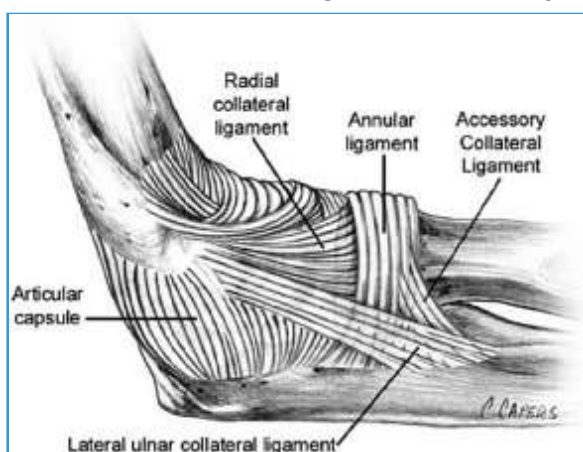
- Pathophysiology
 - mechanism of injury
 - fall on an outstretched hand
 - elbow in extension and forearm in pronation
 - leads to most force transmitted from wrist to radial head
- Associated conditions
 - incidence
 - 30% have associated soft tissue or skeletal injuries
 - types
 - ligamentous/ interosseous injuries
 - lateral collateral ligament (LCL) injury
 - most common (up to 80% on MRI)
 - medial collateral ligament (MCL) injury
 - Essex-Lopresti injury
 - radial head fracture
 - distal radioulnar joint (DRUJ) injury
 - interosseus membrane injury
 - elbow fractures & dislocations
 - coronoid fracture
 - olecranon fracture
 - Monteggia fracture/dislocation
 - terrible triad
 - posterolateral elbow dislocation
 - radial head fracture
 - coronoid fracture
 - carpal fractures
 - scaphoid fracture

- Anatomy

- Osteology
 - proximal radius consists of

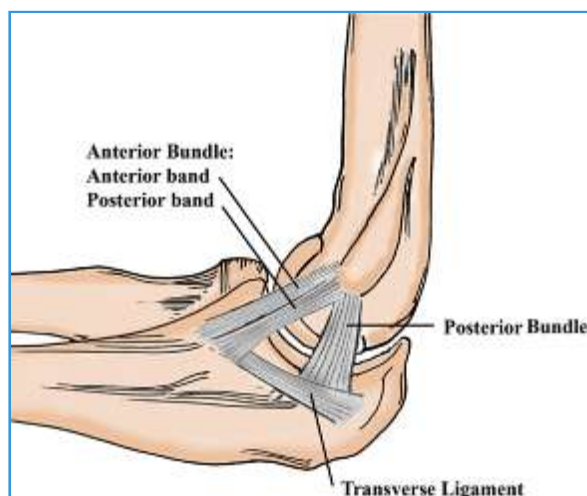


- radial head
- radial neck
- radial tuberosity
- radial shaft
- radial head
 - head-neck osteology
 - the radial head is 15° offset from the neck (not collinear)
 - anterolateral third of radial head lacks subchondral bone
 - easily fractured in this area
 - articular surface
 - has 40° oval-shaped concavity that articulates with capitellum
 - nonarticular portion
 - 90-110° of radial head defined by the projections of the radial styloid and Lister's tubercle
 - considered a safe zone for hardware placement
- Arthrology
 - radiocapitellar joint
 - a pivot joint
 - 60% load transfer across elbow joint
 - fracture or resection of the radial head decreases surface area available for load transfer and decreases stability
 - proximal radial ulnar joint (PRUJ)
 - ulnar portion of radial head that articulates with the lesser sigmoid notch of the ulna
 - important for forearm pronation and supination
- Ligaments
 - lateral collateral ligament complex

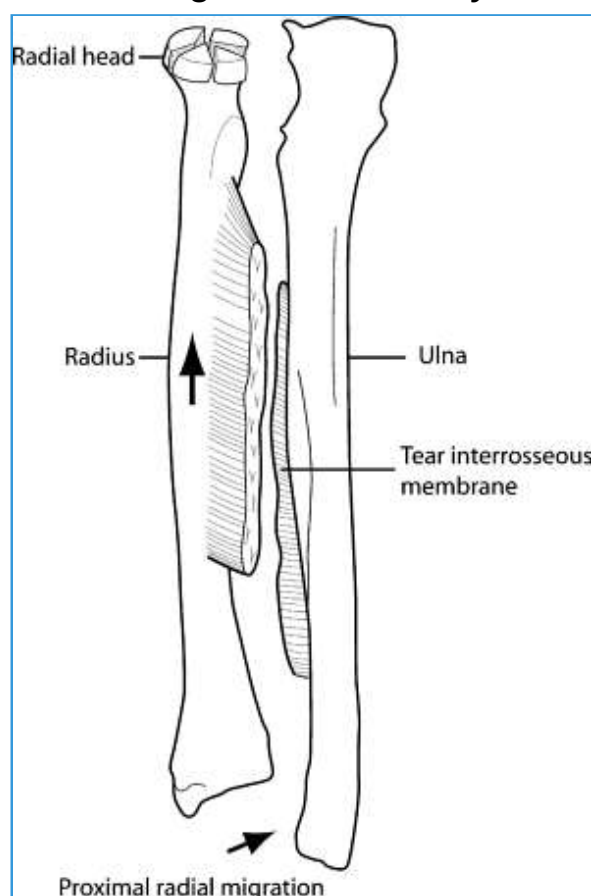


- lateral ulnar collateral ligament (LUCL)
 - inserts onto supinator crest of ulna.
 - primary stabilizer to varus and external rotation (hypersupination) stress
 - more important stabilizer near elbow extension
 - deficiency results in posterolateral rotatory instability
- radial collateral ligament (RCL)
 - inserts into annular ligament
- annular ligament
 - originates and inserts on the anterior and posterior aspects of the lesser sigmoid notch, respectively
 - stabilizes the proximal radioulnar joint by maintaining the radial head in contact with the ulna

- accessory lateral collateral ligament
- medial (ulnar) collateral ligament (MCL)



- three bundles
 - anterior bundle
 - primary stabilizer to valgus stress (radial head is second)
 - posterior bundle
 - transverse bundle
- Biomechanics
 - radial head confers two types of stability to the elbow
 - valgus stability
 - secondary restraint to valgus load at the elbow, important if MCL deficient
 - longitudinal stability
 - restraint to proximal migration of the radius
 - contributions from interosseous membrane and DRUJ
 - load-sharing from wrist to radiocapitellar joint is dependent on radiocapitellar surface area
 - loss of longitudinal stability occurs with Essex-Lopresti injury pattern

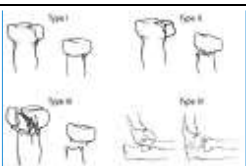


- radial head fracture + DRUJ injury + interosseous membrane disruption
 - radial head must be fixed or replaced to restore stability, preventing proximal migration of the radius and ulnocarpal impaction

• Classification

- Common

○

■ Mason Classification (Modified by Hotchkiss and Broberg-Morrey)		
■ Type I	■ Nondisplaced or minimally displaced (<2mm), no mechanical block to rotation	■    
■ Type II	■ Displaced >2mm or angulated, possible mechanical block to forearm rotation	■  
■ Type III	■ Comminuted and displaced, mechanical block to motion	■  
■ Type IV	■ Radial head fracture with associated elbow dislocation	■  

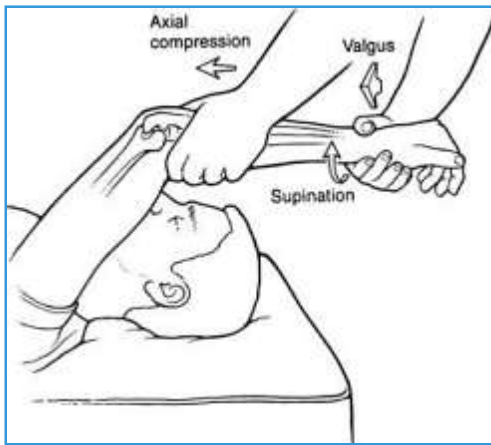
○ Advanced

○

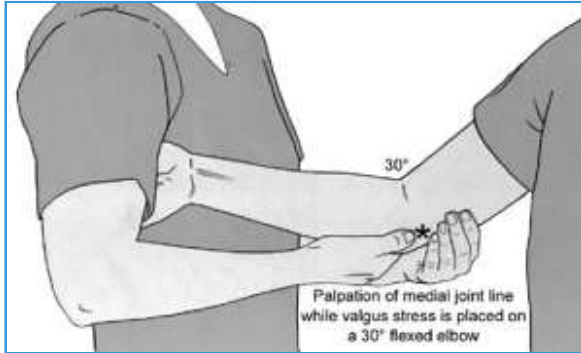
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- valgus stress test (tests MCL)



- DRUJ
 - palpate wrist for tenderness
 - translation in sagittal plane > 50% compare to contralateral side is abnormal
 - if difficult to determine on exam, can get dynamic CT scan in neutral, pronation and supination for subtle injury
- interosseous membrane
 - palpate along interosseous membrane for tenderness
 - radius pull test (performed at the time of surgery)
 - >3mm translation concerning for longitudinal forearm instability (Essex-Lopresti)

• Imaging

- Radiographs
 - recommended views
 - AP and lateral elbow



- AP and lateral forearm/wrist
- findings
 - fracture with or without displacement/intra-articular involvement
 - may see anterior/posterior fat pad sign indicating occult minimally displaced fracture

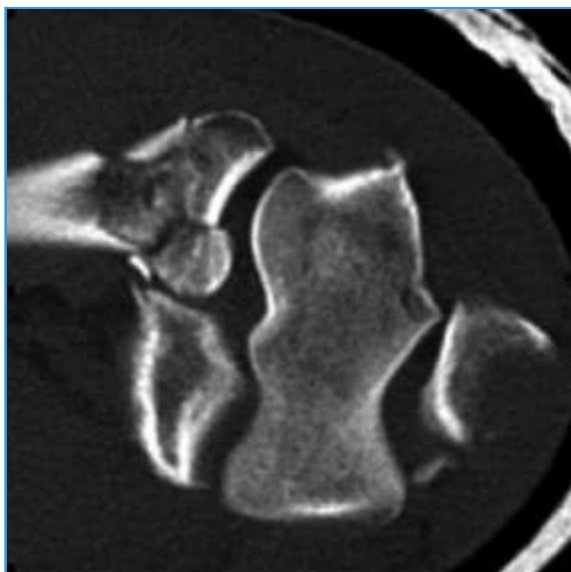


- demonstrates intra-articular hemarthrosis
- posterior fat pad sign more sensitive for fracture
- must rule out concomitant involvement of forearm/wrist
- additional views
 - radiocapitellar view (Greenspan view)



- oblique lateral view of elbow
- beam angled 45 degrees cephalad
- allows visualization of the radial head without coronoid overlap
- helps detect subtle fractures of the radial head

○ CT



- indications
 - comminuted fractures
 - further delineate fragments
 - complex fracture dislocations
- findings
 - may be helpful in planning surgical technique/approaches

• Treatment

○ Nonoperative

- **short period of immobilization (3-7 days) followed by early ROM**
 - indications
 - isolated minimally displaced fractures with no mechanical blocks (Mason Type I)
 - outcomes
 - good results in 85% to 95% of patients
 - beware elbow stiffness with prolonged immobilization

○ Operative

- **open reduction internal fixation (ORIF)**
 - indications

- Mason Type II with mechanical block
- Mason Type III where ORIF feasible
- presence of other complex ipsilateral elbow injuries
- techniques
 - screw(s) only



- plate + screw(s)



- outcomes
 - >90% good-excellent outcomes in Mason II fractures, with variable outcomes in Mason III fractures
 - # fragments
 - ORIF shown to have worse outcome when more than 3 fragments present compared to ORIF with 3 or less fragments
 - >50% rate of unsatisfactory outcomes after ORIF with > 3 fragments
 - isolated vs. complex
 - ORIF isolated radial head fractures versus complex radial head fractures (other associated fracture/dislocation) show no significant difference in outcomes at 4 years
 - isolated fractures trended towards better Patient-Rated Elbow Evaluation score, lower complication rate and lower rate of secondary capsular release
- **fragment excision (partial excision)**
 - indications
 - older, lower demand adults with complex fractures but no associated instability
 - fragments less than 25% of the surface area of the radial head or 25%-33% of capitellar surface area
 - outcomes
 - even small fragment excision may lead to instability
- **radial head resection (complete excision)**



- indications
 - low demand, sedentary patients
 - in a delayed setting for continued pain of an isolated radial head fracture
- contraindications
 - presence of destabilizing injuries
 - forearm interosseous ligament injury (>3mm translation with radius pull test)
 - coronoid fracture
 - MCL deficiency
- outcomes

- worse outcomes with regards to strength, function and motion compared to ORIF
 - higher percentage of arthritis (73%) compared to contralateral uninjured elbow after excision
- **radial head arthroplasty**
 - indications
 - comminuted fractures (Mason Type III) with more than 3 fragments
 - severe plastic deformity of radial head
 - nonunion/malunion
 - elbow fracture-dislocations
 - terrible triad or Monteggia variants
 - with involvement of >30% of articular surface of radial head
 - Essex-Lopresti lesions
 - radial head excision will exacerbate elbow/wrist instability and may result in proximal radial migration and ulnocarpal impingement
 - outcomes
 - radial head fractures requiring replacement have shown good clinical outcomes with metallic implants
 - compared to ORIF for fracture-dislocations and Mason Type III fractures, arthroplasty results in greater stability, lower complication rate and higher patient satisfaction
- **retrograde titanium nail reduction and stabilization**
 - indications
 - not yet considered mainstream treatment as it is in the pediatric population
 - outcomes
 - small powered case studies show good outcomes

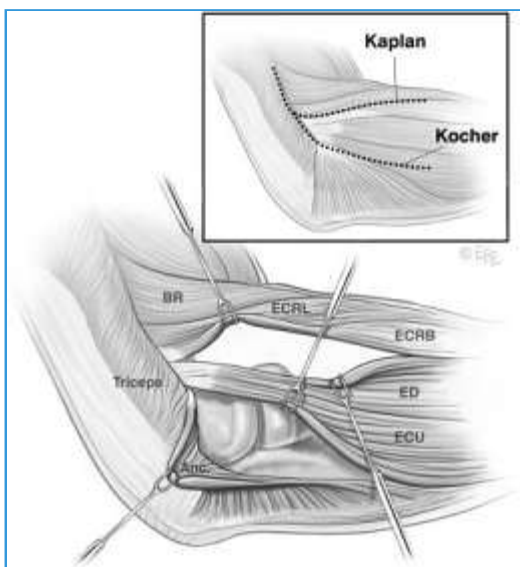
• Techniques

○ Nonoperative management

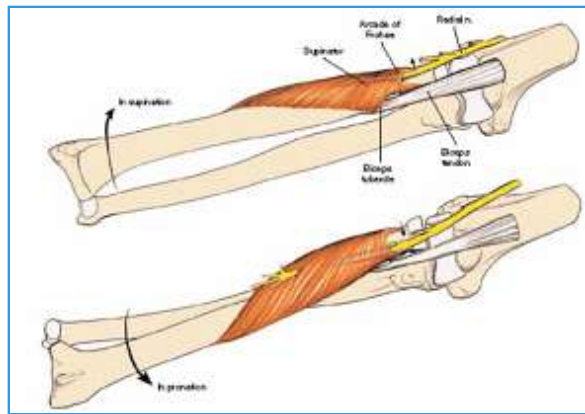
- Sling (preferred) or posterior long arm splint
 - 3-7 days only to prevent stiffness

○ ORIF

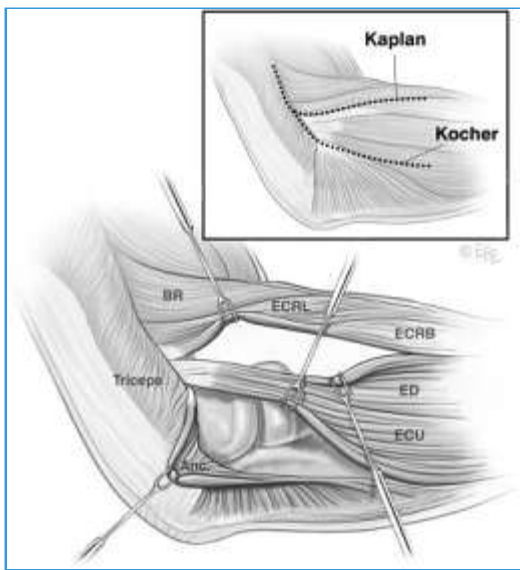
- approaches
 - Kocher approach
 - interval
 - between ECU (PIN) and anconeus (radial n.)



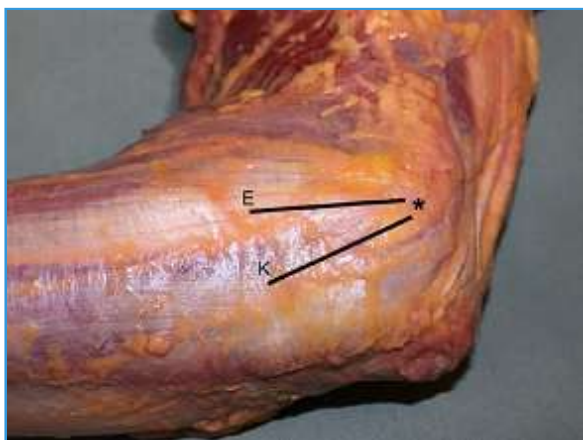
- key steps
 - incise posterior fibers of the supinator
 - incise capsule in mid-radiocapitellar plane
 - anterior to crista supinatoris to avoid damaging LUCL
- pros
 - less risk of PIN injury than Kaplan approach (more posterior)
 - PIN crosses the proximal radius from anterior to posterior within the supinator muscle 4 cm distal to radial head
 - in both Kocher and Kaplan approaches, the forearm should be pronated to protect PIN
 - PIN originates approximately 1.2mm from radiocapitellar joint
 - pronation pulls the nerve anterior and away from the surgical field



- more extensile
- cons
 - risk of destabilizing elbow if capsule incision is too posterior and LUCL is violated , which lies below the equator of the capitellum
 - recommended when LCL is already disrupted (i.e., associated dislocation)
- Kaplan approach
 - interval
 - between EDC (PIN) and ECRB (radial n.)

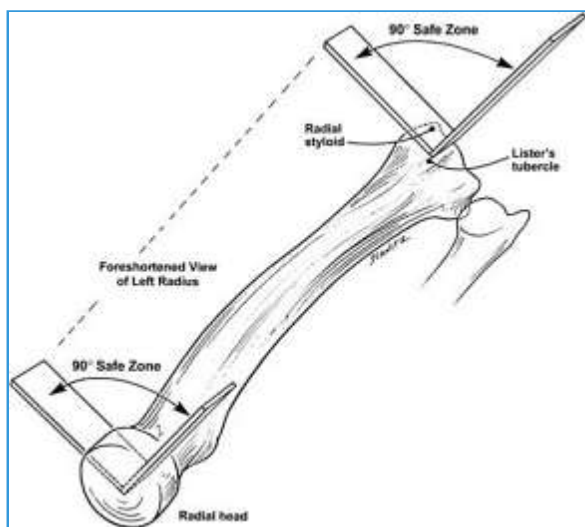


- key steps
 - incise mid-fibers of supinator
 - incise capsule anterior to mid-radiocapitellar plane (have access)
- pros
 - less risk of disrupting LUCL and destabilizing elbow than Kocher approach (more anterior)
 - improved exposure of anterior fractured fragments when screw fixation is performed
- cons
 - greater risk of PIN and radial nerve injury
 - less extensile
- extensor digitorum communis (EDC) split



- interval
 - incision made longitudinally through middle of EDC to origin on lateral epicondyle
- pros
 - improved access to anterior half of radial head
 - reduced risk of iatrogenic injury to lateral collateral ligament complex
- posterior approach
 - interval
 - no true intermuscular interval
 - raising a large lateral skin flap
 - indications
 - associated olecranon or Monteggia fracture

- pros
 - access to both medial and lateral sides of elbow
 - utilitarian approach when the medial aspect of the elbow is planned to be exposed using the same posterior midline skin incision
- cons
 - less popular currently due to skin flap related complications
- technique
 - screw(s)
 - best utilized alone in simple partial articular patterns
 - headless compression screws (Hebert) if placed in articular surface
 - better elbow range of motion and functional outcome scores at 1 year compared to plate fixation
 - plate(s) + screws
 - fractures involving head and neck
 - mini-fragment (1.5 - 2.0 mm) plates and screws utilized
 - posterolateral plate placement
 - safe zone (non-articular area) consists of 90-110° arc defined by the projections of the radial styloid and Lister's tubercle



- this zone is straight lateral with arm in neutral rotation to avoid impingement of ulna with forearm rotation
 - bicipital tuberosity is the distal limit of plate placement
 - anything distal to that will endanger PIN
 - countersink implants on articular surface
 - plate removal relatively common in order to restore forearm rotation
- complications
 - PIN injury
 - destabilization of lateral ligament complex
 - articular surface penetration with screws
 - mechanical block to motion by hardware
- **Fragment Excision**
 - approach
 - Kocher or Kaplan approach as described
 - technique
 - if fracture is <25% of surface area of radial head and does not compromise elbow stability, fragment can be excised
 - complications
 - elbow instability if fragment excised is too large
- **Radial Head Resection**
 - approach
 - Kocher or Kaplan approach
 - technique
 - remove enough head to fully remove comminuted aspects of radial head
 - attempt to keep annular ligament intact
 - complications
 - muscle weakness
 - wrist pain
 - valgus elbow instability
 - heterotopic ossification

- elbow arthritis
- proximal radial migration
- decreased strength
- cubitus valgus

○ Radial head arthroplasty

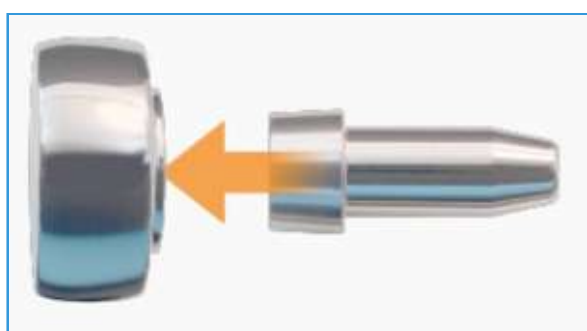


- approach
 - Kocher
 - Kaplan
 - EDC split
- technique
 - metal prostheses
 - loose stemmed prosthesis
 - acts as a stiff spacer
 - thought to "settle in" to anatomic position throughout arc of motion
 - press-fit prosthesis
 - depend on osteointegration and tight canal fit
 - may be more prone to incorrect intramedullary positioning given tight fit
 - bipolar prosthesis
 - has an articulation in the head-neck junction
 - thought to allow better articulation of radial head to capitellum throughout arc of motion
 - may facilitate elbow instability when the radial head angles in reference to the radial stem
 - pyrocarbon prostheses
 - pyrocarbon implant thought to better approximate modulus of cartilage and decrease risk of capitellar wear from metallic radial head implant
 - currently still under investigation
 - silicon replacements (Sylastic)
 - no longer used
 - independent risk factor for revision surgery
 - implant fracture
 - reactive synovitis
- implant design
 - monoblock



- head and stem are a single connected piece implanted together

▪ modular



- head and stem are 2 distinct pieces that are attached upon implantation
- complications
 - overstuffing of joint that leads to capitellar wear problems and malalignment instability



- excessive length produces abnormal loads through the capitellum and is associated with pain, stiffness and progressive capitellar erosion
- incorrect diameter radial head prosthesis has cam effect which produces abnormal loads through the lateral aspect of the trochlea and the lesser sigmoid notch
- best assessed by direct visualization and fluoroscopy
 - proximal implant should align with proximal lesser sigmoid notch
 - deepest point of the radial head dish should be at same height as lateral coronoid facet
 - range of motion should be assessed in flexion and extension and should be smooth
 - the radial head should remain properly aligned with the capitellum with elbow flexion and extension as well as with forearm pronation and supination
- loosening
 - higher likelihood in press-fit prosthesis, with potential need for revision surgery
 - any implant may be fixed with bone cement if needed
- implant dissociation
 - bipolar prosthesis
 - modular prosthesis with defective locking mechanism of the head on the stem, leading to metallosis and pain

• Complications

- Surgical Site Infection
 - treatment
 - incision and drainage
 - consider radial head excision if osteomyelitis present
 - consider hardware/implant removal when infection complicates ORIF or radial head replacement
 - six weeks of intravenous antibiotics, possibly followed by oral antibiotics if hardware/prosthesis retained
- Secondary displacement of fracture
 - incidence
 - occurs in < 5% of fractures initially treated nonoperatively
 - treatment
 - fixation may be necessary

- serial radiographs do not change management
- Posterior interosseous nerve injury (with operative management)
 - risk factors
 - dissection distal to biceps tuberosity in ORIF
 - overaggressive retraction at radial neck
 - treatment
 - if neuropraxia suspected, begin conservatively
 - cock-up wrist splint, therapy
 - may order EMG after several months of conservative management if not improving
 - may need tendon transfer if permanent
- Elbow stiffness & loss of forearm rotation
 - incidence
 - 3-20%
 - risk factors
 - prolonged immobilization
 - intra-articular fracture involvement
 - malunion/nonunion
 - heterotopic ossification
 - treatment
 - nonoperative
 - first-line management includes supervised exercise therapy with static or dynamic progressive elbow splinting over a 6 month period
 - primary goal is to achieve "functional" elbow range of motion
 - 100° flexion arc (30°-130°) and 100° of rotation (50° pronation & 50° supination)
 - operative
 - contracture release with or without radial head removal or replacement
 - anconeus or Achilles allograft interposition arthroplasty
- Radiocapitellar joint arthritis
 - risk factors
 - fracture with intra-articular displacement
 - use of metallic radial head replacement
 - worse with overstuffing
 - treatment
 - nonoperative
 - activity modification
 - anti-inflammatories
 - injections
 - operative
 - radial head resection
 - anconeus or Achilles allograft interposition arthroplasty
 - radiocapitellar hemiarthroplasty
 - limited outcome data present
 - no implants currently available
- Heterotopic ossification (HO)
 - risk factors
 - CNS injury
 - burns
 - elbow fracture/dislocation with significant soft tissue injury
 - treatment
 - prevention
 - consider 6-week course of indomethacin to minimize risk after fracture/dislocation
 - post-operative radiation
 - controversial
 - operative removal
 - ensure HO is mature before resection
 - most have satisfactory outcome despite residual flexion contracture
 - ~10% have recurrence

- Loss of hardware fixation
 - treatment
 - revision fixation
 - radial head replacement
 - radial head removal

28- Elbow Dislocation

- summary

- Elbow Dislocations are common elbow injuries which can be characterized as simple or complex depending on associated injury to nearby structures.
- Diagnosis can be made with plain radiographs. CT studies can be helpful to evaluate for loose bodies or for surgical planning.
- Treatment is closed reduction followed by a short period of immobilization for stable simple elbow dislocations. Surgical management is indicated for complex elbow dislocations associated with fractures or persistent instability.

- Epidemiology

- Incidence
 - elbow dislocations are the most common major joint dislocation second to the shoulder
 - most common dislocated joint in children
 - account for 10-25% of injuries to the elbow
 - posterolateral is the most common type of dislocation (80%)
- Demographics
 - predominantly affects patients between age 10-20 years old

- Etiology

- Pathophysiology
 - mechanism for posterolateral dislocation
 - usually a combination of
 - axial loading
 - supination/external rotation of the forearm
 - valgus posterolateral force
 - a varus posteromedial mechanism (combined with axial load and forearm external rotation) has also been reported
 - posterior dislocations may involve more than one injury mechanism
 - pathoanatomy
 - associated with complete or near complete circular disruption of capsuloligamentous stabilizers
 - pathoanatomic cascade
 - progression of injury is from lateral to medial
 - LCL fails first (primary lesion)
 - by avulsion of the lateral epicondylar origin
 - midsubstance LCL tears are less common but do occur
 - MCL fails last depending on degree of energy

- Anatomy

- Static and dynamic stabilizers confer stability to the elbow
 - static stabilizers (primary)
 - ulnohumeral joint
 - anterior bundle of the MCL
 - LCL complex (includes the LUCL)
 - static stabilizers (secondary)
 - radiocapitellar joint
 - joint capsule
 - origins of the common flexor and extensor tendons
 - dynamic stabilizers
 - muscles that cross the elbow joint, which apply compressive (stabilizing) force
 - anconeus

- brachialis
- triceps

○ See complete Anatomy and Biomechanics of Elbow

• Classification

- Anatomic description
 - based on anatomic location of olecranon relative to humerus
 - posterolateral
 - most common
- Simple vs. complex
 - simple



- elbow dislocation with no associated fracture
- accounts for 50-60% of elbow dislocations
- complex



- elbow dislocation with associated fracture
- may take form of
 - terrible triad injury
 - elbow dislocation associated with a LUCL tear, radial head fracture, and coronoid tip fracture

- radial head fractures occur in up to 10% of elbow dislocations
- varus posteromedial rotatory instability
 - elbow injury associated with an LCL tear and a coronoid fracture
 - radial head fracture unlikely
 - coronoid fracture characteristics
 - medial facet fracture
 - comminuted

• Presentation

- Symptoms
 - pain and swelling
- Physical exam
 - important to assess
 - the status of the skin - evaluate for open injuries
 - presence of compartment syndrome
 - neurovascular status
 - status of wrist and shoulder
 - concomitant injuries occur in 10-15% of elbow dislocations

• Imaging

- Radiographs
 - recommended views
 - AP and lateral views
 - assess joint congruency, especially after attempted reduction
 - oblique views
 - assess for associated periarticular fractures
- CT scan
 - indications
 - suspicion of complex injury pattern
 - useful to identify associated periarticular fractures

• Treatment

- Nonoperative
 - **closed reduction and splinting at least 90° for 5-10 days, early therapy**
 - indications
 - acute simple stable dislocations
 - recurrent instability after simple dislocations is rare (<1-2% of dislocations)
- Operative
 - **ORIF (coronoid, radial head, olecranon), LCL repair, +/- MCL repair**
 - indications
 - acute complex elbow dislocations
 - persistent instability after reduction
 - elbow requires >50-60° to maintain reduction
 - reduction cannot be performed closed
 - often due to entrapped soft tissue or osteochondral fragments
 - **open reduction , capsular release, and dynamic hinged elbow fixator**
 - indications
 - chronic dislocations
 - postoperative
 - hinged external fixator indicated in chronic dislocation to protect the reconstruction and allow early range of motion

• Technique

- **Closed reduction with splinting**
 - ensure patient has sufficient analgesia to allow for adequate muscle relaxation
 - reduction maneuver requires a combination of:

- inline traction to improve coronal displacement
- forearm supination to shift the coronoid under the trochlea
- elbow flexion while placing direct pressure on tip of olecranon
- a palpable "clunk" can be appreciated after most reductions
- assess post reduction stability
 - elbow is often unstable in extension
 - elbow is often unstable to valgus stress
 - test by stressing elbow with forearm in pronation to lock the lateral side
- place post-reduction posterior mold splint in flexion and appropriate forearm rotation
 - splint in at least 90° of elbow flexion
 - if LCL is disrupted - elbow will be more stable in pronation
 - if MCL is disrupted - elbow will be more stable in supination
- obtain post-reduction radiographs
 - if joint is concentric, immobilize (5-10 days) and start early therapy
 - obtain repeat radiographs at 3-5 days and 10-14 days to confirm reduction
- Rehabilitation
 - initial
 - immobilize for 5-10 days
 - immobilization for >3 weeks results in poor final ROM outcomes
 - early
 - supervised (therapist) active and active assist range-of-motion exercises within stable arc
 - extension block brace is used for 3-4 weeks
 - proceed with light duty use 2 weeks from injury
 - late rehabilitation
 - extension block is decreased such that by 6-8 weeks after the injury full stable extension is achieved
- **ORIF of coronoid, radial head, repair of LCL +/- MCL**
 - approach depends on the pathology
 - Kocher approach (ECU/anconeus)
 - used to address the LCL complex, common extensor tendon origin, coronoid, capitellum, and/or radial head fractures
 - when approaching joint (ie, for radial head fractures) during deep dissection, make incision slightly anterior to midline of the radial head to protect the posterior fibers of the LCL complex
 - take care with retractor placement to avoid injury to the PIN
 - medial approach
 - used to address the MCL, flexor/pronator mass origin, and/or comminuted coronoid fractures
 - identify and protect the ulnar nerve
 - posterior approach
 - reconstruction
 - coronoid fractures
 - ORIF
 - rarely needed, as most fractures involve only the coronoid tip (proximal to insertion of brachialis)
 - typically approached laterally, but can also be addressed via a medial approach, especially if comminuted
 - radial head fractures
 - ORIF
 - when placing fixation on the proximal radius, one must be aware of the "safe zone" (a 90° arc in the radial head that does not articulate with the proximal ulna)
 - the "safe zone" can be identified by its relationship to Lister's tubercle and the radial styloid
 - radial head arthroplasty
 - indicated if radial head can not be reconstructed
 - if radial head is replaced the replacement should be anatomic and restore normal length/size
 - this improves the varus and external rotatory stability of the elbow, but stability isn't restored until LCL is addressed
 - excision of the radial head leads to varus/external rotatory instability when the LCL function is absent
 - LCL
 - repaired or reconstructed

- extensor origin avulsion is common and may be repaired
- MCL
 - if instability persists following LCL repair, the MCL is repaired or reconstructed
- hinged external fixator
 - only necessary if elbow remains unstable after attempt at fixation as described above
- postoperative care
 - depending on stability of the elbow, active ROM exercises may commence while using a brace
 - an extension block may or may not be used

- Complications

- Early stiffness
 - loss of terminal extension is the most common complication after closed treatment of a simple elbow dislocation
 - early, active ROM can help prevent this from occurring
 - static, progressive splinting can be helpful after inflammation has decreased
 - often between 6-8 weeks after surgery
- Varus posteromedial instability
 - injury to the LCL and fracture of the anteromedial facet of the coronoid
 - solid fixation of the anteromedial facet is critical for functional outcome and prevention of arthrosis
- Neurovascular injuries
 - brachial artery injuries (rare) typically associated with open dislocations
 - ulnar nerve injury typically results from stretch
 - median nerve injury (rare) typically associated with brachial artery injury
- Compartment syndrome
- Damage to articular surface
- Recurrent instability
- Heterotopic ossification
 - may require excision to improve elbow range of motion
- Contracture/stiffness
 - correlated with immobilization beyond 3 weeks

29- Terrible Triad Injury Of Elbow

Images

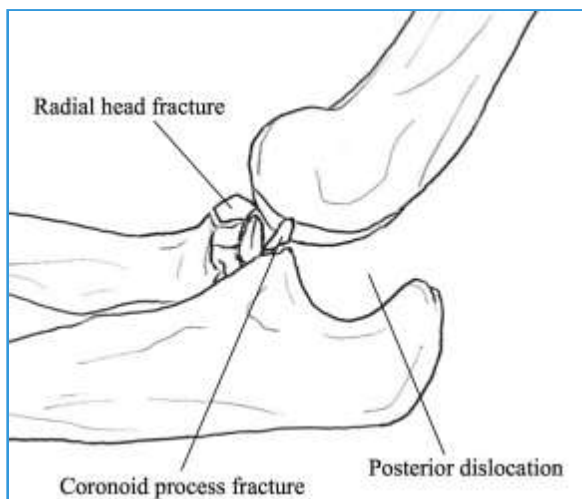


- summary

- Terrible Triad Injury of Elbow is a traumatic injury pattern of the elbow characterized by elbow dislocation, radial head/neck fracture, and a coronoid fracture.
- Diagnosis can be made with plain radiographs of the elbow. CT studies are helpful for surgical planning.
- Treatment is generally ORIF versus radial head arthroplasty, LCL reconstruction, coronoid ORIF, and possible MCL reconstruction.

- Etiology

- Characterized by presence of



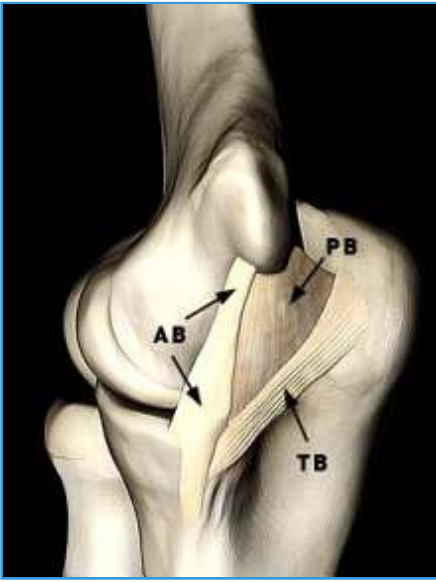
- elbow dislocation (often associated with posterolateral dislocation or LCL injury)
- radial head or neck fracture
- coronoid fracture
- Pathophysiology
 - mechanism
 - fall on extended arm that results in a combination of
 - valgus, axial, and posterolateral rotatory forces
 - produces posterolateral dislocation
 - pathoanatomy
 - structures of elbow fail from lateral to medial
 - LCL disrupted first
 - anterior capsule injured next
 - possible MCL disruption

- Anatomy

- Radial head
 - a primary restraint to posterolateral rotatory instability (PLRI)
 - secondary valgus stabilizer
 - forearm in neutral rotation, lateral portion of articular margin devoid of cartilage
 - roughly between radial styloid and listers tubercle
- Coronoid process
 - provides an anterior and varus buttress to ulnohumeral joint
 - resists posterior subluxation beyond 30 deg of flexion

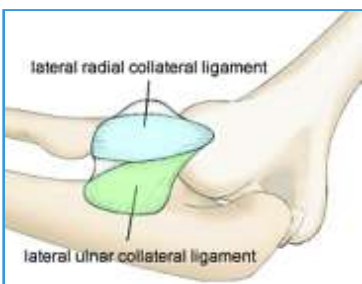
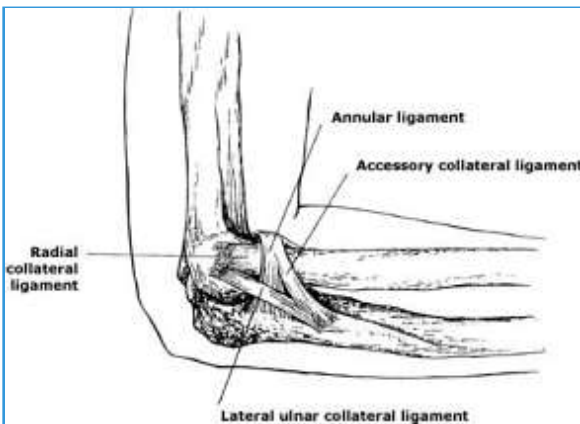
- fracture fragment typically has some anterior capsule attached
 - useful in repair

- Medial collateral ligament



- three components
 - anterior bundle
 - most important to stability, restraint to valgus and posteromedial rotatory instability
 - inserts on sublime tubercle (anteromedial facet of coronoid)
 - specifically inserts 18.4mm dorsal to tip of coronoid process
 - posterior bundle
 - transverse ligament

- Lateral collateral ligament



- inserts on supinator crest distal to lesser sigmoid notch
- the primary restraint to posterolateral rotatory instability
- four components
 - lateral ulnar collateral ligament (most important for stability)
 - radial collateral ligament
 - annular ligament
 - accessory collateral ligament
- when injured is usually avulsed off of the lateral epicondyle

- Presentation

- Symptoms
 - patients complain of pain, clicking and locking with elbow in extension
- Physical exam
 - possible varus / valgus instability patterns
 - distal radial ulnar joint must be evaluated for possible Essex-Lopresti injury

- Imaging

- Radiographs



- evaluate for concentricity of ulnohumeral and radiocapitellar joints
- line drawn through center of radial neck should intersect the center of the capitellum regardless of radiographic projection
- evaluate lateral radiograph for coronoid fracture
- need prereduction and postredcution films
- consider PA and lateral films of wrist and forearm when indicated
- CT
 - often utilized for better evaluation of coronoid fracture
 - 3D imaging for determining fracture line propagation

• Treatment

- Nonoperative
 - **immobilize in 90 deg of flexion for 7-10 days**
 - indications (rare)
 - ulnohumeral and radiocapitellar joints must be concentrically reduced
 - radial head fx must not meet surgical indications
 - coronoid fx must be small
 - elbow should be sufficiently stable to allow early ROM
 - technique
 - one week of immobilization followed by progressive ROM
 - active motion initiated with resting splint at 90 degrees and forearm pronation, avoiding terminal extension
 - static progressive extension splinting at night after 4-6 weeks
 - strengthening protocol after 6 weeks
- Operative
 - **ORIF versus radial head arthroplasty, LCL reconstruction, coronoid ORIF, possible MCL reconstruction**

- indications
 - terrible triad elbow injury that includes an unstable radial head fracture, a type III coronoid fracture, and an associated elbow dislocation
 - coronoid fractures involving less than 10% of the coronoid do not confer elbow stability in cadaveric studies and therefore do not require repair
 - should instability persist after addressing the radial head and the LCL complex in the presence of a small coronoid fracture, the next best step is MCL reconstruction
- Techniques
 - **ORIF vs replacement of radial head, coronoid ORIF, LCL reconstruction, and possible MCL reconstruction**
 - approach
 - posterior skin incision advantageous
 - allows access to both medial and lateral aspect of elbow
 - lower risk of injury to cutaneous nerves
 - more cosmetic
 - technique
 - radial head ORIF vs. arthroplasty
 - radial head ORIF indicated if non comminuted fractures that involve < 40% articular surface
 - 1.5, 2.0, or 2.4mm countersunk screws
 - plate if necessary; 2.0 plates cause minimal loss of motion even when placed on radial neck
 - plate position should be posterolateral
 - safe zone: 90-110 arc from radial styloid to Lister's tubercle with arm in neutral rotation
 - radial head arthroplasty indicated for comminuted radial head fxs (> 3 pieces)
 - implant should articulate 2mm distal to the tip of the coronoid process
 - radial head resection without replacement is **NOT** indicated in presence of Essex-Lopresti lesion or in ligamentously injured elbows
 - if <25% head damaged or fragments not reconstructable and nonarticulating, can excise fractured portion if elbow stable (rarely indicated)
 - coronoid ORIF
 - can be fixed through radial head defect laterally
 - sutures, suture anchors, screws, or rarely plate fixation.
 - suture passed through 2 drill holes
 - posterior to anterior lag screws if fragment large
 - basal coronoid fxs (rare) fixed with anteromedial or medial plate on proximal ulna
 - FCU split approach preferred for rare isolated coronoid fractures
 - LCL repair
 - usually avulsed from origin on lateral epicondyle
 - reattach with suture anchors or transosseous sutures
 - must be reattached at center of capitellar curvature on lateral epicondyle
 - if MCL is intact, LCL is repaired with forearm in pronation
 - if MCL injured, LCL is repaired with forearm in supination to avoid medial gapping due to overtightening
 - repairs are performed with elbow at 90 degrees of flexion
 - MCL repair
 - indicated if instability on exam after LCL and fracture fixation, especially with extension beyond 30 degrees
 - postoperative
 - elbow fixators - hinged or static
 - consider when instability is noted after complete bone and soft tissue repair
 - immobilization
 - can immobilize elbow in flexion with forearm pronation to provide stability against posterior subluxation
 - if both MCL and LCL were repaired, splint in flexion and neutral rotation
 - rehabilitation
 - initiate active ROM exercises 48 hours after surgery to improve functional outcomes

- Complications

- Instability

- more common following type I or II coronoid fractures
 - Failure of internal fixation
 - most common following repair of radial neck fractures
 - poor vascularity leading to osteonecrosis and nonunion
 - Post-traumatic stiffness
 - very common complication
 - initiate early ROM to prevent
 - Heterotopic ossification
 - consider prophylaxis in pts with head injury or in setting of revision surgery
 - Post-traumatic arthritis
 - due to chondral damage at time of injury and/or residual instability
- Prognosis
 - Historically poor outcomes secondary to
 - persistent instability
 - stiffness
 - arthrosis

30- Capitellum Fractures

Images



- summary

- Capitellum Fractures are traumatic intra-articular elbow injuries involving the distal humerus at the capitellum.
- Diagnosis is made using plain radiographs of the elbow.
- Treatment may be nonoperative for nondisplaced fractures but any displacement generally requires anatomic open reduction and internal fixation.

- Epidemiology

- Incidence
 - 1% of elbow fractures
 - 6% of all distal humerus fractures

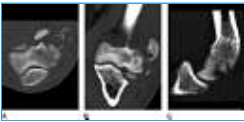
- Etiology

- Pathophysiology
 - mechanism of injury
 - typically, low-energy fall on outstretched hand
 - direct, axial compression with the elbow in a semi-flexed position creates shear forces
 - pathoanatomy
 - radiocapitellar joint is an important static stabilizer of the elbow
 - capitellar fracture can cause potential block to motion and instability due to loss of the radiocapitellar articulation
- Associated conditions
 - concomitant injuries to radial head and/or LUCL can occur up to 60% of the time

- Anatomy

- Radiocapitellar articulation
 - essential to longitudinal and valgus stability of the elbow
 - can also lead to coronal plane instability with capitellar excision if medial structures are not intact
 - integral relationship with the posterolateral ligamentous complex of the elbow (i.e. LUCL)

- Classification

■ Bryan and Morrey Classification (with McKee modification)		
■ Type I	■ Large osseous piece of the capitellum involved ■ Can involve trochlea	■ 
■ Type II	■ Kocher-Lorenz fracture ■ Shear fracture of articular cartilage ■ Articular cartilage separation with very little subchondral bone attached	■ 
■ Type III	■ Broberg-Morrey fracture ■ Severely comminuted ■ Multifragmentary	■ 
■ Type IV	■ McKee modification ■ Coronal shear fracture that includes the capitellum and trochlea	■ 

- Presentation

- History
 - fall on outstretched arm (typically fall from standing)
 - typically, elbow is in semi-flexed elbow position
- Symptoms
 - elbow pain, deformity
 - swelling
 - wrist pain may also occur
- Physical exam
 - inspection and palpation
 - ecchymosis, swelling
 - diffuse tenderness
 - range of motion & instability
 - may have mechanical block to flexion/extension and/or rotation
 - neurovascular exam

- Imaging

- Radiographs
 - recommended
 - AP and lateral of the elbow
 - best demonstrated on lateral radiograph



- "double arc" sign created from subchondral bone of capitellum and lateral part of trochlea

○ CT

- delineates fracture anatomy and classification



• Treatment

○ Nonoperative

- **posterior splint immobilization for < 3 weeks**
 - indications
 - nondisplaced Type I fractures (<2 mm displacement)
 - nondisplaced Type II fractures (<2 mm displacement)

○ Operative

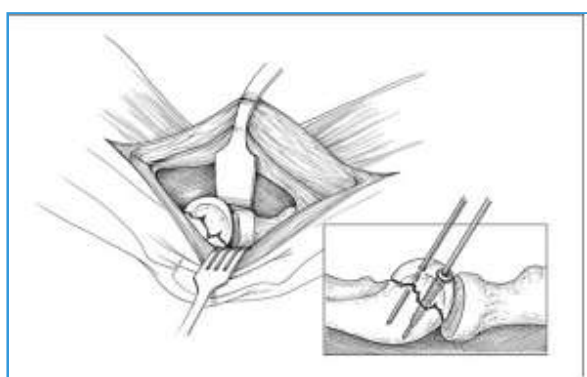
- **open reduction and internal fixation**
 - indications
 - displaced Type I fractures (>2 mm displacement)
 - Type IV fractures
 - technique
 - ORIF with lateral column approach
 - indications
 - isolated capitellar fractures
 - type IV fractures that can have trochlear involvement
 - ORIF with posterior approach with or without olecranon osteotomy
 - indications
 - capitellar fractures with associated fractures/injuries to distal humerus/olecranon and/or medial side of the elbow
- **arthroscopic-assisted ORIF**
 - indications
 - isolated type I fractures with good bone stock
- **fragment excision**
 - indications
 - displaced Type II fractures (>2 mm displacement)
 - displaced Type III fractures (>2 mm displacement)
- **total elbow arthroplasty**
 - indications
 - unreconstructable capitellar fractures in elderly patients with associated medial column instability

• Technique

○ ORIF with lateral column approach

- approach

- lateral approach recommended for isolated Type I and Type IV fx
- supine positioning
- lateral skin incision centered over the lateral epicondyle extending to 2cm distal to the radial head



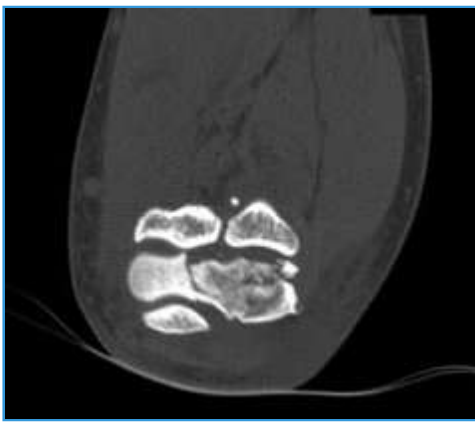
- technique
 - headless screw fixation
 - minifragment screw using posterior to anterior fixation
 - counter sink screw using anterior to posterior fixation



- mini-fragment or capitellar plates can be used to capture fractures with proximal extension



- avoid disruption of the blood supply that comes from the posterolateral aspect of the elbow
- do not destabilize LUCL
- **ORIF with posterior approach with or without olecranon osteotomy**
 - approach
 - indicated when more extensive articular work is needed



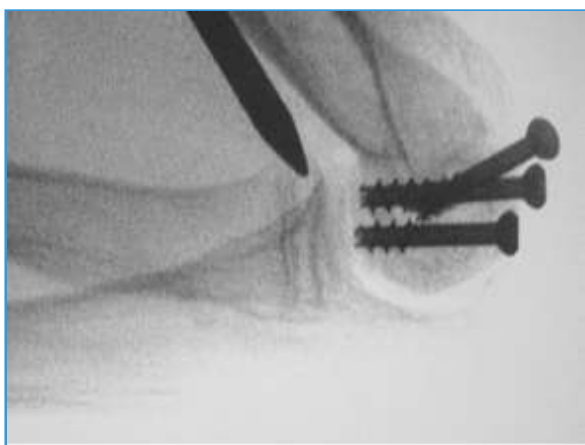
- can also be used when concomitant medial sided injuries and/or distal humeral fractures require more fixation
- lateral decubitus positioning
- long-posterior based incision along the elbow
 - radial and ulnar based flaps allow access to both medial and lateral sides of elbow
- technique
 - fracture-pattern specific
 - independent headless compression/cannulated screws for capitellar component
 - supplemental fixation for concomitant pathology
 - parallel or orthogonal distal humerus plates
 - radial head arthroplasty/ORIF
 - LUCL/UCL repair via bone tunnels or suture anchors
- **Arthroscopic-assisted ORIF**
 - approach
 - definitive indications not fully known
 - experienced arthroscopists, indicated for isolated capitellar fractures
 - supine or lateral positioning (dependent on desire for anterior or posterior access)



- 70 degree scope can be helpful in gaining access
- can be combined with limited open technique for fracture manipulation
- technique
 - standard portals (anteromedial, anterolateral, posterolateral)
 - proximal anterolateral portal established under fluoroscopic guidance to place trocar to allow for reduction of fracture fragment



- extend elbow and push fragment with trocar for reduction
 - flex radial head past 90 to lock reduction
- anteromedial and posterolateral portals allow for fracture debridement
- freer elevator can help maintain reduction while cannulated/headless compression screws are placed under fluoroscopic guidance (typically posterior to anterior in direction)



- Complications

- Elbow contracture/stiffness (most common)
- Nonunion (1-11% with ORIF)
- Ulnar nerve injury
- Heterotopic ossification (4% with ORIF)
- AVN of capitellum
- Nonunion of olecranon osteotomy
- Instability
- Post-traumatic arthritis
- Cubital valgus
- Tardy ulnar nerve palsy
- Infection

- Prognosis

- Most patients will gain functional range of motion but have residual stiffness
- Surgical treatment results are generally favorable
 - reoperation rates as high as 48% (mostly due to stiffness)

31- Radius And Ulnar Shaft Fractures

- Summary

- Radius and ulnar shaft fractures, also known as adult both bone forearm fractures, are common fractures of the forearm caused by either direct trauma or indirect trauma (fall).
- Diagnosis is made by physical exam and plain orthogonal radiographs.
- Treatment is generally surgical open reduction and internal fixation with compression plating of both the ulna and radius fractures.

- Epidemiology

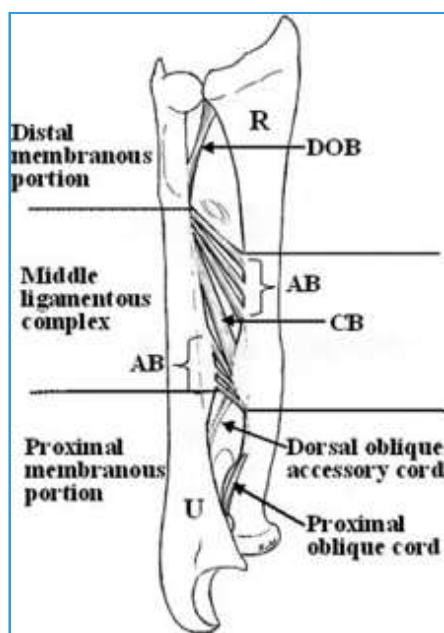
- Demographics
 - highest incidence in
 - men between age 10 and 20
 - women over age of 60

- Etiology

- Pathophysiology
 - mechanism of injury
 - direct trauma
 - direct blow to forearm
 - indirect trauma
 - motor vehicle accidents
 - falls from height
 - axial load applied to the forearm through the hand
- Associated conditions
 - elbow and DRUJ injuries
 - Galeazzi fractures
 - Monteggia fractures
 - Essex-Lopresti injuries
 - compartment syndrome
 - evaluate compartment pressures if concern for compartment syndrome

- Anatomy

- Osteology
 - axis of rotation of forearm runs through radial head (proximal) and ulna fovea (distal)
 - distal radius effectively rotates around the distal ulna in pronosupination
- Ligaments
 - Interosseous membrane (IOM)
 - occupies the space between the radius and ulna
 - permits rotation of the radius around the ulna
 - comprised of 5 ligaments



- central band is key portion of IOM to be reconstructed
- accessory band
- distal oblique bundle
- proximal oblique cord
- dorsal oblique accessory cord

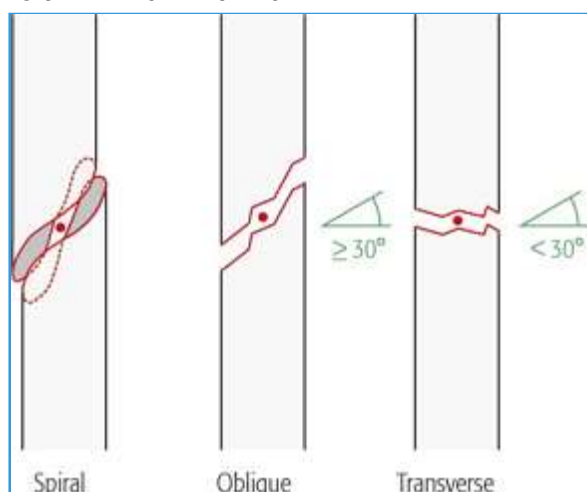
• Classification

◦ Descriptive

- closed versus open
- location
- comminuted, segmental, multi-fragmented
- displacement
- angulation
- rotational alignment

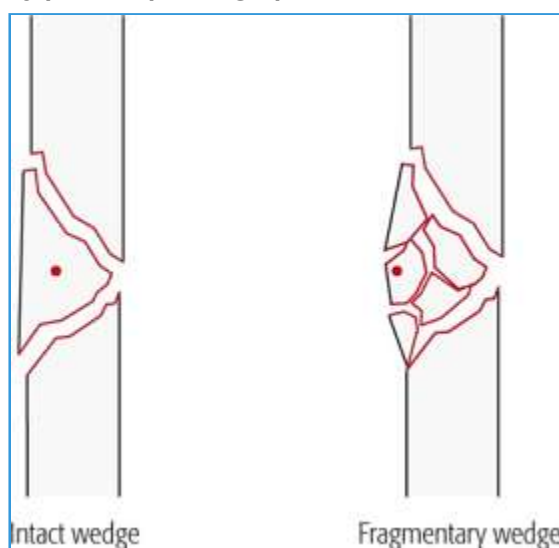
◦ OTA classification

- radial and ulna diaphyseal fractures
- Type A (simple)



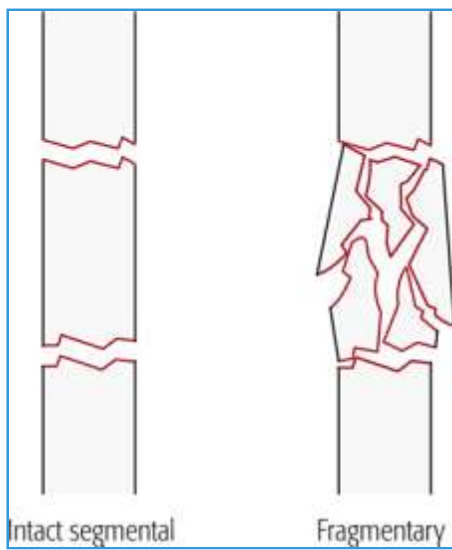
- simple fracture that is spiral (A1), oblique (A2), or transverse (A3)

- Type B (wedge)



- wedge fracture that is intact (B2) or fragmentary (B3)

- Type C (multifragmentary)



- multifragmentary fracture that is intact segmental (C2) or fragmentary segmental (C3)

• Presentation

- Symptoms
 - pain and swelling
 - loss of forearm and hand function
- Physical exam
 - inspection
 - gross deformity
 - open injuries
 - check for tense forearm compartments
 - neurovascular exam
 - assess radial and ulnar pulses
 - document median, radial, and ulnar nerve function
 - provocative tests
 - pain with passive stretch of fingers
 - alert to impending or present compartment syndrome

• Imaging

- Radiographs
 - recommended views
 - AP and lateral views of the forearm



- additional views
 - oblique forearm views for further fracture definition
 - ipsilateral AP and lateral of the wrist and elbow
 - to evaluate for associated fractures or dislocation
 - radial head must be aligned with the capitulum on all views

• Treatment

- Nonoperative
 - **cast or brace immobilization**
 - indications
 - rare
 - completely nondisplaced fractures in patients who are not surgical candidates

- modality
 - bracing
 - functional fracture brace
 - casting
 - Muenster cast with good interosseous mold



- outcomes
 - high rates of non-union associated with non-operative management

○ Operative

■ external fixation

- indications
 - severe soft tissue injury (Gustilo IIIB)

■ ORIF

- indications
 - nearly all both bone fractures in surgical candidates
 - Gustilo I, II, and IIIa open fractures may be treated with primary ORIF
- outcomes
 - goal is for cortical opposition, compression and restoration of forearm anatomy
 - most important variable in functional outcome is to restore the radial bow



- > 95% union rates of simple both bone fractures with compression plating

■ ORIF with bone grafting

- indications
 - open fractures with significant bone loss
 - bone loss that is segmental or associated with open injury (primary or delayed grafting in open injuries)
 - nonunions of the forearm
- outcomes
 - use of autograft may be critical to achieve fracture union

■ IM nailing

- indications
 - very poor soft-tissue integrity

- outcomes
 - not preferred due to lack of rotational and axial stability and difficulty maintaining radial bow
 - high nonunion rate
 - IMN do not provide compression across fracture site

• Techniques

◦ Functional brace or Muenster cast

- technique
 - cast/brace should extend just above elbow to control forearm rotation
 - monitor very closely (~1 week) for displacement
 - should be worn for at least 6 weeks.

◦ External fixation



- technique
 - 2nd and 3rd metacarpal shaft can both be utilized for distal pin placement
 - pin diameter should not exceed 4 mm

◦ ORIF

- approach
 - fixation of the fracture with less comminution restores length and may facilitate reduction of other bone
 - usually performed through separate approaches due to risk of synostosis
 - radius
 - volar (Henry) approach to radius
 - best for distal 1/3 and middle 1/3 radial fractures
 - dorsal (Thompson) approach to radius
 - can be utilized for proximal 1/3 radial fractures
 - ulna
 - subcutaneous approach to ulna shaft
- technique
 - 3.5 mm DCP plate (AO technique) is standard



- 4.5 plates no longer used due to increased rate of refracture following removal
- longer plates are preferred due to high torsional stress in forearm
 - may require contouring of plate
- compression mode preferred to achieve anatomic primary bony healing
 - to minimize strain, six cortices proximal and distal to fracture should be engaged
- locked plates are increasingly indicated over conventional plates in osteoporotic bone
- bridge plating may be used in extensively comminuted fractures
- interfragmentary lag screws (2.0 or 2.7 screws) if necessary
- open fractures
 - irrigation and debridement should be performed to remove any contaminated tissue or bony fragments without soft tissue attachments
- plate placement
 - placement of plates on dorsal (tension) side is biomechanically superior but volar placement offers better place seating and soft tissue coverage
- postoperative care
 - early ROM unless there is an injury to proximal or distal joint
 - should be managed with a period of non-weight bearing due to risk of secondary displacement of the fracture
 - generally 6 weeks
- **ORIF with bone grafting**
 - technique
 - cancellous autograft is indicated in radial and ulnar fractures with significant bone loss
 - vascularized fibula grafts can be used for large defects and have a lower rate of infection
 - Masquelet technique (induced-membrane technique) can also be utilized in cases of non-union or open fractures with significant bone loss
 - 2 stage technique
 - 1st stage: I&D, cement spacer and temporizing fixation



- 2nd stage: placement of bone graft into induced membrane and definitive fixation

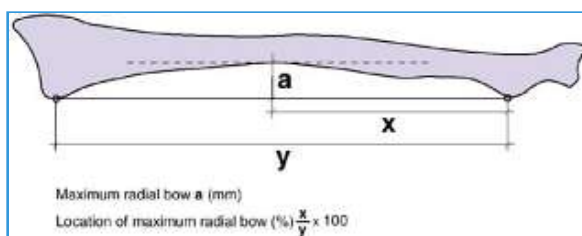


- **IM nailing**
 - approach
 - ulnar nail
 - inserted through the posterior olecranon
 - radial nail
 - inserted between the extensor tendons near Listers tubercle
 - technique
 - nails may need to be bent to accommodate for the radial bow
 - may use a small incision at fracture site to facilitate passing of nail
- **Complications**
 - Synostosis
 - incidence
 - reported between 3 to 9%
 - risk factors
 - associated with ORIF using a single incision approach
 - treatment
 - heterotopic bone excision can be performed with low recurrence risk as early as 4-6 months post-injury when prophylactic radiation therapy and/or indomethacin are used postoperatively
 - Infection
 - incidence
 - 3% incidence with ORIF
 - risk factors
 - open fractures
 - Compartment syndrome
 - incidence
 - up to 15% depending on mechanism and fracture characteristics
 - risk factors
 - high energy crush injury
 - open fractures
 - low velocity GSWs
 - vascular injuries
 - coagulopathies (DIC)
 - Nonunion
 - incidence
 - < 5% after compression plating
 - up to 12% in extensively comminute fractures treated with bridge plating
 - risk factors
 - extensive comminution
 - poorly applied plate fixation
 - IMN fixation
 - treatment
 - atrophic nonunions can be treated with 3.5 mm plates and autogenous cancellous bone grafting
 - Infection and atrophic nonunions can also be treated with the Masquelet technique

- Malunion
 - risk factors
 - direct correlation between restoration of radial bow and functional outcome
- Neurovascular injury
 - risk factors
 - PIN injury with Monteggia fxs and Henry (volar) approach to middle and upper third radial diaphysis
 - Type III open fxs
 - treatment
 - observe for three months to see if nerve function returns
 - explore if no return of function after 3 months
- Refracture
 - incidence
 - up to 10% with early removal
 - risk factors
 - removing plate too early
 - plates should not be removed < 1 year from implantation
 - large plates (4.5 mm)
 - comminuted fractures
 - persistent radiographic lucency
 - treatment
 - wear functional forearm brace for 6 weeks and protect activity for 3 months after plate removal

- Prognosis

- Functional results depend on the restoration of radial bow



- malunion of the radius and ulna with angulation > 20 degrees is likely to limit forearm rotation

32- Distal Radius Fractures

Images



• Summary

- Distal radius fractures are the most common orthopaedic injury and generally result from fall on an outstretched hand.
- Diagnosis is made clinically and radiographically with orthogonal radiographs of the wrist
- Treatment can be nonoperative or operative depending on fracture stability and fracture displacement as well as patient age and activity demands

• Epidemiology

- Incidence
 - accounts for 17.5% of all fractures in adults
- Demographics
 - more common in females (2-3:1)
 - bimodal distribution
 - younger patients due to high energy mechanisms
 - older patients due to low energy mechanisms (i.e. FOOSH)
- Anatomic location
 - 50% are intra-articular
- Risk factors
 - osteoporosis
 - high incidence of distal radius fractures in women > 50 years old
 - distal radius fractures are a predictor of subsequent fractures
 - DEXA scan is recommended for women with distal radius fractures

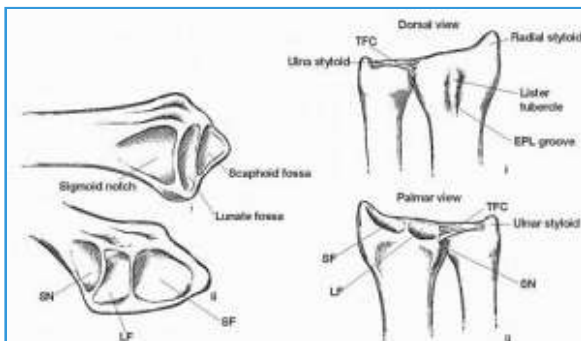
• Etiology

- Pathophysiology

- mechanism of injury
 - fall on outstretched hand (FOOSH) is most common in older population
 - higher energy mechanism more common in younger patients
- Associated conditions
 - DRUJ injuries
 - radial styloid fractures
 - indicates higher energy mechanism
 - soft tissue injuries - seen in 70%
 - TFCC injury (40%)
 - scapholunate ligament injury (30%)
 - lunotriquetral ligament injury (15%)

• Anatomy

- Distal radius
 - responsible for 80% of axial load
 - articulates with



- scaphoid
 - via scaphoid fossa
- lunate
 - via lunate fossa
- distal ulna
 - via ulnar/sigmoid notch
- comprised of 3 columns
 - radial column
 - includes the radial styloid and scaphoid fossa
 - functions
 - attachment sites for the brachioradialis tendon, long radiolunate ligament, and radioscaphocapitate ligament
 - serves as a buttress to resist radial carpal translation
 - functions as a load-bearing platform for activities performed with the wrist in ulnar deviation
 - holds the carpus out to length radially, allowing a more uniform distribution of load across the scaphoid and lunate facets
 - serves as an anchor for the radioscaphocapitate ligament that prevents ulnar translation of the carpus
 - intermediate column
 - lunate fossa
 - functions
 - transmits load from the carpus to the forearm
 - ulnar column
 - includes the TFCC and distal ulna
 - functions
 - stability of the DRUJ
 - forearm motion

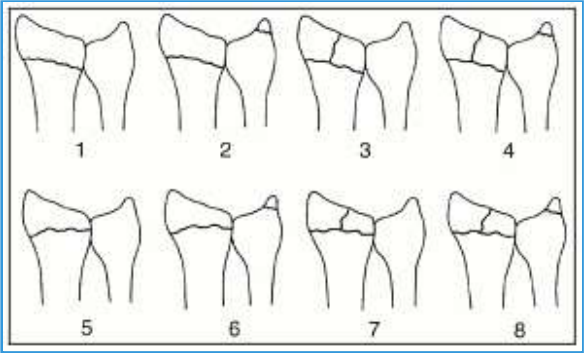
• Classification

- Fernandez

Fracture Type/Location Based on the Mechanism of Injury	Associated Mechanism Displacement	Stability Stability: Not able to maintain position after closed reduction	Displacement Pattern	Stability of Fracture	Associated Injuries Other bones, ligaments, nerves, tendons, vessels, or joint capsule	Recommended Treatment
TYPE I Isolated fracture of the distal radius	Distal forearm Radius Distal 1/3	Stable	Simple Transverse or oblique fracture	Stable Displacement less than 10mm Angulation less than 10°	None	Conservative Closed reduction if displaced more than 10mm or angulation more than 10°
TYPE II Isolated fracture of the distal radius	Distal forearm Radius Distal 1/3	Unstable	Simple Transverse or oblique fracture	Unstable Displacement more than 10mm Angulation more than 10°	None	Open reduction and internal fixation
TYPE III Comminuted fracture of the distal radius	Distal forearm Radius Distal 1/3	Unstable	Complex Transverse or oblique fracture	Unstable Displacement more than 10mm Angulation more than 10°	None	Open reduction and internal fixation
TYPE IV Isolated fracture of the distal radius and ulna	Distal forearm Radius and ulna Distal 1/3	Unstable	Simple Transverse or oblique fracture	Unstable Displacement more than 10mm Angulation more than 10°	None	Open reduction and internal fixation
TYPE V Comminuted fracture of the distal radius and ulna	Distal forearm Radius and ulna Distal 1/3	Unstable	Complex Transverse or oblique fracture	Unstable Displacement more than 10mm Angulation more than 10°	None	Open reduction and internal fixation

- based on mechanism of injury

- Frykman



- based on joint involvement (radiocarpal and/or radioulnar) +/- ulnar styloid fracture

- Melone

Fracture	Description
Type I	Four components (radial shaft, radial styloid, dorsal medial and volar medial fragment) are undisplaced or show variable displacement of the medial complex as a unit. Such fractures show minimal comminution and are stable after closed reduction
Type II	There is significant displacement of the medial complex as a unit with a comminution of radial metaphysis and instability (die punch fracture)
Type III	Displacement and instability are similar to type II, with the spike fragment of the radial shaft component often projecting into the flexor compartment (spike fractures)
Type IV	There is severe disruption of the radial articular surface and the dorsal and volar medial fragments show wide separation or rotation. There are extensive soft tissue damage and nerve injury (split fractures)
Type V	Fracture results from a severe force comprising both compression and crush that cause extensive comminution, often extending from the articular surface to the diaphysis

- divides intra-articular fractures into 4 types based on displacement

- AO



- comprehensive but cumbersome

- Eponyms

■ Eponyms		
■ Die-punch fx	■ Depressed fracture of the lunate fossa of the articular surface of the distal radius	■  ■ 
■ Barton's fx	■ Fracture-dislocation of radiocarpal joint with intra-articular fx involving the volar or dorsal lip (volar Barton or dorsal Barton fx)	■ 
■ Chauffer's fx	■ Radial styloid fx	■ 
■ Colles' fx	■ Low energy, dorsally displaced, extra-articular fx	■ 
■ Smith's fx	■ Low energy, volarly displaced, extra-articular fx	■ 

- Presentation

- History
 - usually a fall onto outstretched hand (FOOSH)
 - Symptoms
 - wrist pain
 - wrist swelling
 - wrist deformity
 - Physical exam
 - inspection
 - ecchymosis & swelling
 - diffuse tenderness
 - visible deformity if displaced
 - motion
 - limited by pain

- Imaging

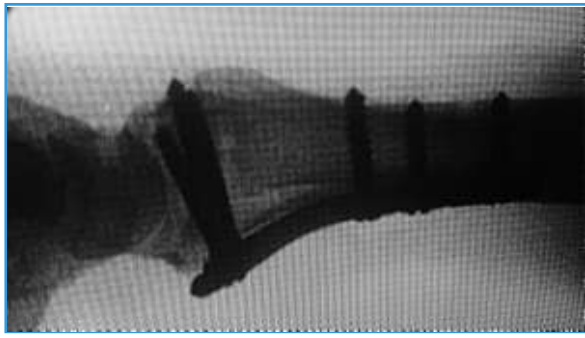
- Radiographs
 - recommended views
 - AP
 - lateral
 - oblique
 - findings

- Radiographic criteria
 - | ■ <i>Measurement</i> | ■ <i>Normal</i> | ■ <i>Acceptable criteria</i> | ■  |
|---------------------------|-----------------|---|---|
| ■ Radial height (AP) | ■ 13mm | ■ < 5mm shortening | ■  |
| ■ Radial inclination (AP) | ■ 23° | ■ Change < 5° | ■  |
| ■ Articular stepoff (AP) | ■ Congruous | ■ < 2 mm stepoff | ■  |
| ■ Volar tilt (Lateral) | ■ 11° | ■ Dorsal angulation < 5° or within 20° of contralateral distal radius | ■  |
 - CT
 - indications
 - evaluate intra-articular involvement
 - surgical planning
 - MRI
 - indications
 - evaluate for soft tissue injury
 - TFCC injuries
 - scapholunate ligament injuries (DISI)
 - lunotriquetral injuries (VISI)
- Treatment
 - Nonoperative
 - **closed reduction and splint/cast immobilization**
 - indications
 - extra-articular
 - < 5mm radial shortening
 - dorsal angulation < 5° or within 20° of contralateral distal radius
 - Operative
 - **CRPP**
 - indications
 - extra-articular fracture with stable volar cortex
 - outcomes
 - 82-90% good results if used appropriately
 - **ORIF**
 - indications
 - radiographic findings indicating instability (pre-reduction radiographs best predictor of stability)
 - dorsal angulation > 5° or > 20° of contralateral distal radius
 - volar or dorsal comminution
 - displaced intra-articular fractures > 2mm
 - radial shortening > 5mm
 - associated ulnar fracture
 - associated ulnar styloid fractures do not require fixation
 - severe osteoporosis
 - articular margin fractures (dorsal and volar Barton's fractures)
 - the volar ulnar corner (critical corner) supports the volar lunate facet with its strong radiolunate ligament attachments
 - failure to address this fragment can result in volar carpal subluxation
 - comminuted and displaced extra-articular fractures (Smith's fractures)
 - die-punch fractures
 - progressive loss of volar tilt and radial length following closed reduction and casting
 - **external fixation**
 - indications
 - open fractures
 - highly comminuted fractures
 - medically unstable patients unable to undergo a lengthy procedure

- outcomes
 - important adjunct with 80-90% good/excellent results
 - alone cannot reliably restore 10° palmar tilt
 - therefore usually combined with percutaneous pinning technique or plate fixation
- **Techniques**
 - **Closed reduction and splint/cast immobilization**
 - technique
 - reduction
 - requires adequate anesthesia
 - apply longitudinal traction and volar/dorsal pressure to the distal fracture fragment
 - immobilization
 - avoid positions of extreme flexion and ulnar deviation (Cotton-Loder Position)
 - due to risk of carpal tunnel syndrome
 - rehabilitation
 - no significant benefit of physical therapy over home exercises for simple distal radius fractures treated with cast immobilization
 - outcomes
 - repeat closed reductions have < 50% satisfactory results
 - LaFontaine predictors of instability
 - radial shortening is the most predictive of instability, followed by dorsal comminution
 - severe osteoporosis
 - associated ulnar fracture
 - dorsal comminution > 50%, palmar comminution, intraarticular comminution
 - dorsal angulation > 20°
 - initial displacement > 1cm
 - initial radial shortening > 5mm
 - higher loss of reduction with 3 or more of LaFontaine criteria
 - Meta-analyses and systematic reviews demonstrate no difference in functional outcomes between closed treatment versus operative methods in elderly patients (>65 years old)
 - complications specific to this treatment
 - acute carpal tunnel syndrome
 - EPL rupture
 - **CRPP**
 - technique
 - Kapandji intrafocal technique
 - K wires are placed dorsally into the fracture and used as reduction tools until they are driven into the proximal radius
 - Rayhack technique with arthroscopically assisted reduction
 - complications specific to this treatment
 - radial sensory nerve injury
 - pin tract infections
 - **ORIF**
 - technique guides
 - distal radius extra-articular fracture ORIF with volar approach
 - distal radius intra-articular fracture ORIF with dorsal approach
 - types
 - volar plating
 - preferred over dorsal plating
 - associated with irritation of both flexor and extensor tendons
 - rupture of FPL is most common with volar plates
 - associated with plate placement distal to watershed area, the most volar margin of the radius closest to the flexor tendons
 - can have hyperesthesia over the base of the thenar eminence due to palmar cutaneous nerve injury during retraction of the digital flexor tendons when plating the distal radius
 - new volar locking plates offer improved support to subchondral bone

- dorsal plating
 - indicated for displaced intra-articular distal radius fractures with dorsal comminution
 - historically associated with extensor tendon irritation and rupture
 - technique
 - can combine with external fixation and percutaneous pinning
 - perform bone grafting if complex and comminuted
 - study showed improved results with arthroscopically-assisted reduction
 - volar lunate facet fragments may require fragment-specific fixation to prevent early postoperative failure
 - complications specific to this treatment
 - screw penetration into the radiocarpal joint or DRUJ
 - assess intra-articular screws with a 23 degree elevated lateral view
 - assess dorsal cortex penetration with a skyline view
 - tendon rupture
 - outcomes
 - no benefit of therapist-directed physical therapy compared to home exercise program
- **External fixation**
 - technique guides
 - distal radius fracture spanning external fixator
 - distal radius fracture non-spanning external fixator
 - types
 - spanning ex-fix
 - useful for fractures with small articular fragment
 - non-spanning ex-fix
 - useful for fractures with large articular fragment
 - technique
 - relies on ligamentotaxis to maintain reduction
 - place radial shaft pins under direct visualization to avoid injury to superficial radial nerve
 - avoid overdistract (carpal distraction < 5mm in neutral position) and excessive volar flexion and ulnar deviation
 - limit duration to 8 weeks and perform aggressive OT to maintain digital ROM
 - complications specific to this treatment
 - malunion
 - nonunion
 - stiffness and decreased grip strength
 - pin complications (infections, fractures through pin site, skin difficulties)
 - pin site care comprising daily showers and dry dressings recommended
 - neurologic (iatrogenic injury to radial sensory nerve , median neuropathy, RSD)
- **Complications**
 - Median nerve neuropathy (CTS)
 - incidence
 - most frequent neurologic complication
 - seen in 1-12% of low energy fxs and 30% of high energy fxs
 - risk factors
 - prevent by avoiding immobilization in excessive wrist flexion and ulnar deviation (Cotton-Loder position)
 - treatment
 - **acute carpal tunnel release**
 - indications
 - progressive paresthesias, weakness in thumb opposition
 - paresthesias that do not respond to reduction and last > 24-48 hours
 - Ulnar nerve neuropathy
 - risk factors
 - DRUJ injury
 - EPL rupture
 - risk factors
 - nondisplaced distal radial fractures have a higher rate of spontaneous rupture of the EPL tendon

- extensor mechanism is thought to impinge on the tendon following a nondisplaced fracture and causes either a mechanical attrition or a local area of ischemia in the tendon
- volar plating with screw fixation that penetrates the dorsal cortex and is proud dorsally



- treatment
 - **EIP to EPL transfer**
- FPL rupture
 - risk factors
 - very distal volar plate placement on the radius (distal to watershed line) is associated with FPL rupture
 - due to physical contact of tendon on plate and subsequent tendinopathy
- Radiocarpal arthrosis (2-30%)
 - incidence
 - 90% young adults will develop symptomatic arthrosis if articular stepoff > 1-2mm
 - may also be nonsymptomatic
- Malunion/nonunion
 - intra-articular malunion
 - treatment
 - **revision** at > 6 weeks
 - extra-articular angulation malunion
 - treatment
 - **opening wedge osteotomy with ORIF and bone grafting**
 - delayed procedure associated with higher need for bone grafting and a more difficult procedure
 - radial shortening malunion
 - radial shortening associated with greatest loss of wrist function and degenerative changes in extra-articular fractures
 - treatment
 - **ulnar shortening**
- ECU or EDM entrapment
 - risk factors
 - DRUJ injury
- Compartment syndrome
- RSD/CRPS
 - prevention
 - AAOS 2010 clinical practice guidelines recommend vitamin C supplementation to prevent incidence of RSD postoperatively
 - subsequent analyses show no benefit to vitamin C
 - strong evidence to suggest the efficacy of prompt physiotherapy, lidocaine, ketamine, bisphosphonates, sympathectomy and brachial plexus blocks
- Prognosis
 - Poor functional outcomes associated with
 - worker's compensation
 - low socioeconomic status
 - low education levels
 - low bone density
 - Successful outcomes correlate with
 - accuracy of articular reduction
 - restoration of anatomic relationships
 - early efforts to regain motion of wrist and fingers

33- Monteggia Fractures

Images



- Summary

- A Monteggia fracture is defined as a proximal 1/3 ulna fracture with an associated radial head dislocation.
- Diagnosis is made with forearm and elbow radiographs to check for congruency of the radiocapitellar joint in the setting of an ulna fracture.
- Treatment can be isolated closed reduction in the pediatric population (if radiocapitellar joint remains stable). Adults and unstable injuries generally require ORIF of the ulna.

- Epidemiology

- Incidence
 - rare in adults
 - more common in children with peak incidence between 4 and 10 years of age
 - different treatment protocol for children

- Etiology

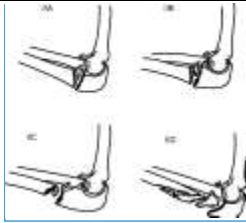
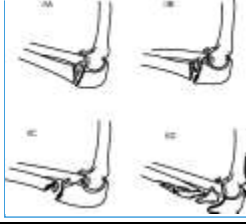
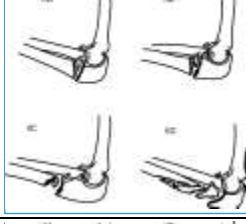
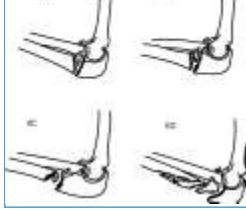
- Associated injuries
 - may be part of complex injury pattern including
 - olecranon fracture-dislocation
 - radial head fx
 - coronoid fx
 - LCL injury
 - terrible triad of elbow

- Anatomy

- Ligament
 - annular ligament

- Classification

■ Bado Classification			
■ Type I	■ 60%	■ Fracture of the proximal or middle third of the ulna with anterior dislocation of the radial head (most common in children and young adults)	■ 
■ Type II	■ 15%	■ Fracture of the proximal or middle third of the ulna with posterior dislocation of the radial head (70 to 80% of adult Monteggia fractures)	■ 
■ Type III	■ 20%	■ Fracture of the ulnar metaphysis (distal to coronoid process) with lateral dislocation of the radial head	■ 
■ Type IV	■ 5%	■ Fracture of the proximal or middle third of the ulna and radius with dislocation of the radial head in any direction	■ 

■ Jupiter Classification of Type II Monteggia Fracture-Dislocations		
■ Type IIA	■ Coronoid level	■ 
■ Type IIB	■ Metaphyseal-diaphyseal junction	■ 
■ Type IIC	■ Distal to coronoid	■ 
■ Type IID	■ Fracture extending to distal half of ulna	■ 

- Presentation

- Symptoms
 - pain and swelling at elbow joint
 - Physical exam
 - inspection
 - may or may not be obvious dislocation at radiocapitellar joint
 - should evaluate skin integrity
 - ROM & instability
 - may be loss of ROM at elbow due to dislocation
 - neurovascular exam
 - PIN neuropathy
 - radial deviation of hand with wrist extension
 - weakness of thumb extension
 - weakness of MCP extension
 - most likely nerve injury

- Imaging

- Radiographs
 - recommended view
 - AP and Lateral of elbow, wrist, and forearm
 - CT scan

- helpful in fractures involving coronoid, olecranon, and radial head

• Treatment

- Nonoperative
 - **closed reduction**
 - indications
 - more common and successful in children
 - must ensure stability and anatomic alignment of ulna fracture
 - technique
 - cast in supination for Bado I and III
- Operative
 - **ORIF of ulna shaft fracture**
 - indications
 - acute fractures which are open or unstable (long oblique)
 - comminuted fractures
 - most Monteggia fractures in adults are treated surgically
 - **ORIF of ulna shaft fracture, open reduction of radial head**
 - indications
 - failure to reduce radial head with ORIF of ulnar shaft only
 - ensure ulnar reduction is correct
 - complex injury pattern
 - Monteggia "variants" with associated radial head fracture
 - **IM Nailing of ulna**
 - indications
 - transverse or short oblique fracture

• Techniques

- **ORIF of ulnar shaft fracture**
 - approach
 - lateral decubitus position with arm over padded support
 - midline posterior incision placed lateral to tip of olecranon
 - develop interval between flexor carpi ulnaris and anconeus along ulnar border proximally, and interval between FCU and ECU distally
 - techniques
 - with proper alignment of ulna radial head usually reduces and open reduction of radial head is rarely needed
 - failure to align ulna will lead to chronic dislocation of radial head
- **ORIF of radial head**
 - approach
 - posterolateral (Kocher) approach
 - technique
 - annular ligament often found interposed in radiocapitellar joint preventing anatomic reduction after ulnar ORIF
 - treatment based on involved components (radial head, coronoid, LCL)

• Complications

- PIN neuropathy
 - up to 10% in acute injuries
 - treatment
 - **observation for 2-3 months**
 - spontaneously resolves in most cases
 - if no improvement obtain nerve conduction studies
- Malunion with radial head dislocation
 - usually caused by failure to obtain anatomic alignment of ulna
 - treatment
 - **ulnar osteotomy and open reduction of the radial head**

- Prognosis

- If diagnosis is delayed greater than 2-3 weeks complication rates increase significantly

34- Galeazzi Fractures

Images



• Summary

- A galeazzi fracture is a distal 1/3 radial shaft fracture with an associated distal radioulnar joint (DRUJ) injury.
- Diagnosis can be suspected with a distal radius fracture with widening of the radioulnar joint on AP wrist radiographs and volar/dorsal subluxation of the radioulnar joint on lateral wrist radiographs.
- Treatment is generally ORIF of the distal radius followed by assessing the stability of the DRUJ which may warrant subsequent immobilization, DRUJ pinning or ORIF of the DRUJ.

• Epidemiology

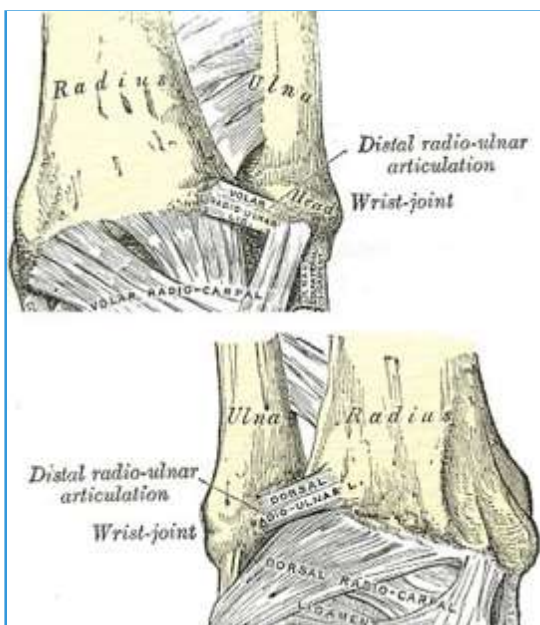
- Incidence of DRUJ instability
 - if radial fracture is <7.5 cm from articular surface
 - unstable in 55%
 - if radial fracture is >7.5 cm from articular surface
 - unstable in 6%

• Etiology

- Mechanism
 - direct wrist trauma
 - typically dorsolateral aspect
 - fall onto outstretched hand with forearm in pronation

• Anatomy

- DRUJ
 - sigmoid notch
 - found along ulnar border of distal radius
 - is a shallow concavity for the articulating ulnar head
 - volar and dorsal radioulnar ligaments



- function as the primary stabilizers of the DRUJ
- most stable in supination

• Classification

◦ OTA classification of radius/ulna

▪ OTA classification of radius/ulna		
▪ 22-A2.3	▪ Radius/ulna, diaphyseal, simple fracture of radius with dislocation of DRUJ	▪ 
▪ 22-A3.3	▪ Radius/ulna, diaphyseal, simple fracture of both bones (distal zone radius) with dislocation of DRUJ	▪ 
▪ 22-B2.3	▪ Radius/ulna, diaphyseal, wedge fracture of radius with dislocation of DRUJ	▪ 
▪ 22-B3.3	▪ Radius/ulna, diaphyseal, wedge of both bones with dislocation of DRUJ	▪ 

• Presentation

- Symptoms
 - pain, swelling, deformity
- Physical exam
 - point tenderness over fracture site
 - ROM
 - test forearm supination and pronation for instability
 - DRUJ stress
 - causes wrist or midline forearm pain

• Imaging

- Radiographs
 - recommended views
 - AP and lateral views of forearm, elbow, and wrist
 - findings
 - signs of DRUJ injury
 - ulnar styloid fx
 - widening of joint on AP view
 - dorsal or volar displacement on lateral view
 - radial shortening (≥5mm)

• Treatment

- Operative
 - **ORIF of radius with reduction and stabilization of DRUJ**
 - indications
 - all cases, as anatomic reduction of DRUJ is required
 - acute operative treatment far superior to late reconstruction

• Techniques

- **ORIF of radius**
 - approach
 - volar (Henry) approach to radius
 - plate fixation
 - perform anatomic plate fixation of radial shaft
 - radial bow must be restored/maintained
- **Reduction & stabilization of DRUJ**
 - approach
 - dorsal capsulotomy
 - reduction technique
 - immobilization in supination (6 weeks)
 - indicated if DRUJ stable following ORIF of radius
 - percutaneous pin fixation



- indicated if DRUJ reducible but unstable following ORIF of radius
- cross-pin ulna to radius
 - leave pins in place for 4-6 weeks
- open surgical reduction
 - indicated if reduction is blocked
 - suspect interposition of ECU tendon
- open reduction internal fixation
 - indicated if a large ulnar styloid fragment exists
 - fix styloid and immobilize in supination

• Complications

- Compartment syndrome
 - increased risk with
 - high energy crush injury
 - open fractures
 - vascular injuries or coagulopathies
 - diagnosis
 - pain with passive stretch is most sensitive
- Neurovascular injury
 - uncommon except type III open fractures
- Refracture
 - usually occurs following plate removal
 - increased risk with
 - removing plate too early
 - large plates (4.5mm)
 - comminuted fractures
 - persistent radiographic lucency
 - prevention
 - do not remove plates before 18 months after insertion
 - amount of time needed for complete primary bone healing
- Nonunion
- Malunion
- DRUJ subluxation
 - displaced by gravity, pronator quadratus, or brachioradialis

35- Isolated Ulnar Shaft Fracture

- Summary

- Isolated ulnar shaft fractures are rare fractures of the forearm caused by either direct blow to the forearm ("nightstick" fracture) or indirect trauma (fall).
- Diagnosis can be made primarily by physical exam and plain radiographs.
- Minimally displaced (< 50% displacement and < 10° of angulation) are often treated nonsurgically, while treatment has historically been surgical open reduction and internal fixation with compression plating for displaced fractures.

- Epidemiology

- Incidence
 - rare
 - < 1% of upper extremity fractures
- Demographics
 - highest incidence in
 - men between age 10 and 20
 - women over age of 60

- Etiology

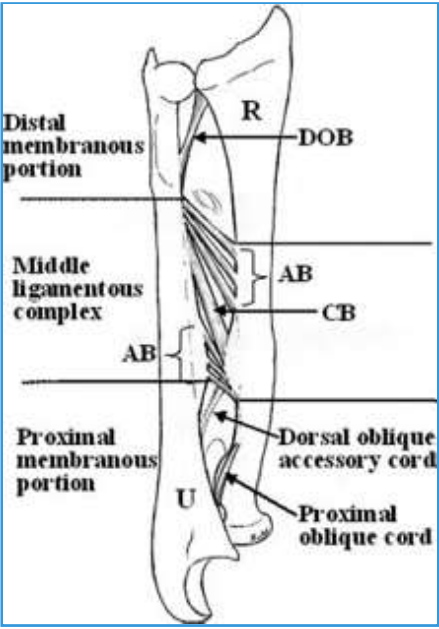
- Pathophysiology
 - mechanism of injury
 - direct trauma
 - direct blow to forearm ("nightstick" fracture)
 - indirect trauma
 - motor vehicle accidents
 - falls from height
 - axial load applied to the forearm through the hand
- Associated conditions
 - elbow and DRUJ injuries
 - Monteggia fractures



- Essex-Lopresti injuries
- compartment syndrome
 - evaluate compartment pressures if concern for compartment syndrome

- Anatomy

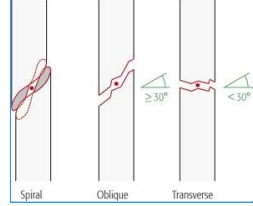
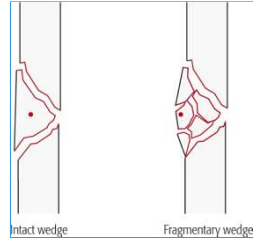
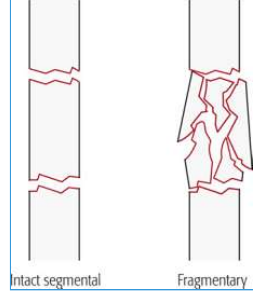
- Osteology
 - axis of rotation of forearm runs through radial head (proximal) and ulna fovea (distal)
 - distal radius effectively rotates around the distal ulna in prono-supination
 - the ulna and radius form a functional unit; mal-angulation of ulna fractures can lead to limitation of forearm rotation
- Ligaments
 - Interosseous membrane (IOM)
 - occupies the space between the radius and ulna
 - permits rotation of the radius around the ulna
 - comprised of 5 ligaments



- central band is key portion of IOM to be reconstructed
- accessory band
- distal oblique bundle
- proximal oblique cord
- dorsal oblique accessory cord

- Classification

- Descriptive
 - closed versus open
 - location
 - comminuted, segmental, multi-fragmented
 - displacement
 - angulation
 - rotational alignment
- OTA Classification

■ OTA classification		
■ Type A	■ Simple fracture ■ Spiral (A1) ■ Oblique (A2) ■ Transverse (A3)	■ 
■ Type B	■ Wedge fracture ■ Intact (B2) ■ Fragmentary (B3)	■ 
■ Type C	■ Multifragmentary fracture ■ Intact segmental (C2) ■ Fragmentary (C3)	■ 

- Presentation

- Symptoms
 - pain and swelling
 - loss of forearm and hand function
- Physical exam
 - inspection
 - gross deformity
 - open injuries
 - check for tense forearm compartments
 - neurovascular exam
 - assess radial and ulnar pulses
 - document median, radial, and ulnar nerve function
 - provocative tests

- pain with passive stretch of fingers
 - alert to impending or present compartment syndrome

• Imaging

◦ Radiographs

- recommended views
 - AP and lateral views of the forearm



- additional views
 - oblique forearm views for further fracture definition
 - ipsilateral AP and lateral of the wrist and elbow
 - to evaluate for associated fractures or dislocation
 - radial head must be aligned with the capitulum on all views

• Treatment

◦ Nonoperative

- **cast or brace immobilization, soft compression dressing**



- indications
 - isolated nondisplaced or distal 2/3 ulna shaft fx (nightstick fx) with
 - < 50% displacement and
 - < 10° of angulation
- modality
 - bracing
 - functional fracture brace
 - casting
 - Muenster cast with good interosseous mold
 - soft compression dressings
 - allowing immediate mobilization
- outcomes
 - union rates > 92% if above criteria met
 - similar union and functional outcomes with casting and bracing/soft compression dressings

- Operative
 - **external fixation**
 - indications
 - severe soft tissue injury (Gustilo IIIB)
 - **ORIF**
 - indications
 - displaced distal 2/3 isolated ulna fractures
 - proximal 1/3 isolated ulna fractures
 - Gustilo I, II, and IIIa open fractures may be treated with primary ORIF
 - outcomes
 - goal is for cortical opposition, compression, and restoration of forearm anatomy
 - **ORIF with bone grafting**
 - indications
 - open fractures with significant bone loss (bone grafting often performed in a delayed fashion)
 - nonunions
 - outcomes
 - use of autograft is critical to achieve fracture union
 - technique
 - cancellous autograft
 - indications
 - ulnar fractures with significant bone loss
 - vascularized fibula grafts
 - indications
 - can be used for large defects and have a lower rate of infection
 - Masquelet technique
 - indications
 - utilized in cases of non-union or open fractures with significant bone loss
 - **IM nailing**
 - indications
 - poor soft-tissue integrity
 - outcomes
 - recent studies have shown similar union rates compared to ORIF for isolated ulnar shaft fractures
- Techniques
 - **Cast or brace immobilization, soft compression dressing**
 - technique
 - cast/brace may extend just above elbow to control forearm rotation, however, randomized studies have shown no difference in outcomes between above elbow and below elbow immobilization
 - monitor very closely (~1 week) for displacement
 - should be worn for at least 6 weeks
 - Some authors have advocated for immediate mobilization as tolerated
 - **External fixation**
 - technique
 - 2nd and 3rd metacarpal shaft can both be utilized for distal pin placement
 - pin diameter should not exceed 4 mm
 - **ORIF**
 - approach
 - subcutaneous approach to ulna shaft
 - technique
 - 3.5 mm DCP plate (AO technique) is standard



- 4.5 plates no longer used due to increased rate of re-fracture following removal
- compression mode preferred when the fracture allows to achieve anatomic primary bony healing
 - to minimize strain, six cortices proximal and distal to fracture should be engaged
- locked plates are increasingly indicated over conventional plates in osteoporotic bone
- bridge plating may be used in extensively comminuted fractures
- interfragmentary lag screws (2.0 or 2.7 screws) if necessary
- open fractures
 - irrigation and debridement should be performed to remove any contaminated tissue or bony fragments without soft tissue attachments
- postoperative care
 - early ROM unless there is an injury to proximal or distal joint
 - should be managed with a period of non-weight bearing due to risk of secondary displacement of the fracture
 - generally 6 weeks
- **ORIF with bone grafting**
 - technique
 - bone graft options
 - cancellous autograft
 - iliac crest, proximal tibia, reamer-irrigator-aspirator (RIA)
 - vascularized fibula grafts
 - Masquelet technique ("induced-membrane" technique) can also be utilized in cases of non-union or open fractures with significant bone loss
 - 2 stage technique
 - 1st stage: I&D, cement spacer and temporizing fixation



- 2nd stage: placement of bone graft into "induced membrane" and definitive fixation
 - Studies show optimal time frame for bone grafting to be 4-6 weeks after placement of cement spacer

- **IM nailing**

- approach
 - inserted through the posterior olecranon
- technique
 - may use a small incision at fracture site to facilitate passing of nail

- **Complications**

- Infection

- incidence
 - 3% incidence with ORIF
- risk factors
 - open fractures

- Compartment syndrome

- incidence
 - up to 15% depending on mechanism and fracture characteristics
- risk factors
 - high energy crush injury
 - open fractures
 - low velocity GSWs
 - vascular injuries
 - coagulopathies (DIC)

- Nonunion

- incidence
 - < 5% after compression plating
 - up to 12% in extensively comminuted fractures treated with bridge plating
- risk factors
 - extensive comminution
 - poorly applied plate fixation
- treatment
 - atrophic nonunions can be treated with 3.5 mm plates and autogenous cancellous bone grafting

- Infection and atrophic nonunions can also be treated with the Masquelet technique
- Hypertrophic nonunions treated with debridement and compression plating

- Malunion



- risk factors
 - direct correlation between restoration of radial bow and functional outcome

- Neurovascular injury

- risk factors
 - PIN injury with Monteggia fxs
 - Type III open fxs
- treatment
 - observe for three months to see if nerve function returns
 - explore if no return of function after 3 months

- Refracture

- incidence
 - up to 10% with early hardware removal
- risk factors
 - removing plate too early
 - plates should not be removed < 1 year from implantation
 - large plates (4.5 mm)
 - comminuted fractures
 - persistent radiographic lucency
- treatment
 - wear functional forearm brace for 6 weeks and protect activity for 3 months after plate removal

- Prognosis

- For minimally displaced and angulated fractures (< 50% displacement and < 10° of angulation), nonoperative management has equivalent clinical outcomes to surgical treatment.

36- Distal Radial Ulnar Joint Druj Injuries

Images



• Introduction

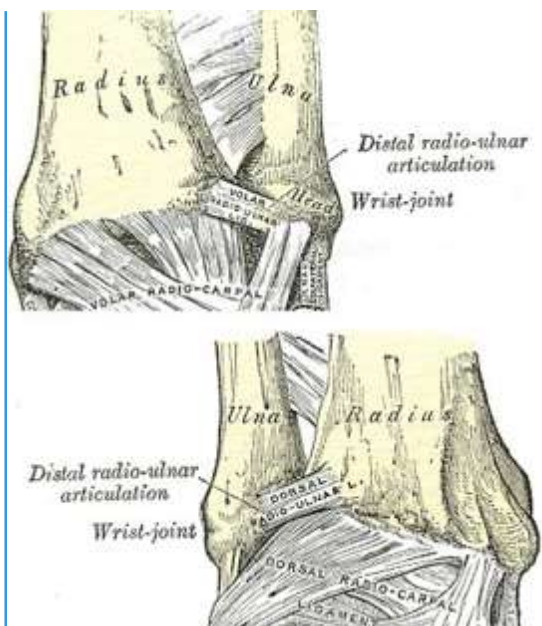
- Frequently occur with distal radius fractures but must be considered independently
 - common cause of pain and limited ROM after distal radius fractures
 - often underappreciated and ignored

• Etiology

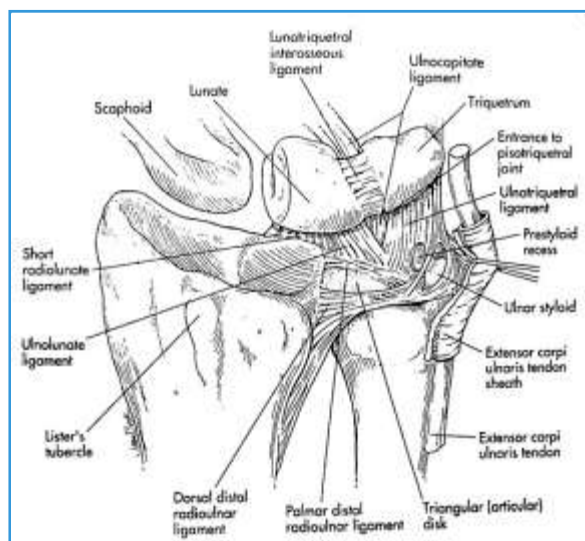
- Associated conditions
 - ulnar styloid and distal ulna fractures
 - TFCC tears
 - ulnar impaction syndrome
 - Essex-Lopresti injuries
 - Galeazzi fractures

• Anatomy

- DRUJ
 - arthrology
 - articulation occurs between the ulnar head and sigmoid notch (a shallow concavity found along ulnar border of distal radius)
 - most stable in supination
 - primary stabilizers
 - volar and dorsal radioulnar ligaments



- TFCC



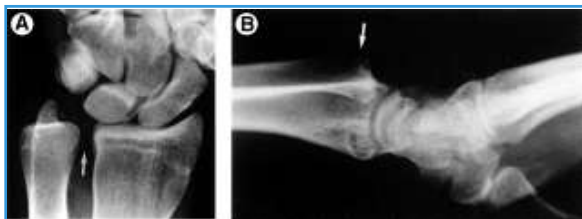
- TFCC attaches to the fovea at the base of the ulnar styloid
- components include
 - central articular disc
 - meniscal homologue
 - volar and dorsal radioulnar ligaments
 - ulnolunate and ulnotriquetral ligament origins
 - floor of the ECU tendon sheath
- biomechanics
 - joint motion includes both rotation and translation

• Presentation

- Symptoms
 - pain and instability with acute DRUJ dislocation
 - associated with open distal radius fractures
 - dorsal wrist pain and limited pronosupination with post-traumatic arthritis
- Physical exam
 - post-traumatic arthritis
 - snapping and crepitus
 - proximal rotation of the forearm with compression of the ulna against the radius elicits pain
 - decreased grip strength

• Imaging

○ Radiographs



- AP shows widening of the DRUJ
- lateral shows dorsal displacement
 - instability of the DRUJ is present when the ulnar head is subluxed from the sigmoid notch by its full width with the arm in neutral rotation
- Dynamic CT
 - useful in the diagnosis of subtle chronic DRUJ instability
 - sequential CT scans are performed with the forearm in neutral and full supination and pronation
 - >50% translation compared to the contralateral side is abnormal
- MRI
 - useful in the identification of TFCC injuries



- Treatment

- Nonoperative
 - **closed reduction, immobilization**
 - indications
 - DRUJ instability resulting from purely ligamentous injury
 - techniques
 - closed reduction and immobilization in a position of stability for 4 weeks
 - dorsal instability is stable with the forearm in supination
 - volar instability is stable in pronation
 - outcomes
 - interposition of ECU may impede closed reduction
- Operative
 - **DRUJ pinning, radioulnar ligament repair**
 - indications
 - highly unstable DRUJ
 - techniques
 - pinning across joint with 0.062-inch K-wires

- Ulnar Styloid Fractures

- Reflects high degree of initial fracture displacement
- Fractures through base often associated with TFCC rupture and instability
- In the absence of instability, ulnar styloid nonunions are not associated with worse outcomes
- Treatment
 - nonoperative
 - **cast immobilization**
 - indications
 - nondisplaced fractures proximal to the ulnar styloid
 - operative
 - **ORIF, symptomatic fragment excision**
 - indications
 - displaced fractures through the base with associated instability
 - sigmoid notch fractures
 - Galeazzi fracture patterns
 - TFCC avulsions in the face of an unstable DRUJ
 - techniques
 - preserve ulnar attachments of TFCC with fragment excision

- TFCC Tears

- Etiology
 - Mechanism of injury
 - wrist extension, forearm pronation
 - in pronation, volar ligaments prevent dorsal subluxation
 - in supination, dorsal ligaments prevent volar subluxation
- Classification
 - type I - traumatic
 - type II - degenerative (ulnocarpal impaction)
 - IIA - TFCC thinning
 - IIB - IIA + lunate and/or ulnar chondromalacia
 - IIC - IIB + TFCC perforation
 - IID - IIC + LT ligament disruption
 - IIE - IID + ulnocarpal and DRUJ arthritis
- Treatment
 - nonoperative
 - **immobilization, NSAIDS**
 - indications
 - all acute traumatic TFCC tears

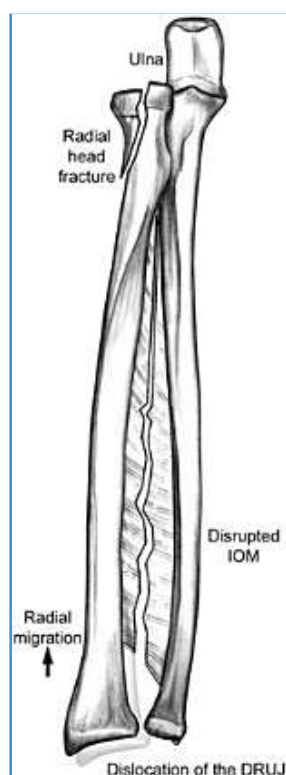
- operative
 - **arthroscopic vs. open debridement and/or repair**
 - indications
 - failure of nonoperative management
 - persistent symptoms
 - techniques
 - type I injuries
 - arthroscopic vs. open debridement and/or repair
 - type II injuries
 - TFCC pathology treated with arthroscopic or open debridement
 - ulnocarpal impaction treated with ulnar shortening osteotomy (in the absence of DRUJ arthrosis) or wafer resection of the ulnar head

• Ulnar Impaction Syndrome

- Radial shortening leads to positive ulnar variance and altered mechanics
- Sequelae includes
 - lunate chondromalacia
 - degenerative TFCC tears
- Operative treatment
 - TFCC debridement
 - radial osteotomy
 - ulnar shortening
 - distal ulnar resection (Wafer procedure)
 - preserve ulnar attachment of TFCC

• Essex-Lopresti Injuries

- Radial head fracture with an interosseous membrane injury extending to DRUJ



- unstable relationship between ulna and radius
- leads to proximal migration of the radius
- results in secondary DRUJ pathology and ulnocarpal abutment
- Treatment
 - treat bony pathology (radial head or shaft)
 - pin DRUJ for 6 weeks in neutral to facilitate ligamentous healing
 - if pinning fails (or the initial injury is missed) radial head replacement may be required

• Galeazzi Fractures

- Distal one-third fracture of the radius and a DRUJ injury
- ECU entrapment may cause DRUJ to be irreducible
- Treatment
 - nonoperative
 - **splint in supination**

- indications
 - rarely indicated for stable injuries
- operative
 - **radial ORIF and DRUJ pinning**
 - indications
 - often required to achieve a stable reduction

• Complications

◦ DRUJ arthrosis

- treatment
 - resection arthroplasty (resect distal ulna)
 - matched resection vs. Darrach
 - Darrach procedure



- reserved for low-demand, elderly patients
 - an unstable, painful proximal ulna stump may result
 - hemiresection or interposition arthroplasty
 - ulnar insertion of TFCC is preserved
 - radioulnar impingement is prevented by soft tissue interposition
 - Sauve-Kapandji procedure



- DRUJ fusion with creation of a proximal ulnar neck pseudoarthrosis
 - ulnar head prosthetic replacement
 - creation of a one-bone forearm
 - ultimate salvage procedure that eliminates forearm rotation

• Prognosis

- Primary method to prevent disability related to DRUJ injuries is anatomic reduction of the distal radius which often results in an anatomically-reduced DRUJ

37- Radioulnar Synostosis

Images



- Introduction

- Bony bridge which develops between radius and ulna secondary to a specific event
 - must differentiate from congenital radioulnar synostosis

- Epidemiology

- Incidence
 - 3% to 9%
- Risk factors
 - trauma related
 - Monteggia fracture
 - both bone forearm fractures at the same level
 - open fracture,
 - significant soft-tissue lesion
 - comminuted fracture
 - high energy fracture
 - associated head trauma
 - bone fragments on the interosseous membrane
 - treatment related
 - use of one incision for both radius and ulna
 - delayed surgery > 2 weeks
 - screws that penetrate interosseous membrane
 - bone grafting into interosseous membrane
 - prolonged immobilization

- Anatomy

- Forearm anatomy

- Presentation

- History
 - previous trauma or surgery in forearm
- Symptoms
 - pain with incomplete synostosis
 - no pain with complete synostosis
- Physical exam
 - pronation and supination blocked both actively and passively

- Imaging

- Radiographs

- recommended views
 - AP and lateral of forearm, elbow, and wrist
- findings
 - bony bridge between radius and ulna



- Treatment

- Operative

- **surgical resection of synostosis, irradiation, and indomethacin**

- indications
 - mature post-traumatic synostosis that impairs function
 - excision indicated at 4-6 months
 - timing is controversial
 - excision too early can lead to recurrence
 - excision too late can lead to surrounding joint contractures

- results
 - results of resection are poor except for midshaft synostosis

- **proximal radial excision**

- indications
 - reserved for patients who have a proximal radioulnar synostosis that is too extensive to allow a safe resection, involves the articular surface, and is associated with an anatomic deformity.
 - results
 - can provide forearm rotation
 - associated with radioulnar and/or elbow instability

38- Sacral Fractures

Images



• Summary

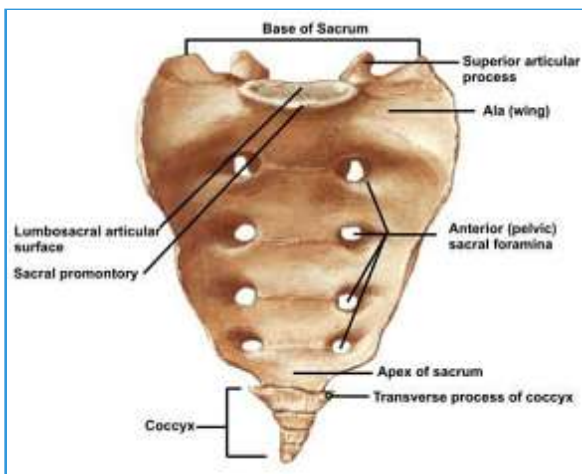
- Sacral fractures are common pelvic ring injuries that are under-diagnosed and often associated with neurologic compromise.
- Diagnosis can be made with pelvis radiographs but frequently require pelvic CT scan for full characterization.
- Treatment may be nonoperative or operative depending on fracture displacement, associated pelvic ring instability and patient activity demands.

• Epidemiology

- Incidence
 - common in pelvic ring injuries (30-45%)
- Bimodal distribution
 - young adults
 - as a result of high energy trauma
 - elderly
 - as a result of low energy falls
- Associate injuries
 - 25% are associated with neurologic injury
 - frequently missed
 - 75% in patients who are neurologically intact
 - 50% in patients who have a neurologic deficit

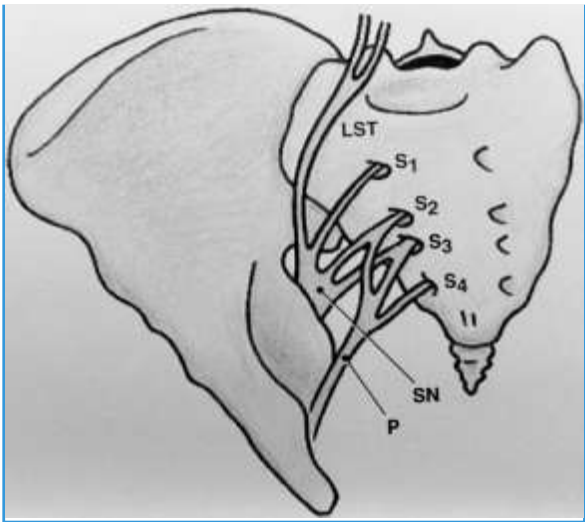
• Anatomy

◦ Osteology



- formed by fusion of 5 sacral vertebrae
- articulates with
 - 5th lumbar vertebra proximally
 - coccyx distally
 - ilium laterally at sacroiliac joints
- contains 4 foramina which transmit sacral nerves

○ Nerves



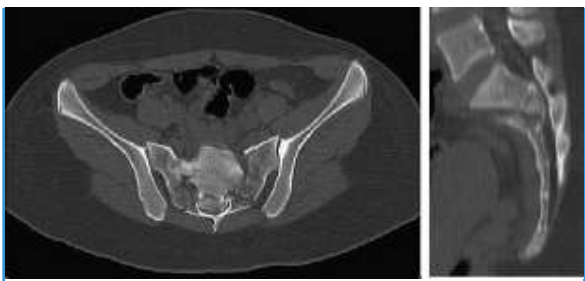
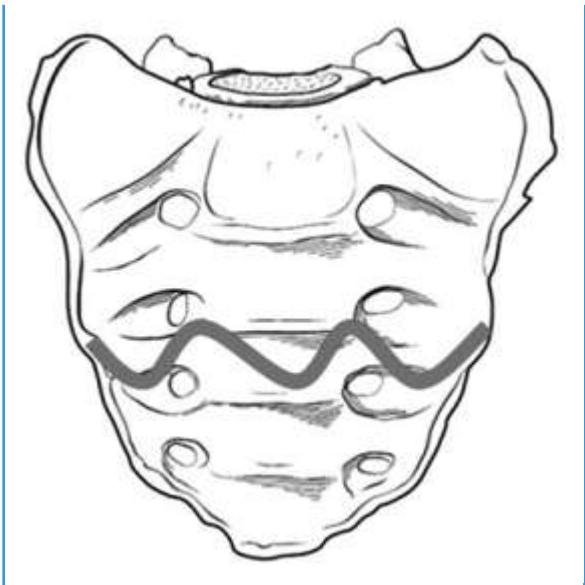
- L5 nerve root runs on top of sacral ala
- S1-S4 nerve roots are transmitted through the sacral foramina
 - S1 and S2 nerve roots carry higher rate of injury
- lower sacral nerve roots (S2-S5)
 - function
 - anal sphincter tone / voluntary contracture
 - bulbocavernosus reflex
 - perianal sensation
 - unilateral preservation of nerves is adequate for bowel and bladder control
- Biomechanics
 - transmission of load distributed by first sacral segment through iliac wings to the acetabulum

• Classification

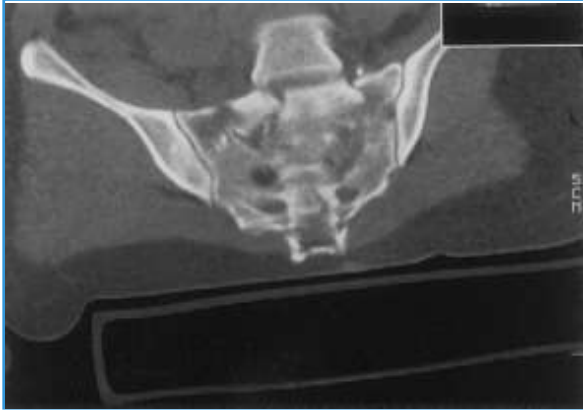
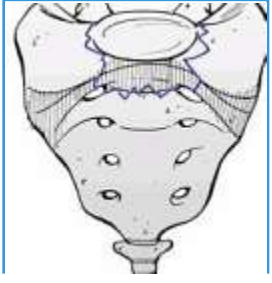
○ Denis classification

■ Denis classification		
■ Zone 1	■ F racture lateral to foramina ■ M ost common (50%) ■ N erve injury rare (5%). -usually occurs to L5 nerve root	■
■ Zone 2	■ F racture through foramina ■ M ay be stable vs. unstable ■ Z one 2 fracture with shear component highly unstable ■ Un stable fractures have higher risk of nonunion and poor functional outcome	■
■ Zone 3	■ Fra cture medial to foramina into the spinal canal ■ Highest rate of neurologic deficit (60%) ■ - bowel, bladder, and sexual dysfunction	■

○ Transverse sacral fractures



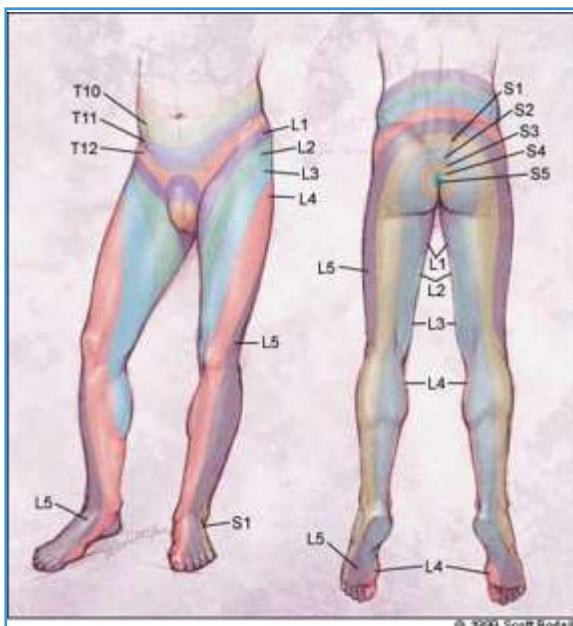
- higher incidence of nerve dysfunction
- U-type sacral fractures



- results from axial loading
- represent spino-pelvic dissociation
- high incidence of neurologic complications

• Presentation

- History
 - motor vehicle accident or fall from height most common
 - repetitive stress
 - insufficiency fracture in osteoporotic adults
- Symptoms
 - peripelvic pain
- Physical exam
 - inspection
 - soft tissue trauma around pelvis should raise concerns for pelvic or sacral fracture
 - palpation
 - test pelvic ring stability by internally and externally rotating iliac wings
 - palpate for subcutaneous fluid mass indicative of lumbosacral fascial degloving (Morel-Lavallee lesion)
 - perform vaginal exam in women to rule-out open injury
 - neurologic exam
 - rectal exam
 - light touch and pinprick sensation along S2-S5 dermatomes



- perianal wink
- bulbocavernosus and cremasteric reflexes
- vascular exam
 - distal pulses
 - if different consider ankle-brachial index or angiogram

• Imaging

- Radiographs

- only show 30% of sacral fractures
- recommended views
 - AP
 - lateral
 - effective screening tool for sacral fractures
 - often of poor quality
 - inlet view



- best assessment of sacral spinal canal and superior view of S1

- outlet view



- provides true AP of sacrum

- findings
 - L4 or L5 transverse process fractures
 - asymmetric foramina
 - anterior pelvic ring disruptions
 - stepladder sign



- seen on AP view
- results from displacement with overriding of transverse fracture fragments
- indicates disruption of anterior sacral foramina and lumbrosacral facets

○ CT

- diagnostic study of choice
- recommend coronal and sagittal reconstruction views

○ MRI

- recommended when neural compromise is suspected

• Treatment

○ Nonoperative

- **progressive weight-bearing +/- orthosis**
 - indications
 - <1 cm displacement and no neurologic deficit
 - insufficiency fractures

- Operative
 - **surgical fixation**
 - indications
 - displaced fractures >1 cm
 - soft tissue compromise
 - persistent pain after non-operative management
 - displacement of fracture after non-operative management
 - **surgical fixation with decompression**
 - indications
 - any evidence of neurologic injury

- Techniques

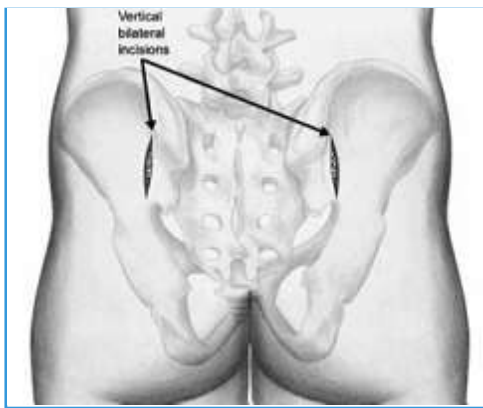
- **Percutaneous screw fixation**
 - screws may be placed as sacroiliac, trans-sacral or trans-iliac trans-sacral



- useful for sagittal plane fractures
- technique
 - screws placed percutaneously under fluoroscopy
 - beware of L5 nerve root
 - avoid overcompression of fracture
 - may cause iatrogenic nerve dysfunction
 - screw placement posterior to the ICD ensures safe screw placement
 - non-dysmorphic sacrum
- cons
 - may result in loss of fixation or malreduction
 - does not allow for removal of loose bone fragments
 - do not use in osteoporotic bone
- **Posterior tension band plating**

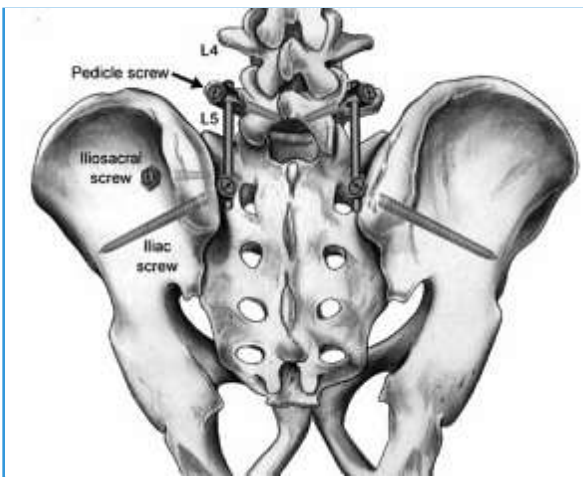


- approach
 - posterior two-incision approach



- technique
 - may use in addition to iliosacral screws
- pros
 - allows for direct visualization of fracture
- cons
 - wound healing complications

○ **Iliosacral and lumbopelvic fixation**



- approach
 - posterior approach to lower lumbar spine and sacrum
- technique
 - pedicle screw fixation in lumbar spine
 - iliac screws parallel to the inclination angle of outer table of ilium
 - longitudinal and transverse rods
- pros
 - shown to have greatest stiffness when used for an unstable sacral fracture
- cons
 - invasive

○ **Decompression of neural elements**

- technique
 - indirect
 - reduction through axial traction
 - direct
 - posterior approach followed by laminectomy or foraminotomy

• **Complications**

- Venous thromboembolism
 - often as a result of immobility

- Iatrogenic nerve injury
 - may result from
 - overcompression of fracture
 - improper hardware placement
 - Malreduction
 - more common with vertically displaced fractures
- Prognosis
 - Presence of a neurologic deficit is the most important factor in predicting outcome
 - Displacement confers an increased risk of neurologic dysfunction
 - Mistreated fractures may result in
 - lower extremity deficits
 - urinary dysfunction
 - rectal dysfunction
 - sexual dysfunction

39- Pelvic Ring Fractures

Images



• Summary

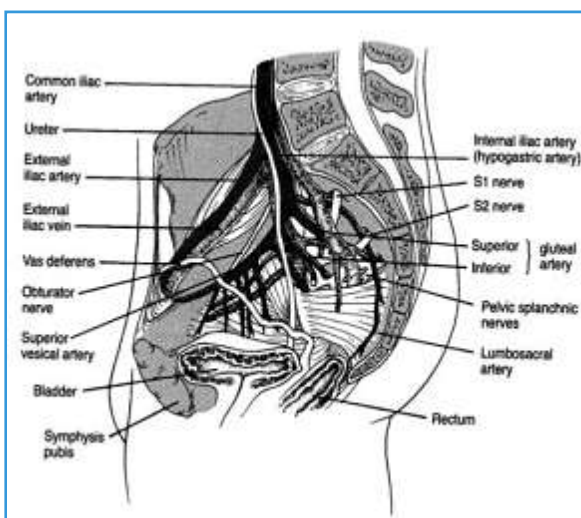
- Pelvic ring fractures are high energy fractures of the pelvic ring which typically occur due to blunt trauma.
- Diagnosis is made radiographically with pelvic radiographs and further characterized with CT scan.
- Treatment is typically operative fixation depending on degree of pelvis instability, fracture displacement and patient activity demands.

• Etiology

- Associated injuries
 - orthopaedics
 - chest injury in up to 63%
 - long bone fractures in 50%
 - spine fractures in 25%
 - non-orthopaedic
 - urogenital
 - sexual dysfunction up to 50%
 - head and abdominal injury in 40%
- Pediatric pelvic ring fractures
 - children with open triradiate cartilage have different fracture patterns than do children whose triradiate cartilage has closed
 - if triradiate cartilage is open the iliac wing is weaker than the elastic pelvic ligaments, resulting in bone failure before pelvic ring disruption
 - for this reason fractures usually involve the pubic rami and iliac wings and rarely require surgical treatment

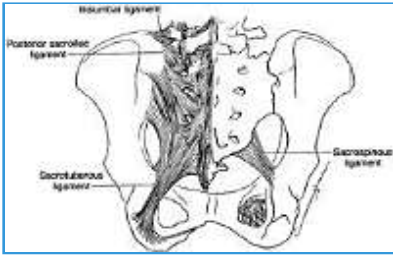
• Anatomy

- Osteology
 - ring structure made up of the sacrum and two innominate bones
 - stability dependent on strong surrounding ligamentous structures
 - displacement can only occur with disruption of the ring in two places
 - neurovascular structures intimately associated with posterior pelvic ligaments



- high index of suspicion for injury of internal iliac vessels or lumbosacral plexus

- Ligaments



- anterior
 - symphyseal ligaments
 - resist external rotation
- pelvic floor
 - sacrospinous ligaments
 - resist external rotation
 - sacrotuberous ligaments
 - resist shear and flexion
- posterior sacroiliac complex (posterior tension band)
 - strongest ligaments in the body
 - more important than anterior structures for pelvic ring stability
 - anterior sacroiliac ligaments
 - resist external rotation after failure of pelvic floor and anterior structures
 - interosseous sacroiliac
 - resist anterior-posterior translation of pelvis
 - posterior sacroiliac
 - resist cephalad-caudad displacement of pelvis
 - iliolumbar
 - resist rotation and augment posterior SI ligaments

- Vascular

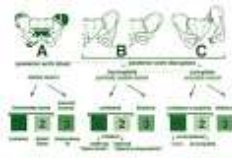
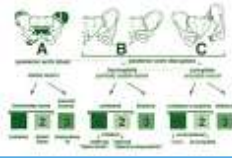
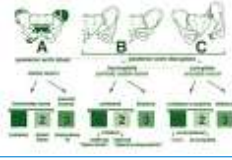
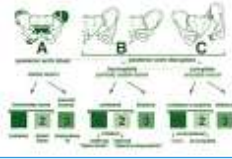
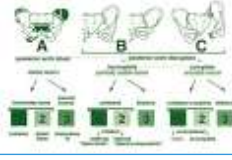
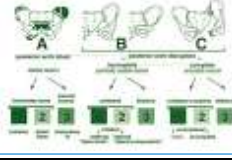
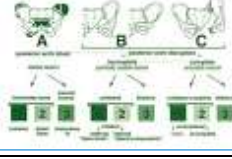
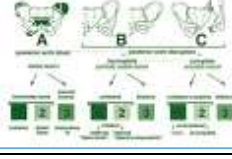
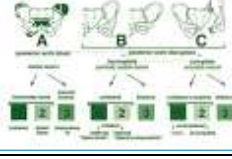
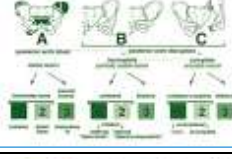
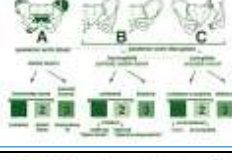
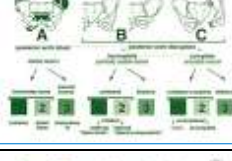
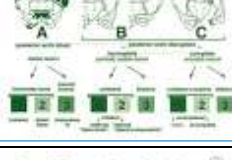
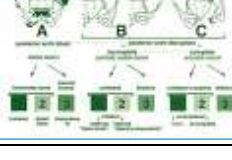
- common iliac system begins near L4 at bifurcation of abdominal aorta
 - external iliac artery courses anteriorly along pelvic brim and emerges as the common femoral artery distal to the inguinal ligament
 - internal iliac artery dives posteriorly near SI joint and divides in the posterior division (giving off superior gluteal artery) and anterior division (becoming obturator artery)
- corona mortis is a connection between the obturator and external iliac systems
 - mean distance of 6.2cm from the pubic symphysis
- venous plexus in posterior pelvis accounts for 90% of the hemorrhage associated with pelvic ring injuries

- Neurologic

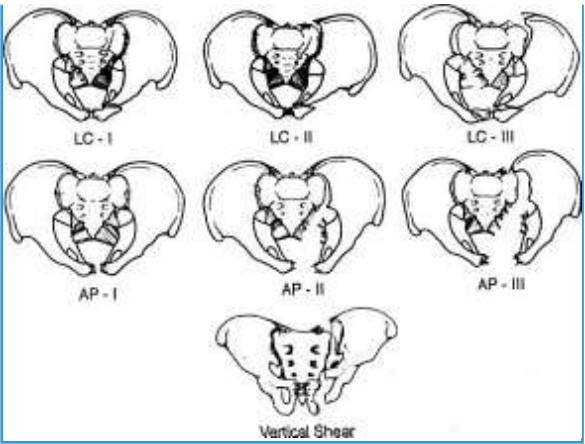
- Lumbosacral trunk crosses anterior sacral ala and SI joint
- L5 nerve root exits below L5 TP and courses over sacral ala 2cm medial to SI joint

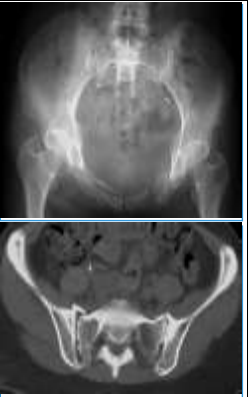
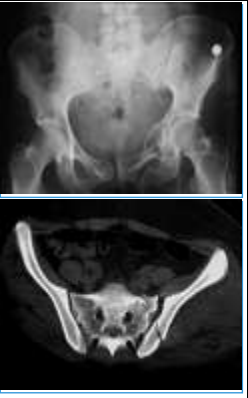
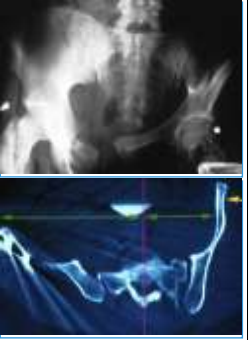
- Classification

- **Tile classification**

■ Tile classification		
■ A: Stable		
■	■ A1: fracture not involving the ring (avulsion or iliac wing fracture) ■	■ ■ 
■	■ A2: stable or minimally displaced fracture of the ring	■ 
■	■ A3: transverse sacral fracture (Denis zone III sacral fracture)	■ 
■ B: Rotationally unstable, vertically stable		
■	■ B1: open book injury (external rotation)	■ 
■	■ B2: lateral compression injury (internal rotation)	■ 
■	■ B2-1: with anterior ring rotation/displacement through ipsilateral rami	■ 
■	■ B2-2-with anterior ring rotation/displacement through contralateral rami (bucket-handle injury)	■ 
■	■ B3: bilateral	■ 
■ C: Rotationally and vertically unstable		
■	■ C1: unilateral	■ 
■	■ C1-1: iliac fracture	■ 
■	■ C1-2: sacroiliac fracture-dislocation	■ 
■	■ C1-3: sacral fracture	■ 
■	■ C2: bilateral with one side type B and one side type C	■ 
■	■ C3: bilateral with both sides type C	■ 

○ **Young-Burgess Classification**



Anterior Posterior Compression (APC)		
APC I	Symphysis widening < 2.5 cm	
APC II	Symphysis widening > 2.5 cm. Anterior SI joint diastasis. Posterior SI ligaments are intact. Disruption of sacrospinous and sacrotuberous ligaments.	
APC III	- Disruption of anterior and posterior SI ligaments (SI dislocation). Disruption of sacrospinous and sacrotuberous ligaments. - APCIII associated with vascular injury	
Lateral Compression (LC)		
LC I	Oblique or transverse ramus fracture and ipsilateral anterior sacral ala compression fracture.	
LC II	Rami fracture and ipsilateral posterior ilium fracture dislocation (crescent fracture).	
LC III	- Ipsilateral lateral compression and contralateral APC (windswept pelvis). - Common mechanism is rollover vehicle accident or pedestrian vs auto.	
Vertical Shear (VS)		
Vertical shear	- Posterior and superior directed force. - Associated with the highest risk of hypovolemic shock (63%); mortality rate up to 25%	

Physical Exam

- Symptoms
 - pain & inability to bear weight
- Physical exam
 - inspection
 - test stability by placing gentle rotational force on each iliac crest
 - low sensitivity for detecting instability
 - perform only once
 - look for abnormal lower extremity positioning
 - external rotation of one or both extremities



- limb-length discrepancy
- skin
 - scrotal, labial or perineal hematoma, swelling or ecchymosis
 - flank hematoma
 - lacerations of perineum
 - degloving injuries (Morel-Lavallee lesion)



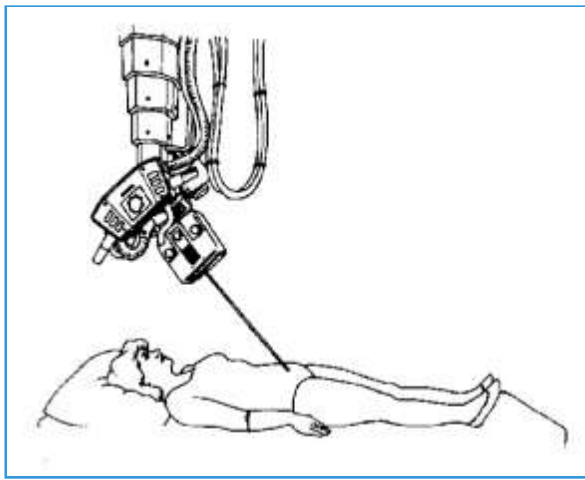
- neurologic exam
 - rule out lumbosacral plexus injuries (L5 and S1 are most common)
 - rectal exam to evaluate sphincter tone and perirectal sensation
 - up to 10-15% of patients will sustain neurologic injury
- urogenital exam
 - most common finding is gross hematuria
 - more common in males (21% in males, 8% in females)
- vaginal and rectal examinations
 - mandatory to rule out occult open fracture

• Imaging

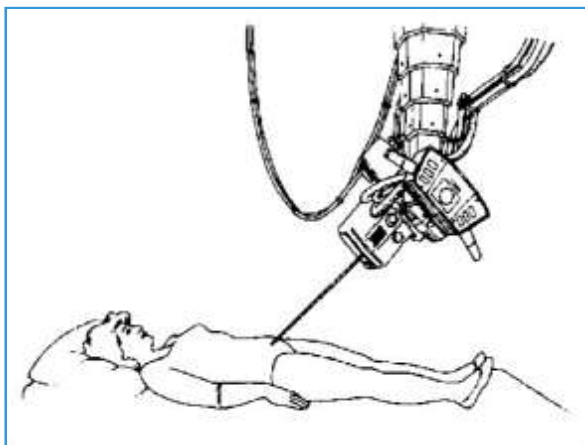
- Radiographs
 - recommended views
 - AP



- part of initial ATLS evaluation
 - look for asymmetry, rotation or displacement of each hemipelvis
 - evidence of anterior ring injury needs further imaging
- inlet



- xray beam angled 40° caudad (may be as little as 25 degrees)
 - adequate image when S1 overlaps S2 body (i.e. perpendicular to S1 endplate)
- ideal for visualizing
 - anterior or posterior translation of the hemipelvis
 - internal or external rotation of the hemipelvis
 - widening of the SI joint
 - sacral ala impaction
- outlet



- xray beam angled ~40° cephalad (may be as much as 60 degrees)
 - adequate image when pubic symphysis overlies S2 body
- ideal for visualizing
 - vertical translation of the hemipelvis
 - flexion/extension of the hemipelvis
 - disruption of sacral foramina and location of sacral fractures
- Single-leg stance AP pelvis ("flamingo views")
 - Patient alternates with right and left foot up while AP pelvis is obtained
 - Used in evaluation of suspected chronic pelvic ring instability
 - Examiner measures vertical translation of the pubic bones
 - Serves as a means of assessing pathologic motion at the SI joint
- findings

- radiographic signs of instability



- > 5 mm displacement of posterior sacroiliac complex
- presence of posterior sacral fracture gap
- avulsion fractures (ischial spine, ischial tuberosity, sacrum, transverse process of 5th lumbar vertebrae)

○ CT

- routine part of pelvic ring injury evaluation



- better characterization of posterior ring injuries
- helps define comminution and fragment rotation
- visualize position of fracture lines relative to sacral foramina
- radiographic signs of sacral dysmorphism:
 - anterior up-sloping upper sacral ala
 - irregular, non-circular, sacral nerve root tunnels
 - residual S1 disk
 - tongue-and-groove SI joint

• Studies

○ Serum labs

- hgb
- serum lactate
- base excess

• Initial Management & Resuscitation

○ Bleeding Source

- intraabdominal (present in up to 40% of cases)
- intrathoracic
- retroperitoneal
- extremity (thigh compartments)
- pelvic
 - common sources of hemorrhage
 - venous injury (80%)
 - shearing injury of posterior thin walled venous plexus
 - leads to retroperitoneal hematoma (can hold up to 4L of blood)
 - bleeding cancellous bone
 - uncommon sources of hemorrhage
 - arterial injury (10-20%)
 - superior gluteal most common (posterior ring injury, APC pattern)
 - internal pudendal (anterior ring injury, LC pattern)
 - obturator (LC pattern)

○ Treatment

- **resuscitation**

- PRBC:FFP:Platelets ideally should be transfused 1:1:1
 - this ratio shown to improve mortality in patients requiring massive transfusion
- pelvic binder/sheet**
 - indications
 - initial management of an unstable ring injury
 - should be centered over the greater trochanters
 - contraindications
 - hypothetical risk of over-rotation of hemipelvis and hollow viscus injury (bladder) in pelvic fractures with internal rotation component (LC)
 - no clinical evidence exists of this complication occurring
 - pitfalls
 - binder can mask pelvic ring injuries, creating false negative radiographs and CT images
 - stress examination under anesthesia may be indicated in patients who present to the trauma slot in a pelvic binder, hemodynamic instability, and negative pelvis radiographs/CT scan
- external fixation**
 - indications
 - pelvic ring injuries with an external rotation component (APC, VS, CM)
 - unstable ring injury with ongoing blood loss
 - should be placed before emergent laparotomy
 - contraindications
 - ilium fracture that precludes safe application
 - acetabular fracture
- angiography / embolization**
 - indications
 - controversial and based on multiple variables including:
 - protocol of institution, stability of patient, proximity of angiography suite , availability and experience of IR staff
 - CT angiography useful for determining presence or absence of ongoing arterial hemorrhage (98-100% negative predictive value)
 - contraindications
 - not clearly defined
 - technique
 - selective embolization of identifiable bleeding sources
 - in patients with uncontrolled bleeding after selective embolization, bilateral temporary internal iliac embolization may be effective
 - repeat angiography if patient continues to be hypotensive after embolization
 - recurrent hemorrhage from previously embolized artery is common
 - complications include gluteal necrosis and impotence

- Definitive Treatment

- Overview by Classification

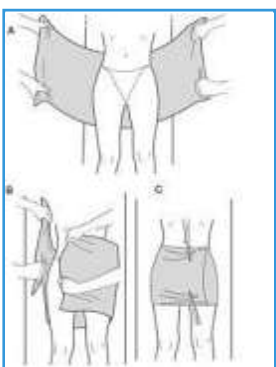
Definitive treatment of Anterior Posterior Compression (APC) injuries		
APC I	Non-operative. Protected weight bearing	
APC II	Anterior symphyseal plate or external fixator +/- posterior fixation	
APC III	Anterior symphyseal multi-hole plate or external fixator and posterior stabilization with SI screws or plate/screws	
Definitive treatment of Lateral Compression (LC) injuries		
LC I	- Non-operative. -Protected weight bearing (complete, comminuted sacral component. -Weight bearing as tolerated (simple, incomplete sacral fracture)	
LC II	Open reduction and internal fixation of ilium	
LC III	- Posterior stabilization with plate or SI screws as needed. - Percutaneous or open based on injury pattern and surgeon preference.	
Definitive treatment of Vertical Shear (VS) injuries		
Vertical Shear	- Posterior stabilization with plate or SI screws as needed. - Percutaneous or open based on injury pattern and surgeon preference.	

- Nonoperative
 - **weight bearing as tolerated**
 - indications
 - mechanically stable pelvic ring injuries including
 - LC1
 - anterior impaction fracture of sacrum and oblique ramus fractures with < 1cm of posterior ring displacement
 - APC1
 - traumatic widening of symphysis < 2.5 cm with intact posterior pelvic ring
 - isolated pubic ramus fractures
 - parturition-induced pelvic diastasis
 - bedrest and pelvic binder in acute setting with diastasis less than 4cm
- Operative
 - **ORIF**
 - indications
 - symphysis diastasis > 2.5 cm
 - SI joint displacement > 1 cm
 - sacral fracture with displacement > 1 cm
 - displacement or rotation of hemipelvis
 - open fracture
 - chronic pain and diastasis in parturition-induced diastasis or acute setting >4-6cm
 - technique
 - for open fractures aggressive debridement according to open fracture principles
 - **anterior subcutaneous pelvic fixator (INFIX)**
 - indications
 - same indications as anterior external fixation and symphyseal plating
 - complications
 - heterotopic ossification, femoral nerve injury, infection
 - **diverting colostomy**
 - indications
 - consider in open pelvic fractures
 - especially with extensive perineal injury or rectal involvement

• Techniques

○ Pelvic Binding

- technique



- centered over greater trochanters to effect indirect reduction
 - do not place over iliac crest/abdomen
 - ineffective and precludes assessment of abdomen
 - may augment with internal rotation of lower extremities and taping at ankles
 - transition to alternative fixation as soon as possible
 - prolonged pressure from binder or sheet may cause skin necrosis
 - working portals may be cut in sheet to place percutaneous fixation
 - early pelvic binding and CT have been associated with underestimation of pelvic ring instability
 - fluoroscopic exam under anesthesia can be used to assess stability in these circumstances
- **External fixation**
 - theoretically works by decreasing pelvic volume
 - stability of bleeding bone surfaces and venous plexus in order to form clot
 - pins inserted into ilium

- supra-acetabular pin insertion
- single pin in column of supracetabular bone from AIIS towards PSIS
 - obturator outlet view
 - helps to identify pin entry point
 - iliac oblique view
 - helps to direct pin above greater sciatic notch
 - obturator oblique inlet view
 - helps to ensure pin placement within inner and outer table
 - AIIS pins can place the lateral femoral cutaneous nerve at risk
 - pedicle screws with internal subcutaneous bar may be used
- superior iliac crest pin insertion
- multiple half pins in the superior iliac crest
 - place in thickest portion of ilium (gluteal pillar)
 - may be placed with minimal fluoroscopy

○ **ORIF**

- anterior ring stabilization
 - single superior plate
 - apply through rectus-splitting Pfannenstiel approach
 - may perform in conjunction with laparotomy or GU procedure
- posterior ring stabilization
 - anterior SI plating
 - risk of L4 and L5 injury with placement of anterior sacral retractors
 - iliosacral screws (percutaneous)
 - good for sacral fractures and SI dislocations
 - safe zone is in S1 vertebral body
 - outlet radiograph view best guides superior-inferior screw placement
 - inlet radiograph view best guides anterior-posterior screw placement
 - in sacral dysmorphism, the safe zone in S2 is larger
 - L5 nerve root injury complication with errors in screw placement
 - entry point best viewed on lateral sacral view and pelvic outlet views
 - risk of loss of reduction highest in vertical sacral fracture patterns
 - posterior SI "tension" plating
 - can have prominent HW complications
- anterior and posterior ring stabilization
 - necessary in vertically unstable injuries
- ipsilateral acetabular and pelvic ring fractures
 - in general, reduction and fixation of the pelvic ring should be performed first

○ **Rehabilitation**

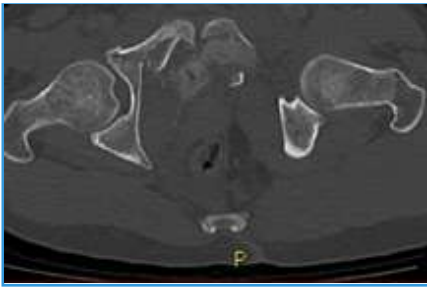
- stable fractures treated nonsurgically
 - patients may mobilize immediately with protected weight bearing after stable fracture pattern in confirmed (may require post-mobilization views to confirm stability)
- unstable fractures treated surgically
 - patient mobility and weight bearing depend on the location of the posterior pelvic ring fracture
 - mobility includes weight-of-limb weight bearing ipsilateral to the posterior pelvic injury with full weight bearing on contralateral side
 - patients with bilateral posterior pelvic ring injuries limited to bed-to-chair transfers only
 - when radiographic healing has occurred weight bearing can be gradually advanced

• **Complications**

○ Urogenital Injuries

- present in 12-20% of patients with pelvic fractures
 - higher incidence in males (21%)
- includes
 - posterior urethral tear
 - most common urogenital injury with pelvic ring fracture
 - bladder rupture

- may see extravasation around the pubic symphysis



- associated with mortality of 22-34%

- diagnosis

- made with retrograde urethrocytogram
- indications for retrograde urethrocytogram include
 - blood at meatus
 - high riding or excessively mobile prostate
 - hematuria

- treatment

- **suprapubic catheter placement**

- suprapubic catheter is a relative contraindication to anterior ring plating

- **surgical repair**

- rupture should be repaired at the same time or prior to definitive fixation in order to minimize infection risk

- complications

- long-term complications common (up to 35%)
 - urethral stricture - most common
 - impotence
 - anterior pelvic ring infection
 - incontinence
 - parturition sequelae (i.e. caesarean section)

- Neurologic injury

- L5 nerve root runs over sacral ala joint
- may be injured if SI screw is placed too anterior
- anterior subcutaneous pelvic fixator may give rise to LFCN injury (most common) or femoral nerve injury

- DVT and PE

- DVT in ~ 60%, PE in ~ 27%, fatal PE in 2%
- prophylaxis essential
 - mechanical compression
 - pharmacologic prevention (LMWH or Lovenox)
 - vena caval filters (closed head injury)

- Chronic instability

- rare complication; can be seen in nonoperative cases
- presents with subjective instability and mechanical symptoms
- diagnosed with alternating single-leg-stance pelvic radiographs (flamingo views)

- Infection

- risk factors include:
 - obesity
 - diabetes
 - prolonged operation time
 - prolonged ICU stay
 - larger amount of packed red blood cell transfusions,
 - associated genitourinary and abdominal trauma
 - open fractures
 - preoperative angioembolization is controversial

- Prognosis

- High prevalence of poor functional outcome and chronic pain
- Poor outcome associated with
 - SI joint incongruity of > 1 cm
 - high degree initial displacement

- malunion or residual displacement
- leg length discrepancy > 2 cm
- nonunion
- neurologic injury
- urethral injury
- Mortality rate 1-15% for closed fractures, as much as 50% for open fractures
 - hemorrhage is leading cause of death overall
 - closed head injury is the most common for lateral compression injuries
 - increased mortality associated with
 - systolic BP <90 on presentation
 - age >60 years
 - increased Injury Severity Score (ISS) or Revised Trauma Score (RTS)
 - need for transfusion > 4 units
 - APC III injury

40- SI Dislocation And Crescent Fractures

- Summary

- Sacroiliac (SI) dislocations and crescent fractures include a spectrum of injuries involving the pelvis which can lead to instability and pelvic malalignment.
- Diagnosis requires pelvic radiographs with CT scan.
- Treatment is generally operative with reduction and fixation of both the anterior and posterior pelvis ring as needed.

- Epidemiology

- Spectrum of injuries that include
 - incomplete (Sacroiliac) SI dislocation
 - posterior SI ligaments remain intact
 - rotationally unstable
 - complete SI dislocations
 - posterior SI ligaments ruptured
 - vertically and rotationally unstable
 - SI fracture-dislocation (crescent fracture)
 - iliac wing fracture that enters the SI joint
 - injury to posterior ligaments vary
 - combination of vertical iliac fx and SI dislocation
 - posterior ilium remains attached to sacrum by posterior SI ligaments
 - anterior ilium dislocates from sacrum with internal rotation deformity
 - when ilium fragment remains with sacrum it is termed a crescent fracture

- Pathophysiology

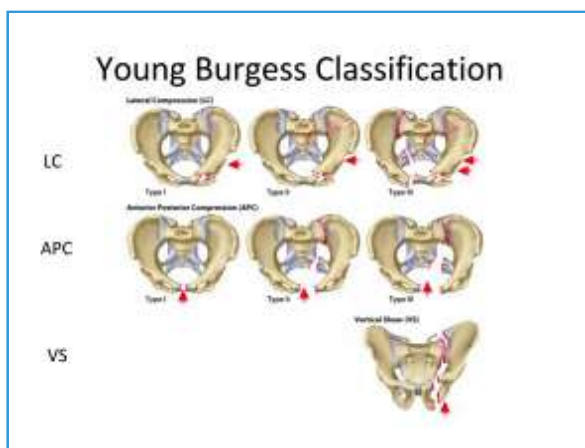
- Mechanism of injury
 - lateral compression force
 - usually high energy
- Pathoanatomy
 - degree of injury to posterior structures determines pelvic stability
 - Iliac wing fractures may be associated with open wounds and may involve bowel entrapment

- Anatomy

- Ligaments
 - the SI joint is stabilized by the posterior pelvic ligaments
 - sacrospinous
 - sacrotuberous
 - anterior sacroiliac
 - posterior sacroiliac
- Nerves
 - the L5 nerve root crosses the sacral ala approximately 2 cm medial to SI joint
- Blood supply
 - the superior gluteal artery runs across SI joint
 - exits pelvis via greater sciatic notch

- Classification

- No classification system specifically for SI injury
 - included in Young- Burgess and Tile classification of pelvic fractures
 - crescent fractures described as LC-2 injury according to Young-Burgess



• Presentation

- Symptoms
 - pelvic pain
- Physical Exam
 - assess hemodynamic status
 - perform detailed neurological exam
 - abdominal assessment to look for distention
 - rectal exam
 - examine urethral meatus for blood

• Imaging

- Radiographs



- recommended views
 - AP pelvis
 - inlet and outlet views

- CT scan



- evaluation of sacral fractures
- posterior pelvis better delineated

• Treatment

- Operative
 - **immediate skeletal traction**
 - indications
 - vertical translation of the hemipelvis
 - **anterior ring ORIF**
 - indications
 - incomplete SI dislocations with pubic symphyseal diastasis
 - **anterior and posterior ring ORIF**
 - indications

- complete SI dislocations
 - vertically unstable require anterior and posterior pelvic ring fixation

▪ **ORIF of ilium**

- indications
 - crescent fracture
 - required to restore posterior SI ligaments and pelvic stability

• Techniques

◦ **Closed Reduction and Percutaneous Fixation**

- positioning
 - intraoperative traction may aid in reduction
 - small midline bump under sacrum may assist with SI screw placement
- imaging
 - inlet view
 - shows anterior-posterior position of SI joint(s) for screw placement



- outlet view
 - shows cephalad-caudad position of SI joint(s) for screw placement



- lateral sacral view
 - ensures safe placement of SI or sacral screws relative to the anterior cortex of the sacral ala and the nerve root tunnel
- complications
 - L5 nerve root at risk with anterior perforation of iliosacral screw as nerve goes inferiorly over sacral ala

◦ **ORIF**

- approach
 - anterior approach
 - lateral window with elevation iliocostalis back to SI joint
 - posterior approach
 - for fixation of crescent fragment to intact ilium
- fixation
 - plates
 - iliosacral lag screws (SI screws)

• Complications

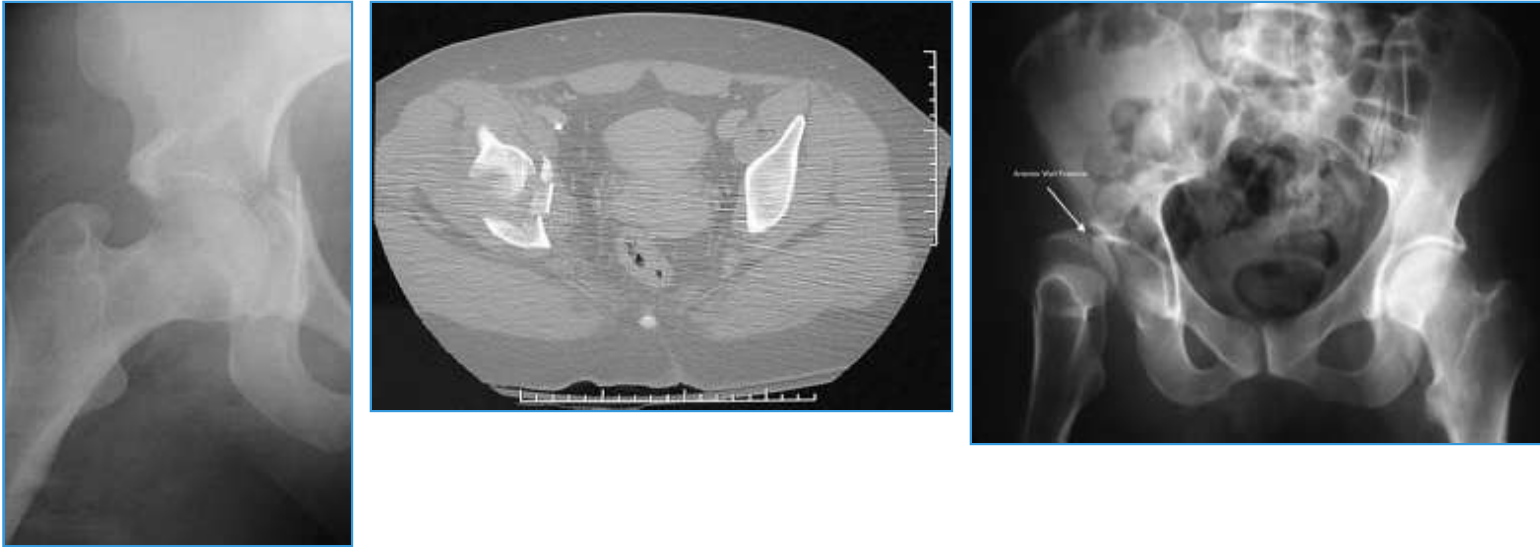
- DVT
 - 35%-50%
- Neurological injury
- Loss of reduction and failure of fixation

- Prognosis

- Primarily based on accurate and stable reduction of SI joint

41- Acetabular Fractures

Images



• Summary

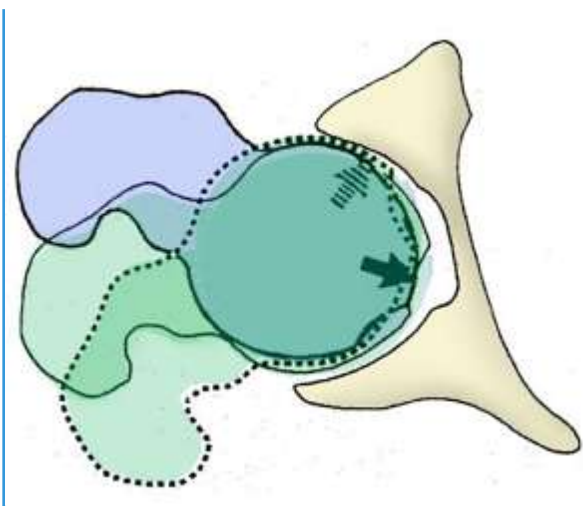
- Acetabulum fractures are pelvis fractures that involve the articular surface of the hip joint and may involve one or two columns, one or two walls, or the roof within the pelvis.
- Diagnosis can be made radiographically with dedicated pelvis radiographs (including Judet views) but frequently require CT pelvis for surgical planning.
- Treatment can be nonoperative for non-displaced fractures but displaced injuries require anatomic open reduction and internal fixation to minimize development of post-traumatic osteoarthritis.

• Epidemiology

- Incidence
 - ~ 4 per 100,000 per year
- Demographics
 - fractures occur in a bimodal distribution
 - high energy trauma in younger patients (e.g., motor vehicle accidents)
 - low energy trauma in elderly patients (e.g., fall from standing height)

• Etiology

- Pathoanatomy



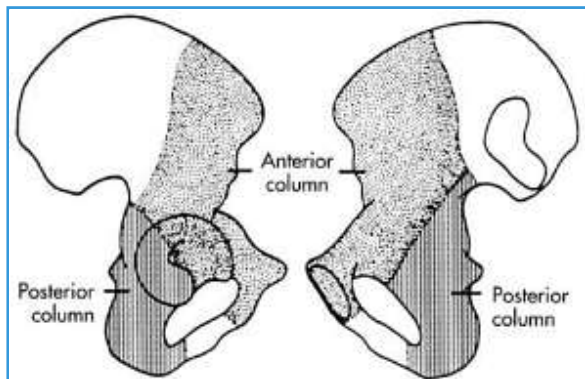
- fracture pattern predominately determined by
 - force vector
 - position of femoral head at time of injury
 - bone quality (e.g., age)
- Associated conditions
 - orthopaedic manifestations
 - lower extremity injury (36%)
 - nerve palsy (13%)
 - most commonly seen in transverse + posterior wall fracture patterns
 - most commonly affects the peroneal division of the sciatic nerve
 - spine injury (4%)

- systemic injuries
 - head injury (19%)
 - chest injury (18%)
 - abdominal injury (8%)
 - genitourinary injury (6%)

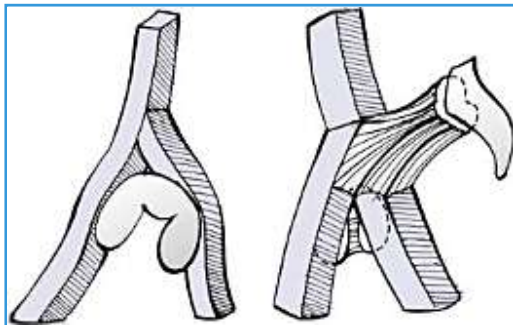
• Anatomy

○ Osteology

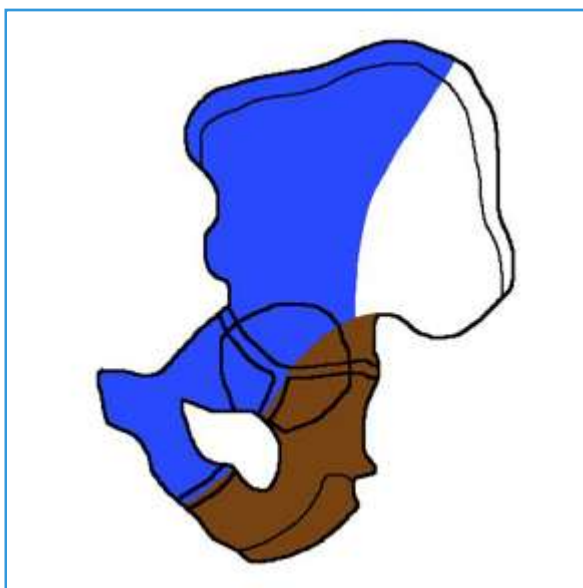
- acetabular inclination & anteversion
 - mean lateral inclination of 40 to 48 degrees
 - anteversion of 18 to 21 degrees
- column theory
 - acetabulum is supported by two columns of bone



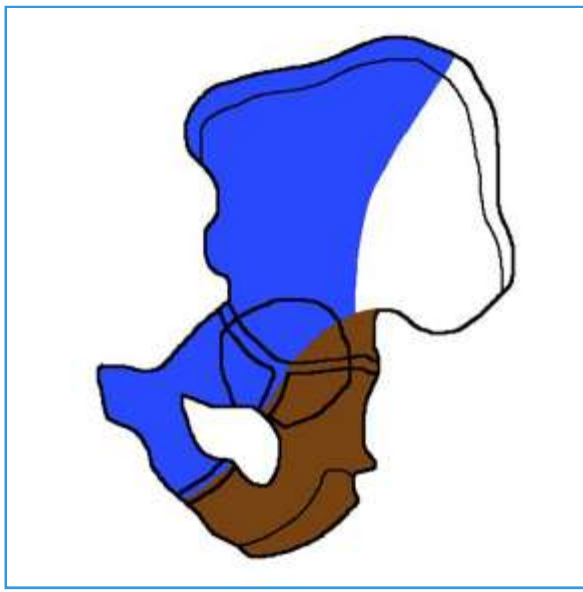
- form an "inverted Y"



- connected to sacrum through sciatic buttress
 - posterior column



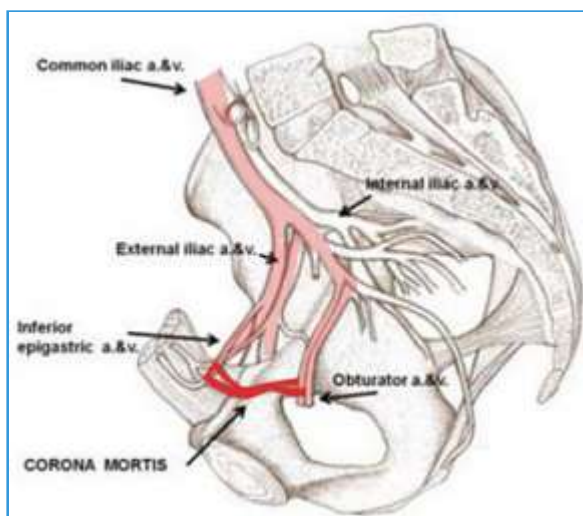
- comprised of
 - quadrilateral surface
 - posterior wall and dome
 - ischial tuberosity
 - greater/lesser sciatic notches
- anterior column



- comprised of
 - anterior ilium (gluteus medius tubercle)
 - anterior wall and dome
 - iliopectineal eminence
 - lateral superior pubic ramus

○ Vascular

- corona mortis

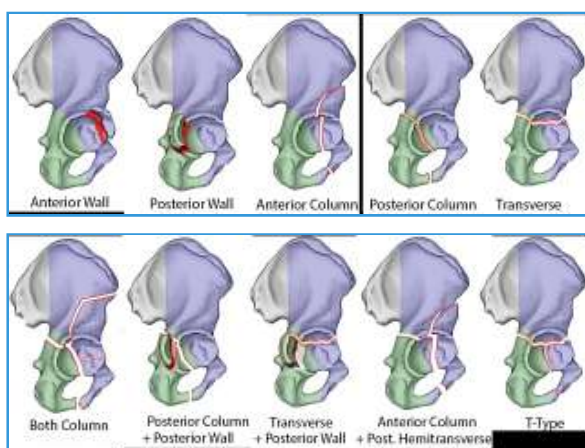


- anastomosis of external iliac (epigastric) and internal iliac (obturator) vessels
- at risk with lateral dissection over superior pubic ramus

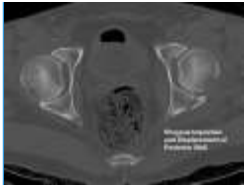
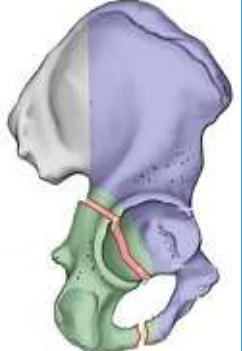
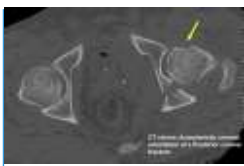
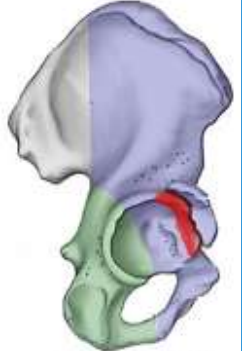
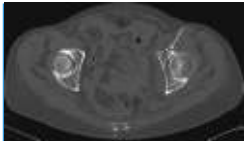
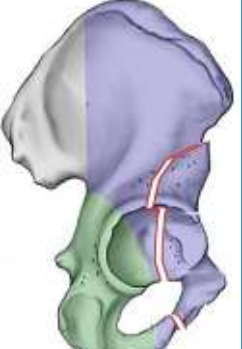
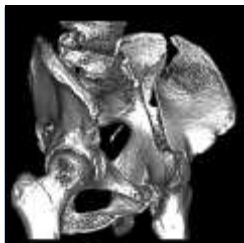
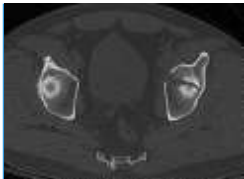
• Letournel Classification

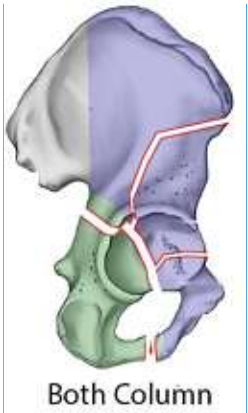
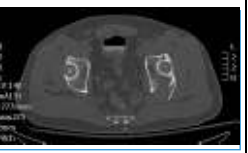
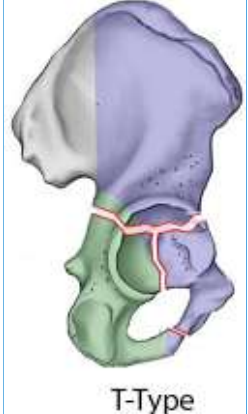
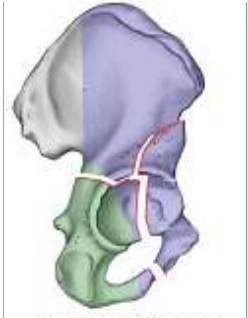
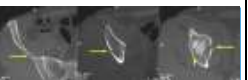
○ Judet and Letournel

- most common referenced classification system
 - classified as 5 elementary and 5 associated fracture patterns

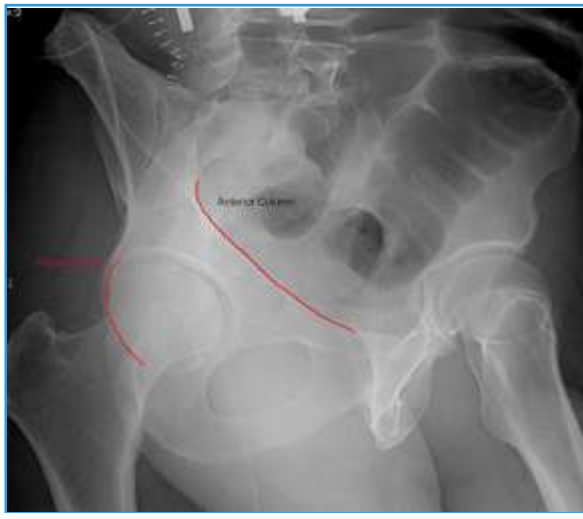


- most common fracture patterns
 - younger
 - posterior wall
 - transverse fracture "family"
 - transverse
 - T-type
 - transverse + posterior wall
 - elderly
 - anterior column (e.g., quadrilateral plate fractures)
 - anterior column, posterior hemitransverse
 - associated both column fractures

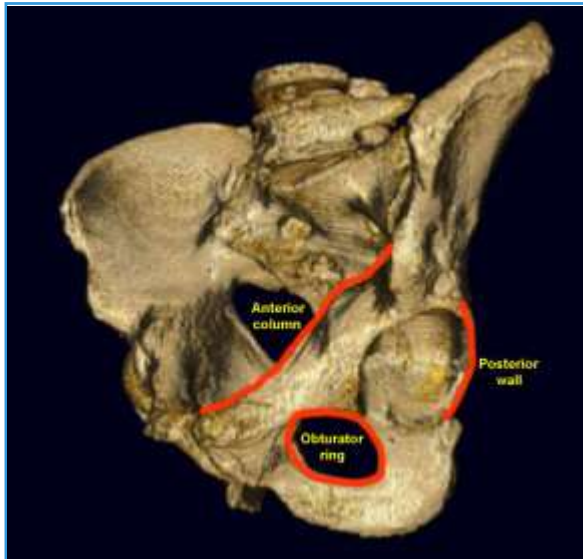
■ Elementary patterns						
	■ <i>Illustration</i>	■ <i>AP</i>	■ <i>Obturator ob.</i>	■ <i>Iliac ob.</i>	■ <i>CT</i>	■ <i>Comments</i>
■ Posterior wall	■  Posterior Wall	■ 	■ 	■ 	■ 	■ Most common ■ "gull sign" on obturator oblique view ■ Check for injury to superior gluteal NV bundle
■ Posterior column	■  Posterior Column	■ 	■ 	■ 	■ 	■ Check for injury to superior gluteal NV bundle
■ Anterior wall	■  Anterior Wall	■ 	■ 	■ 	■ 	■ Very rare
■ Anterior column	■  Anterior Column	■ 	■ 	■ 	■ 	■ More common in elderly patient with fall from standing
■ Transverse	■  Transverse	■ 	■ 	■ 	■ 	■ Axial CT shows anterior to posterior fx line ■ Only elementary fx to involve both columns

■ Associated patterns						
	■ <i>Illustration</i>	■ <i>AP</i>	■ <i>Obturator ob.</i>	■ <i>Iliac ob.</i>	■ <i>CT</i>	■ <i>Comments</i>
■ Associated Both Column	■  Both Column	■ 	■ 	■ 	■ 	■ Characterized by dissociation of the articular surface from the innominate bone ■ "spur sign" on obturator oblique
■ Transverse + Post. Wall	■ 	■ 	■ 	■ 	■ 	■ Most common associated fx ■ Associated with the highest incidence of nerve injury
■ T-type	■  T-Type	■ 	■ 	■ 	■ 	■ May need combined approach
■ Anterior column or wall + Post. hemitransverse	■  Anterior Column + Post. Hemitransverse	■ 	■ 	■ 	■ 	■ Most common in elderly patients
■ Post. column + Post. wall	■  Posterior Column + Posterior Wall	■ 	■ 	■ 	■ 	■ Only associated fracture that does not involve both columns

- Imaging
 - Radiographs
 - Recommended views
 - AP
 - judet
 - obturator oblique



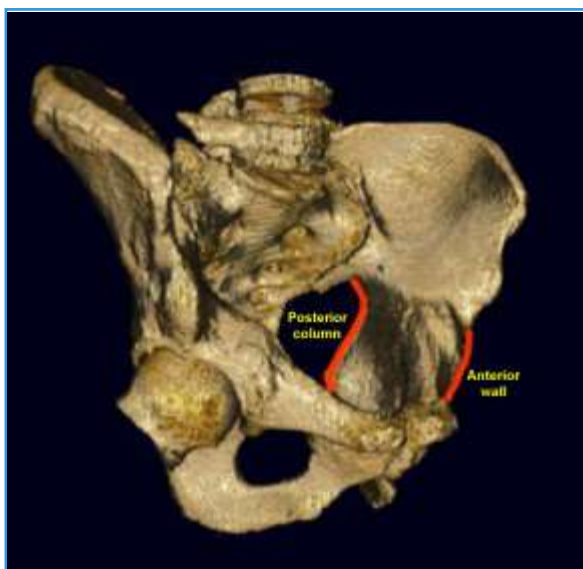
- shows profile of obturator foramen



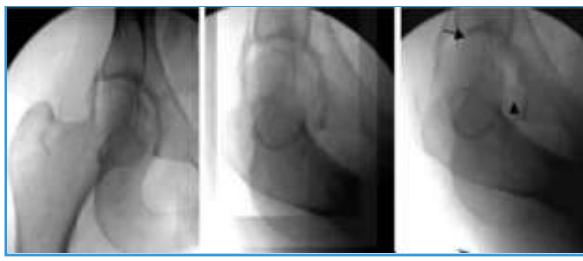
- shows anterior column and posterior wall
- iliac oblique



- shows profile of involved iliac wing
- shows posterior column and anterior wall

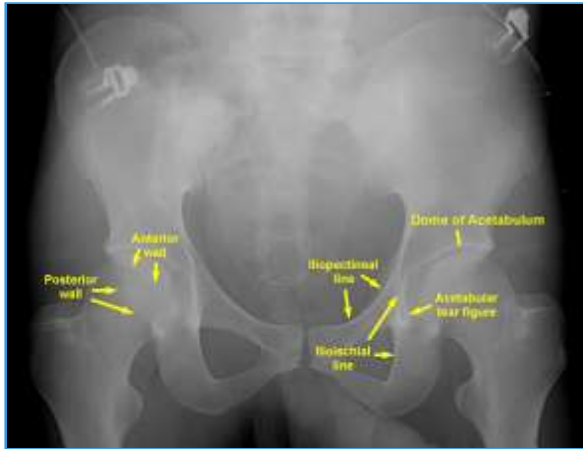


- Optional views
 - inlet/outlet if concerned for pelvic ring involvement
 - examination under anesthesia (EUA)
 - used to assess posterior wall stability
 - hip positioned in flexion, adduction and axial load
 - obtain obturator oblique view
 - opening of the medial clear space suggests instability of the posterior wall fracture



■ Findings

- radiographic landmarks of the acetabulum

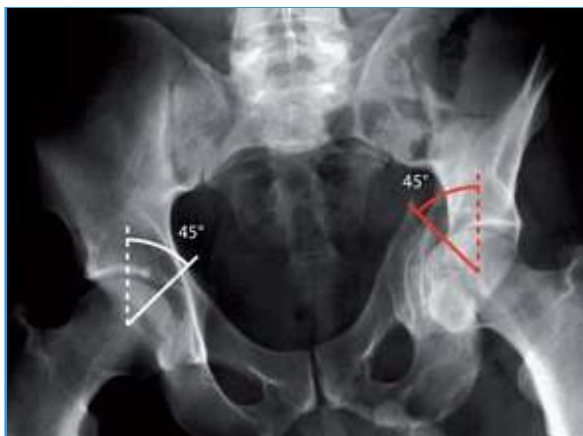


- iliopectineal line (anterior column)
- iliioischial line (posterior column)
- anterior wall
- posterior wall
- teardrop
- weight bearing roof

- superior acetabular rim may show os acetabuli marginalis superior which can be confused for fracture in adolescents

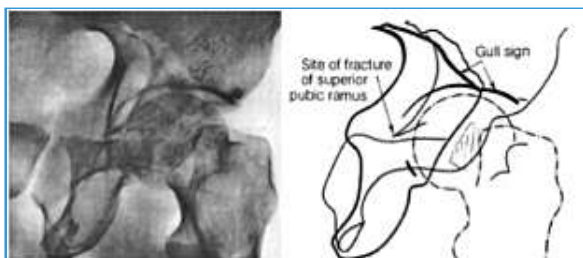
- Shenton's line

- roof arc angle



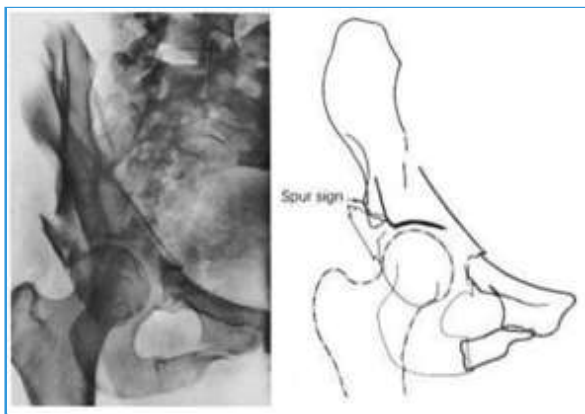
- angle between vertical line through femoral head and line through fracture
- helps to define fracture pattern stability
- considered stable if the fracture line exits outside the weight bearing dome of the acetabulum
- defined as $< 45^\circ$ on AP, obturator and iliac oblique views
- not applicable for associated both column or posterior wall pattern because no intact portion of the acetabulum to measure

- gull sign



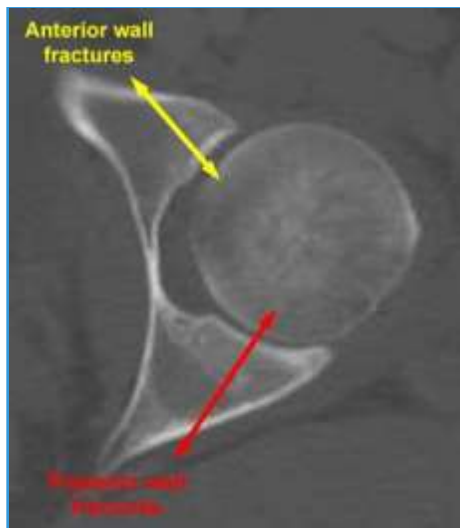
- represents impaction of superomedial roof
- seen on iliac oblique view
- pathognomic for posterior wall fractures

- spur sign

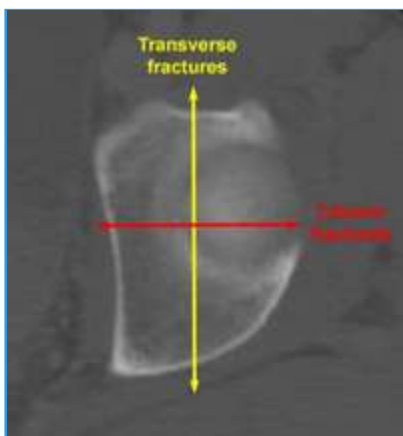


- represents most caudal part of intact ilium due to medialization of articular components
- seen on obturator oblique view
- pathognomic for ABC fractures

○ CT scan



- indications
 - now considered a gold standard in management
- findings
 - fracture pattern orientation
 - define fragment size and orientation



- identify marginal impaction



- identify loose bodies (e.g., post-reduction)
- look for articular gap or step-off
- roof-arc measurements
 - view
 - 2 mm fine cuts on axial view
 - findings
 - assess stability of the weight bearing dome based on the exiting fracture line
 - defined as an intact subchondral ring in the superior 10 mm of the acetabulum
 - > 2 mm incongruity in the articular segment is considered unstable

- Duplex doppler ultrasound
 - indications
 - delayed presentation to treating hospital
 - rule out DVT
- Treatment
 - Nonoperative
 - **protected weight bearing for 6-8 weeks**
 - indications
 - patient factors
 - high operative risk (e.g., elderly patients, presence of DVT)
 - morbid obesity
 - open contaminated wound
 - late presenting > 3 weeks
 - fracture characteristics
 - minimally displaced fracture (< 2 mm)
 - < 20% posterior wall fractures
 - treatment based on size of posterior wall is controversial
 - recommend an exam under anesthesia (EUA) using fluoroscopy best method to test stability
 - femoral head congruency with weight bearing roof (out of traction)
 - both column fracture pattern with secondary congruence (out of traction)
 - displaced fracture with roof arcs > 45° in AP and Judet views or >10 mm on axial CT cuts
 - technique
 - skeletal traction NOT required if stable fracture pattern, outside the weight-bearing dome
 - activity as tolerated with crutches/walker
 - weight-bearing
 - lowest joint reactive forces seen with toe-touch weight bearing and passive hip abduction
 - greatest joint contact force seen when rising from a chair on the affected extremity
 - DVT prophylaxis
 - close radiographic follow-up
 - Operative treatment
 - **open reduction and internal fixation**



- indications
 - patient factors
 - < 3 weeks from date of injury
 - physiologically stable
 - adequate soft-tissue envelope
 - no local infection
 - pregnancy is not contraindication to surgical fixation
 - fracture factors
 - displacement of roof (> 2 mm)
 - unstable fracture pattern (e.g. posterior wall fracture involving > 40-50%)
 - marginal impaction
 - intra-articular loose bodies
 - irreducible fracture-dislocation
- approaches
 - anterior
 - ilioinguinal

- iliofemoral
 - modified stoppa
- posterior
 - Kocher-Langenbach
- combined
 - extended iliofemoral
- techniques
 - factors considered for fixation methodology
 - location (column and/or wall) and level (high or low) of the fracture pattern
 - amount of displacement
 - marginal impaction
 - associated injury
 - fixation modalities
 - column fixation strategies
 - reconstruction bridging plate and screws
 - percutaneous column screws
 - cable fixation
 - wall fixation strategies
 - bridge plate and screws
 - lag screw and neutralization plate
 - spring (butress) plate
- outcomes
 - timing
 - associated hip dislocations should be reduced within 12 hours for improved outcomes
 - incarcerated fragments upon reduction can be treated with urgent ORIF or placement of skeletal traction and delayed ORIF
 - worse outcomes with fixation of fracture > 3 weeks from time of injury
 - earlier operative treatment associated with increased chance of anatomic reduction
 - peri-operative
 - clinical outcome correlates with quality of articular reduction
 - postoperative CT scan is most accurate way to determine posterior wall accuracy of reduction which has greatest correlation with clinical outcome
 - ideally articular reduction <2mm
 - post-operative
 - greatest stress on acetabular repair occurs when rising from a seated position using the affected leg, and occurs in the posterior superior portion of the acetabulum
 - functional outcomes most strongly correlate with hip muscle strength and restoration of gait postoperatively
- **total hip arthroplasty**



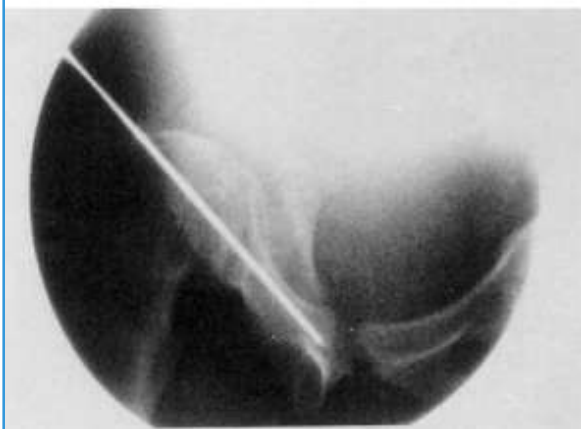
- indications
 - usually elderly patients with
 - significant osteopenia and/or significant comminution
 - pre-existing arthritis
 - post-traumatic arthritis in all ages
- techniques
 - timing
 - immediate vs. delayed THA
 - immediate THA (with, or without, fracture fixation)

- wall fractures
 - buttress plate with multi-hole cup
- column fracture
 - cage and cup constructs
- delayed THA
- outcomes
 - patients older than 60 years have approx. a 30% late conversion rate to THA after acetabular fractures
 - 10-year implant survival noted to be around 75-80%

• Techniques

◦ Percutaneous fixation with column screws

- approach
 - anterograde (from iliac wing to ramus)
 - retrograde (from ramus to iliac wing)
 - posterior column screws
- imaging



- obturator outlet best view to rule out joint penetration



- iliac inlet view best to determine anteroposterior position of screw within the pubic ramus
- obturator inlet view best to determine position of a supraacetabular screw within tables of the ilium



○ **ORIF**

- approaches
 - approach depends on fracture pattern
 - two approaches can be combined

■ Approaches		
	■ <i>Indications</i>	■ <i>Risks</i>
■ Anterior Approach (Ilioinguinal)	■ Anterior wall and anterior column ■ Both column fracture ■ Posterior hemitransverse	■ Femoral nerve injury ■ LFCN injury ■ Thrombosis of femoral vessels ■ Laceration of corona mortis in 10-15%.
■ Posterior Approach (Kocher-Langenbach)	■ Posterior wall and posterior column fx ■ Most transverse and T-shaped ■ Combination of above	■ Increased HO risk compared with anterior approach ■ Sciatic nerve injury (2-10%) ■ Damage to blood supply of femoral head (medial femoral circumflex)
■ Extensile Approach (extended iliofemoral)	■ Only single approach that allows direct visualization of both columns ■ Associated fracture pattern 21 days after injury ■ Some transverse fxs and T types ■ Some both column fxs (if posterior comminution is present)	■ Massive heterotopic ossification ■ posterior gluteal muscle necrosis
■ Modified Stoppa Approach	■ Access to quadrilateral plate to buttress comminuted medial wall fractures	■ Corona mortis must be exposed and ligated in this approach

● **Complications**

- Post-traumatic DJD
 - most common complication
 - 80% survival noted at 20 years for patients s/p ORIF
 - risk factors for DJD include
 - age >40
 - associated fracture patterns
 - concomitant femoral head injury
 - treat with hip fusion or THA

- Heterotopic ossification
 - highest incidence with extensile approach
 - treat with
 - indomethacin x 5 weeks post-op
 - low dose external radiation (no difference shown in direct comparison)
 - lowest incidence with anterior ilioinguinal approach
- Osteonecrosis



- 6-7% of all acetabular fractures
 - 18% of posterior fracture patterns
- DVT and PE
- Infection
- Bleeding
- Neurovascular injury
 - risk factor
 - highest incidence with transverse + posterior wall fractures
- Intraarticular hardware placement
- Abductor muscle weakness

• Prognosis

- Poor outcomes are associated with:
 - multi-system trauma
 - increasing age
 - poor articular congruency
 - associated femoral head articular injury
 - post-traumatic arthritis

42- Hip Dislocation

Images



- summary

- Hip dislocations are traumatic hip injuries that result in femoral head dislocation from the acetabular socket.
- Diagnosis can be made with hip radiographs to determine the direction of dislocation and CT scan studies to assess for associated injuries.
- Treatment is urgent reduction to minimize risk of avascular necrosis followed by CT scan to assess for associated injuries that may require surgical treatment (loose bodies, femoral head fractures, acetabular fractures).

- Epidemiology

- Incidence
 - rare, but high incidence of associated injuries

- Etiology

- Pathophysiology
 - mechanism is usually young patients with high energy trauma
- Pathoanatomy
 - Hip joint inherently stable due to
 - bony anatomy
 - soft tissue constraints including
 - labrum
 - capsule
 - ligamentum teres

- Classification

- Simple vs. Complex
 - simple
 - pure dislocation without associated fracture
 - complex
 - dislocation associated with fracture of acetabulum or proximal femur
- Anatomic classification
 - posterior dislocation (90%)
 - occur with axial load on femur, typically with hip flexed and adducted
 - axial load through flexed knee (dashboard injury)



- position of hip determines associated acetabular injury
 - increasing flexion and adduction favors simple dislocation
- associated with
 - osteonecrosis
 - posterior wall acetabular fracture
 - femoral head fractures

- sciatic nerve injuries
- ipsilateral knee injuries (up to 25%)
- anterior dislocation
 - associated with femoral head impaction or chondral injury
 - occurs with the hip in abduction and external rotation
 - inferior ("obturator") vs. superior ("pubic")
 - hip extension results in a superior (pubic) dislocation
 - Clinically hip appears in extension and external rotation
 - flexion results in inferior (obturator) dislocation
 - Clinically hip appears in flexion, abduction, and external rotation

• Presentation

- Symptoms
 - acute pain, inability to bear weight, deformity
- Physical exam
 - ATLS
 - 95% of dislocations with associated injuries
 - posterior dislocation (90%)
 - most common
 - associated with posterior wall and anterior femoral head fracture
 - hip and leg in slight flexion, adduction, and internal rotation



- detailed neurovascular exam (10-20% sciatic nerve injury)
- examine knee for associated injury or instability
- chest X-ray ATLS workup for aortic injury
- anterior dislocation
 - hip and leg in extension, abduction, and external rotation



• Imaging

- Radiographs
 - recommended views
 - AP
 - cross-table lateral
 - used to differentiate between anterior vs. posterior dislocation
 - scrutinize femoral neck to rule out fracture prior to attempting closed reduction
 - obtain AP, inlet/outlet, judet views after reduction
 - findings

- loss of congruence of femoral head with acetabulum
- disruption of shenton's line



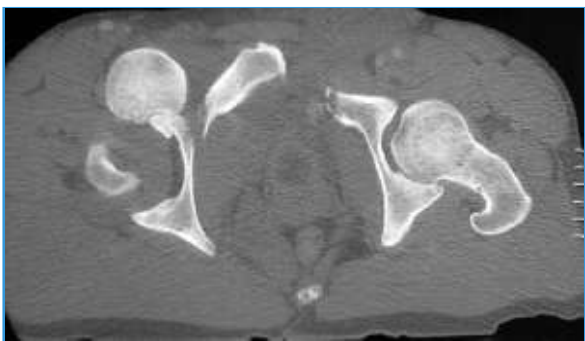
- arc along inferior femoral neck + superior obturator foramen
- anterior dislocation
 - femoral head appears larger than contralateral femoral head
 - femoral head is medial or inferior to acetabulum
- posterior dislocation



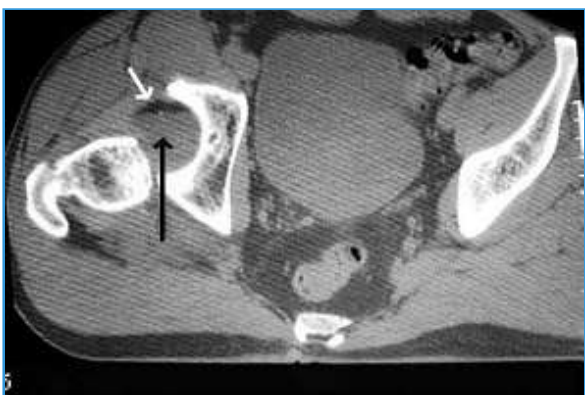
- femoral head appears smaller than contralateral femoral head
- femoral head superimposes roof of acetabulum
- decreased visualization of lesser trochanter due to internal rotation of femur

○ CT

- helps to determine direction of dislocation, loose bodies, and associated fractures
 - anterior dislocation



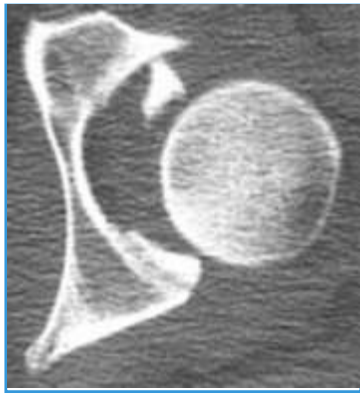
- posterior dislocation



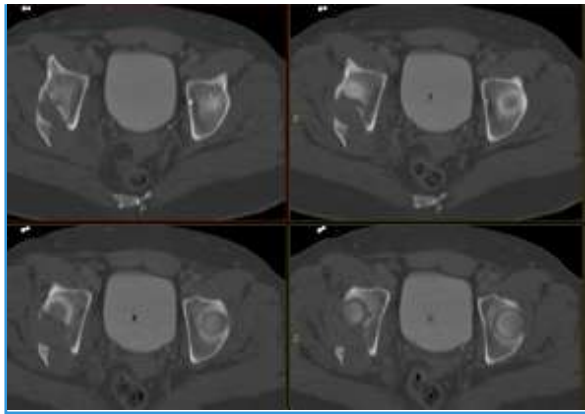
- post reduction CT must be performed for all traumatic hip dislocations to look for
 - femoral head fractures



- loose bodies



- acetabular fractures



- MRI
 - controversial and routine use is not currently supported
 - useful to evaluate labrum, cartilage and femoral head vascularity

• Treatment

- Nonoperative
 - **emergent closed reduction within 12 hours**
 - indications
 - acute anterior and posterior dislocations
 - contraindications
 - ipsilateral displaced or non-displaced femoral neck fracture
- Operative
 - **open reduction and/or removal of incarcerated fragments**
 - indications
 - irreducible dislocation
 - radiographic evidence of incarcerated fragment
 - delayed presentation
 - non-concentric reduction
 - should be performed on urgent basis
 - **ORIF**
 - indications
 - associated fractures of
 - acetabulum
 - femoral head
 - femoral neck
 - should be stabilized prior to reduction
 - **arthroscopy**
 - indications
 - no current established indications
 - potential for removal of intra-articular fragments
 - evaluate intra-articular injuries to cartilage, capsule, and labrum

• Techniques

- **Closed reduction**
 - perform with patient supine and apply traction in line with deformity regardless of direction of dislocation
 - must have adequate sedation and muscular relaxation to perform reduction
 - assess hip stability after reduction
 - post reduction CT scan required to rule out
 - femoral head fractures
 - intra-articular loose bodies/incarcerated fragments

- may be present even with concentric reduction on plain films
- acetabular fractures

- post-reduction

- for simple dislocation, follow with protected weight bearing for 4-6 weeks

- **Open reduction**

- approach

- posterior dislocation
 - posterior (Kocher-Langenbeck) approach
- anterior dislocation
 - anterior (Smith-Petersen) approach

- technique

- may place patient in traction to reduce forces on cartilage due to incarcerated fragment or in setting of unstable dislocation
- repair of labral or other injuries should be done at the same time

- **Complications**

- Post-traumatic arthritis

- up to 20% for simple dislocation, markedly increased for complex dislocation

- Femoral head osteonecrosis

- 5-40% incidence
- Increased risk with increased time to reduction

- Sciatic nerve injury

- 8-20% incidence
- associated with longer time to reduction

- Recurrent dislocations

- less than 2%

43- Ilium Fractures

Images



- Summary

- Ilium fractures are high energy pelvic fractures that are often unstable and typically progress from the iliac crest to the greater sciatic notch.
- Diagnosis can be made with pelvis radiographs but frequently require pelvic CT scan for full characterization.
- Treatment may be nonoperative or operative depending on fracture displacement, associated pelvic ring instability and patient activity demands.

- Epidemiology

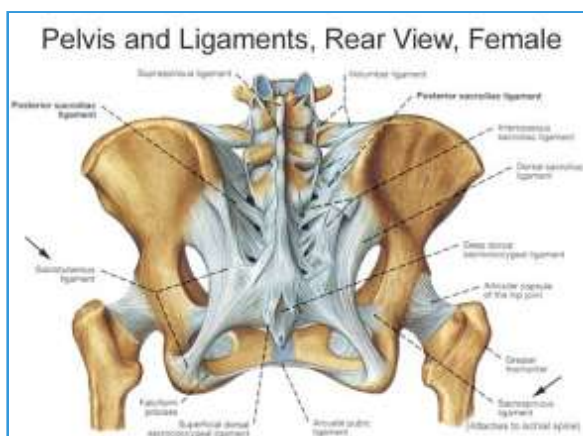
- Associated injuries
 - Iliac wing fractures have high incidence of associated injuries
 - open injuries



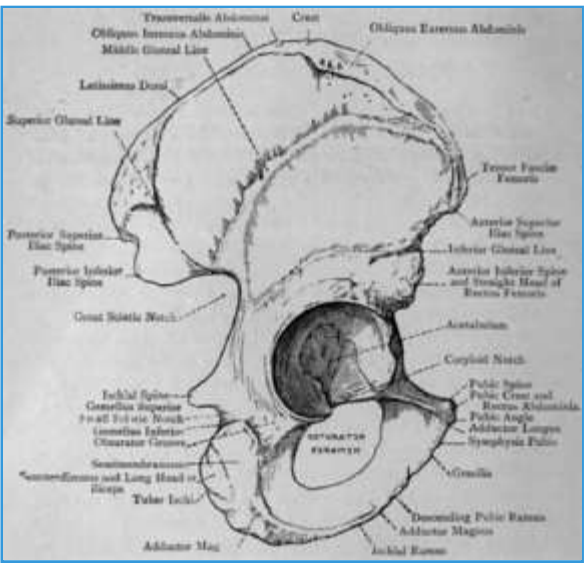
- bowel entrapment
- soft tissue degloving

- Anatomy

- Osteology
 - pelvic girdle is comprised of



- sacrum
- 2 innominate (coxal) bones



- each formed from the union of 3 bones: ilium, ischium, and pubis
- ilium
 - 2 important anterior prominences
 - anterior-superior iliac spine (ASIS)
 - origin of sartorius and transverse and internal abdominal muscles
 - anterior-inferior iliac spine (AIIS)
 - origin of direct head of rectus femoris and iliofemoral ligament (Y ligament of Bigelow)
 - posterior prominences
 - posterior-superior iliac spine (PSIS)
 - located 4-5 cm lateral to the S2 spinous process
 - posterior-inferior iliac spine (PIIS)

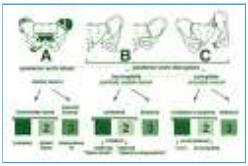
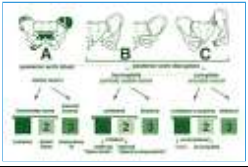
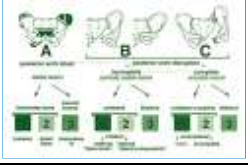
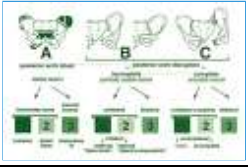
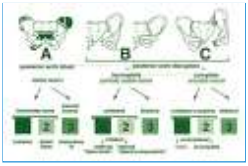
• Imaging

- Plain radiographs
 - standard set of AP pelvis , inlet/outlet , and judet views
 - helpful for evaluating the iliac wing in addition to pelvic stability and possible acetabular involvement
- CT scan
 - carefully assess CT scan for signs of bowel entrapment
 - evaluate for presence of gas or air in the soft tissues which can be associated with open injury or bowel disruption

• Classification

- No specific classification for iliac wing fractures
- Generally described as specific subtypes of more common classification systems

■ Tile Classification

■	■ Tile Classification	
■	■ Stable (intact posterior arch)	
■		■ 
■		■ 
■		■ 
■	■ Partially stable (incomplete disruption of posterior arch)	
■		■ 
■	■ Unstable (complete disruption of posterior arch)	
■		■ 

- Treatment
 - Nonoperative
 - **mobilization with an assist device**
 - indications
 - nondisplaced fractures
 - isolated iliac wing fractures
 - Operative
 - **open reduction and internal fixation**
 - indications
 - displaced fractures of ilium
- Techniques
 - **Wound Management**
 - evaluate all wounds for
 - soft tissue disruption or internal degloving injury
 - possible soft tissue or bowel entrapment in the fracture site
 - prophylactic antibiotics as appropriate
 - serial debridements as necessary
 - **Open Reduction Internal Fixation**
 - approach
 - posterior approach
 - ilioinguinal approach
 - Stoppa approach (lateral window)
 - recommend early reconstruction
 - single pelvic reconstruction plate or lag screw along the iliac crest
 - percutaneous screws and reduction techniques possible as well
 - supplemented with a second reconstruction plate or lag screw at the level of the pelvic brim or sciatic buttress
 - coordination with trauma team
 - injury to bowel may require diversion procedures
 - plan surgical intervention with trauma team to minimize recurrent trips to the operating room
- Complications
 - Malunion with deformity of the iliac wing
 - Internal iliac artery injury
 - Bowel perforation
 - Lumbosacral plexus injury

44- Distal Femur Fractures

Images



• Summary

- Distal femur fractures are traumatic injuries involving the region extending from the distal metaphyseal-diaphyseal junction to the articular surface of the femoral condyles.
- Diagnosis is made radiographically with CT studies often required to assess for intra-articular extension.
- Treatment is generally operative with ORIF, intramedullary nail, or distal femur replacement depending on available bone stock, age of patient, and patient activity demands.

• Epidemiology

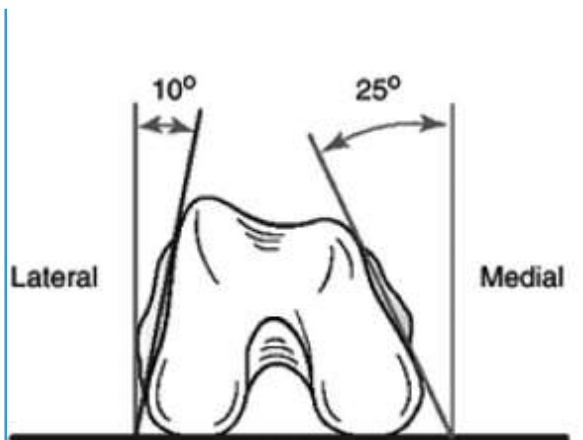
- Incidence
 - Common
 - 3-6% of femur fractures
 - <1% of all fractures
- Demographics
 - bimodal distribution
 - young healthy males
 - elderly osteopenic females

• Pathophysiology

- Mechanism
 - young patients
 - high energy with significant displacement
 - older patients
 - low energy, often fall from standing, in osteoporotic bone, usually with lesser degree of displacement

• Anatomy

- Osteology
 - anatomical axis of the distal femur is 6-11 degrees of valgus
 - medial condyle extends more distal than lateral
 - distal femur becomes trapezoidal in cross-section towards the knee
 - lateral cortex of femur slopes ~10 degrees, medial cortex slopes ~25 degrees in the axial plane

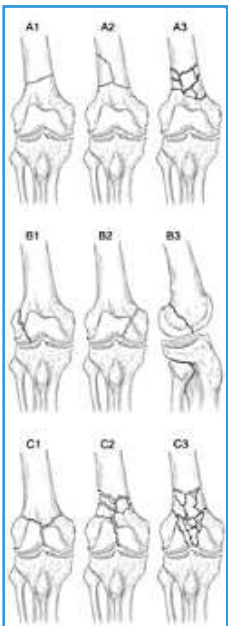


- posterior halves of both condyles are posterior to the posterior cortex of femoral shaft
- Muscles
 - key deforming forces
 - quadriceps

- hamstrings
 - adductor magnus
 - gastrocnemius
- Ligaments
 - anterior cruciate ligament (ACL)
 - posterior cruciate ligament (PCL)
 - medial collateral ligament (MCL)
 - lateral collateral ligament (LCL)
- Biomechanics
 - hamstring and quadriceps
 - cause the femur to shorten
 - adductor magnus
 - leads to distal femoral varus or valgus
 - direction of deformity is dependent on the location of comminution and the relation of fracture lines to the adductor tubercle
 - gastrocnemius
 - extension at the fracture site (apex posterior)
 - rotation of condyles when an intercondylar split is present

• Classification

- Descriptive
 - supracondylar
 - intercondylar
- OTA: 33

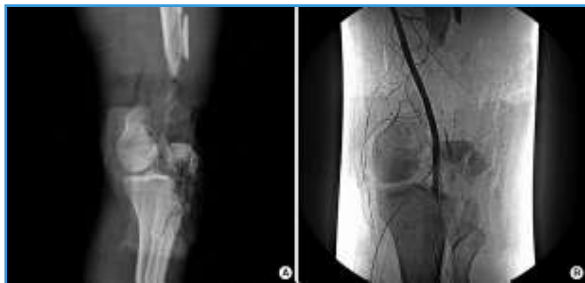


- A: extraarticular
 - B: partial articular
 - portion of the articular surface remains in continuity with shaft
 - 33B3 is in the coronal plane (Hoffa fragment)
 - C: complete articular
 - articular fragment separated from the shaft

• Presentation

- History
 - patients commonly present after fall or traumatic event
- Symptoms
 - common symptoms
 - pain of distal femur that is made worse with knee movement
 - inability to weight-bear
- Physical exam
 - inspection
 - tenderness , swelling , ecchymosis of the distal thigh and knee
 - varus or valgus deformity
 - knee effusion may be present with intraarticular involvement
 - evaluate for wounds concerning for an open fracture

- 5-10% of supracondylar fractures
- neurovascular exam
 - vascular evaluation



- potential for injury to popliteal artery if significant displacement
- Ankle-brachial index (ABI) should be performed if there is a concern for vascular injury
 - angiography is indicated if <0.9
 - >0.9 = 99% negative predictive value
 - <0.9 = 97% specific and 95% sensitive for major arterial injury

• Imaging

◦ Radiographs

- recommended views
 - AP
 - lateral
- additional views
 - traction views
 - AP, lateral, and oblique traction views can help characterize injury but are painful for the patient
 - adjacent joints
 - obtain imaging of entire femur to rule out associated injuries
 - contralateral femur
 - consider views of the contralateral femur for pre-operative planning and templating
- findings
 - can be difficult to visualize intraarticular extension
 - condyles are malrotated in sagittal plane with respects to each other
 - sagittal intra-articular splut is most common
 - Hoffa fracture



- intra-articular distal femoral fracture in the coronal plane
- 38% incidence
- seen on the lateral view
- missed in up to 31% of cases
- lateral condyle fractures
 - 80% incidence
- in elderly patients, evaluate for any pre-existing knee DJD
- CT scan
 - indications
 - preoperative planning
 - evaluating intra-articular involvement

- after external fixation to assess pattern, comminution, and intraarticular extension
- findings
 - separate osteochondral fragments in the area of the intercondylar notch
 - coronal plane fracture (Hoffa fracture) in 40%



- lateral femoral condyle fractures in 80%

○ Angiography

- indications
 - ankle-brachial index (ABI) <0.9
 - obvious signs of vascular injury
 - i.e., hard and soft signs (pulselessness, rapidly expanding hematoma, massive bleeding, etc.)
- findings
 - identifies vascular segments with diminished flow
 - vascular injury
 - displaced distal femur fractures may result in injury to the popliteal artery

• Treatment

○ Nonoperative

- **hinged knee brace**
 - indications (rare)
 - stable, nondisplaced fractures
 - nonambulatory patient
 - patient with significant comorbidities presenting an unacceptably high degree of surgical/anesthetic risk
 - outcomes
 - variable and dependent on multiple factors including patient characteristics and fracture pattern

○ Operative

- **external fixation**
 - indications
 - temporizing measure to restore length, alignment, and stability
 - unstable, polytrauma
 - soft tissues not amenable to surgical incisions and internal fixation, or until the patient is stable
 - contamination requiring multiple debridements
 - definitive treatment
 - severe open and/or comminuted fractures
 - patients unstable for surgery
 - outcomes
 - variable and dependent on multiple factors including patient characteristics, fracture pattern, and degree of soft tissue injury
 - 92-100% union rates reported at an average of 4-6 months when used as definitive treatment
- **open reduction internal fixation (ORIF)**
 - indications
 - displaced fracture
 - intra-articular fracture
 - traditional 95 degree devices contraindicated in Hoffa fractures
 - periprosthetic fracture with osteoporotic bone
 - nonunion
 - fixed-angle plates required for metaphyseal comminution
 - non-fixed angle plates are prone to varus collapse
 - outcomes
 - variable and dependent on multiple factors including patient characteristics and fracture pattern

- dual plating (lateral + medial plate) offers greatest degree of axial and torsional stiffness
- nonunion rates up to 18%
- no difference in fixation failure, reoperation rates, or nonunion with early weightbearing as tolerated and protected weightbearing in extra-articular distal femur fractures

▪ **retrograde intramedullary nail**



- indications
 - extraarticular fractures
 - simple intraarticular fractures
 - periprosthetic fractures with implants with an "open-box" design
 - distal femoral replacements do not allow retrograde nail fixation
 - traditionally, 4 cm of intact distal femur needed but newer implants with very distal interlocking options may decrease this number
 - independent screw stabilization of intraarticular components placed around nail
- outcomes
 - variable and dependent on multiple factors including patient characteristics and fracture pattern
 - high union rates reported, more symmetric callus formation compared to plates
 - reduced rates of malunion and higher patient satisfaction compared to ORIF has been reported
- **arthroplasty and distal femoral replacement**
 - indications
 - arthroplasty
 - preexisting osteoarthritis with amenable fracture pattern
 - distal femoral replacement
 - low demand patients
 - un-reconstructable fracture
 - fracture around prior total knee arthroplasty with loose component
 - osteoarthritis
 - outcomes
 - variable and dependent on multiple factors including patient characteristics and fracture pattern
 - may have improved ambulatory status and decreased nonunion compared to other methods of fixation
 - reduced longevity compared with internal fixation
 - allows immediate weight bearing

• Techniques

○ **Hinged knee brace**

- technique
 - full time bracing for 6-8 weeks
 - closed-chain ROM exercises at 3-4 weeks
 - restricted weight-bearing until evidence of fracture union
 - serial radiographs to assess for displacement
- complications
 - wounds from immobilization and bracing
 - knee stiffness

○ **External Fixation**

- technique
 - avoid pin placement in the area of planned plate placement, if possible
- complications
 - pin tract infections

○ **Open Reduction Internal Fixation (ORIF)**

- approach
 - lateral
 - suitable for all fracture types
 - arthrotomy for direct reduction of articular components
 - minimally invasive lateral modified anterior (swashbuckler)

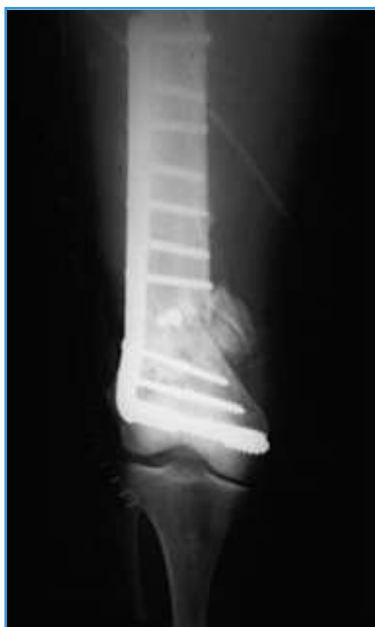
- best when used for extraarticular fractures
- distal incision large enough to insert plate sub-muscularly
- screws placed through smaller proximal incisions
- midline anterior incision that angles slightly lateral
- lateral parapatellar arthrotomy
- facilitates articular and lateral distal femur exposure
- lateral parapatellar
 - fractures with complex articular extension
 - extend incision into quadriceps tendon to evert patella
 - can be used for Hoffa fracture
- medial parapatellar
 - used for complex medial femoral condyle fractures
- medial
 - most often used for type B2 and B3 patterns
 - can be used to augment fixation with medial plate in type C3 patterns
- medial/lateral posterior
 - used for very posterior Hoffa fragment fixation
 - patient placed in the prone position
 - midline incision over the popliteal fossa
 - develop a plane between medial and lateral gastrocnemius
 - capsulotomy to visualize fracture
- technique
 - goals
 - anatomic joint reduction with rigid fixation
 - restore articular surface before fixation of extraarticular component
 - stable fixation of articular component to diaphysis for early ROM
 - preservation of vascularity
 - direct visualization of the joint allows perfect reduction of intraarticular fractures with lag screw fixation before attaching the articular block to the proximal fragment
 - Hoffa fragments can be captured with an anterior to posterior screw
- locking plates



- allows better control of coronal plate compared to 95° angled blade plate and dynamic condylar screw
- multi-plane screw trajectory allows fixation of coronal (Hoffa) fragments
- lag screws with locked screws (hybrid construct)
 - intercondylar fractures (usually in conjunction with locked plate)
 - coronal plane fractures
- locking screw constructs don't rely on bone-plate contact for stability
 - helpful when pre-contoured plates do not precisely match patient anatomy
- potential to create too stiff of construct leading to nonunion or plate failure
- NOT an appropriate construct for isolated medial femoral condyle fractures
- non-fixed angle plate
 - risk of varus malalignment
 - high risk with metaphyseal comminution
- blade plate fixation



- requires precise initial implantation of the blade into the distal fragment
- contraindicated in type C3 fractures
- may provide poor fixation osteoporotic bone
- dynamic condylar screw



- precise sagittal plane alignment is not necessary as plate rotates around the barrel
- large amount of bone removed, may provide poor fixation in osteoporotic bone
- complications
 - nonunion
 - knee stiffness

○ **Retrograde intramedullary nail**



- approach
 - transtendon approach
 - mid substance longitudinal patellar tendon split
 - medial parapatellar
 - no articular extension
 - 2.5 cm incision parallel to medial aspect of patellar tendon
 - no attempt to visualize articular surface
 - articular extension present
 - continue approach 2-8 cm cephalad
 - incise extensor mechanism 10 mm medial to the patella
 - eversion of patella not typically necessary
 - need to stabilize articular segments before nail placement
- technique
 - insertion requires $\geq 70^\circ$ knee flexion
 - articular reduction and fixation before nail placement
 - lag screws placed out of the intended IMN path
 - starting point at the superior margin of Blumensaat line (lateral) and center of intercondylar notch (AP)
 - blocking screws facilitate reduction and strengthen the construct
 - short nails are rarely indicated
 - implant should reach lesser trochanter to reduce risk of vascular injury
- complications
 - postoperative knee pain
 - IMN for periprosthetic fractures may result in recurvatum deformity
 - box design requires a posterior starting point

○ Arthroplasty and distal femoral replacement

- approach
 - extensile anterior, lateral, or medial
 - use previous scar if possible
- technique
 - resect fracture to allow full weight-bearing
- complications
 - mechanical failure
 - endoprosthetic metal or polyethylene component fracture
 - aseptic loosening
 - modular component disassociation
 - polyethylene wear synovitis

• Complications

- Knee pain/stiffness
 - treatment
 - early ROM
 - physical therapy
- Symptomatic hardware
 - risk factors

- lateral plate
 - pain with knee flexion/extension due to IT band contact with the plate
- medial screw placement
 - excessively long screws can irritate medial soft tissues
 - determine appropriate intercondylar screw length by obtaining an AP radiograph of the knee with the leg internally rotated 30 degrees
- treatment
 - hardware removal

○ Malunions



- risk factors
 - common deformities after plating include rotation, hyperextension (recurvatum), and coronal malalignment
 - " golf-club " deformity arises from medial translation of the articular block when the plate is placed too posterior distally
 - percutaneous submuscular fixation with pre-contoured locking plate
 - often rotational malalignment
 - malalignment is more common with IM nails
- treatment
 - revision internal fixation with osteotomy
 - functional results satisfactory if malalignment is within 5 degrees in any plane

○ Nonunions



- incidence
 - up to 19%, most commonly in metaphyseal area with articular portion healed (comminution, bone loss and open fractures more likely in metaphysis)
- risk factors
 - associated with soft tissue stripping in metaphyseal region
- treatment
 - revision ORIF and autograft indicated
 - consider changing fixation technique to improve biomechanics

○ Infection

- risk factors
 - diabetics with foot ulcers
- treatment
 - debridement
 - culture-specific antibiotics
 - hardware removal if fracture stability permits

○ Implant failure

- incidence
 - up to 9%
- risk factors
 - improper bridge plating techniques
 - short working length construct
 - stainless steel implants may be inferior to titanium
- Loss of fixation
 - varus collapse (most common)
 - plate fixation associated with toggling of distal non-fixed-angle screws used for comminuted metaphyseal fractures
 - IM nail fixation
 - Proximal (diaphyseal) screw failure
 - associated with short plates and nonlocked diaphyseal fixation

45- Femoral Neck Fractures

Images



• Summary

- Femoral neck fractures are common injuries to the proximal femur associated with increased risk of avascular necrosis, and high levels of patient morbidity and mortality.
- Diagnosis is generally made radiographically with orthogonal radiographs of the hip.
- Treatment is generally operative with open reduction and internal fixation versus arthroplasty depending on the age of the patient, activity demands and pre-injury mobility.

• Epidemiology

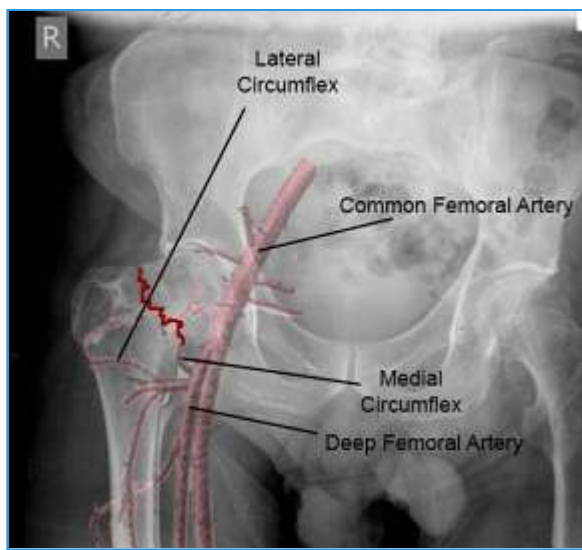
- Incidence
 - common
 - increasingly common due to aging population
- Demographics
 - women > men
 - Caucasians > African Americans
 - United states has highest incidence of hip fx rates worldwide

• Etiology

- Pathophysiology
 - healing potential
 - femoral neck is intracapsular, bathed in synovial fluid
 - lacks periosteal layer
 - callus formation limited, which affects healing
- Mechanism
 - high energy in young patients
 - low energy falls in older patients
- Associated injuries
 - femoral shaft fractures
 - 6-9% associated with femoral neck fractures
 - treat femoral neck first followed by shaft

• Anatomy

- Osteology
 - normal neck shaft-angle 130 +/- 7 degrees
 - normal anteversion 10 +/- 7 degrees
- Blood supply to femoral head



- major contributor is medial femoral circumflex (lateral epiphyseal artery)
- some contribution to anterior and inferior head from lateral femoral circumflex
- some contribution from inferior gluteal artery
- small and insignificant supply from artery of ligamentum teres
- displacement of femoral neck fracture will disrupt the blood supply and cause an intracapsular hematoma (effect is controversial)

- Classification

■ Garden Classification ■ (based on AP radiographs and does not consider lateral or sagittal plane alignment)		
■ Type I	■ Incomplete fx (valgus impacted)	■ 
■ Type II	■ Complete fx, nondisplaced	■ 
■ Type III	■ Complete fx, partially displaced	■ 
■ Type IV	■ Complete fx, fully displaced	■ 
■ Simplified Garden Classification		
■ Nondisplaced	■ Includes Garden I and II	■
■ Displaced	■ Includes Garden III and IV	■
■ Pauwels Classification ■ (based on vertical orientation of fracture line)		
■ Type I	■ < 30 deg from horizontal	■
■ Type II	■ 30 to 50 deg from horizontal	■
■ Type III	■ > 50 deg from horizontal (most unstable with highest risk of nonunion/AVN)	■

• Presentation

- Symptoms
 - impacted and stress fractures
 - slight pain in the groin or pain referred along the medial side of the thigh and knee
 - displaced fractures
 - pain in the entire hip region
- Physical exam
 - impacted and stress fractures

- no obvious clinical deformity
- minor discomfort with active or passive hip range of motion, muscle spasms at extremes of motion
- pain with percussion over greater trochanter
- displaced fractures
 - leg in external rotation and abduction, with shortening

• Imaging

- Radiographs
 - Recommended views
 - AP
 - traction-internal rotation AP hip is best for defining fracture type
 - cross-table lateral
 - full-length femur
 - Optional views
 - consider obtaining dedicated imaging of uninjured hip to use as template intraop
- CT
 - helpful in determining displacement and degree of comminution in some patients
- MRI
 - helpful to rule out occult fracture
 - not helpful in reliably assessing viability of femoral head after fracture
- Bone scan
 - helpful to rule out occult fracture
 - not helpful in reliably assessing viability of femoral head after fracture
- Duplex Scanning
 - indication
 - rule out DVT if delayed presentation to hospital after hip fracture

• Treatment

- Nonoperative
 - **observation alone**
 - indications
 - may be considered in some patients who are non-ambulators, have minimal pain, and who are at high risk for surgical intervention
- Operative
 - **ORIF**
 - indications
 - displaced fractures in young or physiologically young patients
 - ORIF indicated for most pts <50 years of age
 - female sex associated with increased reoperation rate
 - **cannulated screw fixation**
 - indications
 - nondisplaced transcervical fx
 - Garden I or II in the physiologically elderly
 - displaced transcervical fx in young patient
 - achieve reduction to limit vascular insult
 - reduction must be anatomic, so open if necessary
 - **sliding hip screw**
 - indications
 - basicervical fracture
 - vertical fracture pattern in a young patient
 - sliding hip screw biomechanically superior to cannulated screws (may not be clinically superior)
 - consider placement of additional cannulated screw above sliding hip screw to prevent rotation
 - **hemiarthroplasty**
 - indications
 - controversial
 - debilitated elderly patients

- metabolic bone disease
- cemented hemiarthroplasty
 - decreased fracture rates
 - improved short and medium term mobility
- **total hip arthroplasty**
 - indications
 - controversial
 - older active patients
 - patients with preexisting hip osteoarthritis
 - more predictable pain relief and better functional outcome than hemiarthroplasty
 - Garden III or IV in patient < 85 years

-
- **Techniques**

- **General Surgical Consideration**

- time to surgery
 - controversial
 - reduction method and quality has more pronounced effect on healing than surgical timing
- elderly patients with hip fractures should be brought to surgery as soon as medically optimal
 - the benefits of early mobilization cannot be overemphasized
 - improved outcomes in medically fit patients if surgically treated less than 4 days from injury
 - preoperative echocardiograms have been shown to delay the time to surgery without any effect on treatment decisions
- treatment approach based on
 - degree of displacement
 - physiologic age of the patient (young is < than 50 years old)
 - ipsilateral femoral neck and shaft fractures
 - priority goes to fixing femoral neck because anatomic reduction is necessary to avoid complications of AVN and nonunion
- fixation with implants that allow sliding
 - permit dynamic compression at fx site during axial loading
 - can cause shortening of femoral neck
 - prominent implants
 - affects biomechanics of hip joint
 - lower physical function on SF-36
 - decreased quality of life
 - anatomic reduction with intraop compression and placement of length stable devices decrease shortening
- open versus closed reduction
 - worse outcomes with displacement > 5 mm (higher rate of osteonecrosis and nonunions)
 - no consensus on which reduction approach is superior
 - multiple closed reduction attempts are associated with higher risk of osteonecrosis of the femoral head

- **ORIF**

- approach
 - limited anterior Smith-Peterson
 - 10cm skin incision made beginning just distal to AIIS
 - incise deep fascia
 - develop interval between sartorius and TFL
 - external rotation of thigh accentuates dissection plane
 - LFCN is identified and retracted medially with sartorius
 - identify tendinous portion of rectus femoris, elevate off hip capsule
 - open capsule to identify femoral neck
 - Watson-Jones
 - used to gain improved exposure of lower femoral neck fractures
 - skin incision approx 2cm posterior and distal to ASIS, down toward tip of greater trochanter
 - incision curved distally and extended 10cm along anterior portion of femur
 - incise deep fascia
 - develop interval between TFL and gluteus medius

- anterior aspect of gluteus medius and minimus is retracted posteriorly to visualize anterior hip capsule
- capsule sharply incised with Z-shape incision
- capsulotomy must remain anterior to lesser trochanter at all times to avoid injury to medial femoral circumflex artery
- reduction (method may vary)
 - evacuate hematoma
 - place A to P k-wires into femoral neck/head proximal to fracture to use as joysticks for reduction
 - insert starting k-wire (for either cannulated screw or sliding hip screw) into appropriate position laterally, up to but not across the fracture
 - once reduction obtained, drive starting k-wire across fracture
 - insert second threaded tipped k-wire if adding additional fixation

○ **Cannulated Screw Fixation**

- technique
 - three screws if noncomminuted (3 screw inverted triangle shown to be superior to two screws)
 - order of screw placement (this varies)
 - 1-inferior screw along calcar
 - 2-posterior/superior screw
 - 3-anterior/superior screw
 - obtain as much screw spread as possible in femoral neck
 - inverted triangle along the calcar (not central in the neck) has stronger fixation and higher load to failure
 - four screws considered for posterior comminution
 - clear advantage of additional screws not proven in literature
 - starting point at or above level of lesser trochanter to avoid fracture
 - avoid multiple cortical perforations during guide pin or screw placement to avoid development of lateral stress riser

○ **Hemiarthroplasty**

- approach
 - posterior approach has increased risk of dislocations
 - anterolateral approach has increased abductor weakness
- technique
 - cemented superior to uncemented
 - unipolar vs. bipolar

○ **Total Hip Replacement**

- technique
 - should consider using the anterolateral approach and selective use of larger heads in the setting of a femoral neck fracture
- advantages
 - improved functional hip scores and lower re-operation rates compared to hemiarthroplasty and internal fixation
- complications
 - higher rate of dislocation with THA (~ 10%)
 - about five times higher than hemiarthroplasty

• **Complications**

○ **Osteonecrosis**

- incidence of 10-45%
- recent studies fail to demonstrate an association between time to fracture reduction and subsequent AVN
- increased risk with
 - increase initial displacement
 - AVN can still develop in nondisplaced injuries
 - nonanatomical reduction
 - sliding hip screw
 - reported by the FAITH study
- treatment
 - major symptoms not always present when AVN develops
 - young patient

- > 50% involvement then treat with FVFG vs THA

- older patient

- prosthetic replacement (hemiarthroplasty vs THA)

○ Nonunion

- incidence of 5 to 30%

- increased incidence in displaced fractures
- no correlation between age, gender, and rate of nonunion

- varus malreduction most closely correlates with failure of fixation after reduction and cannulated screw fixation.

- treatment

- **valgus intertrochanteric osteotomy**

- indicated in patients after femoral neck nonunion
 - can be done even in presence of AVN, as long as not severely collapsed
 - turns vertical fx line into horizontal fx line and decreases shear forces across fx line

- **free vascularized fibula graft (FVFG)**

- indicated in young patients with a viable femoral head

- **arthroplasty**

- indicated in older patients or when the femoral head is not viable
- also an option in younger patient with a nonviable femoral head as opposed to FVFG

- **revision ORIF**

○ Dislocation

- higher rate of dislocation with THA (~ 10%)

- about seven times higher than hemiarthroplasty

○ Failure rates

- high early failure rates in fixation group, which stabilizes after 2 years

- 2-year follow-up (elderly population >70 years) with displaced femoral neck fractures

- 46% with fixation techniques
- 8% with arthroplasty techniques

- 2-to-10 year follow-up

- failure rate approx. 2-4%, respectively

- overall failure rates still higher in fixation vs. arthroplasty at 10-year follow-up

- sliding hip screw with lower reoperation rates compared to cannulated screws

- displaced femoral neck fractures
- basicervical femoral neck fractures
- current smokers

○ Reducing complications with co-management service

- orthopaedic geriatric co-management of trauma patients has been demonstrated to yield

- decreased mortality, post-operative complications, time to surgery, length of stay (though conflicting results on length of stay)

- improved post-operative mobility at 4 months

- important to mitigate risks of hospital delirium which may lead to increased length of stay

○ Loss of independence

- requiring walking aids and assisted living following fracture surgery

- the timed up and go (TUG) test has been identified as a reliable predictor of a patient's need for post-operative assistive devices

- Normal TUG is <12 seconds in all age groups
- Persistent use of ambulatory aids is predicted if TUG > 26 seconds

- associated factors

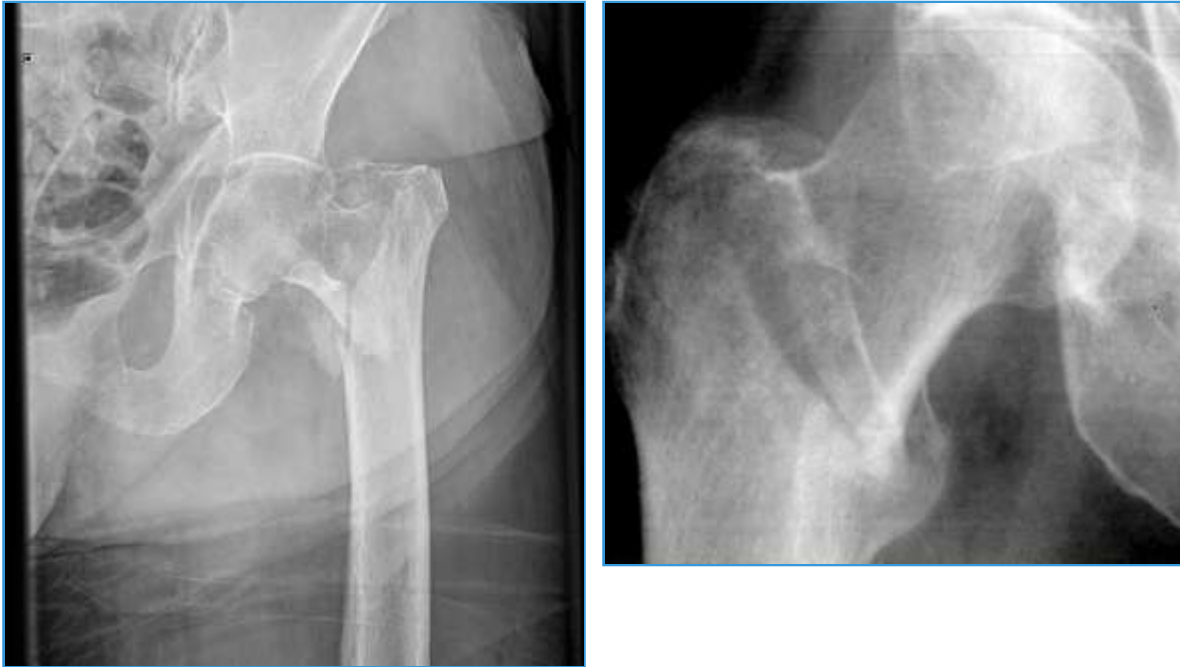
- age >80 years
- ASA class >1
- prior walking aid use
- current tobacco use
- implant placement quality
- nondisplaced fracture
- not requiring revision surgery

• Prognosis

- Most expensive fracture to treat on per-person basis
- Mortality
 - ~25-30% at one year (higher than vertebral compression fractures)
- Predictors of mortality
 - pre-injury mobility is the most significant determinant for post-operative survival
 - in patients with chronic renal failure, rates of mortality at 2 years postoperatively, are close to 45%
 - mortality risk is decreased at 30 days and at 1 year post-op when surgical intervention is performed within 24 hours of admission

46- Intertrochanteric Fractures

Images



• Summary

- Intertrochanteric Fractures are common extracapsular fractures of the proximal femur at the level of the greater and lesser trochanter that are most commonly seen following ground-level falls in the elderly population.
- Diagnosis is made with orthogonal radiographs of the hip. MRI is most helpful to evaluate occult hip fractures.
- Treatment is generally operative with sliding hip screw versus cephalomedullary nail depending on fracture stability.

• Epidemiology

- Incidence
 - account for ~50% of hip fractures
 - 150,000 intertrochanteric fractures per year in US
 - 500 per 100,000 population per year for elderly female
 - 200 per 100,000 population per year for elderly male
- Demographics
 - age
 - average ~80 years old
 - typically older age than femoral neck fractures
 - female: male ratio between 2:1 and 8:1
- Risk factors
 - proximal humerus fractures increase risk of hip fracture for 1 year
 - osteoporosis
 - advancing age
 - increased number of comorbidities
 - increased dependency with ADLs

• Etiology

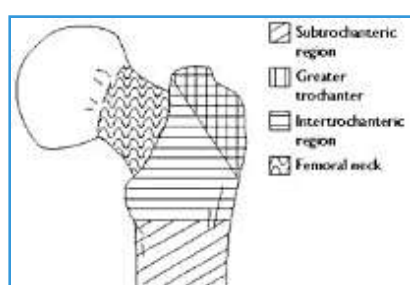
- Pathophysiology
 - mechanism
 - elderly
 - low energy falls in osteoporotic patients
 - young
 - high energy trauma
- Associated conditions
 - osteoporosis
 - recurrent falls
 - dementia

- parkinsons
- unsteady gait
- visual impairment
- medications

• Anatomy

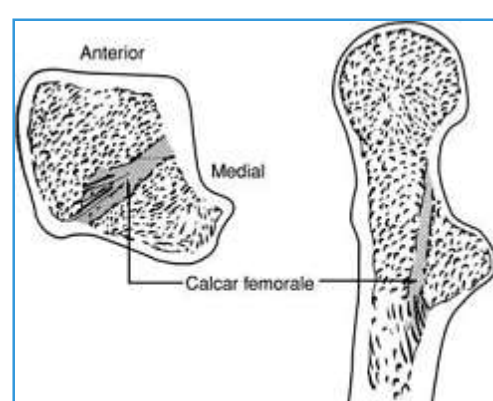
○ Osteology

- neck shaft angle 130 ± 7 degrees
- anteversion 10 ± 7 degrees
- intertrochanteric area exists between greater and lesser trochanters



▪ calcar femorale

- vertical wall of dense bone that extends from posteromedial aspect of femoral shaft to posterior portion of femoral neck

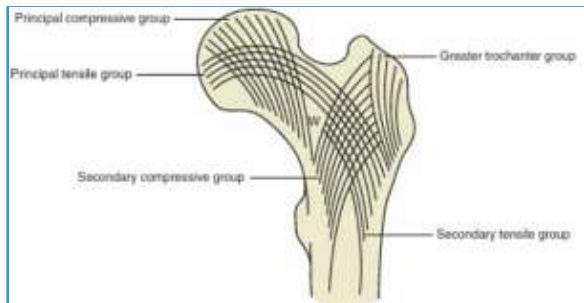


- level of involvement helps determine stable versus unstable fracture patterns
- radius of curvature of femur
 - average 114-120 cm
 - factors that decrease radius of curvature (increased bowing)
 - elderly
 - asian
 - short stature

○ Muscles

- deforming forces on proximal segment
 - flexion
 - iliopsoas
 - sartorius
 - rectus femoris
 - pectineus
 - external rotation
 - piriformis
 - superior gemellus
 - obturator internus
 - inferior gemellus
 - quadratus femoris
 - abduction
 - gluteus maximus
 - gluteus medius
 - gluteus minimus
 - tensor fascia lata
- deforming forces on distal segment
 - adduction and shortening
 - adductor longus
 - adductor brevis
 - adductor magnus

- gracilis
- overall varus alignment
- Blood supply
 - rich collateral circulation reduces risk of nonunion
 - trochanteric anastomosis
 - ascending branch of medial circumflex femoral artery (MFCA)
 - ascending branch of lateral circumflex femoral artery (LFCA)
 - deep branch of superior gluteal artery
 - inferior gluteal artery
 - transverse branch of LFCA and MFCA
 - periosteum and surrounding muscles
- Biomechanics



- Ward's triangle
 - area of lowest BMD in femoral neck bordered by 3 main compressive/tensile trabeculae
 - primary compressive trabeculae
 - extends from medial femoral head along calcar and excellent support to proximal femur
 - vertically oriented with a triangular configuration
 - principal tensile trabeculae
 - forms an arc through the superior cortex of the femoral head and neck
 - extends from greater trochanter to inferior aspect of femoral head below fovea
 - secondary compressive trabeculae
 - fan-like configuration crossing from greater trochanter to lesser and also comprises calcar

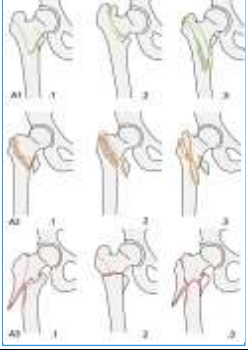
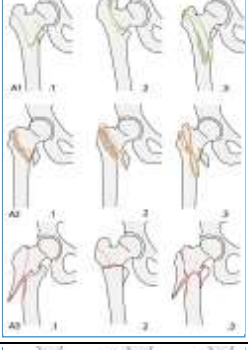
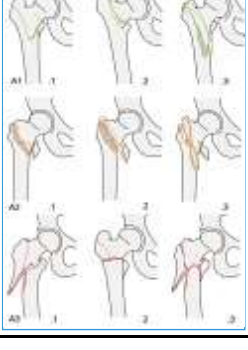
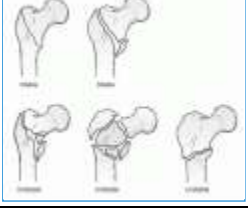
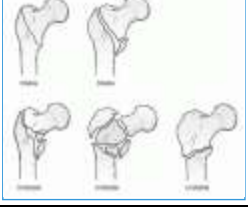
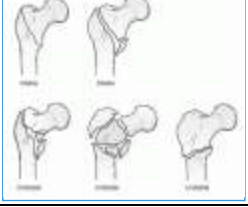
• Classification

- Stability
 - most commonly used and reliable classification
 - two types
 - stable
 - definition
 - intact posteromedial cortex
 - clinical significance
 - will resist medial compressive loads once reduced
 - unstable
 - definition
 - fracture will collapse into varus or shaft will displace medially
 - examples
 - large or comminuted posteromedial cortex
 - i.e. lesser trochanteric fragment
 - reverse obliquity or transtrochanteric
 - fracture line extending from medial cortex out through lateral cortex



- subtrochanteric extension
- other considerations

- lateral wall thickness
 - measured from 3 cm distal from innominate tubercle at 135 degrees to the fracture site
 - <20.5 mm suggest risk of postoperative lateral wall fracture
 - should be treated with cephalomedullary nail (CMN) rather than sliding hip screw (SHS)
 - key role in stabilizing proximal femur by providing lateral buttress

■ AO/OTA Classification		
■ 31A -A1	■ peritrochanteric simple two part ■ intact lateral cortex	■ 
■ 31A-A2	■ peritrochanteric with separate posteromedial fragment ■ intact lateral cortex	■ 
■ 31A-A3	■ fracture extends through lateral and medial cortex	■ 
■ Evans classification (based on post-reduction stability)		
■ Stable fracture	■ posteromedial cortex intact or minimal comminution ■ able to resist compressive loads	■ 
■ Unstable fracture	■ greater comminution of posteromedial cortex ■ can be converted to a stable pattern if medial cortical opposition obtained	■ 
■ Reverse obliquity	■ unstable due to medial displacement of femoral shaft due to adductors	■ 

• Presentation

- History
 - mechanism of injury
 - low-energy most common in elderly
 - higher-energy may be associated with other injuries
 - pre-injury functional status
 - predictor of postoperative functional status
 - antecedent hip pain
 - presence of OA or pathological fracture
 - history of anticoagulation
 - factors into surgical timing
 - list of comorbidities (ASA classification)
- Symptoms
 - acute onset of hip pain
 - inability to ambulate
- Physical Exam

- inspection
 - shortened, externally rotated lower extremity
- palpation
 - tenderness over greater trochanter
- motion
 - pain with log roll and axial load
 - unable to perform active straight leg raise
- assess thigh compartments
- neurovascular assessment

- Imaging

- Radiographs

- recommended views
 - AP pelvis
 - AP hip
 - cross table lateral
 - full length femur
 - optional
 - traction internal-rotation view
 - improve accuracy of fracture classification with direct impact on surgical planning
 - findings
 - AP pelvis



- compare to contralateral hip and assess neck shaft angle

- AP hip



- defines fracture pattern

- cross-table lateral



- helps assess for posterior cortex comminution

- full length femur
 - assess subtrochanteric extension
 - possibility of pathological fracture
 - estimate length of intramedullary nail
 - assess femoral bowing
 - assess canal diameter
- CT
 - indication
 - second line imaging to evaluate for occult fracture
 - no access or contraindication to MRI
 - views
 - thin, 1-2 mm slice cuts
 - diagnostic accuracy
 - sensitivity 86%
 - specificity 98%
- MRI
 - indication
 - occult hip fracture
 - AAOS recommendation: moderate strength
 - isolated greater trochanteric fracture to evaluate for intertrochanteric extension
 - findings
 - bone marrow edema STIR or fat-suppressed T2
 - line of decreased intensity on T1 coronal view corresponding with signal on T2 and STIR
 - diagnostic accuracy
 - sensitivity
 - T1-weighted 100% (most sensitive)
 - T2-weighted 84%
- Bone scan
 - indication
 - contraindication to MRI
 - rarely used
 - improved access to MRI and CT
 - delay in care
 - false negative up to 72 hours from injury
 - diagnosis accuracy
 - variable with sensitivity up to 98%

• Treatment

- Nonoperative
 - indications
 - nonambulatory patients
 - high risk for perioperative mortality
 - skin breakdown at surgical site
 - incomplete fractures
 - modalities
 - non-weight bearing with early mobilization from bed to chair
 - outcomes
 - high mortality rate
 - 84.4% at 1-year
 - higher rates of pneumonia, UTI, decubitus ulcers, and DVT
 - low risk of displacement with occult fracture
- Operative
 - **intramedullary hip screw (cephalomedullary nail)**
 - indications
 - stable fracture patterns
 - AAOS recommendation: strong for use of either SHS or CMN

- unstable fracture patterns
 - AAOS recommendation: strong for use of CMN
- reverse obliquity fractures
 - AAOS recommendation: strong for use of CMN
 - 56% failure rate when treated with SHS
- subtrochanteric extension
 - AAOS recommendation: strong for use of CMN
- lack of integrity of femoral wall
 - associated with increased displacement and collapse when treated with SHS
 - increased risk of lateral wall fracture with decreasing lateral wall thickness
- technique
 - short CMN
 - long CMN
- outcomes
 - stable fracture pattern
 - similar clinical and radiographic outcomes for SHS vs CMN
 - unstable fracture pattern
 - lower reoperation rate with CMN
 - CMN use has significant increased over last decade
- **open reduction and internal fixation (ORIF)**
 - indications
 - stable fracture pattern
 - AAOS recommendation: strong for use of either SHS or CMN
 - techniques
 - sliding hip compression (SHS) screw (most common)
 - proximal femur locking plate
 - 95 degree blade plate (rarely used)
 - outcomes
 - similar outcomes for stable fracture patterns when compared to CMN
- **arthroplasty**
 - indications (rare)
 - salvage for failed internal fixation
 - severely comminuted fractures
 - preexisting severe degenerative hip arthritis
 - severely osteoporotic bone that is unlikely to hold internal fixation

• Techniques

- **Intramedullary hip screw (cephalomedullary nail)**
 - pros
 - biologically friendly with potentially closed technique
 - less estimated blood loss (EBL)
 - can be used in unstable fracture patterns
 - decreased bending strain on implant
 - load sharing device with shorter lever arm on implant
 - intramedullary buttress limits shaft medialization
 - cons
 - periprosthetic fracture
 - higher implant cost than sliding hip screw
 - violation of hip abductors for insertion
 - approach
 - supine on fracture table
 - lateral decubitus on radiolucent table
 - technique
 - short vs long CMN
 - controversial
 - AAOS recommendation: limited

- short CMN
 - advantage
 - ease of use
 - decreased OR time
 - decreased EBL
 - lower implant cost
- long CMN
 - advantage
 - theoretical benefit of protecting entire femur
 - disadvantage
 - increased OR time
 - increased EBL
 - increased radiation exposure
 - possible mismatch of implant bow and femur
- outcomes
 - similar functional outcomes, peri-implant fracture, and cutout rate
 - short nail can tolerate up to 3-4 cm of subtrochanteric extension
- lag screw versus helical blade
 - controversial
 - lag screw
 - proven track record
 - femoral head rotation during insertion
 - helical blade
 - theoretical benefit of compacting cancellous bone around blade during insertion
 - avoids removal of bone with reamer
 - biomechanical studies showing higher cutout resistance
- complication
 - lag screw or helical blade cutout
 - anterior perforation of femur
 - perimplant fracture
- **Open reduction and internal fixation**
 - Sliding hip compression screw
 - technique
 - must obtain correct neck-shaft relationship
 - lag screw with tip-apex distance <25 mm is associated with reduced failure rates
 - 4 hole plates show no benefit clinically or biomechanically over 2 hole plates
 - pros
 - allows dynamic interfragmentary compression
 - lower implant cost
 - no violation of hip abductors
 - cons
 - open technique
 - increased blood loss
 - not advisable in unstable fracture patterns
 - excessive fracture collapse
 - limb shortening
 - medialization of shaft
 - anterior spike malreduction in left-sided, unstable fractures due to screw torque
 - place derotational wire or screw prior to lag screw insertion
- proximal femoral locking plate
 - indication
 - infrequently used
 - consider in young patient with unstable fracture
 - pros
 - allow for intraoperative fracture compression
 - avoid excessive postoperative fracture compression
 - maintain limb length

- avoid shaft medicalization
- cons
 - limited evidence
 - highly dependent on surgeon experience
 - must obtain anatomic reduction

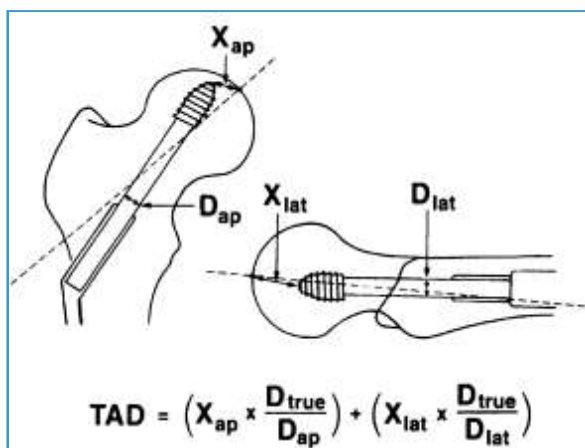
◦ Arthroplasty

- technique
 - long stem with calcar-replacing prosthesis often needed
 - must attempt fixation of greater trochanter to shaft
- pros
 - possible early return to unrestricted weight bearing
 - not reliant on internal fixation in osteoporotic bone
- cons
 - increased blood loss and OR time
 - increased cost
 - may require prosthesis that some surgeons are less familiar with

• Complications

◦ Implant failure and cutout

- incidence
 - occurs in 4-20%
 - usually occurs within first 4 months
- risk factors
 - older age
 - osteoporosis
 - fracture type
 - quality of reduction
 - tip-apex distance (TAD)



- sum of distances from tip of lag screw to apex of femoral head on AP and lateral
 - after adjusting for magnification
 - goal TAD <25mm
 - TAD >45 mm associated with 60% failure rate
- treatment
 - young
 - **c orrective osteotomy and/or revision open reduction and internal fixation**
 - elderly or articular injury from screw cutout
 - total hip arthroplasty
- Nonunion and malunion
 - incidence
 - <2%
 - uncommon due to good blood supply
 - varus malreduction can occur with excessively lateral starting point (>3mm)
 - leads to varus collapse and screw cutout
 - diagnosis
 - hip pain with persistent radiolucent defect at fracture site 4-7 months after surgery
 - CT scan may help confirm diagnosis
 - rule out infection
 - treatment

- valgus intertrochanteric osteotomy + bone grafting
 - arthroplasty
 - screw cutout has damaged hip joint
 - Peri-implant fracture
 - incidence
 - 1-3% at 1 year
 - no significant difference between short and long CMN
 - short CMN typically fracture just distal to tip of nail
 - long CMN typically fracture more around the rod (as opposed to the tip)
 - risk factors
 - distal interlocking screw protective against fracture
 - treatment
 - short CMN
 - distally inserted lateral femoral plate with cables
 - revise to long CMN
 - long CMN
 - closed reduction and insertion of distal locking screw
 - distal femoral plating (fracture distal to tip)
 - Anterior perforation of the distal femur
 - incidence
 - mostly seen with insertion of long CMN
 - decreased with improvements in nail radius of curvature to better match patient anatomy
 - risk factors
 - mismatch of the radius of curvature of the femur (shorter) and implant (longer)
 - posterior starting point on the greater trochanter
 - Postoperative anemia and transfusions
 - blood transfusion
 - >30% postoperative transfusion rate
 - AAOS moderate recommendation
 - transfusion threshold no higher than 8g/dL in asymptomatic postop hip fracture
 - tranexamic acid (TXA)
 - AAOS strong recommendation for use
 - decrease EBL
 - decrease postoperative blood transfusion
- Prognosis
 - Mortality
 - 15-30% mortality risk in the first year following fracture
 - 84.4% at one year with nonoperative treatment
 - Factors that increase mortality
 - male gender (25-30% mortality) vs female (20% mortality)
 - higher in intertrochanteric fracture (vs femoral neck fracture)
 - operative delay of >2 days
 - age >85 years
 - 2 or more pre-existing medical conditions
 - ASA classification (ASA III and IV increases mortality)
 - Factors that decrease mortality
 - Surgery within 48 hours decreases 1 year mortality
 - AAOS moderate recommendation for hip fracture surgery pithing 24-48 hours of admission
 - early medical optimization and co-management with medical hospitalists or geriatricians
 - AAOS strong recommendation for use of interdisciplinary care teams
 - Loss of independence
 - community-dwelling ambulators at 1-year
 - 41% maintain pre-injury ambulatory status
 - 40% more dependent on assistive devices
 - 12% became household ambulators

- 8% became nonfunctional ambulators
- One-third general rule
 - 1/3 regain function
 - 1/3 lose one level of independence
 - 1/3 mortality rate

47- Subtrochanteric Fractures

Images



• Summary

- Subtrochanteric fractures are proximal femur fractures located within 5 cm of the lesser trochanter that may occur in low energy (elderly) or high energy (young patients) mechanisms.
- Diagnosis is made with orthogonal radiographs of the hip in patients that present with inability to bear weight.
- Treatment is generally operative with cephalomedullary nail fixation.

• Epidemiology

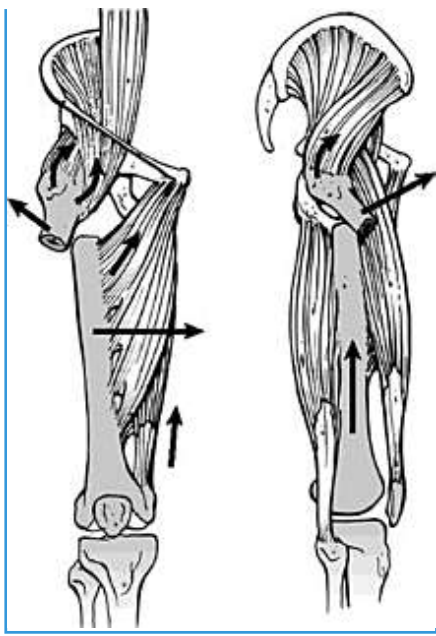
- Incidence
 - common
 - 7 to 34% of femur fractures

• Etiology

- Pathophysiology
 - young patients
 - high-energy mechanism (MVC)
 - elderly patients
 - low-energy mechanism (ground level falls)
 - rule out pathologic or atypical femur fracture



- denosumab or bisphosphonate use, particularly alendronate, can be risk factor
- Pathoanatomy
 - deforming forces on the proximal fragment are



- abduction
 - gluteus medius and gluteus minimus
- flexion
 - iliopsoas
- external rotation
 - short external rotators
- deforming forces on distal fragment
 - adduction & shortening
 - adductors

• Anatomy

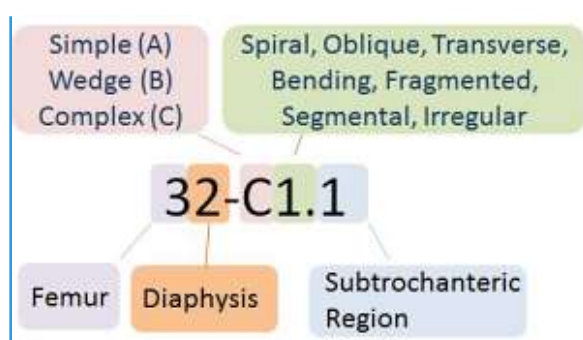
- Biomechanics
 - weight bearing leads to net compressive forces on medial cortex and tensile forces on lateral cortex

• Classification

- Russel-Taylor classification
 - Historically used to differentiate between fractures that would be amenable to an intramedullary nail (type I) and those that required some form of a lateral fixed angle device (type II)
 - Current interlocking options with both trochanteric and piriformis entry nails allow for treatment of type II fractures with intramedullary implants

■ Russel-Taylor Classification		
■ Type I	■ No extension into piriformis fossa	■
■ Type II	■ Extension into greater trochanter with involvement of piriformis fossa ■ Look on lateral xray to identify piriformis fossa extension	■

- AO/OTA classification



7

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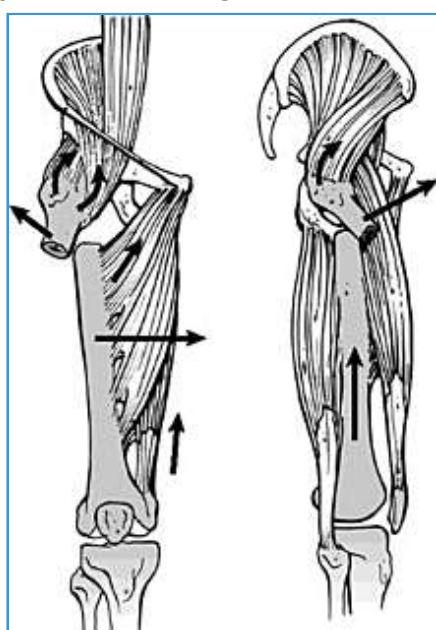
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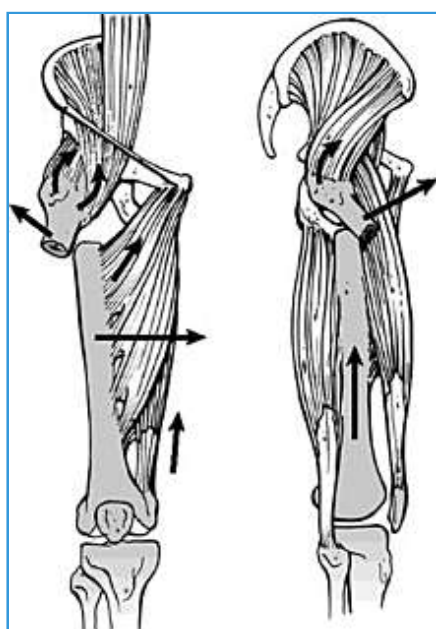
- Symptoms
 - hip and thigh pain
 - inability to bear weight
- Physical exam
 - pain with motion
 - typically associated with obvious deformity (shortening and varus alignment)
 - flexion of proximal fragment may threaten overlying skin

• Imaging

- Radiographs
 - recommended views
 - AP and lateral of the hip
 - AP pelvis
 - full length femur films including the knee
 - optional views
 - traction views may assist with defining fragments in comminuted patterns but is not required
 - findings
 - proximal fragment flexed and abducted



- distal fragment adducted and ER



- bisphosphonate-related fractures have
 - lateral cortical thickening
 - increased diaphyseal cortical thickness
 - transverse vs. short oblique fracture orientation
 - medial spike (if complete fracture)
 - lack of comminution

• Treatment

- Nonoperative
 - **observation with pain management**
 - indications
 - non-ambulatory patients with medical co-morbidities that would not allow them to tolerate surgery

- limited role due to strong muscular forces displacing fracture and inability to mobilize patients without surgical intervention

- Operative

- **intramedullary nailing** (usually cephalomedullary)
 - indications
 - historically Russel-Taylor type I fractures
 - newer design of intramedullary nails has expanded indications
 - most subtrochanteric fractures treated with IM nail
 - patients on bisphosphonate therapy with pain and radiographic evidence of stress fracture
- **fixed angle plate**
 - indications
 - surgeon preference
 - associated femoral neck fracture
 - narrow medullary canal
 - pre-existing femoral shaft deformity

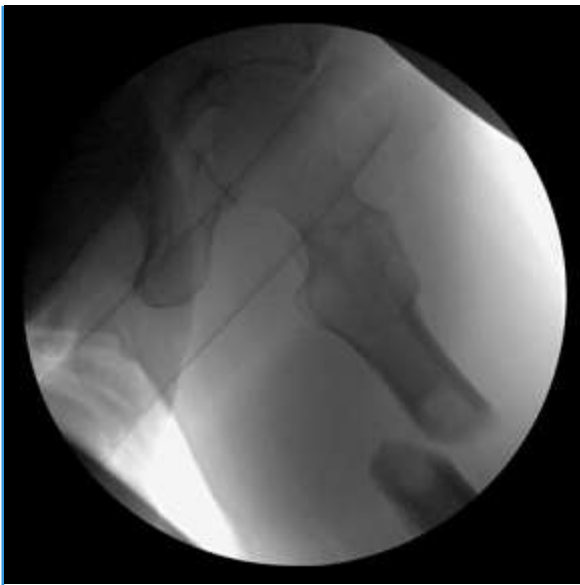
- Techniques

- **Intramedullary Nailing**

- position
 - lateral positioning
 - advantages
 - allows for easier reduction of the distal fragment to the flexed proximal fragment
 - allows for easier access to entry portal, especially for piriformis nail
 - supine positioning
 - advantages
 - protective to the injured spine
 - address other injuries in polytrauma patients
 - easier to assess rotation
- techniques
 - 1st generation nail (rarely used)
 - 2nd generation reconstruction nail
 - cephalomedullary nail
 - trochanteric or piriformis entry portal
 - piriformis nail may mitigate risk of iatrogenic malreduction from proximal valgus bend of trochanteric entry nail



- pros
 - preserves vascularity
 - load-sharing implant
 - stronger construct in unstable fracture patterns
- cons
 - reduction technically difficult
 - nail can not be used to aid reduction
 - fracture must be reduced prior to and during passage of nail
 - may require percutaneous reduction aids or open clamp placement to achieve and maintain reduction



- mismatch of the radius of curvature

- nails with a larger radius of curvature (straighter) can lead to perforation of the anterior cortex of the distal femur
- complications
 - varus malreduction (see complications below)
- **Fixed angle plate**
 - approach



- lateral approach to proximal femur
 - may split or elevate vastus lateralis off later intermuscular septum
 - dangers include perforating branches of profunda femoris
- technique
 - 95 degree blade plate or condylar screw
 - sliding hip screw is contraindicated due to high rate of malunion and failure
 - blade plate may function as a tension band construct
 - femur eccentrically loaded with tensile force on the lateral cortex converted to compressive force on medial cortex
- cons
 - compromise vascularity of fragments
 - inferior strength in unstable fracture patterns

• Complications

- Varus/ procurvatum malunion



- the most frequent intraoperative complication with antegrade nailing of a subtrochanteric femur fracture is varus and procurvatum (or flexion) malreduction
- Nonunion
 - rates of nonunion lowest when using reamed, statically locked IMN
 - can be treated with plating
 - allows correction of varus malalignment
- Bisphosphonate fractures
 - nail fixation
 - increased risk of iatrogenic fracture
 - because of brittle bone and cortical thickening
 - increased risk of nonunion with nail fixation resulting in increased need for revision surgery
 - bisphosphonates must be discontinued

- high rate of progression to fracture of contralateral femur
- plate fixation
 - increased risk of plate hardware failure
 - because of varus collapse and dependence on intramembranous healing inhibited by bisphosphonates

48- Femoral Shaft Fractures

Images



- Summary

- Femoral shaft fractures are high energy injuries to the femur that are associated with life-threatening injuries (pulmonary, cerebral) and ipsilateral femoral neck fractures.
- Diagnosis is made radiographically with radiographs of the femur as well as the hip to rule out ipsilateral femoral neck fractures.
- Treatment generally involves intramedullary nailing which is associated with >95% union rates.

- Epidemiology

- Incidence
 - common
 - 37.1 per 100,000 person annually

- Etiology

- Mechanism
 - traumatic
 - high-energy
 - most common in younger population
 - often a result of high-speed motor vehicle accidents
 - low-energy
 - more common in elderly
 - often a result of a fall from standing
 - gunshot
- Fracture patterns
 - transverse
 - pure bending moment
 - spiral
 - rotational moment
 - oblique
 - uneven bending moment
 - segmental
 - 4-point bending moment
 - comminuted
 - high-speed crush or torsion mechanism

- Associated conditions
 - orthopaedic
 - ipsilateral femoral neck fracture



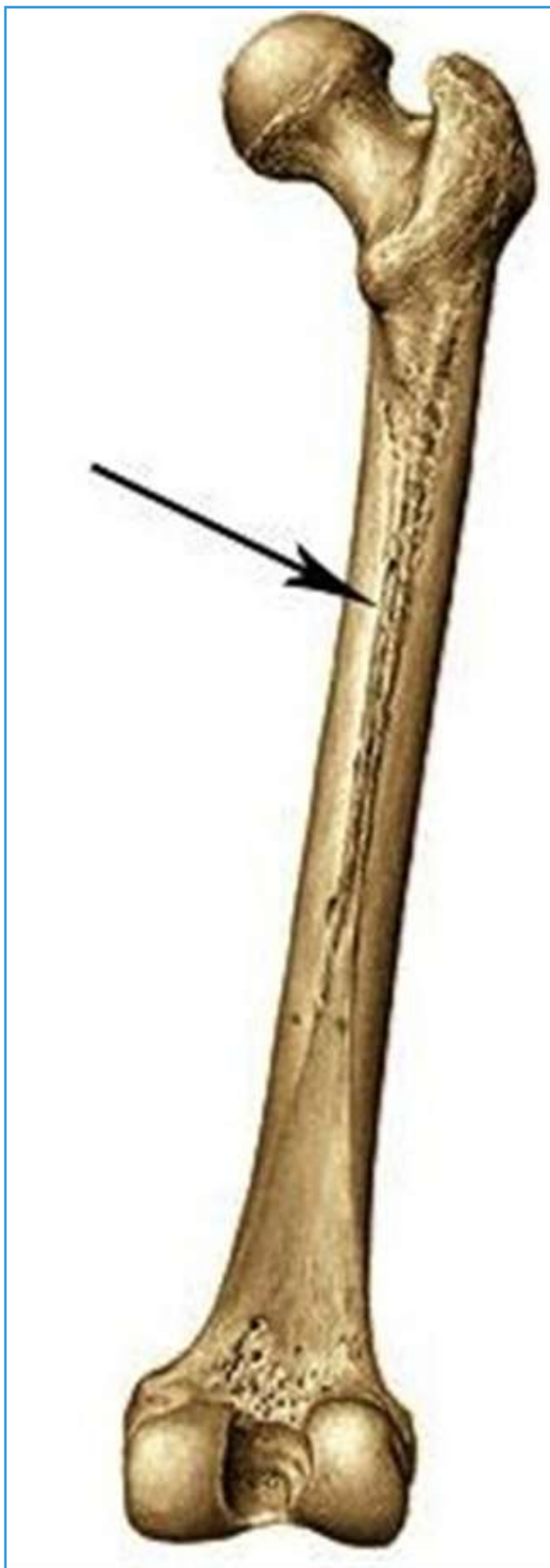
- 2-6% incidence
 - often basicervical, vertical, and nondisplaced
 - lack of displacement due to majority of energy dissipated through femoral shaft
 - missed 19-31% of time
- bilateral femur fractures
 - significant risk of pulmonary complications
 - increased rate of mortality as compared to unilateral fractures
- ipsilateral tibial shaft fractures
- ipsilateral acetabular fracture
- thoracic
 - pulmonary injury
 - early surgical treatment of femur fracture can lead to ARDS
 - approximately 2% of cases
 - treatment can proceed when patient is appropriately resuscitated
- cerebral hemorrhage, subdural hemorrhage
 - early surgical treatment can exacerbate neurologic injury
 - intraoperative hypotension can decrease brain perfusion

• Anatomy

- Osteology
 - largest and strongest bone in the body
 - femur has an anterior bow



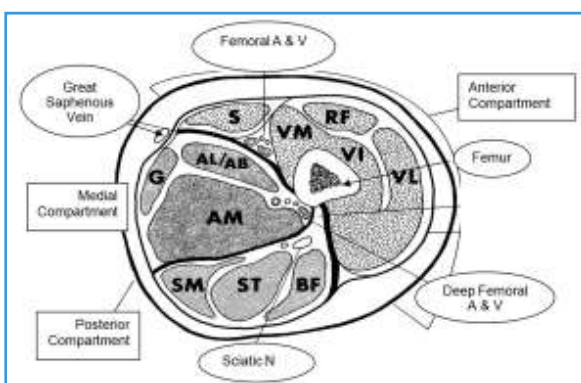
- linea aspera



- rough crest of bone running down middle third of posterior femur
- attachment site for various muscles and fascia
- acts as a compressive strut to accommodate anterior bow to femur

○ Muscles

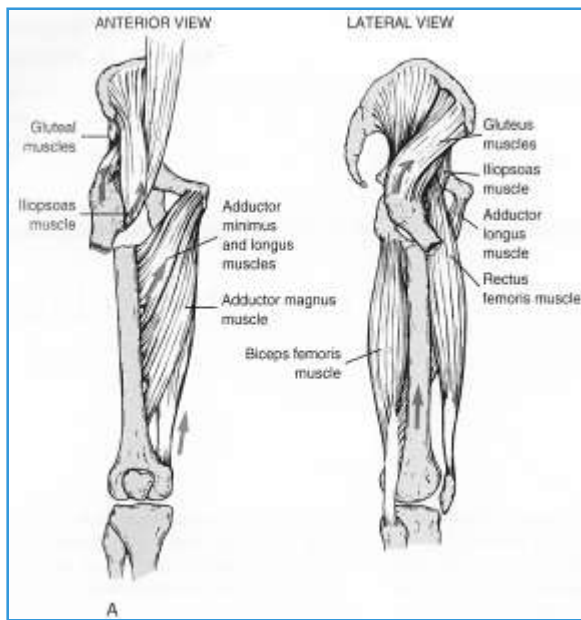
- 3 compartments of the thigh



- anterior
 - sartorius
 - quadriceps
- posterior
 - biceps femoris
 - semitendinosus
 - semimembranosus
- adductor
 - gracilis
 - adductor longus
 - adductor brevis
 - adductor magnus

○ Biomechanics

- musculature acts as a deforming force after fracture



- proximal fragment
 - abducted
 - gluteus medius and minimus abduct as they insert on greater trochanter
 - flexed
 - iliopsoas flexes fragment as it inserts on lesser trochanter
- distal segment
 - varus
 - adductors inserting on medial aspect of distal femur
 - extension
 - gastrocnemius attaches on distal aspect of posterior femur

- Classification

■ W inquist and Hansen Classification		
■ Type 0	■ No comminution	■
■ Type I	■ Insignificant amount of comminution	■
■ Type II	■ Greater than 50% cortical contact	■
■ Type III	■ Less than 50% cortical contact	■

Type IV	Segmental fracture with no contact between proximal and distal fragment



AO/OTA Classification		
32A - Simple	- A1 - Spiral - A2 - Oblique, angle > 30 degrees - A3 - Transverse, angle < 30 degrees	
32B - Wedge	- B1 - Spiral wedge - B2 - Bending wedge - B3 - Fragmented wedge	
32C - Complex	- C1 - Spiral - C2 - Segmental - C3 - Irregular	

• Presentation

- Initial evaluation
 - Advanced Trauma Life Support (ATLS) should be initiated
 - adequate resuscitation
 - normal vital signs
 - HR < 100 bpm
 - SBP >100 mm Hg
 - DBP >70 mm Hg
 - normothermia (> 35° C)
 - adequate urine output
 - 0.5 - 1.0 mL/kg/hr (30 mL/hr)
 - labs
 - lactate <2.5 mmol/L
 - base deficit within -2 and +2
 - IL-6 levels <500 pg/dL
 - gastric mucosal pH >7.3
 - compensated shock
 - commonly missed
 - normotensive
 - tachycardia without fever
 - cool extremities
 - narrowing pulse pressure
 - weak peripheral pulses
 - delayed capillary refill
- Symptoms
 - pain in thigh
- Physical exam
 - inspection

- tense, swollen thigh
 - blood loss in closed femoral shaft fractures is 1000-1500ml
 - for closed tibial shaft fractures, 500-1000ml
 - blood loss in open fractures may be double that of closed fractures
 - affected leg often shortened
 - tenderness about thigh
 - motion
 - examination for ipsilateral femoral neck fracture often difficult secondary to pain from fracture
 - neurovascular
 - must record and document distal neurovascular status
- Imaging
 - Radiographs
 - recommended views
 - AP and lateral views of entire femur
 - AP and lateral views of ipsilateral hip
 - important to rule-out coexisting femoral neck fracture
 - AP and lateral views of ipsilateral knee
 - CT
 - indications
 - may be considered in midshaft femur fractures to rule-out associated femoral neck fracture
 - Ipsilateral femoral neck rule-out protocol
 - dedicated 10° internal rotation AP hip radiographs
 - placed femoral neck in profile
 - fine-cut CT of the hip
 - 2 mm cuts
 - CT Capsular Sign
 - a difference of >1mm capsular distension between injured and uninjured sides on the axial soft tissue window
 - intraoperative fluoroscopic exam of the ipsilateral hip
 - dedicated post-operative radiographs of the affected while patient is still in operating room
- Labs
 - Septic nonunion
 - ESR
 - CRP
 - most sensitive to the presence of a occult infection
 - CBC
 - WBC
 - Adequate resuscitation
 - IL-6
 - less than 500 pg/dL
 - serum lactate
 - less than 2.5 mmol/L
 - base deficit
 - within -2 or +2
- Treatment
 - Nonoperative
 - **long leg cast or hip spica cast**
 - indications
 - nondisplaced femoral shaft fractures in patients with multiple medical comorbidities
 - pediatric patients
 - Operative
 - **antegrade intramedullary nail**
 - indications

- gold standard for treatment of diaphyseal femur fractures
- outcomes
 - stabilization within 24 hours is associated with
 - decreased pulmonary complications (ARDS)
 - decreased thromboembolic events
 - improved rehabilitation
 - decreased length of stay and cost of hospitalization
 - exception is a patient with a closed head injury
 - critical to avoid hypotension and hypoxemia
 - consider provisional fixation (damage control)
- **retrograde intramedullary nail**
 - indications
 - ipsilateral femoral neck fracture
 - f loading knee (ipsilateral tibial shaft fracture)
 - use same incision for tibial nail
 - ipsilateral acetabular fracture
 - does not compromise surgical approach to acetabulum
 - multiple system trauma
 - bilateral femur fractures
 - avoids repositioning
 - morbid obesity
 - avoids difficult of antegrade start point with obesity
 - pregnancy (especially 1st trimester)
 - low radiation exposure to uterus
 - contraindications
 - skeletal immaturity
 - history of knee sepsis
 - soft tissue injury surrounding knee
 - outcomes
 - results are comparable to antegrade femoral nails
 - immediate retrograde or antegrade nailing is safe for early treatment of gunshot femur fractures
- **external fixation with conversion to intramedullary nail within 2-3 weeks**
 - indications
 - unstable polytrauma victim
 - vascular injury
 - severe open fracture
 - outcomes
 - no difference in union rates and infections rates with acute nailing
 - infection rate does increase if ex-fix left in place >28 days
 - reduced risk of ARDS and fat embolism syndrome
- **open reduction internal fixation with plate**
 - indications
 - ipsilateral neck fracture requiring screw fixation
 - fracture at distal metaphyseal-diaphyseal junction
 - inability to access medullary canal
 - outcomes
 - inferior when compared to IM nailing due to increased rates of:
 - infection
 - nonunion
 - hardware failure

• Techniques

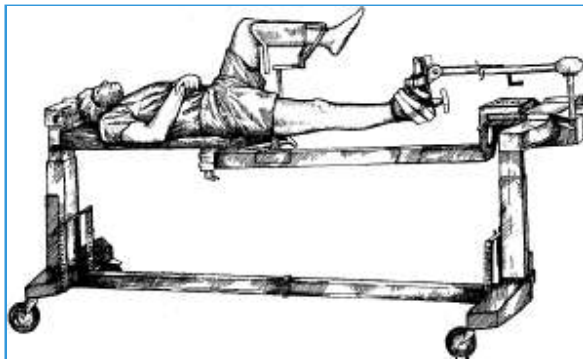
- **Long leg cast or hip spica cast**
 - hip spica casting



- typically used in pediatric patients <5 years of age with length stable fractures
- long leg casting can be used in adult patients who are not surgical candidates
 - need frequent follow-up for skin checks

○ **Antegrade intramedullary nail**

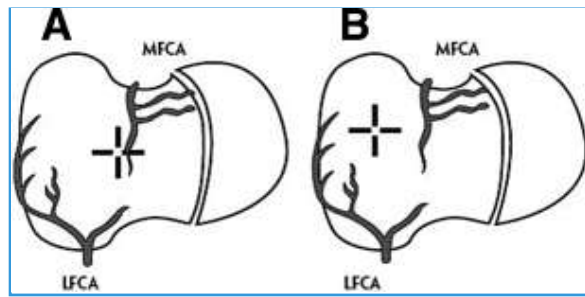
- approach
 - 3 cm incision proximal to the greater trochanter in line with the femoral canal
- technique
 - positioning
 - supine on fracture table



- perineum well seated against post
- nonoperative leg in lithotomy bolster
 - important to ensure adequate positioning to allow C-arm maneuvering during case
- "sloppy" lateral position
 - radiolucent jackson table
 - large bumps placed underneath operative hip
 - places patient in partial decubitus position
- starting points
 - piriformis entry



- pros
 - colinear trajectory with long axis of femoral shaft
- cons
 - starting point more difficult to access, especially in obese patients
 - causes the most significant damage to
 - abductor muscles and tendons
 - may result in abductor limp
 - blood supply to the femoral head
 - may result in AVN in pediatric patients



■ trochanteric entry

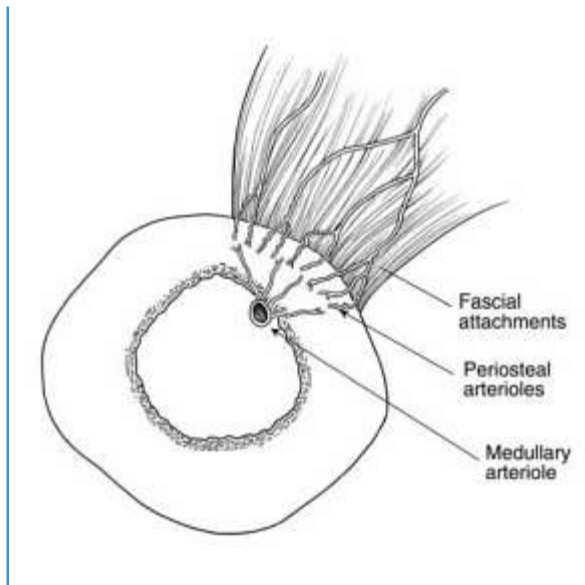


- pros
 - minimizes soft tissue injury to abductors
 - easier starting point than piriformis entry nail
- cons
 - not colinear with the long axis of femoral shaft
 - must use nail specifically designed for trochanteric entry
 - use of a straight nail may lead to varus malalignment
 - too lateral starting point can result in varus malalignment
 - ideal starting point is dependent on the relative position of the greater trochanter to the long axis of the femur
 - just lateral to the long axis of the femur
- entry reamer with soft tissue protector or awl
- pass ball-tip guidewire to desired depth/length of nail
- reaming
 - begining with 8.5 to 9 mm reamer
 - increase by 0.5 mm increments
 - reamed nailing superior to unreamed nailing, with:
 - increased union rates
 - decreased time to union
 - no increase in pulmonary complications
 - indications for unreamed nail
 - consider for patient with bilateral pulmonary injuries
- femoral rod insertion
 - insert femoral nail with 90° of internal rotation
 - leverages the anterior bow of the nail to direct the tip of the nail into the canal
 - avoids medial comminution with nail contact along medial cortex
 - careful mallet nail to appropriate depth after crossing fracture site
- interlocking screws
 - technique
 - computer-assisted navigation for screw placement decreases radiation exposure
 - perfect circles technique



- obtain perfect trajectory of interlock holes with C-arm transducer

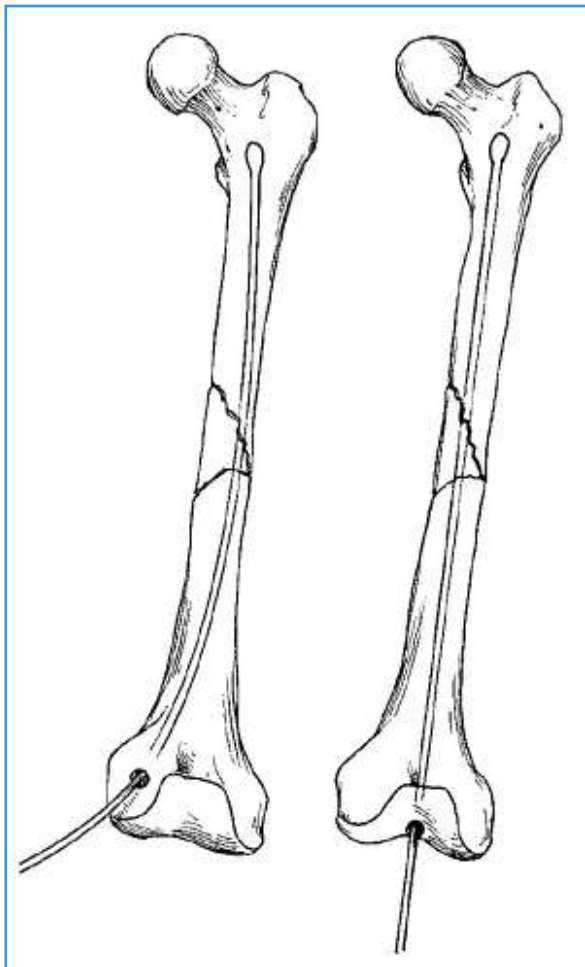
- use the angle of the transducer to guide trajectory of drill
 - widening/overlap of the interlocking hole in the proximal-distal direction
 - correct with adjustment in the abduction/adduction plane
 - widening/overlap of the interlocking hole in the anterior-posterior plane
 - correct with adjustment in the internal/external rotation plane
- reamed nailing has been associated with higher union rates compared to unreamed nailing
 - reaming disrupts endosteal blood supply, but stimulates soft tissue and periosteal blood supply to fracture



- periosteal and soft tissue blood supply is predominate source after fracture
 - reaming extrudes medullary contents into fracture site
 - autologous bone grafting
 - increased micro emboli to lungs with reaming
 - intraoperative echocardiogram studies have not demonstrated this to be significant
 - mild increases in marrow pressure with reaming
 - greatest increase occurs with nail insertion
 - can be decreased with fluted nails
 - allows canal contents to extrude around the nail
 - reaming allows are a larger diameter nail to be placed
 - larger nail is stiffer and is related to the diameter to the 4th power
 - increases the area of isthmic contact with nail
 - no increase in infection rates after reaming open fractures
 - postoperative care
 - weight-bearing as tolerated
 - range of motion of knee and hip is encouraged
 - pros
 - 98-99% union rate
 - low complication rate
 - infection risk 2%
 - cons
 - not indicated for use with ipsilateral femoral neck fracture
 - increased rate of HO in hip abductors with antegrade nailing
 - increased rate of hip pain compared with retrograde nailing
 - mismatch of the radius of curvature of the femoral shaft and intramedullary nails can lead to anterior perforation of the distal femur
- **Retrograde intramedullary nail**



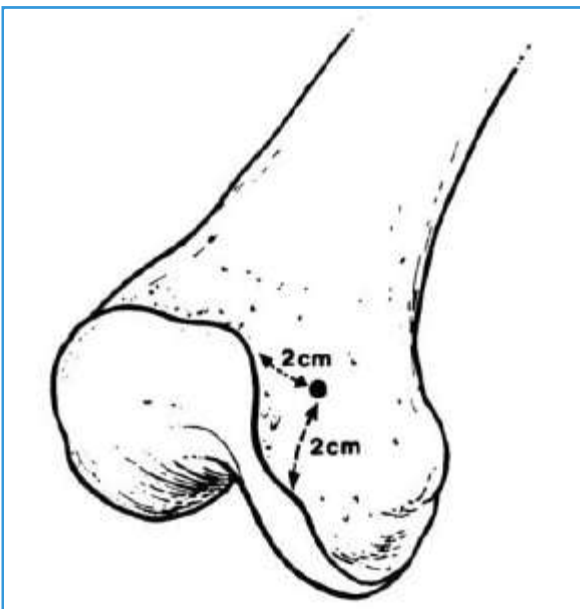
- approach
 - 2 cm incision starting at distal pole of patella
 - medial parapatellar versus transtendinous approaches
 - nail inserted with knee flexed to 30-50 degrees
- technique
 - positioned supine on radiolucent table
 - bump under operative hip
 - radiolucent triangle
 - useful for eliminating extension moment of gastrocnemius in distal fragment
 - entry point



- intercondylar starting point



- center of intercondylar notch on AP view
 - extension of Blumensaat's line on lateral
 - posterior to Blumensaat's line risks damage to cruciate ligaments
 - trajectory in line with the canal on AP and lateral views
- medial condylar starting point



- preserves articular surface
 - requires a curves nail to prevent valgus malalignment

- entry reamer with soft tissue protecting sleeve
- pass ball-tip guidewire
 - should end proximal to lesser trochanter
- ream femoral canal
 - fracture must be reduced to avoid eccentrically reaming the cortex
 - F-tool



- bumps
 - joysticking with Schanz pins
 - manual traction
- start with 8.5 mm reamer
- increase in size by increments of 0.5 mm
- ream canal 1 to 1.5 mm greater than size of intended implant
- insert femoral nail
 - should seat ~1 cm deep to articular surface to prevent patellofemoral symptoms
- place interlocking screws
 - aiming arm used for distal lockings
 - can place first and then mallet the nail to gain compression at fracture with transverse patterns
 - perfect circles technique for proximal interlocks
 - femoral neurovascular bundle safe if screws placed proximal to lesser trochanter
- postoperative care
 - weight-bearing as tolerated
 - range of motion of knee and hip is encouraged
- pros
 - technically easier
 - faster operative times
 - quicker OR set-up
 - allows for addressing other injuries surgically without changing patient position
 - less blood loss than antegrade nailing
 - allows for direct comparison of rotation and leg length to nonoperative extremity
 - union rates comparable to those of antegrade nailing
 - no increased rate of septic knee with retrograde nailing of open femur fractures
- cons
 - knee pain
 - increased rate of interlocking screw irritation
 - cartilage injury
 - cruciate ligament injury with improper starting point
- **External fixation with conversion to intramedullary nail within 2-3 weeks**



- technique
 - safest pin location sites are anterolateral and direct lateral regions of the femur
 - 2 pins should be used on each side of the fracture line
- pros
 - prevents further pulmonary insult without exposing patient to risk of major surgery
 - may be converted to IM fixation within 2-3 weeks as a single stage procedure

- cons
 - pin tract infection
 - knee stiffness
 - due to binding/scarring of quadriceps mechanism
- **Open reduction and internal fixation with plate**



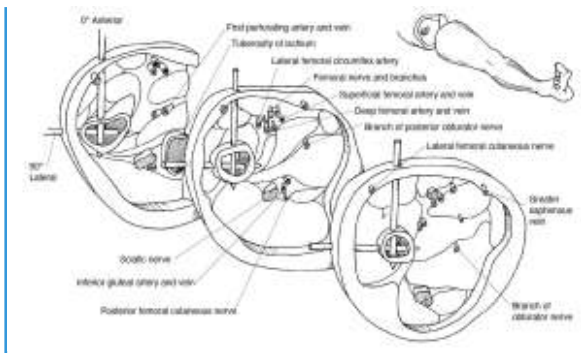
- technique
 - submuscular plating
 - less soft tissue stripping than with direct lateral approach
 - preserves periosteal blood supply to fracture
 - direct lateral approach
 - lateral incision in line with femoral shaft
 - incision iliotibial band fascia
 - elevate vastus lateralis from ITB fascia and posterior septum
 - place chandler over anterior cortex to expose lateral femur
 - reduce fracture with traction and reduction forceps
 - fracture fixation
 - can place interfragmentary screw for simple fracture patterns
 - comminuted fractures will require bridge plate
- **Special considerations**
 - ipsilateral femoral neck fracture



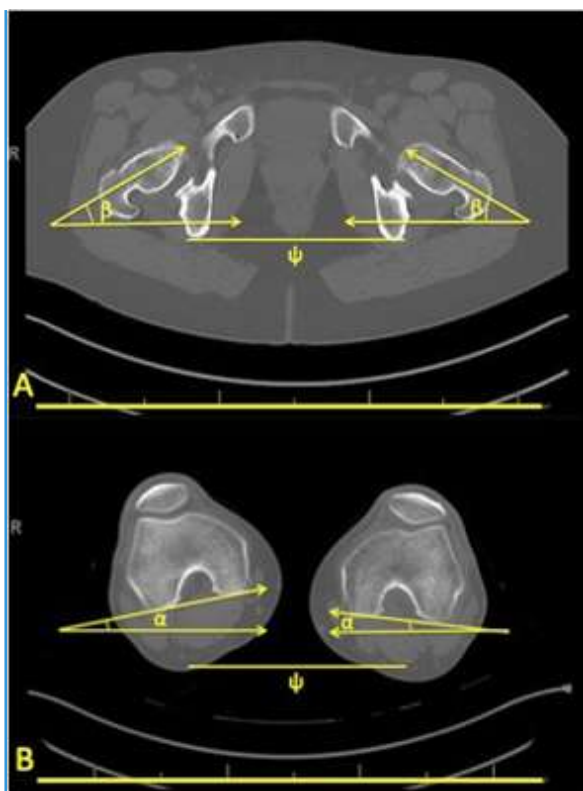
- priority goes to fixing femoral neck because anatomic reduction is necessary to avoid complications of AVN and nonunion
- technique
 - preferred methods
 - usually two-construct fixation
 - screws for neck with retrograde nail for shaft
 - screws for neck and plate for shaft
 - compression hip screw for neck with retrograde nail for shaft
 - single construct fixation is associated with femoral neck fracture displacement and loss of reduction
 - less preferred methods
 - antegrade nail with screws anterior to nail
 - technically challenging
 - usually done if neck fracture is identified after the femoral shaft fracture has been addressed

- **Complications**

- Heterotopic ossification
 - incidence
 - 25%
 - treatment
 - rarely clinically significant
- Pudendal nerve injury
 - incidence
 - 10% when using fracture table with traction
- Femoral artery or nerve injury
 - incidence
 - rare
 - femoral artery is medial to femur if proximal locking screw is placed proximal to lesser trochanter in retrograde nails



- cause
 - can occur when inserting proximal interlocking screws during a retrograde nail
- Malunion and rotational malalignment
 - most accurately determined by the Jeanmart method
 - angle between a line drawn tangential to the femoral condyles and a line drawn through the axis of the femoral neck



- femoral rotation = $\hat{I}^2 - \hat{I}\pm$
 - anterversion and external rotation are positive values for equation
 - retroversion and internal rotation are negative values for equation
 - $R(\hat{I}^2 - \hat{I}\pm) - L(\hat{I}^2 - \hat{I}\pm) = \text{relative alignment}$
- malrotation up to 15 degrees is usually well tolerated
- incidence
 - proximal fractures 30%
 - distal fractures 10%
- risk factors
 - use of a fracture table increases risk of internal rotation deformities when compared to manual traction
 - fracture comminution
 - night-time surgery
- treatment
 - if noticed intraoperatively, remove distal interlocking screws and manually correct rotation
 - if noticed after union, osteotomy is required
- Delayed union

- treatment
 - dynamization of nail with or without bone grafting
- Nonunion
 - incomplete healing within 9 months of injury or no evidence of healing on successive radiographs over 3 months
 - incidence
 - <10%
 - risk factors
 - postoperative use of nonsteroidal anti-inflammatory drugs
 - smoking is known to decrease bone healing in reamed antegrade exchange nailing for atrophic non-unions
 - broken distal interlock screws can be seen on radiographs
 - race between healing and implant failure is lost
 - distal interlock screws are exposed to the greatest stresses
 - undergo 4-point bending stress
 - results in fracture of the interlock screw in the region inside the nail
 - treatment
 - reamed exchange nailing
 - works by increasing construct stiffness, enhanced isthmic fit, and extrusion of reaming contents to nonunion site
 - plate augmentation with nail retention
 - some studies have demonstrated higher union rates than exchange nailing
 - enables full weight bearing
 - compression plating
 - allows compression of the fracture site
 - bone grafting
 - removal of interposed fibrous material
- Infection
 - incidence
 - < 1%
 - treatment
 - removal of nail and reaming of canal
 - external fixation used if fracture not healed
- Weakness
 - quadriceps and hip abductors are expected to be weaker than contralateral side
- Iatrogenic fracture etiologies
 - risk factors
 - antegrade starting point 6mm or more anterior to the intramedullary axis
 - however, anterior starting point improves position of screws into femoral head
 - increased cortical hoop stresses with anterior starting points
 - using an anterior start point for a piriformis nail can result in a proximal femur fracture
 - failure to overream canal by at least .5 mm
- Mechanical axis deviation (MAD)
 - lengthening along the anatomical axis of the femur leads to lateral MAD
 - shortening along the anatomical axis of the femur leads to medial MAD
- Anterior cortical penetration



- due to mismatch of the radius of curvature of the nail to the radius of curvature of the femur
 - average radius of curvature of human femur is 120 +/- 36 cm
- starting points that are too posterior (especially piriformis start points) with relatively straight nails

49- Femoral Head Fractures

Images



• Summary

- Femoral head fractures are rare traumatic injuries that are usually associated with hip dislocations.
- Diagnosis can be made by pelvis/hip radiographs but frequently require CT scan for surgical planning.
- Treatment may be nonoperative or operative depending on the location of the fracture and degree of fracture displacement.

• Epidemiology

- Incidence
 - rare
 - seen in 12% of patients with hip dislocations
 - increased incidence due to higher MVAs and better resuscitation

• Etiology

- Pathophysiology
 - mechanism of injury
 - impaction, avulsion or shear forces involved
 - unrestrained passenger MVA (knee against dashboard)
 - falls from height
 - sports injury
 - industrial accidents
 - pathoanatomy
 - the location and size of the fracture fragment and degree of comminution depend on the position of the hip at the time of dislocation



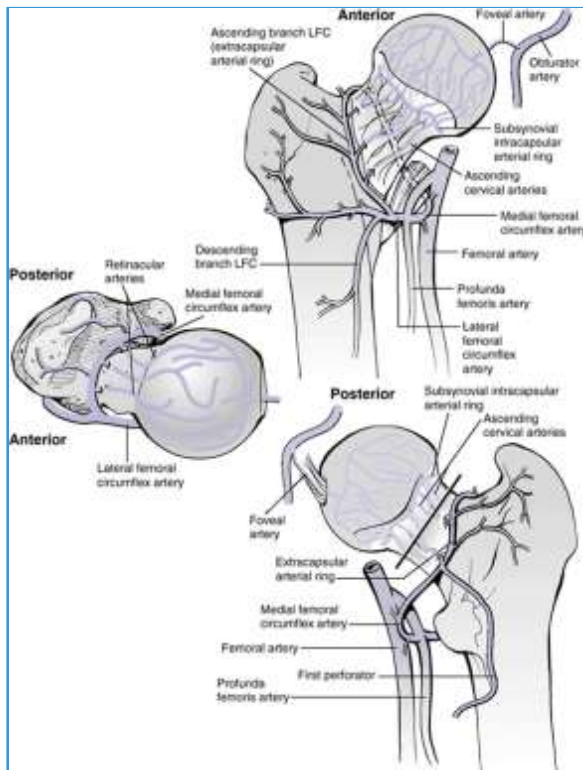
- 5-15% of posterior hip dislocations are associated with a femoral head fracture because of contact between femoral head and posterior rim of acetabulum
 - anterior hip dislocations are associated with impaction/indentation fractures of the femoral head
 - Associated conditions
 - femoral neck fracture (see Pipkin Classification below)

- acetabular fracture (see Pipkin Classification below)
- sciatic nerve neuropraxia
- femoral head AVN
- ipsilateral knee ligamentous instability (knee vs dashboard)

• Anatomy

○ Blood supply

- medial femoral circumflex artery (MFCA)

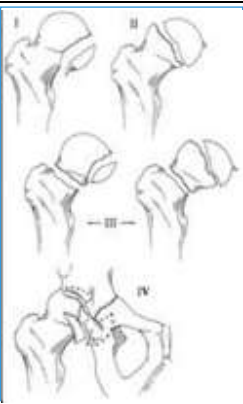
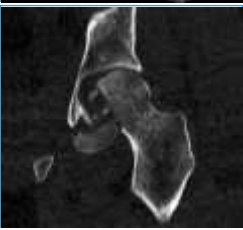
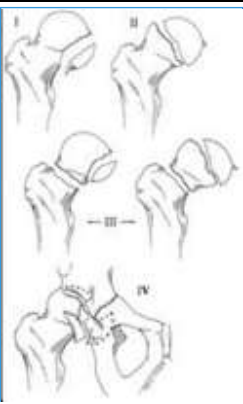
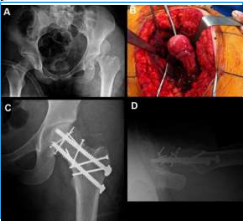
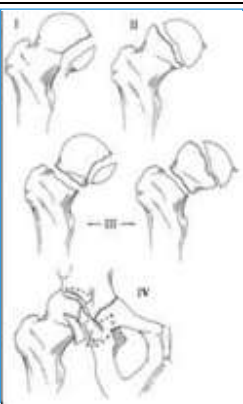
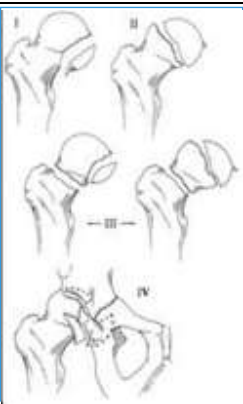


- main blood supply to the weightbearing portion of the femoral head
- MFCA originates from the profunda femoris
- artery to the ligamentum teres
 - lesser blood supply (10-15%)
 - from the obturator artery or MFCA
 - supplies perifoveal area

• Classification

○

■ Pipkin Classification

■ Type I	■ Fracture below fovea/ ligamentum (small) ■ Does not involve the weight-bearing portion of the femoral head	■
■ Type II	■ Fracture above fovea/ ligamentum (larger) ■ Involves the weight-bearing portion of the femoral head	■
■ Type III	■ Type I or II with an associated femoral neck fracture ■ High incidence of AVN	■
■ Type IV	■ Type I or II with associated acetabular fx (usually posterior wall fracture)	■

● Presentation

○ History

- frontal impact MVA with knee striking dashboard
 - fall from height
 - Symptoms
 - localized hip pain
 - unable to bear weight
 - other symptoms associated with impact
 - Physical exam
 - inspection
 - shortened lower limb
 - with large acetabular wall fractures, little to no rotational asymmetry is seen
 - posterior dislocation
 - limb is flexed, adducted, internally rotated
 - anterior dislocation
 - limb is flexed, abducted, externally rotated
 - ipsilateral knee
 - ligamentous stability
 - neurovascular
 - may have signs of sciatic nerve injury
- Imaging
 - Radiographs
 - recommended views
 - AP pelvis, hip series
 - both pre-reduction and post-reduction
 - judet views
 - associated acetabular fracture
 - inlet and outlet views
 - associated pelvic ring injury
 - CT scan
 - indications
 - post reduction to evaluate for loose bodies and presence/size of fracture fragments
 - findings
 - femoral head fracture (size, location, comminution)
 - plane of femoral head fracture
 - intra-articular fragments
 - posterior pelvic ring injury
 - impaction
 - acetabular fracture
 - Treatment
 - Nonoperative
 - **hip reduction**
 - indications
 - acute dislocations
 - reduce hip dislocation within 6 hours
 - outcomes
 - 5-40% incidence of femoral head osteonecrosis
 - increased risk with increased time to reduction
 - **TDWB x 4-6 weeks, restrict adduction and internal rotation**
 - indications
 - Pipkin I
 - nondisplaced Pipkin II with < 1 mm step off
 - no interposed fragments
 - stable hip joint
 - outcomes
 - satisfactory results if <1mm step off

- serial radiographs required
- development of post-traumatic arthritis based on joint incongruity and initial cartilage damage

○ Operative

▪ **ORIF**

- indications
 - Pipkin II with > 1 mm step off
 - if performing removal of loose bodies in the joint
 - associated neck or acetabular fx (Pipkin type III and IV)
 - polytrauma
 - irreducible fracture-dislocation
 - Pipkin IV
 - treatment dictated by characteristics of acetabular fracture
 - small posterior wall fragments can be treated nonsurgically and suprafoveal fractures can then be treated through an anterior approach
- outcomes
 - outcomes mimic those of their associated injuries (hip dislocations and femoral neck fractures)
 - high rate of AVN and catastrophic failure following ORIF of Pipkin III injuries
 - poorer outcomes associated with
 - use of posterior (Kocher-Langenbeck) approach
 - use of 3.0mm cannulated screws with washers

▪ **arthroplasty**

- indications
 - Pipkin I, II (displaced), III, and IV in older patients
 - fractures that are significantly displaced, osteoporotic or comminuted
- outcomes
 - best reserved for older patients
 - higher dislocation risk than THA performed for OA

▪ **arthroscopy**

- indications
 - removal of loose bodies
- outcomes
 - dependent on ability to remove incarcerated fragments and initial cartilage damage

• Techniques

○ **hip reduction**

- technique
 - adequate sedation and muscular relaxation are vital
 - traction in-line with the thigh, extremity slightly adducted, counterforce on pelvis
 - forceful reduction should be avoided
 - obtain post reduction CT

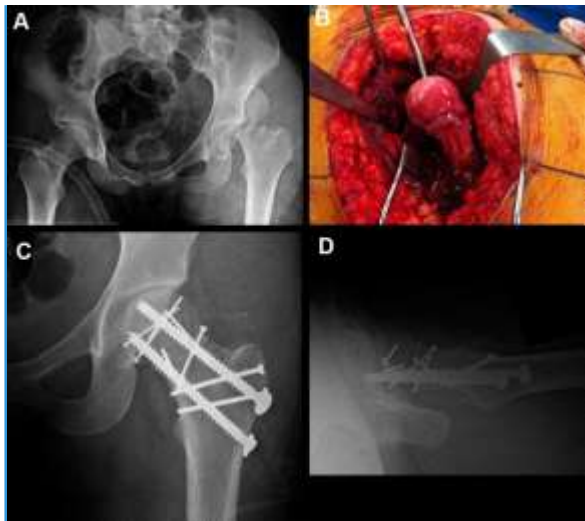
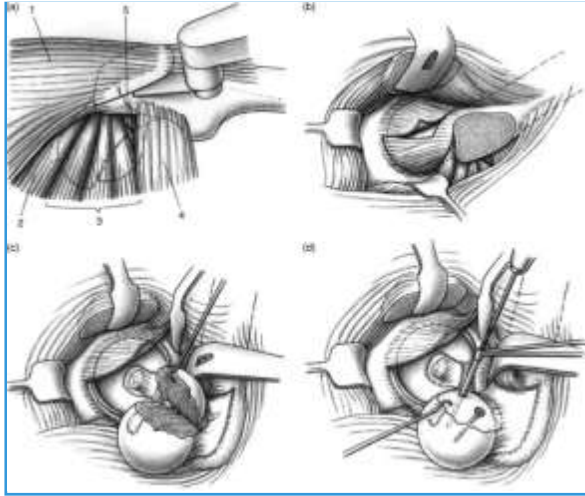
○ **TDWB x 4-6 weeks, restrict adduction and internal rotation**

- technique
 - perform serial radiographs to document maintained reduction

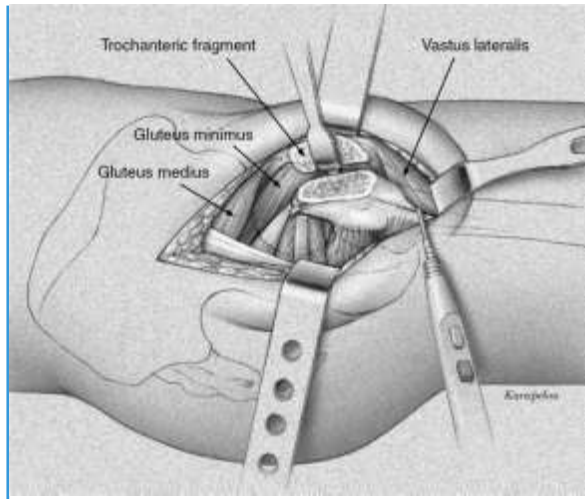
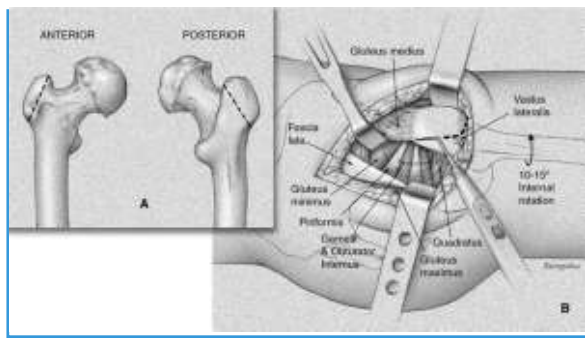
○ **ORIF of femoral head (Pipkin I, II, III)**

- approach
 - anterior (Smith-Peterson) approach
 - utilizes internervous plane between the superior gluteal and femoral nerves
 - improved visualization
 - reduced surgical time
 - improved fracture reduction
 - femoral head fracture is commonly anteromedial
 - lower incidence of AVN
 - less blood loss
 - higher rate of functionally significant HO compared to posterior approach
 - anterolateral (Watson-Jones)

- utilizes intermuscular plane between the tensor fascia lata and gluteus medius (both superior gluteal nerve)
- exposure
 - periacetabular capsulotomy to preserve blood supply to femoral head
- fixation
 - two or more 2.7mm or 3.5mm lag screws



- countersink the heads of the screws to avoid screw head prominence
- headless compression screws
- bioabsorbable screws
- postop
 - rehabilitation
 - mobilization
 - immediate early range of motion
 - weightbearing
 - delay weight bearing for 6-8 weeks
 - stress strengthening of the quadriceps and abductors
 - radiographs
 - radiographs after 6 months to evaluate for AVN and osteoarthritis
- **ORIF of femoral head and acetabulum (Pipkin IV)**
 - approach
 - posterior (Kocher-Langenbeck) approach with digastric osteotomy



- trochanteric osteotomy allows access to both the femoral head fracture and posterior wall acetabular fracture
- preserves the medial circumflex artery supply to the femoral head
- utilizes plane created by splitting of gluteus maximus (no true internervous plane)
- anterior (Smith-Peterson) approach
 - for fixation of suprafoveal fractures
 - small posterior wall fractures may not need to be addressed surgically

○ Arthroplasty

- approach
 - can use any hip approach for arthroplasty
 - posterior (Kocher-Langenbeck) approach provides the best visualization of acetabular posterior wall fracture
- pros & cons
 - allows immediate postoperative mobilization and weightbearing
 - hemiarthroplasty can be utilized if no acetabular fracture present

• Complications

○ Heterotopic ossification



- overall incidence is 6-64%
 - anterior approach has increased heterotopic ossification compared with posterior approach
- treatment
 - administer radiation therapy if there is concern for HO
 - especially if there is an associated head injury

○ AVN

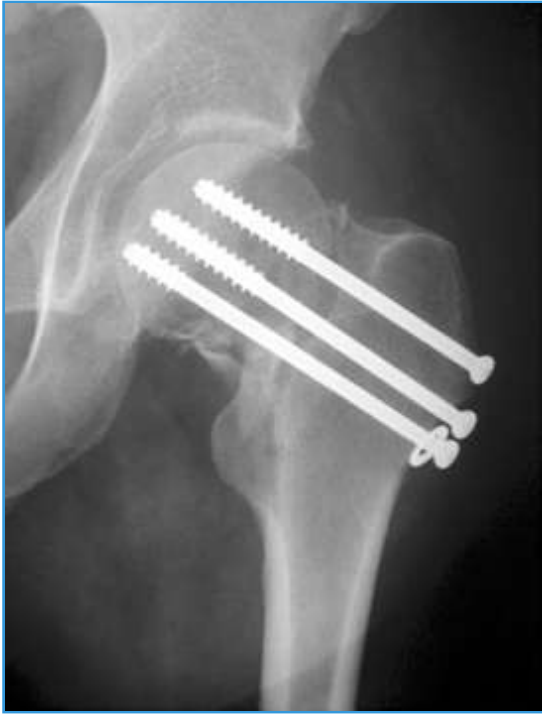
- incidence is 0-23%
 - risk is greater with delayed reduction of dislocated hip
 - anterior approach not associated with increased AVN risk

○ Sciatic nerve neuropraxia

- incidence is 10-23%
 - usually peroneal division of sciatic nerve
 - spontaneous recovery of function in 60-70%
- DJD
 - incidence 8-75%
 - due to joint incongruity or initial cartilage damage
- Decreased internal rotation
 - may not be clinically problematic or cause disability

50- Femoral Neck Fx Nonunion

Images

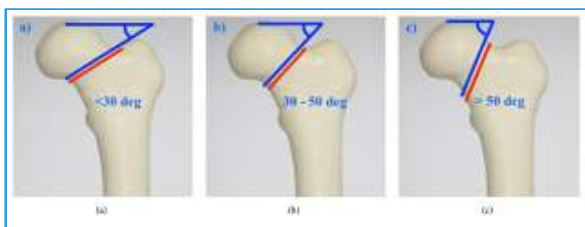


• Summary

- Femoral neck fracture nonunion represents a failure of bony healing after fixation of an intracapsular femoral neck fracture.
- Diagnosis is generally confirmed by radiographs demonstrating residual fracture lines, interval displacement and hardware failure.
- Treatment is operative ranging from valgus intertrochanteric femoral osteotomy to total hip arthroplasty depending on available bone stock, presence of avascular necrosis and patient age.

• Epidemiology

- Incidence
 - occur after 10-30% of femoral neck ORIF
- Demographics
 - increasing age at higher risk for nonunion
- Risk factors
 - fracture morphology
 - significant initial displacement
 - vertically oriented fracture pattern (Pauwels type III)
 - posterior comminution
 - fracture malreduction, particularly with varus malalignment
 - older age
 - delay of fracture fixation >24 hours



• Etiology

- Pathophysiology
 - mechanism of injury
 - initial femoral neck fracture occurs due to high energy trauma in the younger population, and ground-level falls in the elderly
 - nonunion occurs after fracture displacement and/or hardware failure before bony consolidation
 - pathoanatomy
 - femoral neck fractures are intracapsular, placing them at higher risk for nonunion than other hip fractures
 - lack periosteal or extraosseous blood supply

- bathed in synovial fluid which deters fracture healing
- healing is intra-osseous only (no callus formation)
 - achieving and maintaining anatomic reduction is essential

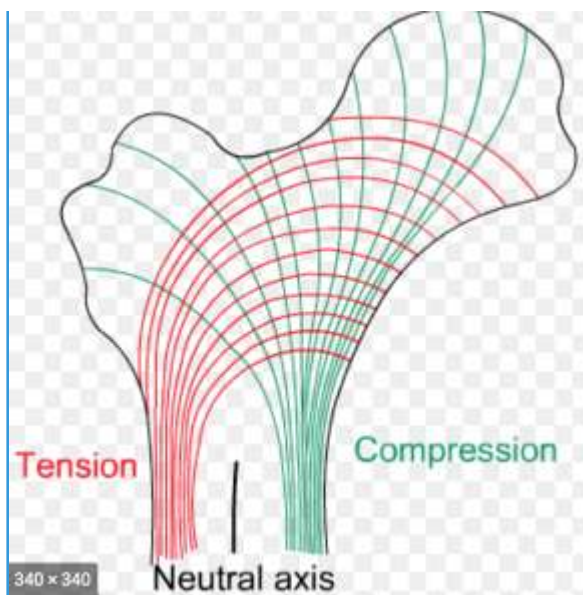
○ Associated conditions

- orthopaedic conditions
 - avascular necrosis (AVN)
 - femoral neck malunion
 - hardware failure
 - surgical site infection leading to septic nonunion
- medical conditions or comorbidities
 - low bone mineral density

• Anatomy

○ Osteology

- normal proximal femur neck shaft-angle $130 \pm 7^\circ$
- normal proximal femur anteversion $10 \pm 7^\circ$
- proximal femur consists of tensile and compressive trabecular groups



○ Muscles

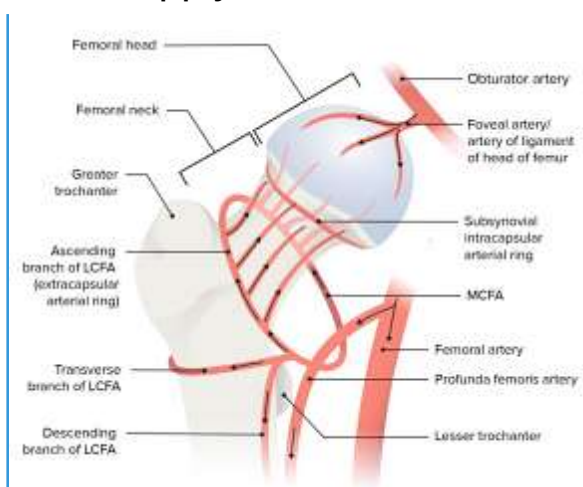
- hip abductors
 - important to preserve neurovascular supply and attachments of abductors to avoid abductor lurch and Trendelenburg gait

○ Ligaments

- iliofemoral, ischiofemoral and pubofemoral ligaments attach to outer hip capsule and help to prevent excessive hip motion

○ Blood Supply

- a confluence of arteries forms an extracapsular arterial ring that divides into the ascending cervical arteries which supply the femoral neck via perforators



- main blood supply in adults is the medial femoral circumflex artery (lateral epiphyseal artery)
- lateral femoral circumflex contributes to anterior arterial ring
- superior and inferior gluteal arteries give small contributions to arterial ring
- artery of ligamentum teres comes from obturator or medial femoral circumflex
 - plays insignificant role in blood supply

- femoral neck fracture with displacement is thought to disrupt the blood supply to the femoral neck

○ Biomechanics

- in double-leg stance, force vector through hip is vertical
- in single-leg stance, force vector through hip is parallel to femoral neck

- compressive load through hip is 4x bodyweight
- repetitive loading can increase tensile forces and lead to superior femoral neck fracture

• Classification

○ Primarily descriptive

■ Leighton's classification		
■ Type 1	■ Inadequate fixation or non-anatomic reduction	■ 
■ Type 2	■ Loss of fixation with fracture displacement	■ 
■ Type 3	■ Fibrous nonunion with no displacement and intact fixation	■ 

• Presentation

○ History

- prior femoral neck fracture
- evaluation of medical history
 - low bone density
 - metabolic disease
 - nutritional deficiencies
 - tobacco use

○ Symptoms

- persistent groin/buttock pain
- pain with weight bearing
- pain with hip extension
- pain may radiate down medial thigh/knee

○ Physical exam

- inspection
 - important to evaluate prior incision for drainage, erythema and to verify approach of prior surgery
- motion
 - discomfort with active or passive range of motion at hip
 - decreased internal rotation
 - antalgic gait
- neurovascular
 - evaluate sciatic and femoral nerve function
- provocative tests
 - pain with log-roll
 - pain with straight leg raise

• Imaging

○ Radiographs



- recommended views
 - AP pelvis and hip
 - cross-table lateral hip
 - full length femur
 - optional views
 - traction/internal rotation hip view
 - contralateral hip films for intraoperative templating
- findings
 - radiolucent fracture lines
 - fracture settling
 - failure of hardware (backing out)
 - perforation of femoral head with hardware
 - change in fracture position by >10mm
 - femoral head collapse (AVN)
 - calcar comminution
 - varus malalignment

○ CT



- indications
 - most definitive way to diagnose femoral neck nonunion
 - useful if diagnosis uncertain or for surgical planning

○ MRI

- indications
 - concern for diagnosis of femoral head AVN in the setting of nonunion

- Bone scan
 - indications
 - may help rule out concomitant femoral head AVN
 - findings
 - may show increased uptake in area of the nonunion
- Studies
 - Labs
 - indications
 - must rule out infection
 - inflammatory markers
 - CBC with manual diff
 - ESR
 - CRP
 - Hip aspiration
 - indications
 - if high suspicion for infection in the setting of elevated inflammatory markers
 - Intraoperative tissue sample
 - if concerned for infection, can send frozen-section for histology before proceeding with further fixation
 - if positive for infection, staged approach preferred

• Treatment

- Nonoperative
 - **observation**
 - indications
 - only indicated in non-ambulatory patients with comorbid conditions
 - outcomes
 - poor functional outcomes with non-operative management
- Operative
 - **revision ORIF**
 - indications
 - not recommended due to:
 - proximal bone loss
 - residual leg length discrepancy
 - high residual failure rates
 - **proximal femoral osteotomy**
 - indications
 - failure of fracture fixation
 - nonunion >3 months postoperatively
 - varus collapse
 - considerations
 - femoral head viability
 - remaining femoral neck bone quality
 - patient age
 - in younger patients, arthroplasty may be less desirable
 - duration of nonunion
 - longer duration may cause contractures, fibrosis and acetabular wear
 - techniques
 - valgus intertrochanteric osteotomy



- most commonly used salvage procedure
 - primary issue is mechanical orientation of fracture in this group

- technique reorients vertical fracture to a horizontal fracture to achieve compression at the nonunion site
- improves abductor function by restoring femoral length and abductor lever arm
- patients may still describe persistent limp due to abductor weakness
- contraindications
 - significant bone loss
 - joint incongruity
 - age > 65 (relative)
- outcomes
 - 80-90% union rates
 - high percentage of associated femoral head AVN but only small percentage remain symptomatic after osteotomy

▪ **bone grafting**



- indications
 - failed prior fixation attempts
 - nonunion remains well aligned with loss of posterior bone stock
- techniques
 - quadratus femoris-vascularized pedicle graft
 - free vascularized fibular grafting
- outcomes
 - may not be as beneficial when fracture malalignment is primary cause of nonunion
 - union rates up to 90%
- **hip hemiarthroplasty**
 - indications
 - low physical demand and more comorbidities
 - cognitive decline
 - techniques
 - cemented vs. uncemented
 - outcomes
 - less extensile than THA
 - lower dislocation rate compared with THA
 - contraindications
 - significant acetabular erosion
- **total hip arthroplasty**
 - indications
 - salvage operation of choice in older patients with femoral neck fracture nonunion
 - prior femoral bony defect
 - poor acetabular bone quality
 - outcomes
 - excellent 10-year survivorship (~90%)
 - improved for patients greater than 65
 - complications
 - dislocation
 - rates may be decreasing with advent of new implant technologies
 - trochanteric nonunion
 - thromboembolic complication
 - loosening
 - infection
- **hip arthrodesis**
 - indications
 - young patients with nonviable femoral heads
 - heavy manual laborers
 - outcomes

- arthroplasty becoming favored over arthrodesis, even at young age

• Technique

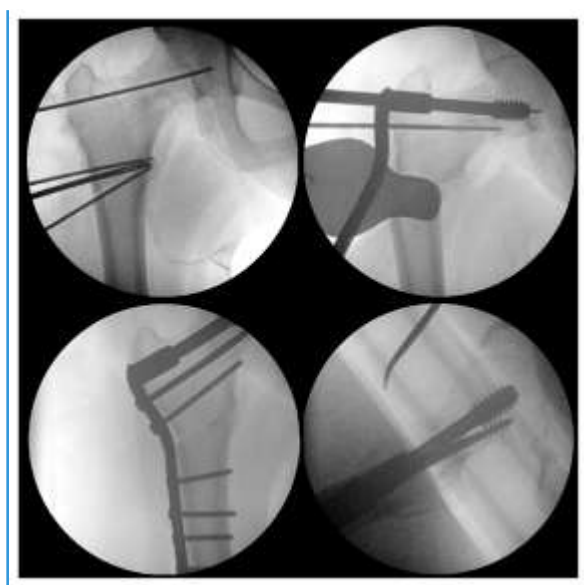
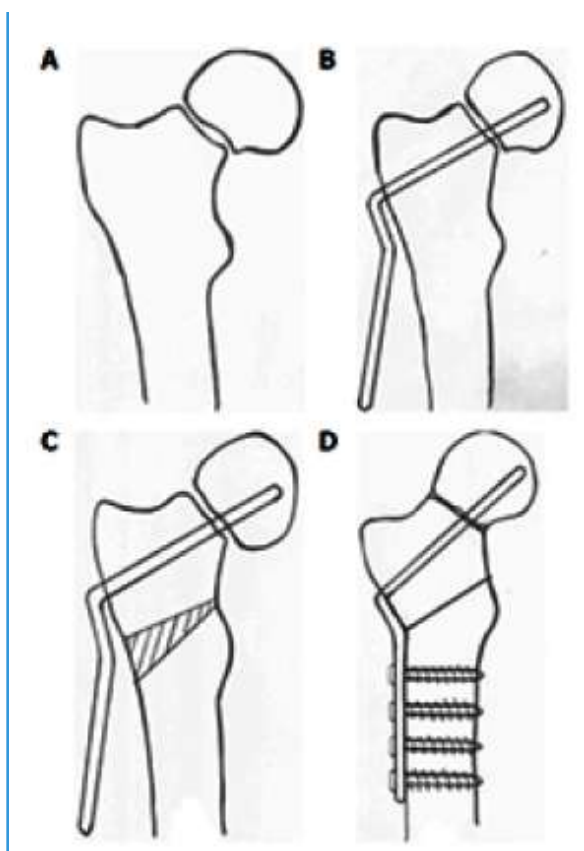
◦ Observation

- bedrest, non-weightbearing on affected extremity
- complications
 - may increase risk for other systemic complications

◦ Revision ORIF

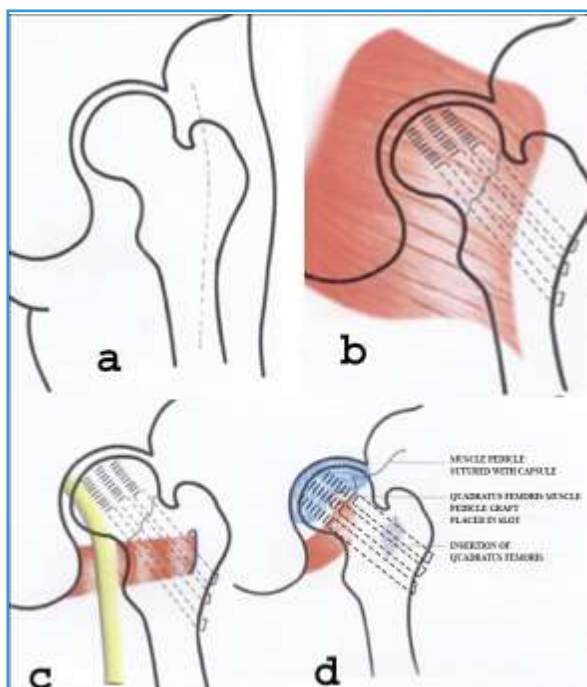
- approach
 - through initial incision when appropriate
- technique
 - removal of hardware, adequate reduction of fracture
 - new stable bony fixation with bone grafting
- complications
 - very high failure rates
 - residual leg length discrepancy

◦ Valgus intertrochanteric osteotomy



- approach
 - direct lateral approach to proximal femur
 - technique
 - goal is to convert vertically oriented fracture to about 30 degrees in order to create compression
 - can use blade plate or sliding hip screw for ultimate fixation
 - complications
 - femoral malrotation
 - excessive medialization of femoral shaft can decrease offset
 - cause abductor efficiency
 - a longer blade can avoid medialization of shaft
- ### ◦ Bone grafting
- approach

- lateral incision just anterior to greater trochanter between 10-15cm long
- technique
 - quadratus femoris-vascularized pedicle graft



- insertion of quadratus taken down off the greater trochanter with a bony flap that is transplanted to the posterior femoral neck and sutured or fixed into place with screws
 - free vascularized fibular grafting
- complications
 - donor site morbidity
 - may need to be combined with mechanical realignment
- **Hip hemiarthroplasty**
 - approach
 - posterior
 - anterolateral
 - direct anterior
 - technique
 - unipolar vs. bipolar
 - recent studies have not shown bipolar femoral heads to provide any benefit over unipolar heads
 - cemented shows superior outcomes, fewer complications than uncemented
 - complications
 - results of failed hip hemiarthroplasty when converted to THA are worse than primary THA.
- **Total hip arthroplasty**
 - approach
 - similar to hip hemiarthroplasty
 - technique
 - there may be residual bony defects in proximal femur from old hardware
 - may have to bypass this area with longer stems
 - may increase risk for intraoperative fracture while reaming the canal
 - poor acetabular bone quality can make cup placement difficult and increase risk for fracture
 - avoid overly aggressive acetabular component impaction
 - augment cup with screws
 - complications
 - dislocation
 - use of larger diameter heads and new implant technology (i.e dual mobility) may be helpful in decreasing dislocation rates
 - increased rates of aseptic loosening
 - risks include patient age < 65 and BMI >30.
- **Hip arthrodesis**
 - approach
 - lateral approach with trochanteric osteotomy
 - technique
 - optimal positioning of hip joint:
 - 20-35° hip flexion
 - 0-5° adduction

- 5-10° external rotation
 - complications
 - adjacent joint arthrosis/pain
 - low back pain
- Complications
 - Concomitant femoral head AVN
 - incidence
 - up to 40% in setting of nonunion
 - around 15% appear to be symptomatic
 - risk factors
 - initial fracture displacement
 - poor reduction
 - treatment
 - **hip arthroplasty**
 - Acetabular cartilage degeneration
 - risk factors
 - associated femoral head AVN or chondral wear
 - treatment
 - **total hip arthroplasty**
 - Trendelenburg gait
 - risk factors
 - loss of femoral offset secondary to abductor inefficiency in nonunion/malunion or valgus producing osteotomy
 - treatment
 - avoiding loss of femoral offset or damage to abductors during salvage operations
 - Prosthetic dislocation
 - incidence
 - 10-20% in salvage total hip arthroplasty group compared to <10% in primary arthroplasty group after femoral neck fracture
 - risk factors
 - abductor insufficiency
 - abnormal hip joint kinematics after nonunion
 - posterior hip approach
 - treatment
 - larger femoral heads, dual mobility implants may decrease risk
 - choose surgical approach to optimize stability
- Prognosis
 - Natural history
 - typically, patients present with pain and difficulty with ambulation months after fixation
 - persistent pain with radiographic lack of healing at 3 months signifies likely nonunion .
 - revision surgery should be considered at this point.
 - Prognostic variables (poor)
 - unfavorable fracture patterns
 - malreduction
 - poor bone quality
 - Survival with treatment
 - valgus intertrochanteric osteotomy
 - eventual union rates of 80-90%
 - hip arthroplasty
 - approximately 90% implant survivorship at 10 years, 75% at 20 years.
 - higher rate of dislocation (up to 10-20%), compared to primary hip arthroplasty

51- Patella Fracture

- summary

- Patella Fractures are traumatic knee injuries caused by direct trauma or rapid contracture of the quadriceps with a flexed knee that can lead to loss of the extensor mechanism.
- Diagnosis can be made clinically with the inability to perform a straight leg raise and confirmed with radiographs of the knee.
- Treatment is either immobilization or surgical fixation depending on fracture displacement and integrity of the extensor mechanism.

- Epidemiology

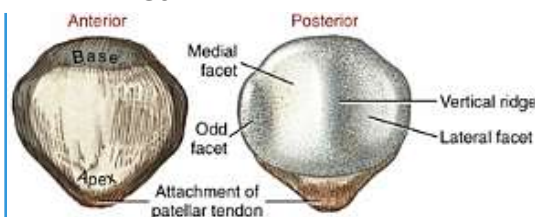
- Incidence
 - account for 1% of all skeletal injuries
 - 6-9% are open fractures
- Demographics
 - male to female 2:1
 - most fractures occur in 20-50 year olds

- Etiology

- Pathophysiology
 - mechanism of injury
 - direct impact
 - due to fall, dashboard injury or other high energy mechanism
 - often causes comminuted fracture pattern with chondral damage
 - retinaculum may remain intact
 - indirect eccentric contraction
 - occurs from rapid knee flexion against contracted quadriceps muscle
 - causes failure in tension
 - often results in transverse fracture or inferior pole avulsion
 - retinacular injury is typical
 - patella sleeve fracture
 - seen in the pediatric population (8-10-year-olds)
 - high index of suspicion required
- Associated conditions
 - orthopaedic conditions
 - femoral neck fracture
 - posterior wall acetabular fracture
 - knee dislocation

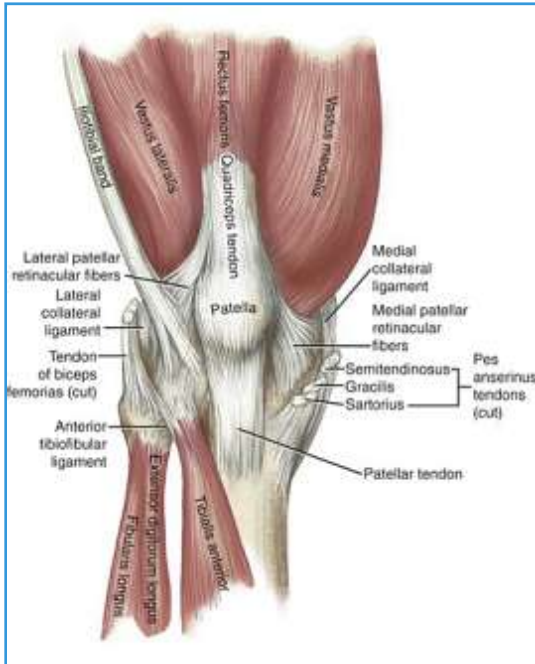
- Anatomy

- Osteology

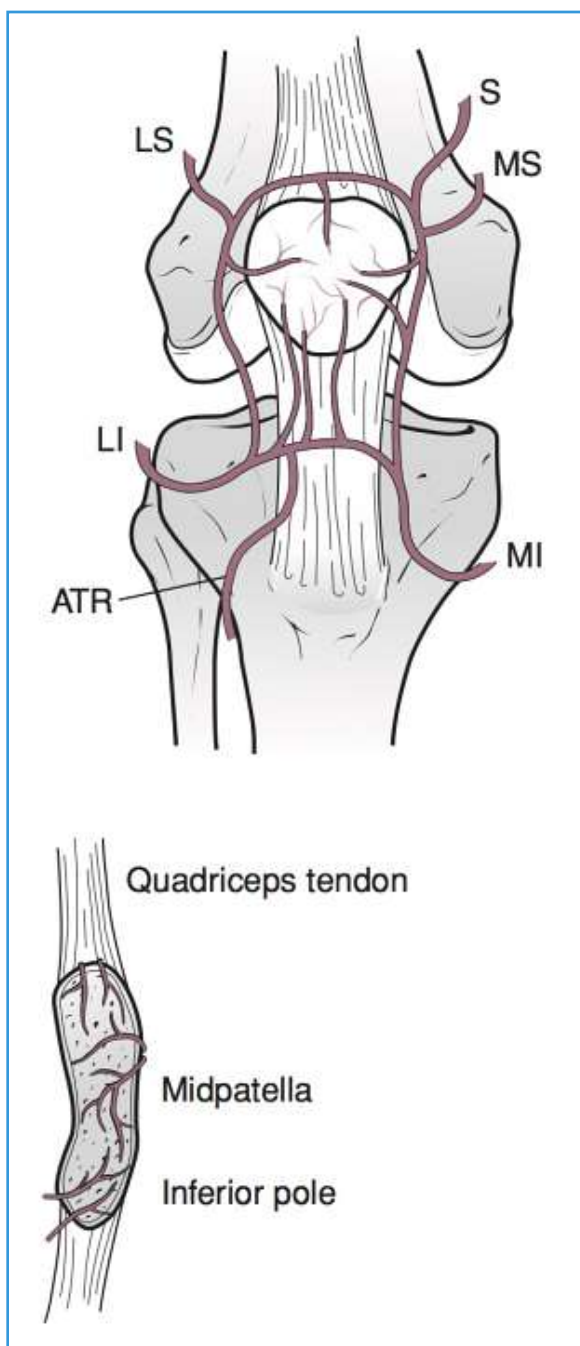


- patella is the largest sesamoid bone in the body
- superior 3/4 of posterior surface covered by articular cartilage
 - articular cartilage thickest in body (up to 1cm)
 - inferior 1/4 devoid of cartilage
- posterior articular surface comprised of two large facets (medial and lateral)
 - lateral facet is larger

- each facet separated into smaller facets and divided by vertical ridge
- bipartite patella (variably present)
 - usually superolateral
 - occurs in approximately 2-3% of population
- Ligaments
 - medial patellofemoral ligament (MPFL)
 - origin between medial epicondyle and adductor tubercle on femur
 - attaches approximately to upper 2/3 of medial patella
 - acts as primary ligamentous restraint to lateral patellar translation
 - most effective from 0-30° of flexion before patella engages trochlear groove
- Tendons



- quadriceps tendon
 - quadriceps tendon and fascia lata attach to anterosuperior margin of patella
 - quadriceps tendon comprised of 3 layers
 - superficial layer formed from rectus femoris tendon
 - middle layer formed by vastus medialis and vastus lateralis tendons
 - deep layer formed by vastus intermedius tendon
- patellar tendon
 - attaches to inferior pole of patella
- retinaculum
 - formed by fascia lata, vastus medialis and vastus lateralis
 - contributes to strength of extensor mechanism
 - should be repaired at time of patellar fixation
- Blood Supply



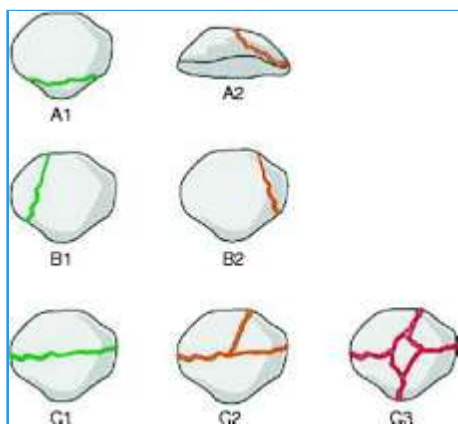
- derives from anastomotic ring originating from geniculate arteries
 - lies anterior to quadriceps tendon and posterior to patellar tendon
- most important blood supply to the patella is located at the inferior pole
- Biomechanics
 - patella increases power and mechanical advantage of extensor mechanism by 30-50% by displacing it anteriorly away from the center of rotation
 - during knee flexion, patella experiences tension from quadriceps and patellar tendon and compressive loads across posterior patella

- Classification

- Descriptive based on fracture pattern

Fracture pattern classification	
Nondisplaced	
Displaced (step-off >2-3mm or fracture gap >1-4mm)	
Transverse	
Pole or sleeve (upper or lower)	
Vertical	
Marginal	
Osteochondral	
Comminuted (stellate)	

AO/OTA classification



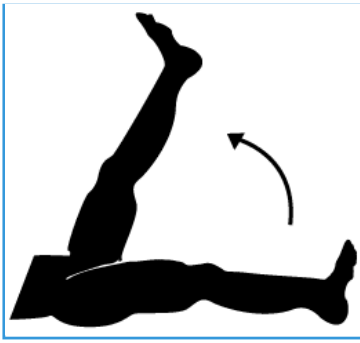
- 34-A: extra articular
- 34-B: partial articular
- 34-C: complete articular

PRESENTATION

- History
 - direct blow to knee or extensor mechanism injury
- Physical exam
 - inspection
 - palpable patellar defect



- significant hemarthrosis
 - lacerations, abrasions in setting of open fracture
 - motion
 - inability to perform straight leg raise



- extensor mechanism and retinaculum disrupted
- can aspirate hemarthrosis and inject local anesthetic if patient unable to perform due to pain
- provocative tests
 - saline load test can be performed to rule out concomitant knee joint involvement

• Imaging

◦ Radiographs

- recommended views
 - AP
 - lateral
 - best view to see transverse fx



- obtained with knee in 30° of flexion if possible
- helps evaluate articular step-off
- axial (sunrise/merchant views)
 - best view to see vertical fx



- findings
 - fracture displacement
 - degree of fracture displacement correlates with degree of retinacular disruption
 - patella alta



- Insall-Salvati ratio > 1.0
 - indicates disruption of patellar tendon
- patella baja
 - Insall-Salvati ratio < 1.0
 - indicates disruption of quadriceps tendon
- criteria dictating treatment
 - articular step-off $> 2\text{-}3\text{ mm}$ and displaced fracture gap $> 3\text{ mm}$ dictate operative management
- CT
 - indications
 - suspected distal pole comminution
 - patellar stress fracture
 - nonunion
 - malunion
 - views
 - sagittal views particularly useful for visualizing distal pole comminution
 - findings
 - change in operative plan in 50% of cases with CT
 - improved understanding of fracture patterns
 - particularly true in distal pole fracture patterns that are unappreciated on plain radiographs
- MRI
 - not typically indicated

• Differential

- Bipartite patella
 - may be mistaken for patella fracture



- smooth, regular borders seen on radiographs
- affects 2-3% of population
- caused by failure to unite secondary ossific nucleus
- characteristic superolateral position
- bilateral in 50% of cases

• Treatment

- Nonoperative
 - **knee immobilized in extension (knee immobilizer, hinged knee brace or cast) with full weight bearing**
 - indications
 - intact extensor mechanism (patient able to perform straight leg raise)
 - nondisplaced or minimally displaced fractures
 - vertical fracture patterns
 - significant medical comorbidities
 - modalities
 - early active ROM with hinged knee brace
 - early WBAT in full extension
 - active & active assist ROM at 1-2 weeks with resistance exercises beginning at 6 weeks
 - outcomes
 - good or excellent results in $>95\%$ of patients with proper indications
- Operative
 - **open reduction and internal fixation (ORIF)**
 - indications
 - preserve patella whenever possible

- extensor mechanism failure (unable to perform straight leg raise)
- open fractures
- fracture articular step-off > 2-3 mm
- displaced articular patella gap > 3 mm
- loose bodies
- osteochondral fractures
- patella sleeve fractures in children
- techniques
 - multiple techniques exist:
 - tension band construct
 - k-wires + wire
 - k-wires + suture
 - cannulated screws + wire
 - cannulated screws + suture
 - plate/screws
 - mini-fragment plate
 - mesh plate
 - may be preferred over tension band in cases of significant articular sided comminution
 - cerclage wiring
 - used alone or as supplement to primary fixation
- outcomes
 - high rates of union (>95%) despite technique
 - rates of nonunion higher with open fracture
 - symptomatic hardware requiring removal is common
 - recommended postoperative protocol
 - WBAT in hinged knee brace with flexion limited to 30° for 4 weeks and progressed incrementally thereafter
- **partial patellectomy +/- tendon advancement**
 - indications
 - comminuted extra-articular inferior pole fracture measuring <40% patellar height
 - only if ORIF is not possible
 - techniques
 - remove least bone possible
 - patellar tendon should be advanced into defect on anterior surface of patella
 - outcomes
 - decreases strength of extensor mechanism to increasing degree based on size of fragment removed
- **total patellectomy +/- tendon advancement**



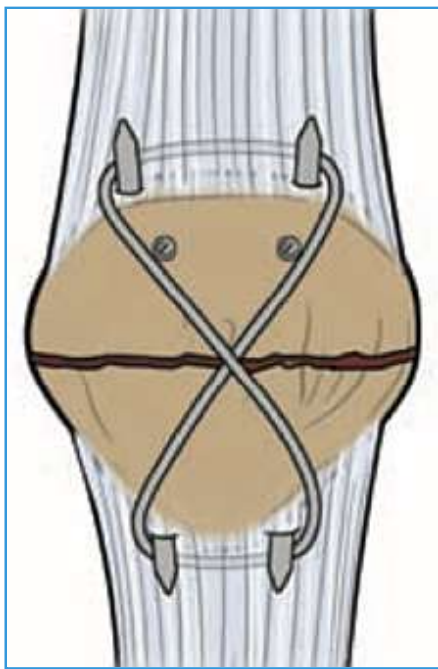
- indications (rare)
 - severe and extensive comminution not amenable to salvage
 - infection
 - tumor
- techniques
 - removal of patella
 - imbrication of quadriceps/patellar tendons
 - advancement of vastus and retinaculum

- outcomes
 - poor outcomes noted
 - decrease in extensor mechanism strength >50%

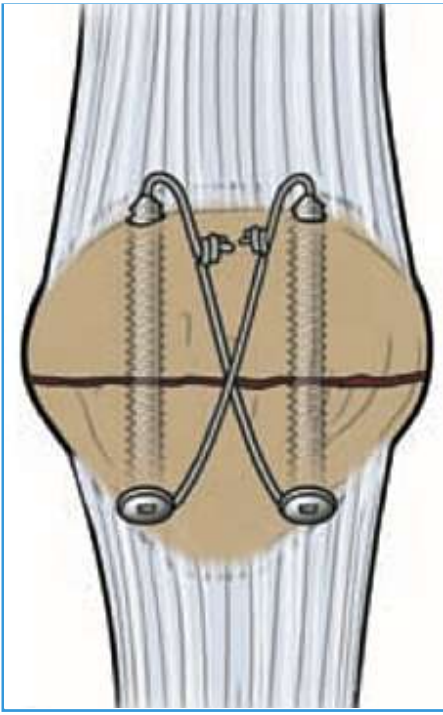
• Techniques

◦ Open reduction and internal fixation (ORIF)

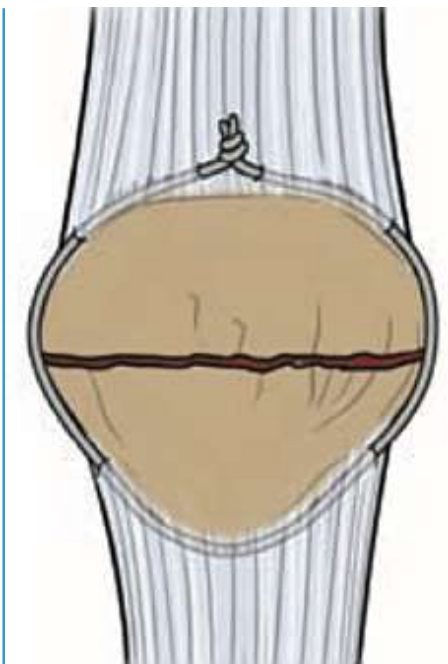
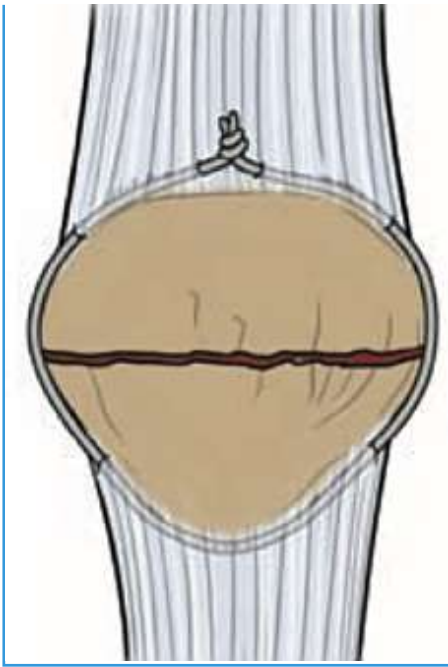
- approach
 - midline longitudinal incision centered over patella
 - expose articular surface either through fracture site or retinacular rents
 - can alternatively perform lateral parapatellar arthrotomy and invert patella if retinaculum is not damaged or if better visualization of articular surface is desired
- technique
 - avoid extensive soft tissue dissection to preserve blood supply and viability of skin flaps
 - retain as much of patella as possible
 - remove devitalized fragments and loose bodies
 - tension band construct
 - converts tensile forces generated by quadriceps complex at anterior surface into compressive forces at articular surface
 - tension band using 0.062 K-wires



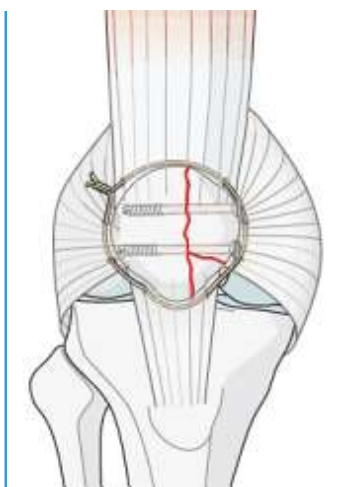
- k-wires + 18-gauge stainless steel wire
 - difficult to manipulate and high re-operation rates due to painful hardware or wire migration
- k-wires + suture
 - has 75% tensile strength of 18-gauge stainless steel wire but performs similarly clinically
 - lower rates of hardware removal when suture used
- tension band using longitudinal 4.0 mm cannulated screws



- biomechanically stronger than K-wires
- plate/screws construct
 - biomechanically superior to tension band construct
 - multiple plate options available
 - mini-fragment plates
 - useful in simple/comminuted fractures
 - helpful in osteoporotic bone
 - mesh plates
 - versatile with multiplanar screw options available
 - effective in stabilizing distal pole fractures with comminution
 - less fracture gapping compared to tension band wiring
- cerclage wiring



- used alone or to augment additional fixation such as interfragmentary lag screws or tension band construct

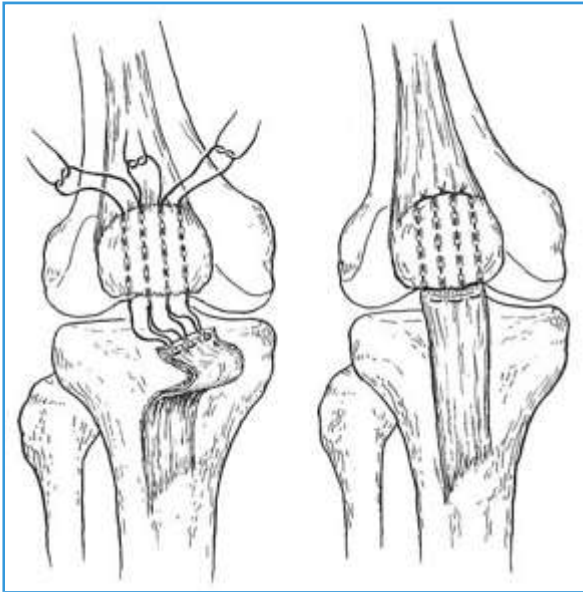


- useful in comminuted fractures
- complications
 - painful hardware/anterior knee pain
 - important to place tension wire at superior aspect of construct where more soft tissue coverage is available
 - consider using braided suture as opposed to 18-gauge stainless steel wire
 - plates may have lower rates of hardware irritation compared to tension banding
 - hardware failure
 - to prevent hardware failure in tension band construct:

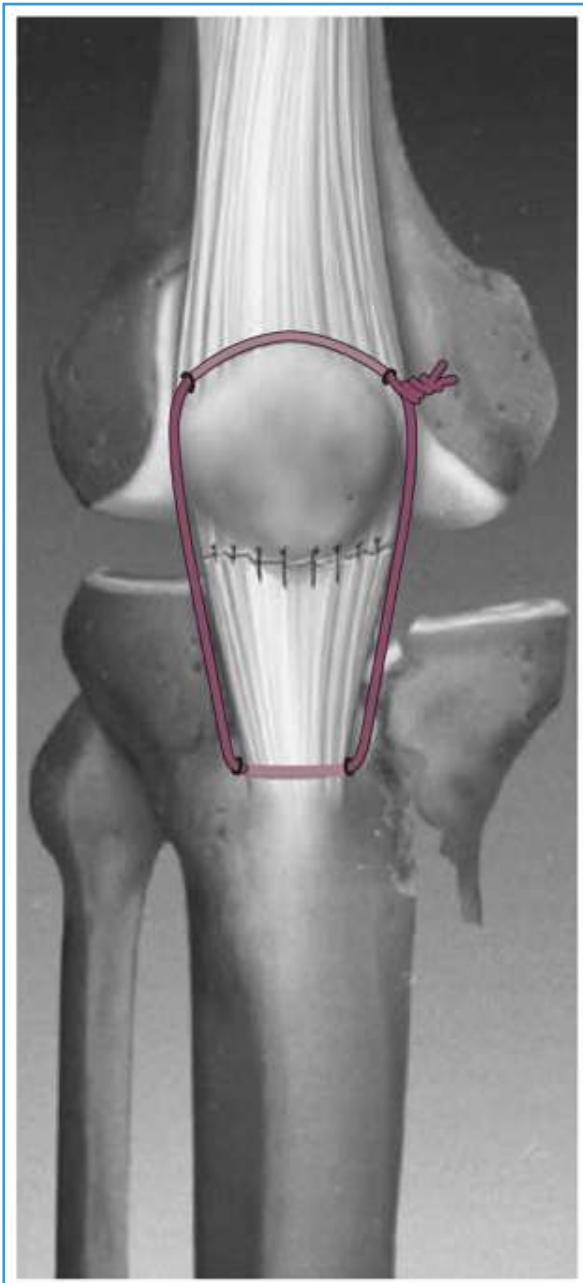
- tension wire in 2 places to apply equivalent tension in both sides of construct
- avoid overextending wire to prevent articular gapping or wire failure
- avoid prominent cannulated screw tips that can cause wire failure

○ **Partial patellectomy +/- tendon advancement**

- approach
 - same as ORIF (see above)
- technique
 - retain as much patella as possible
 - must remove devitalized fragments and loose bodies
 - reattach quadriceps or patellar tendon



- perform with transosseous tunnels or suture anchors with knee in hyperextension
- reattach as close to articular surface as possible
 - prevents patellar tilt and minimizes contact stresses
- perform retinacular repair
- if necessary, reinforce with cerclage suture or wire from quadriceps tendon to tibial tubercle



- complications
 - weakness
 - extensor lag
 - patella baja

○ **Total patellectomy +/- tendon advancement**



- approach
 - same as ORIF (see above)
- technique
 - remove all bony patellar fragments and loose bodies
 - restore integrity of extensor mechanism via imbrication of quadriceps and patellar tendons
 - medial and lateral retinacular repair remain essential
 - consider advancing VMO



- found to have better strength and outcomes
- complications
 - weakness
 - extensor lag
 - may avoid by performing sufficient imbrication

• Complications

- Anterior knee pain
 - risk factors
 - more common with ORIF
 - treatment
 - hardware removal after union
- Symptomatic hardware
 - incidence
 - most common complication, up to 50%
 - risk factors
 - thin body habitus
 - open fractures
 - thought to be due to compromised soft-tissue envelope
 - tension band construct using K-wires
 - treatment
 - hardware removal after union
- Weakness
 - risk factors
 - partial or total patellectomy
 - insufficient retinacular repair
 - treatment

- physical therapy
 - improvement may be limited based on procedure performed
- Loss of reduction
 - incidence
 - 0-22% of cases although catastrophic hardware failure is rare
 - risk factors
 - increasing age
 - osteoporotic bone
 - treatment
 - may require revision ORIF, but if degree of reduction loss is small, may not affect union
- Nonunion
 - incidence
 - <1-5%
 - risk factors
 - open fracture
 - treatment
 - typically well-tolerated
 - revision ORIF with bone grafting
 - can consider partial patellectomy
- Osteonecrosis
 - incidence
 - up to 25%, usually asymptomatic
 - risk factors
 - proximal pole fracture
 - thought to be due to excessive initial fracture displacement
 - treatment
 - can observe these, as most spontaneously revascularize by 2 years
- Infection
 - incidence
 - 0-5%
 - risk factors
 - open fracture
 - rates 10-11%
 - treatment
 - may require I&D, possible hardware removal
- Stiffness
 - risk factors
 - longer period of immobilization
 - open fracture or soft tissue injury
 - concomitant lower extremity injuries
 - treatment
 - usually resolves with aggressive physical therapy after fracture union
- Post-traumatic patellofemoral osteoarthritis
 - incidence
 - up to 50%
 - risk factors
 - degree of traumatic mechanism
 - articular malreduction
 - treatment
 - symptomatic management
 - total knee arthroplasty (TKA)

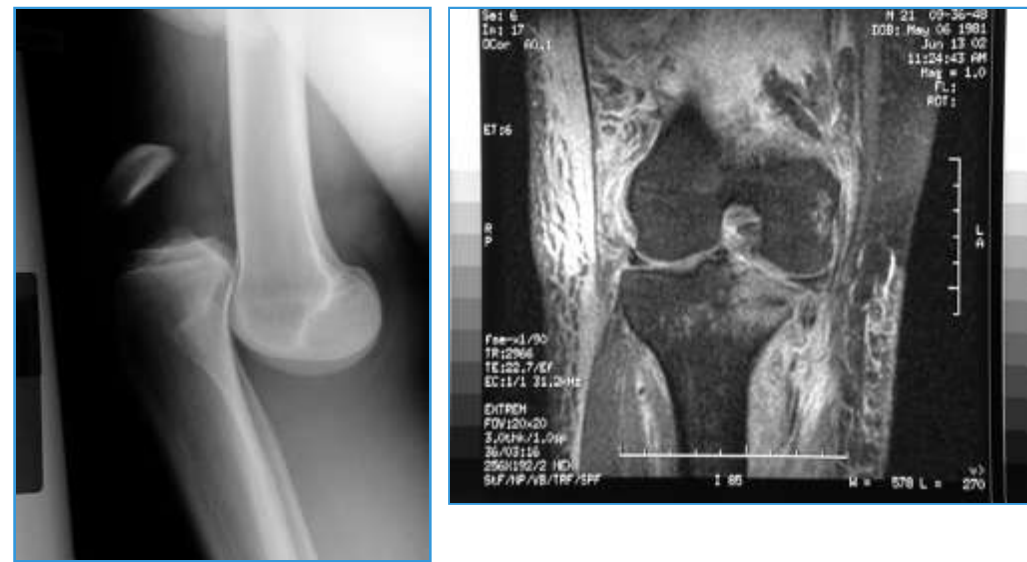
• Prognosis

- Most patella fractures heal uneventfully
 - osteonecrosis reported to occur in up to 25% but not found to affect clinical outcome
- Poor prognostic variables

- significant comminution
 - treated with partial or total patellectomy
- open fracture
- history of smoking

52- Knee Dislocation

Images



• Summary

- Knee dislocations are high energy traumatic injuries characterized by a high rate of neurovascular injury.
- Diagnosis is made clinically with careful assessment of limb neurovascular status. Radiographs should be obtained to document reduction.
- Treatment is generally emergent reduction and stabilization with assessment of limb perfusion followed by delayed ligamentous reconstruction.

• Epidemiology

- Incidence
 - rare
 - 0.02% of orthopedic injuries
 - likely underreported as approximately 50% self-reduce and are misdiagnosed
- Demographics
 - 4:1 male to female ratio
- Location
 - tibiofemoral articulation (knee joint)
- Risk factors
 - morbid obesity is a risk factor for "ultra-low energy" knee dislocations with activities of daily living

• Pathophysiology

- Mechanism of injury
 - high-energy vs low energy
 - high energy is usually from MVC, crush injury, fall from a height, or dashboard injury resulting in axial load to a flexed knee
 - low energy may be from an athletic injury or routine walking
 - hyperextension injury leads to anterior dislocations
 - posteriorly directed force across the proximal tibia (dashboard injuries) leads to posterior dislocations
- Associated injuries
 - vascular injury
 - nerve injury
 - usually common peroneal nerve injury (25% incidence)
 - tibial nerve injury is less common
 - fractures
 - present in 60% of dislocations
 - soft tissue injuries
 - patellar tendon rupture
 - periarticular avulsion
 - displaced menisci

- **Anatomy**
 - Osteology
 - the knee is a ginglymoid joint and consists of tibiofemoral, patellofemoral and tibiofibular articulations
 - Ligaments
 - PCL, ACL, LCL, MCL, and PLC are all at risk for injury
 - main stabilizers of the knee given the limited stability afforded by the bony articulations
 - Blood supply
 - popliteal artery injuries occur often due to tethering at the popliteal fossa
 - proximal - fibrous tunnel at the adductor hiatus
 - distal - fibrous tunnel at soleus muscle
 - geniculate arteries may provide collateral flow and palpable pulses masking a limb-threatening vascular injury
 - Biomechanics
 - the normal range of motion of 0-140 degrees with 8-12 degrees of rotation during flexion/extension

- **Classification**

- Descriptive
 - Kennedy classification based on the direction of displacement of the tibia

▪ Kennedy classification (based on the direction of displacement of the tibia)		
▪ Anterior (30-50%)	▪ most common ▪ due to hyperextension injury ▪ usually involves tear of PCL ▪ an arterial injury is generally an intimal tear due to traction ▪ the highest rate of peroneal nerve injury	▪
▪ Posterior (30-40%)	▪ 2nd most common ▪ due to axial load to the flexed knee (dashboard injury) ▪ the highest rate of vascular injury based on Kennedy classification ▪ has highest incidence of a complete tear of the popliteal artery	▪
▪ Lateral (13%)	▪ due to a varus or valgus force ▪ usually involves tears of both ACL and PCL	▪
▪ Medial (3%)	▪ varus or valgus force ▪ usually disrupted PLC and PCL	▪
▪ Rotational (4%)	▪ usually irreducible ▪ posterolateral is most common rotational dislocation ▪ buttonholing of femoral condyle through the capsule	▪ 

- Schenck Classification
 - based on a pattern of multiligamentous injury of knee dislocation (KD)

▪ Schenck Classification (based on the number of ruptured ligaments)		
▪ KD I	▪ Multiligamentous injury with the involvement of the ACL or PCL	▪
▪ KD II	▪ Injury to ACL and PCL only (2 ligaments)	▪
▪ KD III	▪ Injury to ACL, PCL, and PMC or PLC (3 ligaments). ▪ KDIIM (ACL, PCL, MCL) and KDIIL (ACL, PCL, PLC, LCL).	▪
▪ KD IV	▪ Injury to ACL, PCL, PMC, and PLC (4 ligaments) ▪ Has the highest rate of vascular injury (5-15%)	▪
▪ KD V	▪ Multiligamentous injury with periarticular fracture	▪

- **Presentation**

- Symptoms
 - history of trauma and deformity of the knee
 - knee pain & instability
- Physical exam
 - appearance
 - no obvious deformity
 - 50% spontaneously reduce before arrival to ED
 - may present with subtle signs of trauma (swelling, effusion, abrasions, ecchymosis)

- obvious deformity
 - reduce immediately, especially if absent pulses
 - "dimple sign" - buttonholing of medial femoral condyle through the medial capsule



- indicative of an irreducible posterolateral dislocation
 - a contraindication to closed reduction due to risks of skin necrosis
- vascular exam
 - priority is to rule out vascular injury on exam both before and after reduction
 - serial examinations are mandatory
 - palpate the dorsalis pedis and posterior tibial pulses on injured and contralateral side
 - if pulses are present and normal
 - does not indicate the absence of arterial injury
 - collateral circulation can mask a complete popliteal artery occlusion
 - measure Ankle-Brachial Index (ABI) on all patients with suspected KD
 - if ABI >0.9
 - then monitor with serial examination (100% Negative Predictive Value)
 - if ABI <0.9
 - perform an arterial duplex ultrasound or CT angiography
 - if arterial injury confirmed then consult vascular surgery
 - If pulses are absent or diminished
 - confirm that the knee joint is reduced or perform immediate reduction and reassessment
 - immediate surgical exploration if pulses are still absent following reduction
 - ischemia time >8 hours has amputation rates as high as 86%
 - imaging contraindicated if it will delay surgical revascularization
 - if pulses present after reduction then measure ABI then consider observation vs. angiography
- neurologic exam
 - assess sensory and motor function of peroneal and tibial nerve as nerve deficits often occur concomitantly with vascular injuries
- stability
 - diagnosis based on instability on physical exam (radiographs and gross appearance may be normal)
 - may see recurvatum when held in extension



- assess ACL, PCL, MCL, LCL, and PLC

- Radiographs
 - recommended views
 - pre-reduction AP and lateral of the knee



- may be normal if spontaneous reduction
 - look for asymmetric or irregular joint space
 - look for avulsion fxs (Segond sign - lateral tibial condyle avulsion fx)
 - osteochondral defects
 - post reduction AP and lateral of the knee
 - optional views
 - 45-degree oblique if fracture suspected
- CT
 - indications
 - fracture identified on post reduction plain films
 - obtain post reduction CT for characterization of fracture
 - findings
 - tibial eminence, tibial tubercle, and tibial plateau fractures may be seen
- MRI
 - indications
 - obtain MRI after acute reduction but prior to hardware placement
 - required to evaluate soft tissue injury (ligaments, meniscus) and for surgical planning



• Treatment

- Nonoperative
 - **emergent closed reduction followed by vascular assessment/consult**
 - indications
 - considered an orthopedic emergency
 - vascular consult indicated if
 - pulses are absent or diminished following reduction
 - if arterial injury confirmed by arterial duplex ultrasound or CT angiography
 - **immobilization as definitive management**
 - indications (rare)
 - successful closed reduction without vascular compromise

- most cases require some form of surgical stabilization following reduction
 - outcomes
 - worse outcomes are seen with nonoperative management
 - prolonged immobilization will lead to loss of ROM with persistent instability
- Operative
 - **open reduction**
 - indications
 - irreducible knee
 - posterolateral dislocation
 - open fracture-dislocation
 - obesity (may be difficult to obtain closed)
 - vascular injury
 - **external fixation**
 - indications
 - vascular repair (takes precedence)
 - open fracture-dislocation
 - compartment syndrome
 - obese (if difficult to maintain reduction)
 - polytrauma patient
 - **delayed ligamentous reconstruction/repair**
 - indications
 - instability will require some kind of ligamentous repair or fixation
 - patients can be placed in a knee immobilizer until treated operatively
 - improved outcomes with early treatment (within 3 weeks)
- Technique
 - **Closed reduction**
 - approach
 - anterior dislocation - traction and anterior translation of the femur
 - posterior dislocation - traction, extension, and anterior translation of the tibia
 - medial/lateral - traction and medial or lateral translation
 - rotatory - axial limb traction and rotation in the opposite direction of deformity
 - splinting
 - 20 to 30 degrees of flexion
 - **Open reduction**
 - approach
 - midline incision with a medial parapatellar arthrotomy
 - soft tissue
 - the medial capsule may need to be pulled over medial condyle if buttonholed
 - acute associated soft tissue injuries (patellar tendon rupture, periarticular avulsion, or displaced menisci) may benefit from acute repair
 - bone work
 - periarticular fractures may be fixed acutely or spanned with external fixator depending on surgeon preference
 - instrumentation
 - place knee-spanning external fixator in 20-30 degrees of flexion with knee reduced in AP and sagittal planes
 - **Early ligamentous reconstruction (<3 weeks)**
 - approach
 - arthroscopic versus open
 - arthroscopic may not be possible if large capsular injury and creates a risk of fluid extravasation and compartment syndrome
 - PLC and PMC require open reconstruction given subcutaneous nature and proximity to neurovascular structures
 - soft tissue work
 - arthroscopic reconstruction of ACL and/or PCL

- address intraarticular pathology (menisci, cartilage defects, capsular injury)
- open repair versus reconstruction of collateral ligaments
- outcomes
 - acute (< 3 weeks) and staged reconstruction have equivalent outcomes

• Complications

- Vascular compromise
 - incidence
 - 5-15% in all dislocations
 - 40-50% in anterior or posterior dislocations
 - risk factors
 - KD IV injuries have the highest rate of vascular injuries
 - treatment
 - emergent vascular repair and prophylactic fasciotomies
- Stiffness (arthrofibrosis)
 - incidence
 - most common complication (38%)
 - risk factors
 - more common with delayed mobilization
 - treatment
 - avoid stiffness with early motion
 - arthroscopic lysis of adhesion
 - manipulation under anesthesia
- Laxity and instability
 - incidence
 - 37% of some instability, however, redislocation is uncommon
 - treatment
 - bracing
 - revision reconstruction
- Peroneal nerve injury
 - incidence
 - 25% occurrence of a peroneal nerve injury
 - 50% recover partially
 - risk factors
 - male gender
 - increased BMI
 - associated fibular head fracture
 - treatment
 - AFO to prevent equinus contracture
 - neurolysis or exploration at the time of reconstruction
 - nerve repair or reconstruction or tendon transfers if chronic nerve palsy persists
 - dynamic tendon transfer involves transferring the posterior tibial tendon (PTT) to the foot

• Prognosis

- Complications frequent and rarely does knee return to a pre-injury state

53- Tibial Plateau Fractures

Images



• Summary

- Tibial Plateau fractures are periarticular injuries of the proximal tibia frequently associated with soft tissue injury.
- Diagnosis is made with knee radiographs but frequently require CT scan for surgical planning.
- Treatment is often ORIF in the acute setting versus delayed fixation after soft tissue swelling subsides.

• Epidemiology

- Incidence
 - 1-2% of all fractures
 - 10.3 per 100,000 people annually
- Demographics
 - mean age 52
 - bimodal distribution
 - males in 40s (high-energy trauma)
 - females in 70s (low energy falls)
- Location
 - lateral plateau 70-80%
 - bicondylar 10-30%
 - medial plateau 10-20%

• Etiology

- Mechanism
 - Vector of applied load, amount of energy, and quality of bone determine type of fracture
 - valgus load
 - lateral plateau
 - varus load
 - medial plateau
 - axial load
 - bicondylar
 - combination
 - fracture dislocation
 - high energy
 - usually medial-sided plateau fractures
 - frequently associated with soft tissue injuries
 - low energy
 - usually lateral plateau fractures
- Associated conditions
 - meniscal tears

- lateral meniscal tear
 - more common than medial
 - associated with Schatzker II fracture pattern
 - associated with >10mm articular depression
 - associated with >6mm condylar widening
- medial meniscal tear
 - most commonly associated with Schatzker IV fractures
- ACL injuries
 - more common in type IV and VI fractures (25%)
- compartment syndrome
- associated soft tissue injuries have little bearing on final outcomes
- neurovascular injury
 - commonly associated with Schatzker IV fracture-dislocations
 - common peroneal nerve is most common nerve injury

• Anatomy

○ Osteology

- lateral tibial plateau



- convex in shape
- proximal to the medial plateau
- less dense bone
- medial tibial plateau

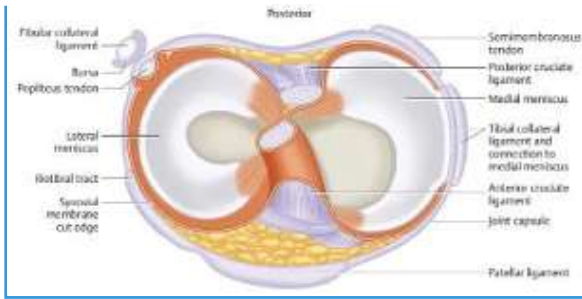


- concave in shape
- distal to the lateral tibial plateau
- alignment of proximal tibia



- posterior tibial slope
 - 6-10 deg
- varus slope
 - 3 deg relative to mechanical axis of tibia

- Ligaments



- ACL

- inserts anteriorly between tibial spines
 - primary restraint against anterior tibial translation
 - secondary stabilizer of tibial rotation

- PCL

- inserts on posterior tibial sulcus below articular surface
 - primary restraint to posterior tibial translation

- MCL

- two components
 - superficial MCL
 - broad insertion on proximal tibia deep to pes anserinus
 - primary stabilizer of valgus stress
 - deep MCL
 - attaches to medial meniscus
 - secondary stabilizer to valgus stress

- LCL

- inserts on anterolateral aspect of fibular head
 - primary restraint to varus stress at 30 deg

- Meniscus

- lateral meniscus
 - covers larger portion of articular surface
 - more mobile
 - easier to assess articular surface laterally through submeniscal arthrotomy due to mobility of meniscus
 - medial meniscus
 - less mobile due to coronary ligaments

- Muscles

- 4 compartments in lower leg
 - anterior compartment
 - lateral compartment
 - superficial posterior
 - deep posterior

- Tendons

- patellar tendon
 - inserts anteriorly on tibial tubercle
 - iliotibial band
 - inserts on anterolateral aspect of proximal tibia at Gerdy's tubercle
 - hamstring tendons
 - pes anserine insert on anteromedial aspect of proximal tibia

- Neurovascular structures

- popliteal artery runs just posterior to knee capsule and bifurcates
 - anterior tibial artery
 - posterior tibial artery
 - tibial nerve
 - courses posteriorly along with popliteal artery
 - sensory: plantar aspect of foot
 - motor: innervates posterior compartments which control ankle plantarflexion and inversion of foot
 - common peroneal nerve
 - course around fibular neck
 - two branches
 - superficial peroneal nerve

- sensory: dorsum of foot (except first dorsal webspace)
- motor: innervates lateral compartment which controls ankle eversion
- deep peroneal nerve
 - sensory: first dorsal webspace of foot
 - motor: innervates anterior compartment which controls ankle dorsiflexion

- Biomechanics

- medial tibial condyle
 - bears 60% of load through knee
- lateral tibial condyle
 - bears 40% of load through knee

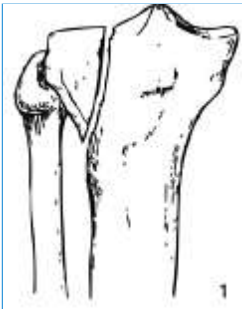
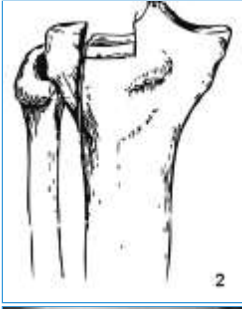
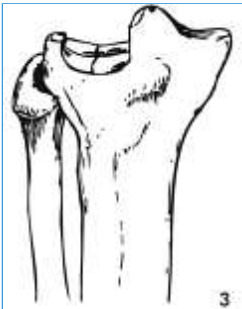
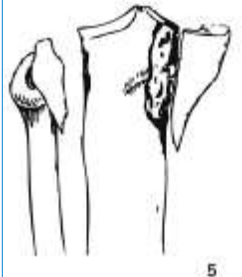
- Kinematics

- flexion-extension 0-140 degrees
 - functional ROM for walking 0-70 degrees
- posterior femoral rollback
 - screw-home mechanism
 - medial tibial plateau is concave creating a pivot point
 - lateral plateau is convex allowing for rollback of femur during flexion
- net effect
 - influences amount of terminal knee flexion
 - tibia externally rotates with knee extension

- Classification

- Schatzker classification

■ Schatzker Classification

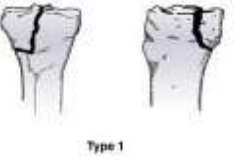
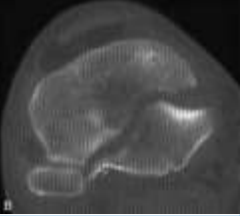
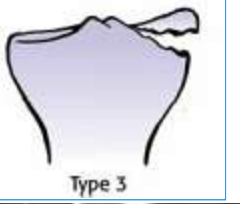
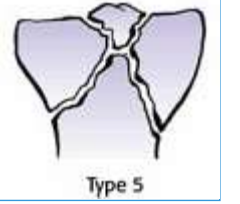
■ Type I	■ Lateral split fracture	■ young patient with strong subchondral bone	■  
■ Type II	■ Lateral Split-depressed fracture	■ most common	■  
■ Type III	■ Lateral Pure depression fracture	■ uncommon, elderly osteoporotic	■  
■ Type IV	■ Medial plateau fracture	■ associated fx-dislocation ■ high rate of NV and ligamentous injuries	■  
■ Type V	■ Bicondylar fracture	■ tibial spines remain continuous with shaft	■  

■ Type VI	■ Metaphyseal-diaphyseal disassociation	■ significant soft-tissue injury

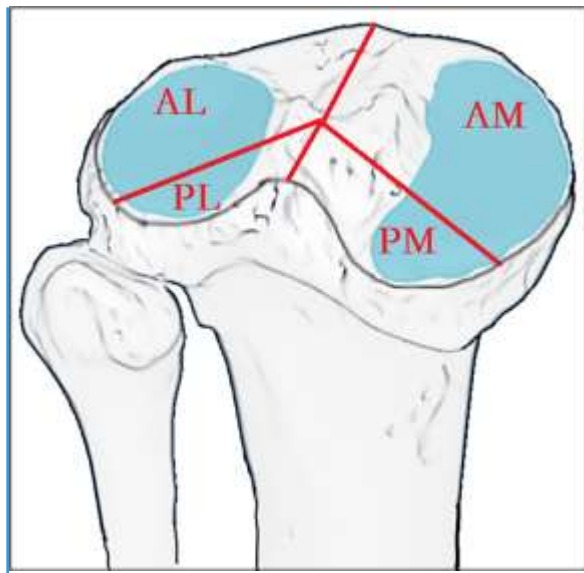
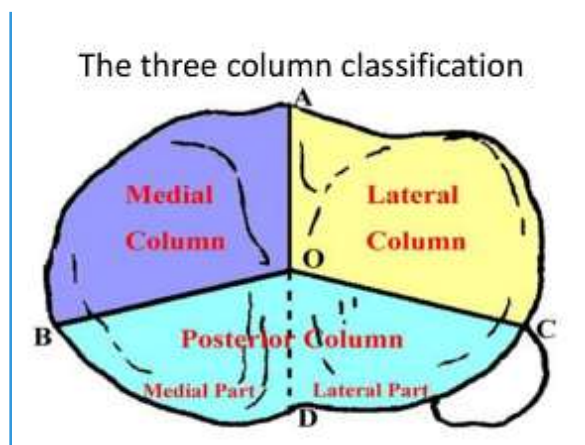


○ **Hohl and Moore Classification**

- Useful for
 - true fracture-dislocations
 - fracture patterns that do not fit into the Schatzker classification (10% of all tibial plateau fractures)
 - fractures associated with knee instability

■ Hohl and Moore Classification of proximal tibia fracture-dislocations		
■ Type I	■ Coronal split fracture	■  Type 1  
■ Type II	■ Entire condylar fracture	■  Type 2
■ Type III	■ Rim avulsion fracture of lateral plateau	■  Type 3 
■ Type IV	■ Rim compression fracture	■  Type 4
■ Type V	■ Four-part fracture	■  Type 5

○ **3-column concept**



- tibial plateau divided into 3 columns
 - medial column
 - lateral column
 - posterior column
- utility
 - includes posterior plateau fractures that are not considered in Schatzker classification
 - helps determine fixation strategy

• Presentation

◦ History

- mechanism of injury
 - high-energy vs low-energy
- unable to bear weight after injury
- baseline functional status
- comorbidities

◦ Physical exam

- inspection
 - look circumferentially to rule-out an open injury
 - assess soft-tissues for timing of operative intervention
- palpation
 - evaluate for compartment syndrome
- varus/valgus stress testing
 - any laxity >10 degrees indicates instability
 - often difficult to perform or deferred in acute setting given pain
 - stability assessed in full extension
- neurovascular exam
 - perform ankle-brachial index if any asymmetry in pulses
 - ABI <0.9 proceed with arteriogram
 - assess tibial and common peroneal nerve function

• Imaging

◦ Radiographs

- recommended views
 - AP
 - lateral
 - oblique
 - oblique is helpful to determine amount of depression

- optional views
 - plateau view
 - 10 degree caudal tilt to match posterior tibial slope
- findings
 - on AP
 - depressed articular surface



- sclerotic band of bone indicating depression
 - abnormal joint alignment
 - fracture plane involving medial/lateral plateau
- on lateral
 - posteromedial fracture lines must be recognized
 - abnormal tibial slope
- CT scan
 - indication
 - negative radiographs with high index of suspicion for tibial plateau fracture
 - preoperative planning
 - obtain after ex-fix if definitive fixation delayed if soft-tissues are not amenable for surgery
 - findings
 - articular depression
 - degree of comminution
 - fracture plane and location
 - posterior coronal split fracture best appreciated on axial and sagittal views
 - lipohemarthrosis indicates an occult fracture
- MRI
 - indications
 - not well established
 - identify meniscal and ligamentous pathology
 - occult fractures

• DIFFERENTIAL

- Distal femur fracture
- Knee dislocation
- Patella instability
- Patella fracture
- Patella tendon rupture
- Quadriceps tendon rupture
- ACL tear
- Meniscus tear

• Treatment

- Nonoperative

- **closed reduction / immobilization**
 - indications
 - minimally displaced split or depressed fractures
 - low energy fracture stable to varus/valgus alignment
 - nonambulatory patients
 - significant comorbidities that preclude surgical intervention
 - modalities
 - patella-tendon-bearing (PTB) cast
 - knee immobilizer
 - hinged knee brace
- Operative
 - **ORIF (acute vs staged)**
 - indications
 - articular depression > 5-10 mm
 - condylar widening > 5mm
 - varus/valgus instability >10 deg
 - medial plateau fractures
 - bicondylar fractures
 - timing
 - acute ORIF
 - lower-energy fractures with mild swelling
 - temporizing knee-spanning external fixation w/ delayed ORIF
 - significant soft tissue injury/swelling
 - polytrauma
 - outcomes
 - restoration of joint stability is strongest predictor of long-term outcomes
 - postoperative infection after ORIF associated with
 - male gender
 - smoking
 - pulmonary disease
 - bicondylar fracture patterns
 - intraoperative time over 3 hours
 - timing of definitive fixation (before, during or after) relative to fasciotomy closure does not increase the risk of infection
 - worse results with
 - ligamentous instability
 - meniscectomy
 - alteration of limb mechanical axis > 5 degrees
 - **external fixation/Ilizarov +/- limited open/percutaneous fixation of articular segment**
 - indications
 - severe open fracture with marked contamination
 - highly comminuted fractures where internal fixation not possible
 - outcomes
 - higher malunion rates
 - **arthroplasty**
 - indications
 - consider in patients >65-years-old with osteoporotic bone
 - outcomes
 - earlier time to weight bearing
 - improved outcomes for primary TKA compared to TKA for failed ORIF
- Techniques
 - **Closed reduction / immobilization**
 - technique
 - NWB or PWB in a hinged-knee brace for 8-12 weeks
 - early passive ROM is important to maintain motion

- **Knee-spanning external fixation (temporary)**

- technique
 - place pins outside area of planned definitive fixation
 - two 5-mm half-pins in femur and two in tibia shaft
 - axial traction applied to fixator
 - indirect reduction of fracture through ligamentotaxis
 - fixator is locked in slight flexion to avoid tensioning posterior NV structures
- advantages
 - allows soft tissue swelling to decrease before definitive fixation
 - decreases rate of infection and wound healing complications
 - restores length and alignment which helps to better characterize fracture on preop CT
- findings
 - transient increase in leg compartment pressures during external fixator placement
 - not been shown to increase risk of compartment syndrome

- **External fixation with limited internal fixation (definitive)**

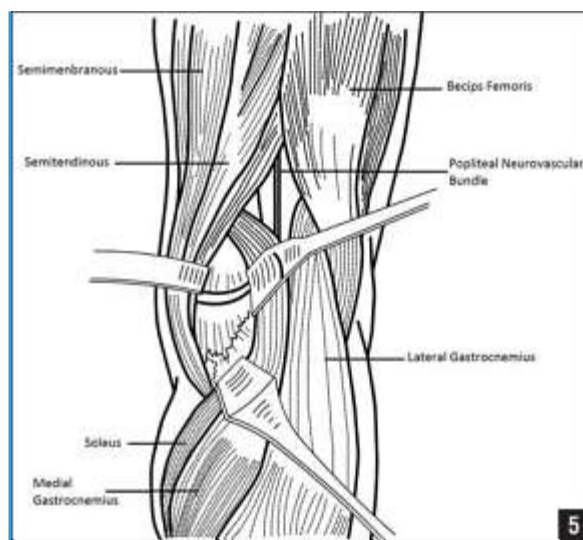
- technique



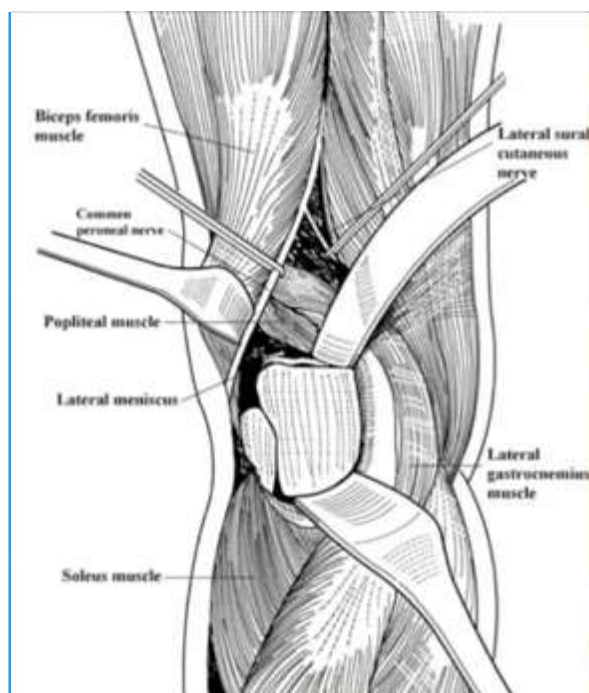
- reduce articular surface either percutaneously or through small incisions
- stabilize reduction with percutaneous lag screws or wires
 - must keep wires >14mm from joint to avoid intracapsular pin placement
- pros
 - minimizes soft tissue insult
- cons
 - pin site complications
 - arthrofibrosis
 - incidence as high as 15% after temporizing external fixator
 - high malunion rates

- **Open reduction internal fixation**

- goals
 - restore alignment
 - coronal
 - sagittal
 - tibial slope
 - normal condylar width
 - congruent articular surface
 - stable knee
 - minimize additional soft tissue trauma
- approach
 - anterolateral approach (most common)
 - supine
 - lazy S or hockey stick incision centered over Gerdy's tubercle
 - elevate anterior compartment musculature and IT band
 - submeniscal arthrotomy to assess articular surface and meniscus tear
 - posteromedial incision
 - supine with leg in figure-4 or prone
 - interval between pes anserinus and medial head of gastrocnemius

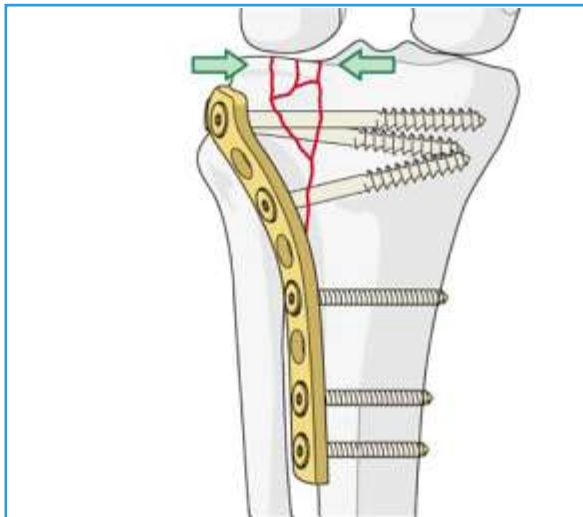


- can be extensile and access posterolateral column
 - release medial head of gastrocnemius off femur
 - elevate soleus and popliteus
- articular surface not routinely visualized directly
 - fluoroscopically or arthroscopically
- posterolateral approach



- prone or lateral
 - biceps and peroneal nerve retracted lateral
 - lateral gastroc and soleus retracted medial
- fibular neck osteotomy
 - posterolateral access infrequently used due higher risk of NV complication
- posterior
 - can be used for posterior shearing fractures
- midline incision (if planning TKA in future)
 - can lead to significant soft tissue stripping and should be avoided
- dual surgical incisions with dual plate fixation
 - indications
 - bicondylar tibial plateau fractures
- reduction
 - assess reduction
 - submeniscal arthrotomy
 - fluoroscopically
 - arthroscopically
 - depressed fragments
 - open fracture split and elevate ("open the book")
 - create cortical window and elevated with bone tamps
- fill metaphyseal void
 - three main options
 - autograft (ICBG - rare)
 - allograft (cancellous chips)
 - bone graft substitutes
 - calcium phosphate cement
 - high compressive strength for filling metaphyseal void

- less subsidence than ICBG
 - osteoconductive
 - biodegradable
 - highly porous
- internal fixation
 - absolute stability constructs should be used to maintain the joint reduction
 - screws
 - can be used in isolation but often used in conjunction with plate fixation
 - isolated depression
 - simple split fracture
 - options
 - raft screws
 - placed in subchondral bone parallel to joint surface to support elevated articular fragments
 - lag screws
 - placed perpendicular to plane of split fractures
 - plate fixation
 - conventional non-locking plates



- buttress plates best indicated for partial articular fractures
 - posteromedial fractures
 - simple split
 - peri-articular locking plates
 - fixed angle mitigates risk of varus collapse
 - comminuted fractures
 - osteoporotic bone
- postoperative
 - hinged knee brace with early passive ROM
 - gentle mechanical compression on repaired osteoarticular segments improves chondrocyte survival
 - NWB or PWB for 8 to 12 weeks

• Complications

- Post-traumatic arthritis
 - incidence
 - 25-35%
 - 3-7% undergo TKA at 10+ years
 - risk factors for arthritis
 - meniscectomy
 - malalignment > 5 deg
 - instability
 - risk factors for future TKA
 - age
 - bicondylar fracture
 - increasing comorbidities
- Compartment syndrome
 - incidence
 - 7-20%
 - risk factors

- Schatzker type IV
 - high-energy mechanism
 - associated fibula fracture
 - fracture length
 - associated plateau-shaft injury
- treatment
 - emergent fasciotomy
- Infection
 - incidence
 - 2-11%
 - risk factors
 - poor surgical timing based on swelling
 - open fractures
 - longer operative time
 - treatment
 - irrigation and debridement + IV abx
 - removal of hardware if loose or grossly infected
 - ex-fix and staged revision ORIF
 - retain hardware if fracture still healing and implant still providing stability
- Nonunion/malunion
 - incidence
 - 2-4%
 - uncommon due to rich blood supply of cancellous bone
 - risk factors
 - Schatzker type VI (metaphyseal-diaphyseal junction)
 - comminution
 - unstable fixation
 - treatment
 - revision osteosynthesis augmented with bone graft
- Knee stiffness
 - incidence
 - 10-25%
 - risk factors
 - increasing age
 - higher BMI
 - severity of fracture
 - prolonged immobilization
 - involvement of tibial eminence
 - polytrauma
 - treatment
 - arthroscopic lysis of adhesions with MUA
 - indicated if unable to achieve 90 deg of flexion within 4 weeks
- Loss of reduction
 - incidence
 - 5-30%
 - risk factors
 - inadequate fixation
 - severity of fracture
 - osteoporosis
 - treatment
 - revision ORIF to address inadequate fixation
 - i.e. posteromedial buttress plate for coronal fracture not captured with lateral plate only
- Deep vein thrombosis
 - incidence
 - nonoperative 9%
 - operative 6%

- Prognosis

- Mortality rate
 - 5% at 1 year
- Return to work
 - 70-90% at 1 year
 - residual dysfunction or reduced work load is common
- Mean ROM
 - 10-145 degrees at 1 year

54- Proximal Third Tibia Fracture

Images



• Summary

- Proximal third tibia fractures are relatively common fractures of the proximal tibial shaft that are associated with high rates of soft tissue compromise and malunion (valgus and procurvatum).
- Diagnosis is made with orthogonal radiographs of the tibia with a CT scan often required to assess for intra-articular extension.
- Treatment generally consists of surgical open reduction and internal fixation (ORIF) versus intramedullary nail fixation.

• Epidemiology

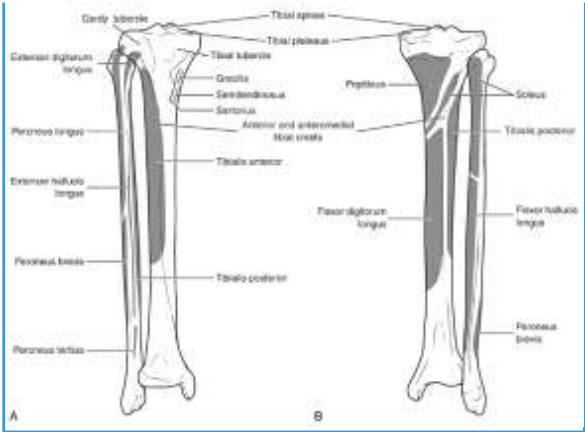
- Incidence
 - common
 - 5-11% of all tibial shaft fractures

• Etiology

- Pathophysiology
 - mechanism
 - low energy
 - result of torsional injury (spiral oblique fracture)
 - indirect trauma
 - high energy
 - direct trauma
- Associated conditions
 - compartment syndrome
 - soft tissue injury
 - critical to outcome
 - severity of muscle injury has the greatest impact on need for amputation

• Anatomy

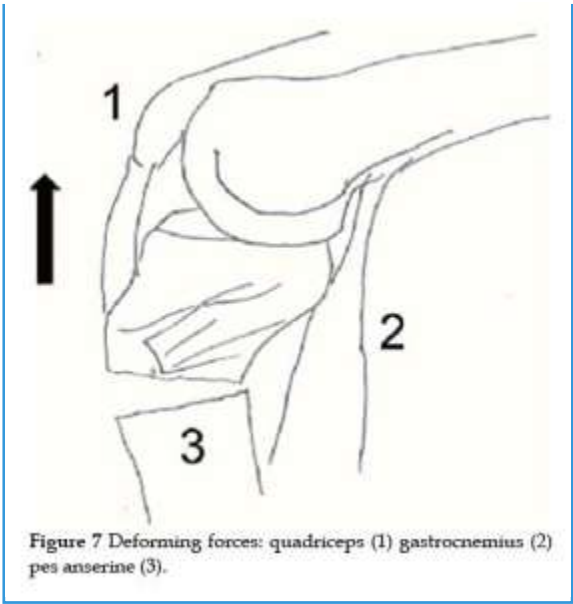
- Osteology
 - proximal tibia
 - triangular
 - wide metaphyseal region
 - narrow distally
- Muscles



- deforming forces
 - patellar tendon
 - proximal fragment into extension



- fracture into apex anterior, or procurvatum
- gastrocnemius



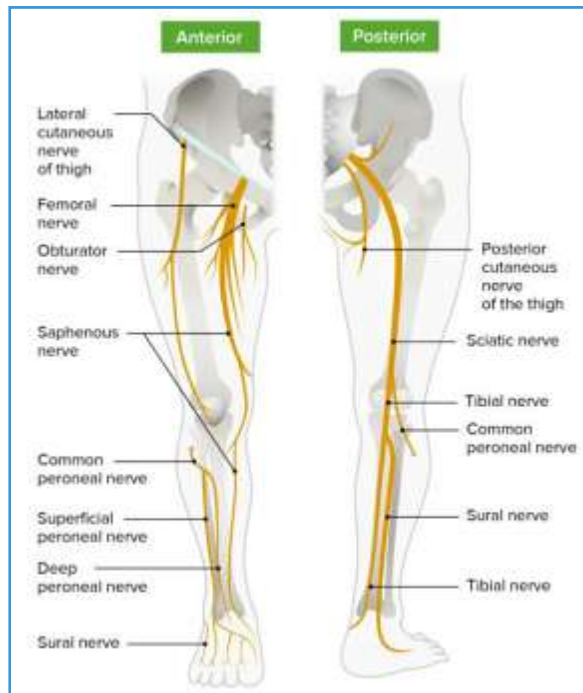
- distal fragment into flexion
- pes anserinus
 - proximal fragment into varus
 - varus deforming force of the fracture
- anterior compartment musculature
 - valgus deforming force of the fracture

•
 Classification

■ AO Classification - 42 		
■ Type A	■ Simple fracture pattern	■ 
■ Type B	■ Wedge fracture pattern	■ 
■ Type C	■ Comminuted fracture pattern	■ 

• Presentation

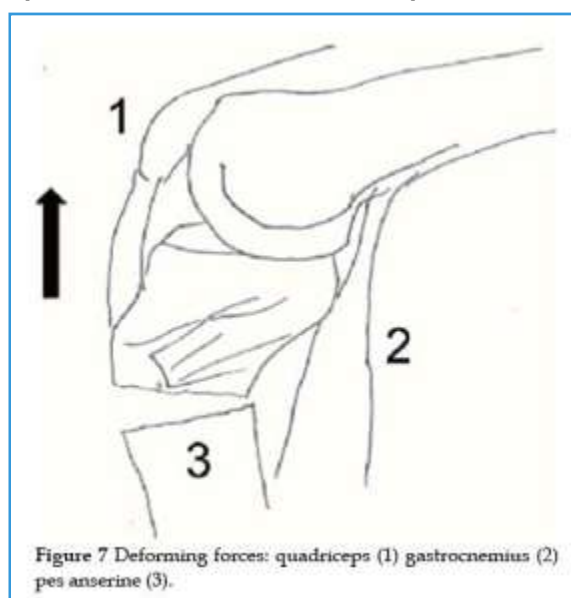
- Symptoms
 - pain, inability to bear weight
- Physical exam
 - inspection
 - contusions
 - blisters
 - open wounds
 - compartments
 - palpation
 - passive motion of toes
 - intracompartmental pressure measurement if indicated
 - neurovascular



- deep peroneal n.
- superficial peroneal n.
- sural n.
- tibial n.
- saphenous n.
- dorsalis pedis
- posterior tibial

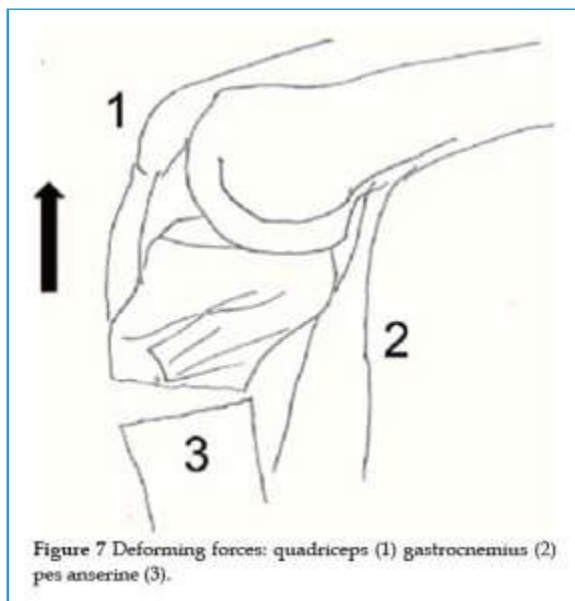
• Imaging

- Radiographs
 - recommended views
 - AP
 - lateral
 - ipsilateral knee, tibia, and ankle
 - findings
 - proximal fracture extended, apex anterior, varus
 - apex extended due to patellar tendon



- varus due to pes anserinus + anterior compartment

- distal fragment flexed
 - flexed due to gastrocnemius



- CT
 - indications
 - question of intra-articular fracture extension

• Differential

- Tibial shaft fx
- Knee dislocation
- Tibial plateau fx

• Diagnosis

- Radiographic
 - diagnosis confirmed by clinical presentation and radiographs

• Treatment

- Nonoperative
 - **closed reduction / cast immobilization**
 - indications
 - closed low energy fractures with acceptable alignment
 - < 5 degrees varus-valgus angulation
 - < 10 degrees anterior/posterior angulation
 - > 50% cortical apposition
 - < 1 cm shortening
 - < 10 degrees rotational alignment
 - outcomes
 - shortening is most difficult to control with nonoperative management
 - angulation and rotational control are difficult to achieve by closed methods
 - extent of shortening and translation on injury radiographs should be expected at time of union

○ Operative

- **external fixation**
 - indications
 - fractures with extensive soft-tissue compromise



- polytrauma
- outcomes
 - higher incidence of malalignment than IMN
- **intramedullary nailing**

- indications
 - enough proximal bone to accept two locking screws (5-6 cm)
- outcomes
 - high rates of malunion with improper technique
 - most common malunion



- valgus
- apex anterior (procurvatum)

▪ percutaneous locking plate



- indications
 - extreme proximal fractures
 - inadequate proximal fixation for IM nailing
 - best suited for transverse or oblique fractures
 - minimal soft-tissue compromise
- outcomes
 - lateral plating with medial comminution can lead to varus collapse
 - long plates may place superficial peroneal nerve at risk
 - higher infection rate than IMN for open fractures

• Techniques

- **Closed reduction / cast immobilization**
 - technique
 - place in long leg cast and convert to functional brace at 4 weeks
 - cast in 10 to 20 degrees of flexion
- **External fixation**
 - technique
 - bi-planar and multiplanar pin fixators are useful
 - circular frames indicated for very proximal fractures
 - can be safely converted to IMN within 7-21 days
- **Intramedullary nailing**
 - approach
 - lateral parapatellar
 - helps maintain reduction for proximal 1/3 fractures

- requires mobile patella
- medial parapatellar approach may lead to valgus deformity
- suprapatellar



- facilitates nailing in semiextended position

■ technique

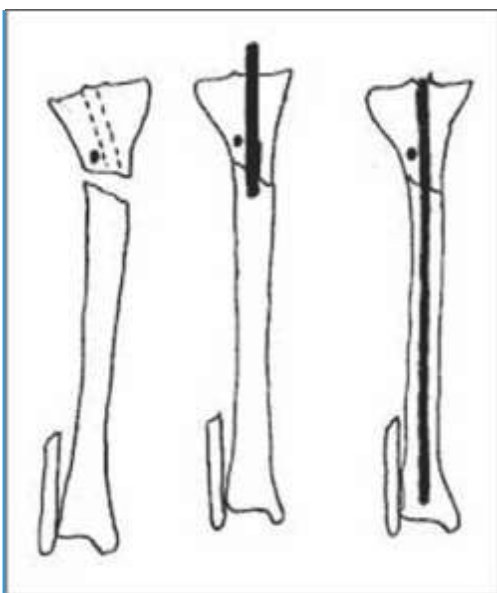
- starting point
 - proximal to the anterior edge of the articular margin
 - just medial to the lateral tibial spine
 - use of a more lateral starting point may decrease valgus deformity
 - use of a medial starting point may create valgus deformity



- fracture reduction techniques
 - blocking (Poller) screws
 - coronal blocking screw



- prevents apex anterior (procurvatum) deformity
- place in posterior half of proximal fragment
- sagittal blocking screw



- prevents valgus deformity
- place on lateral concave side of proximal fragment

- enhance construct stability if not removed
- unicortical plating



- short one-third tubular plate placed anteriorly, anteromedially, or posteromedially across fracture
- secure both proximally and distally with 2 unicortical screws
- universal distractor
 - Schanz pins inserted from medial side, parallel to joint
 - pin may additionally be used as blocking screws
- nail insertion
 - options
 - standard insertion with knee in flexion
 - nail insertion in semiextended position



- may help to prevent apex anterior (procurvatum) deformity
 - neutralizes deforming forces of extensor mechanism
- locking screws
 - statically lock proximally and distally for rotational stability
 - no indication for dynamic locking acutely
 - must use at least two proximal locking screws
- complications
 - malunion
 - valgus and apex anterior (procurvatum)
- **Pecutaneous locking plate**
 - approach
 - anterolateral
 - straight or hockey stick incision anterolaterally from just proximal to joint line (if intra-articular extension) to just lateral to the tibial tubercle and extend distally as needed
 - technique
 - may be used medially or laterally
 - better soft tissue coverage laterally makes lateral plating safer
 - complications
 - superficial peroneal nerve injury with use of a longer plate
 - varus collapse if lateral only plate used with medial comminution

• Complications

- Anterior knee pain
 - incidence
 - occurs in more than 30% of cases treated with IMN
 - resolves with removal of IMN in 50% of cases

- Nonunion
 - infection must be ruled out
 - dynamization if axially stable
- Malunion
 - Most common is valgus and apex anterior (procurvatum)
 - increases long-term risk of arthrosis
 - incidence
 - 20-60% rate of malunion following intramedullary nailing (valgus/procurvatum)
 - prevention
 - laterally based starting point and anterior insertion angle
 - entry of IMN should be in line with the medial border of the lateral tibial eminence
 - blocking screws placed in metaphyseal segment on the concave side of the deformity
 - place laterally to prevent valgus and posterior to prevent procurvatum in proximal fragment
 - this narrows the available space for the IMN
 - direct the nail toward a more centralized position
 - use of provisional unicortical plate
 - semiextended position for nailing
 - universal distractors
 - treatment
 - revision intramedullary nailing
 - osteotomy if fracture has healed
- Prognosis
 - High rate of malunion following intramedullary nailing

55- Tibial Shaft Fractures

Images



• Summary

- Diaphyseal tibial fractures are the most common long bone fracture.
- Diagnosis is confirmed by plain radiographs of the tibia and adjacent joints.
- Treatment is generally operative with intramedullary nailing. In rare cases, external fixation or ORIF is more appropriate depending on the location and orientation of the fracture.

• Epidemiology

- Incidence
 - most common long bone fx
 - make up about 17% of all lower extremity fractures
 - account for 4% of all fractures seen in the Medicare population
- Demographics
 - M > F
 - age bracket
 - bimodal distribution
 - young patients - high energy mechanisms
 - older patients - falls, lower energy mechanisms
- Anatomic location
 - proximal 1/3 tibia fractures account for 5-10% of tibial shaft fractures

• Etiology

- Pathophysiology
 - mechanism of injury
 - low energy (fall from standing, twisting, etc)
 - result of indirect, torsional injury
 - leads to spiral fracture pattern with fibula fracture at a different level
 - high association of posterior malleolus fractures with spiral distal tibia fractures
 - more likely to be associated with a lower degree of soft tissue injury
 - high energy fx (MVA, fall from height, athletics, etc)
 - result of direct force
 - leads to wedge or short oblique fracture that may have significant comminution with fibula fracture at same level
 - more likely to be associated with severe soft tissue injury
 - Oestern and Tscherne II / III
 - open fractures
 - pathoanatomy

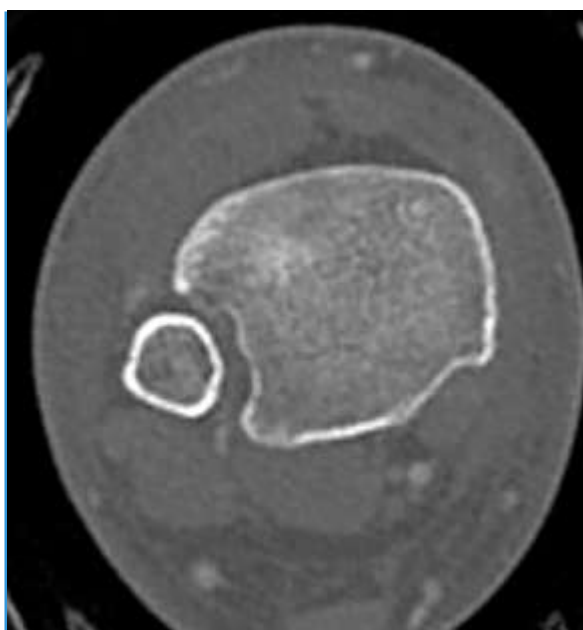
- proximal third tibia fractures



- must rule out extension into tibial plateau on plain films or CT scan
 - high risk for valgus/procurvatum deformity with IM nailing
- distal third tibia fracture



- higher rates of ankle injury seen with distal 1/3 tibia fracture and spiral fracture pattern



- posterior malleolus most common associated ankle injury which, in some cases, may affect syndesmotic stability
 - extension into or adjacent to tibial plafond may require separate/additional fixation and are managed differently than tibial shaft fractures
- associated conditions

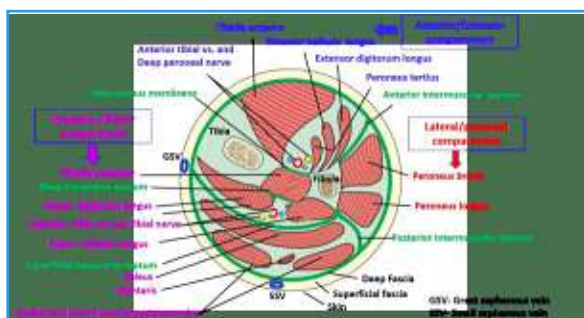
- soft tissue injury
 - severity of muscle injury has highest impact on eventual need for amputation
- compartment syndrome
 - more common in diaphyseal tibial shaft fractures than proximal or distal tibia fractures
 - 8.1% risk in diaphyseal fractures, compared to proximal (1.6%) and distal (1.4%) fractures
 - can occur even in the setting of an open fracture
 - all four compartments must be examined. If patient is unable to participate in examination and concern is high clinically, intracompartmental compartment measurements should be performed
- bone loss
- ipsilateral skeletal injury
 - tibial plateau fractures
 - tibial plafond fractures
 - femoral shaft fractures
 - floating knee is an indication for antegrade tibial nailing and retrograde femoral nailing
 - posterior malleolar fracture
 - distal 1/3 and spiral tibial shaft fractures

• Anatomy

○ Osteology

- tibial shaft is triangular in cross-section
- proximal medullary canal is centered laterally
 - important for start point with IM nailing
- anteromedial tibial crest is composed of dense, cortical bone and rests in a subcutaneous position, making it useful as a landmark
- tibial tubercle sits anterolaterally, approximately 3 cm distal to joint line
 - attachment of patellar tendon
- gerdy's tubercle lies laterally on proximal tibia
 - attachment of iliotibial band
- pes anserinus lies medially on proximal tibia
 - attachment of sartorius, semitendinosus, and gracilis

○ Muscles



- anterior compartment
 - tibialis anterior
 - extensor digitorum longus (EDL)
 - extensor hallucis longus (EHL)
- lateral compartment
 - peroneus longus
 - peroneus brevis
- superficial posterior compartment
 - gastrocnemius (medial/lateral heads)
 - soleus
 - plantaris
- deep posterior compartment
 - popliteus
 - tibialis posterior
 - flexor digitorum longus (FDL)
 - flexor hallucis longus (FHL)

○ Ligaments

- superficial medial collateral ligament (MCL) attaches approximately 5-7 cm distal to joint line deep to the pes anserinus

- adjacent fibula supports attachments for the lateral collateral ligament complex and long head of biceps femoris
- Blood Supply
 - anterior tibial a.
 - peroneal a.
 - posterior tibial a.
 - medial sural a.
 - lateral sural a.
- Nervous System
 - superficial peroneal n.
 - deep peroneal n.
 - tibial n.
 - sural n.
- Biomechanics
 - proximal tibiofibular joint
 - gliding synovial joint
 - tibia is responsible for about 80-85% of lower extremity weight-bearing
 - interosseous membrane
 - fibrous structure interconnecting tibia/fibula which provides axial stability
 - tibiofibular syndesmosis
 - fibula rests in distal tibial incisura and is stabilized by syndesmotic ligaments
 - anterior inferior tibiofibular ligament (AITFL)
 - posterior inferior tibiofibular ligament (PITFL)
 - inferior transverse tibiofibular ligament (ITL)
 - interosseous ligament (IOL) - continuation of interosseus membrane
 - syndesmotic stability can be affected by distal, spiral tibial shaft fractures

- Classification

- Fracture classification is primarily descriptive based on pattern and location

○	■ OTA Classification		
	■ 42A	■ Simple fracture patterns	■ 
	■ 42B	■ Wedge patterns	■ 
	■ 42C	■ Complex/comminuted patterns	■ 
○	■ Oestern and Tscherne Classification of Closed Fracture Soft Tissue Injury		
	■ Grade 0	■ Injuries from indirect forces with negligible soft-tissue damage	■ 
	■ Grade I	■ Superficial contusion/abrasion, simple fractures	■ 
	■ Grade II	■ Deep abrasions, muscle/skin contusion, direct trauma, impending compartment syndrome	■ 
	■ Grade III	■ Excessive skin contusion, crushed skin or destruction of muscle, subcutaneous degloving, acute compartment syndrome, and rupture of major blood vessel or nerve	■ 

■ Gustilo-Anderson Classification of Open Tibia Fractures		
■ Type I	■ Limited periosteal stripping, clean wound < 1 cm	■ 
■ Type II	■ Minimal periosteal stripping, wound >1 cm in length without extensive soft-tissue injury damage	■ 
■ Type IIIA	■ Significant soft tissue injury (often evidenced by a segmental fracture or comminution), significant periosteal stripping, wound usually >5cm in length, no flap required.	■ 
■ Type IIIB	■ Significant periosteal stripping and soft tissue injury, flap required due to inadequate soft tissue coverage (STSG doesn't count). Treat proximal 1/3 fxs with gastrocnemius rotation flap, middle 1/3 fxs with soleus rotation flap, distal 1/3 fxs with free flap.	■ 
■ Type IIIC	■ Significant soft tissue injury (often evidenced by a segmental fracture or comminution), vascular injury requiring repair to maintain limb viability	■ 
■	■ For prognostic reasons, severely comminuted, contaminated barnyard injuries, close-range shotgun/high-velocity gunshot injuries, and open fractures presenting over 24 hours from injury have all been included in the grade III group.	■

- Presentation

- Symptoms
 - severe leg pain
 - inability to bear weight
 - deformity
 - Physical exam
 - inspection
 - deformity / angulation / malrotation
 - contusions
 - blisters
 - open wounds
 - palpation
 - check firmness of each compartment to evaluate for compartment syndrome
 - motion
 - fracture crepitus noted
 - neurovascular
 - peripheral nerve exam
 - deep peroneal n.
 - superficial peroneal n.
 - sural n.
 - tibial n.
 - saphenous n.
 - dorsalis pedis and posterior tibial pulses - compare to contralateral side
 - doppler if necessary
 - CT angiography indicated if pulses not dopplerable

- Imaging

- Radiographs
 - recommended views
 - full-length AP and lateral views of the affected tibia
 - AP, lateral and oblique views of ipsilateral knee and ankle
 - repeat radiographs recommended after splinting or fracture manipulation
 - CT

- indications
 - intra-articular fracture extension or suspicion of plateau/plafond involvement
 - distal 1/3 or spiral tibia fracture
 - used to exclude posterior malleolar fracture
 - also used to identify nonunion
- findings
 - high variation in reported incidence of posterior malleolus fracture with distal 1/3 spiral tibia fractures (25-60%)

• Treatment

○ Nonoperative

■ closed reduction / cast immobilization



- indications
 - closed, low energy fractures with acceptable alignment
 - < 5 degrees varus-valgus angulation
 - < 10 degrees anterior/posterior angulation
 - > 50% cortical apposition
 - < 1 cm shortening
 - < 10 degrees rotational malalignment
 - certain patients who may be non-ambulatory (ie. paralyzed), or those unfit for surgery
- outcomes
 - angulation and rotational alignment are well maintained with casting, however, shortening is hard to control
 - risk of shortening higher with oblique and comminuted fracture patterns
 - mean shortening is 4 mm
 - risk of varus malunion with midshaft tibia fractures and an intact fibula
 - high success rate if acceptable alignment maintained
 - non-union occurs in approximately 1% of patients treated with closed reduction
- Operative
 - **I&D + antibiotics**
 - indications
 - all open tibia fractures require an emergent I&D
 - surgical debridement within 12-24 hours of injury
 - wounds should be irrigated and dressed with saline-soaked gauze in the emergency department before splinting
 - all open tibia fractures require immediate antibiotics
 - should be administered within 3 hours of injury
 - standard abx for open fractures (institution dependent)
 - cephalosporin given continuously for 24 hours after definitive surgery in Grade I, II, and IIIA open fractures
 - aminoglycoside added in Grade IIIB injuries
 - minimal data to support this
 - penicillin administered in farm injuries
 - minimal data to support this
 - theoretically covers Clostridium
 - tetanus vaccination status should be confirmed and appropriate prophylaxis should be administered if necessary
 - outcomes
 - early antibiotic administration is the most important factor in reducing infection

- emergent and thorough surgical debridement is also an important factor
- must remove all devitalized tissue including cortical bone
- **external fixation**
 - indications
 - damage control for polytrauma patients
 - open fractures with soft tissue defects/contamination
 - proximal or distal metaphyseal fractures
 - techniques
 - uniplanar, circular, hybrid external fixators all available
 - should be converted to intramedullary nail within 7-21 days, ideally less than 7 days
 - outcomes
 - longer time to union and worse functional outcomes with definitive external fixation compared to IM nailing in type III open tibia fractures
 - higher incidence of malalignment compared to IM nailing
 - high rate of pin tract infections; avoid intra-articular placement given risk for septic arthritis
- **IM Nailing**
 - indications
 - unacceptable alignment with closed reduction and casting
 - soft tissue injury that will not tolerate casting
 - segmental fx
 - comminuted fx
 - ipsilateral limb injury (i.e., floating knee)
 - polytrauma
 - bilateral tibia fx
 - morbid obesity
 - techniques
 - reamed vs. unreamed nailing
 - reamed nailing allows for larger diameter nail
 - suprapatellar vs. infrapatellar nailing
 - provisional reduction techniques (blocking screws, plating, etc)
 - particularly useful for proximal 1/3 tibial shaft fractures
 - outcomes
 - union rates >80% for closed tibia fractures treated with nailing
 - risks for nonunion: gapping at fracture site, open fracture and transverse fracture pattern
 - shorter immobilization time, earlier time to weight-bearing, and decreased time to union compared to casting
 - decreased malalignment compared to external fixation
 - suprapatellar vs. infrapatellar nailing
 - improved fracture alignment with suprapatellar nailing
 - reamed vs. unreamed nails
 - reamed may have higher union rates and lower time to union than unreamed nails in closed fractures (controversial)
 - reamed nails are safe for use with open fractures, with no evidence of decreased nonunion rates in open fractures
 - recent studies show no adverse effects of reaming (infection, embolism, nonunion)
 - reaming with the use of a tourniquet is not associated with thermal necrosis of the tibial shaft, despite prior studies suggesting otherwise
 - higher rate of locking screw breakage with unreamed nailing
- **open reduction and internal fixation**



- indications

- proximal tibia fractures with inadequate proximal fixation from IM nailing
 - distal tibia fractures with inadequate distal fixation from IM nail
 - tibia fractures in the setting of adjacent implant/hardware (i.e. prior total knee arthroplasty)
- outcomes
 - compared to IM nailing of tibia fractures:
 - larger incision
 - increased risk of wound complications and hardware irritation
 - similar rates of union in closed fractures
 - more difficult hardware removal
 - greater radiation exposure intraoperatively
 - possibly less angular deformity
 - risk of damage to the superficial peroneal nerve during percutaneous screw insertion
 - holes 11,12, and 13 (proximally) of a 13 hole plate place nerve at risk
- **augmentation with rhBMP-2**
 - indications
 - prior studies have demonstrated some use in open tibial shaft fractures
 - outcomes (controversial, as recent studies have not fully supported these findings)
 - accelerate early fracture healing
 - decrease rate of hardware failure
 - decrease need for subsequent autologous bone-grafting
 - decrease need for secondary invasive procedures
 - decrease infection rate
- **amputation**
 - indications
 - no current scoring system to determine if an amputation should be performed
 - relative indications for amputation include
 - significant soft tissue trauma
 - warm ischemia > 6 hrs
 - severe ipsilateral foot trauma
 - outcomes
 - LEAP study
 - most important predictor of eventual amputation is the severity of ipsilateral extremity soft tissue injury
 - most important predictor of infection other than early antibiotic administration is transfer to definitive trauma center
 - study shows no significant difference in functional outcomes between amputation and salvage
 - loss of plantar sensation is not an absolute indication for amputation

• Technique

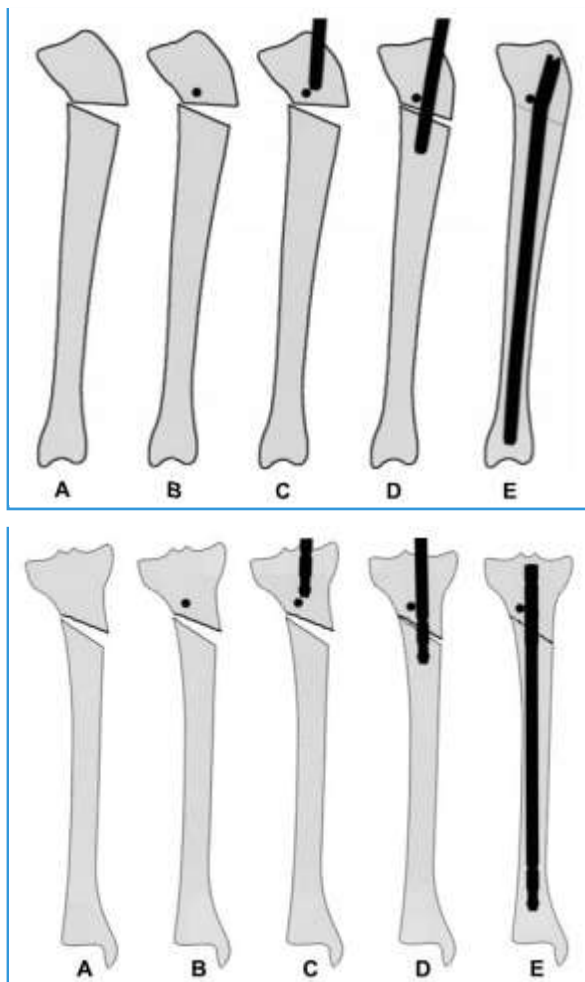
◦ Closed reduction/cast immobilization

- technique
 - long leg casting initially
 - may convert to functional (patellar tendon bearing) brace at around 4 weeks



- close follow-up with repeat radiographs to ensure no displacement
 - can wedge cast to correct slight deformity
 - monitor for skin irritation
- **Irrigation and debridement**
 - timing
 - within 24 hours of initial injury to decrease risk of infection
 - technique
 - sharp debridement of nonviable soft tissue & bone
 - thorough irrigation of contaminated wound

- may require multiple debridements
- immediate closure of open wounds is acceptable if minimal contamination is present and is performed without excessive skin tension
 - if skin cannot be closed, vac-assisted closure should be considered in short-term.
- **External fixation**
 - technique
 - bypass fracture, likely adjacent joint (i.e. open 1/3 tibial shaft fracture with placement of proximal 1/3 tibia and calcaneus/metatarsal pins to span fracture)
 - construct stiffness increased with larger pin diameter, number of pins on each side of fracture, rods closer to bone, and a multiplanar construct
 - complications
 - pin site infections common
- **Intramedullary nailing**
 - approach
 - infrapatellar nailing
 - medial parapatellar
 - most common starting point
 - incision from inferior pole of patella to just above tibial tubercle
 - identify medial edge of patellar tendon, incise
 - insert guidewire as detailed below and ream
 - can lead to valgus malalignment in proximal 1/3 tibial fractures
 - lateral parapatellar
 - helps maintain reduction when nailing proximal 1/3 fractures
 - requires mobile patella
 - patellar tendon splitting
 - gives direct access to start point
 - can damage patellar tendon or lead to patella baja (minimal data to support this)
 - semiextended medial or lateral parapatellar
 - used for proximal and distal tibial fractures
 - skin incision made along medial or lateral border of patella from superior pole of patella to upper 1/3 of patellar tendon
 - knee should be in 5-30 degrees of flexion
 - choice to go medial or lateral is based of mobility of patella in either direction
 - identify starting point and ream as detailed below
 - suprapatellar nailing (transquadriceps tendon)
 - requires special instruments
 - can damage patellofemoral joint
 - easier positioning if additional instrumentation needed
 - more advantageous for proximal or distal 1/3 tibia fractures
- technique
 - starting point
 - starting guidewire is placed in line with medial aspect of lateral tibial spine on AP radiograph, just below articular margin on lateral view
 - in proximal 1/3 tibia fractures starting point should cheat laterally to avoid classic valgus/procurvatum deformity
 - ensure guidewire is aligned with tibia in coronal and sagittal planes as you insert
 - opening reamer is placed over guidewire and ball-tipped guidewire can then be passed
- fracture reduction
 - spanning external fixation (ie. traveling traction)
 - clamps
 - femoral distractor
 - small fragment unicortical plates/screws
 - blocking (poller) screws
 - placed in metaphyseal segment at the concavity of the deformity
 - in proximal 1/3 tibia fractures, posteriorly placed blocking screw in proximal fragment and laterally placed blocking screw in the metaphyseal fragment help direct the nail more centrally, avoiding valgus/procurvatum deformities



- increase biomechanical stability of bone/implant construct by 25%
- unicortical provisional plate
 - not associated with increased infections, wound complications, and nonunion compared to closed-nailing techniques
- reaming
 - reamed nails superior to unreamed nails in closed fractures
 - ensure fracture is reduced before reaming
 - overream by 1.0-1.5mm to facilitate nail insertion
 - confirm guide wire is appropriately placed prior to reaming
 - should be "center-center" in the coronal and sagittal planes distally at the physeal scar
- nail insertion
 - anterior aspect of nail should be lined up with axis of tibia when inserting nail - typically should line up with 2nd metatarsal in absence of tibial deformity
- locking screws
 - statically lock proximal and distally for rotational stability
 - no indication for dynamic locking acutely
 - number of interlocking screws is controversial
 - two proximal and two distal screws in presence of <50% cortical contact
 - consider 3 interlock screws in short segment of distal or proximal shaft fracture
 - prefer multiplanar screw fixation in these short segments
- **Open reduction and internal fixation**
 - approach
 - lateral vs. medial
 - lateral may have more soft tissue interference but may be preferred in setting of soft tissue/wound issues
 - technique
 - generally, minimally invasive plating is used to preserve soft tissues
 - plate attached to external jig to allow for percutaneous insertion of screws
 - must ensure appropriate contour of plate to avoid malreduction
 - complications
 - higher risk for wound issues, particularly in open fractures
 - neurovascular risk
 - superficial peroneal nerve (SPN) commonly at risk laterally
- **Amputation**
 - approach
 - below knee amputation (BKA) vs. above knee amputation (AKA) based on degree of soft tissue damage
 - technique
 - standard BKA vs. ertl/bone block technique
 - complications

- infection
- hematoma
- phantom pain

• Complications

- Anterior knee pain
 - incidence
 - >30-50% with IM nailing
 - risk factors
 - infrapatellar nailing with patellar tendon splitting and paratendon approach
 - suprapatellar nailing may have lower rate of anterior knee pain
 - more common if nail left proud proximally
 - lateral radiograph is best radiographic views to evaluate proximal nail position
 - treatment
 - removal of nail
 - pain relief unpredictable with nail removal
- Malunion
 - incidence
 - all tibial shaft fractures - between 8-10%
 - higher in proximal 1/3 tibia fractures - up to 50%
 - valgus/procurvatum deformity



- patellar tendon pulls proximal fragment into extension, while hamstring tendons and gastrocnemius pull the distal fragment into flexion (procurvatum)
 - distal 1/3 fractures have a higher rate of valgus malunion with IM nailing compared to plating
- risk factors
 - definitive management with casting or external fixation
 - most common deformity is varus with nonsurgical management
 - varus malunion may place patient at risk for ipsilateral ankle pain and stiffness
 - starting point too medial with IM nailing
 - poor reduction intraoperatively
- treatment
 - prevention is most important
 - adequate reduction, proper start point when nailing
 - if malalignment is noted immediately after surgery, return to operating room is appropriate with removal of nail, reduction and nail reinsertion
 - if malunion is appreciated at later followup, eventual nail removal and tibial osteotomy can be considered
- Nonunion (no healing at 9 months)
 - incidence
 - estimated between 2-10%
 - risk factors
 - open fracture
 - cortical contact <50%
 - transverse fracture pattern

- treatment
 - rule out infection
 - nail dynamization if axially stable
 - exchange nailing if not axially stable
 - reamed exchange nailing most appropriate for aseptic, diaphyseal tibial nonunions
 - oblique tibial shaft fractures have the highest rate of union when treated with exchange nailing
 - consider revision with plating in metaphyseal nonunions
 - posterolateral bone grafting if significant bone loss
 - BMP-7 (OP-1) has been shown equivalent to autograft
 - often used in cases of recalcitrant non-unions
 - compression plating has been shown to have a 92-96% union rate after open tibial fractures initially treated with external fixation
 - fibular osteotomy of tibio-fibular length discrepancy associated with healed or intact fibula
- Malrotation
 - incidence
 - highest after IM nailing of distal 1/3 tibia fractures
 - increases risk of adjacent ankle arthrosis
 - treatment
 - should always assess rotation in operating room
 - obtain perfect lateral fluoroscopic image of knee, then rotate c-arm 105-110 degrees to obtain mortise view of ipsilateral ankle
 - may have reduced risk with adjunctive fibular plating
- Compartment syndrome
 - incidence
 - estimated between 1-9%
 - can occur in both closed and open tibia shaft fractures
 - risk factors
 - high energy injuries
 - significant soft tissue injuries
 - treatment
 - emergent four-compartment fasciotomy
- Nerve injury
 - incidence
 - true incidence unknown
 - believed to be a rare complication
 - risk factors
 - LISS plate application without opening for distal screw fixation near plate holes 11-13 put superficial peroneal nerve at risk of injury due to close proximity
 - saphenous nerve can be injured during placement of locking screws
 - transient peroneal nerve palsy can be seen after closed nailing
 - EHL weakness and 1st dorsal webspace decreased sensation
 - treatment
 - usually nonoperatively with variable recovery expected
 - may need AFO if foot drop present
- Infection
 - incidence
 - approximately 5%
 - risk factors
 - open fracture
 - severe soft tissue injury with contamination
 - longer time to definitive soft tissue coverage
 - treatment
 - may require I&D or eventual removal of hardware
 - use of wound vacuum-assisted closure does not decrease risk of infection

56- Tibial Plafond Fractures

• Summary

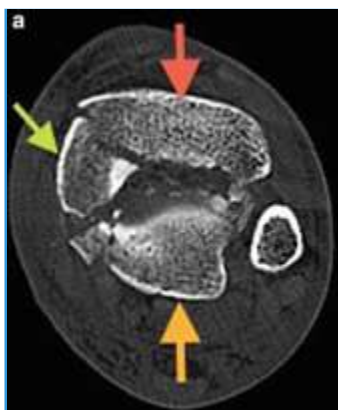
- A tibial plafond fracture (also known as a pilon fracture) is a fracture of the distal end of the tibia, most commonly associated with comminution, intra-articular extension, and significant soft tissue injury.
- Diagnosis is typically made through clinical evaluation and confirmed with plain radiographs.
- Treatment is generally operative with temporary external fixation followed by delayed open reduction internal fixation once the soft tissues permit.

• Epidemiology

- Incidence
 - common
 - 5%-10% of all tibia fractures
 - account for <10% of lower extremity injuries
 - incidence increasing as survival rates after motor vehicle collisions increase
- Demographics
 - average patient age is 35-45 years
 - males > females

• Etiology

- Pathophysiology
 - mechanism
 - high energy axial load (most common)
 - talus is driven into the plafond resulting in articular impaction of the distal tibia
 - falls from height
 - motor vehicle accidents
 - low energy rotational forces (less common)
 - alpine skiing
 - pathoanatomy
 - fracture patterns and comminution determined by position of foot, amplitude of force, and direction of force
 - articular impaction and comminution
 - metaphyseal bone comminution
 - 3 fragments typical with intact ankle ligaments

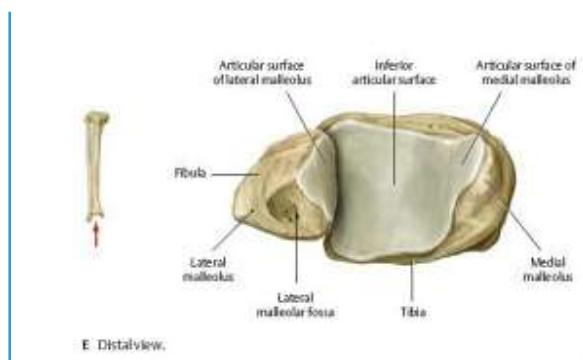


- medial malleolar (deltoid ligament)
 - posterolateral/ Volkmann fragment (posterior-inferior tibiofibular ligament)
 - anterolateral/ Chaput fragment (anterior-inferior tibiofibular ligament)
 - Associated conditions
 - 75% have associated fibula fractures
 - 30% have an ipsilateral lower extremity injury
 - 20% are open fractures
 - 5-10% are bilateral pilon fractures

• Anatomy

- Osteology

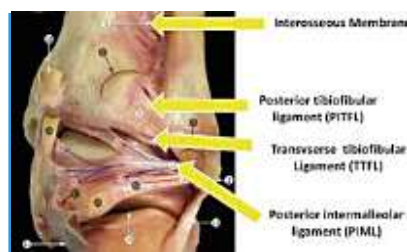
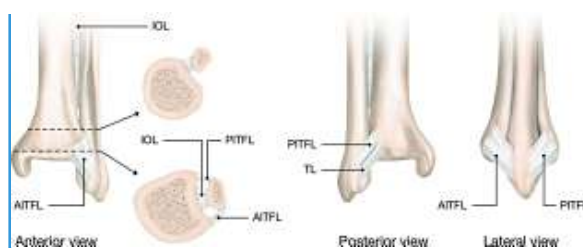
- tibia



- distal tibia forms an inferior quadrilateral surface and pyramid-shaped medial malleolus articulates with the talus and fibula laterally via the fibula notch

- Ligaments

- distal tibiofibular syndesmosis



- anterior-inferior tibiofibular ligament (AITFL)
 - originates from anterolateral tubercle of tibia (Chaput)
 - inserts on anterior tubercle of fibula (Wagstaffe)
- posterior-inferior tibiofibular ligament (PITFL)
 - originates from posterior tubercle of tibia (Volkmann)
 - inserts on posterior part of lateral malleolus
 - strongest component of syndesmosis
- interosseous membrane
- interosseous ligament (IOL)
 - distal continuation of the interosseous membrane
- inferior transverse ligament (ITL)

- Classification

AO/OTA Classification		
43-A	Extra-articular	
43-B	Partial articular	
43-C	Complete articular	
Ruedi and Allgower Classification		
Type I	Nondisplaced	
Type II	Simple displacement with incongruous joint	
Type III	Comminuted articular surface	

- Presentation

- Symptoms

- severe ankle pain
 - ankle deformity
 - inability to bear weight

- Physical exam

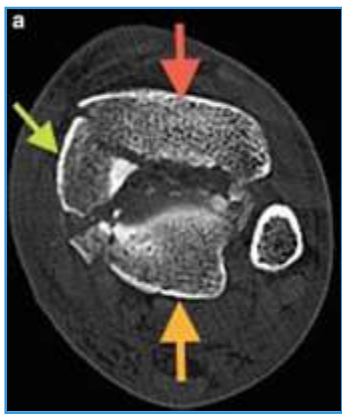
- inspection & palpation
 - ankle tenderness, swelling, abrasions, ecchymosis, fracture blisters, open wounds, and chronic skin/vascular changes

- examine for associated musculoskeletal injuries
- motion
 - ankle motion limited
- neurovascular
 - check DP and PT pulses
 - consider ABIs and CT angiography if clinically warranted
 - look for neurologic compromise
 - check for signs/symptoms of compartment syndrome

• Imaging

◦ Radiographs

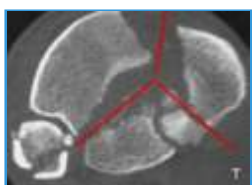
- recommended views
 - AP
 - lateral
 - mortise
 - full-length tibia/fibula and foot x-rays performed for fracture extension
 - lumbar films if appropriate based on exam
- findings
 - 4 classic fracture fragments



- medial malleolus
- anterior malleolus = chaput
- lateral malleolus = wagstaffe
- posterior malleolus = volkmann

◦ CT scan

- indications
 - critical for pre-operative planning
 - articular involvement
 - metaphyseal comminution
 - fracture displacement
 - important to obtain after spanning external fixation as ligamentotaxis allows for better surgical planning
 - fine cuts through the distal tibia
 - 3D reconstructions can be helpful
- findings
 - “Mercedes-Benz”™ sign on axials



• Treatment

◦ Nonoperative

- **cast immobilization**
 - indications
 - stable fracture patterns without articular surface displacement
 - critically ill or non-ambulatory patients
 - significant risk of skin problems (diabetes, vascular disease, peripheral neuropathy)
 - outcomes
 - intra-articular fragments are unlikely to reduce with manipulation of displaced fractures
 - loss of reduction is common

- inability to monitor soft tissue injuries is a major disadvantage
- Operative
 - **temporizing spanning external fixation across ankle joint**
 - indications
 - acute management of most length unstable fractures
 - provides stabilization to allow for soft tissue healing and monitoring
 - capsuloligamentotaxis to indirectly reduce the fracture by tensioning the soft tissues about the ankle
 - keeps fracture fragments out to length
 - fractures with significant joint depression or displacement
 - leave until swelling resolves (generally 10-14 days)
 - not always warranted in length stable pilon fractures
 - outcomes
 - placement of pins out of the zone of injury and planned surgical site is important to reduce infection risks
 - **open reduction and internal fixation (ORIF)**
 - indications
 - definitive fixation for a majority of pilon fractures
 - limited or definitive ORIF can be performed acutely with low complications in certain situations
 - outcomes
 - dependent on articular reduction
 - high rates of wound complications and infections are associated with early open fixation through compromised soft tissue
 - ability to drive
 - brake travel time returns to normal 6 weeks after weight bearing
 - fibula fixation
 - not a necessary step in the reconstruction of pilon fractures
 - may be helpful in specific cases to aid in tibial plafond reduction or augment external fixation
 - higher rates of fibula hardware removal
 - **external fixation/circular frame fixation alone**
 - indications
 - select cases where bone or soft tissue injury precludes internal fixation
 - outcomes
 - thin wire frames and hybrid fixators have high union rate
 - high rates of pin tract infections
 - osteomyelitis and deep infection are rare
 - meta-analysis comparing this method with open reduction and internal fixation found no difference in infection or complication rates between the two groups
 - **intramedullary nailing with percutaneous screw fixation**
 - indications
 - alternative to ORIF for fractures with simple intra-articular component
 - outcomes
 - minimizes soft tissue stripping and useful in patients with soft tissue compromise
 - high union rates
 - increased valgus malunion and recurvatum seen with IMN compared to plate osteosynthesis
 - **primary ankle arthrodesis**
 - indications
 - no definitive indications
 - potential indications
 - severely comminuted, non-reconstructable plafond fractures
 - select elderly populations who cannot tolerate multiple surgeries or prolonged immobilization
 - manual laborers
 - techniques
 - plate and screw fixation
 - retrograde intramedullary TTC nail
 - outcomes
 - theorized quicker recovery process and decreased long term pain
 - increases the risk of adjacent joint arthritis including the subtalar joint and midfoot

- Techniques

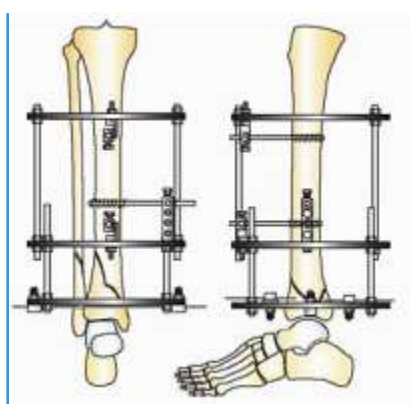
- Cast immobilization

- technique
 - long leg cast for 6 weeks followed by fracture brace and ROM exercises
 - close follow-up and imaging needed to ensure articular congruity and axial alignment

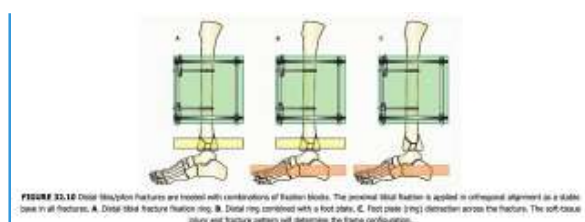
- External fixation (temporary and definitive)

- technique
 - fixator constructs vary with Δ ™ and Λ ™ frames assemblies being most common
 - 2 tibial shaft half pins outside the zone of injury connected to a single transcalcaneal pin
 - consider trans-navicular pin if associated calcaneal fracture
 - consider connecting fixator to the forefoot 1st metatarsal to prevent an equinus contracture
 - joint-spanning articulated vs. nonspanning hybrid ring
 - none have been shown to be superior with respect to ankle stiffness
 - can combine with limited percutaneous fixation using lag screws
 - complications
 - pin site drainage
 - pin/wire tract infections
 - pin site fracture
 - ankle stiffness
 - injury to neurovascular structures
 - anatomic articular reconstruction may not be possible, especially with central depression

- Circular frame fixation



- technique
 - distraction is the key to reduction
 - proximal fixation
 - tibial shaft is used as a fixation base to reduce the fracture
 - two half-pins in the AP plane with rings in an orthogonal position
 - used to support the distal fixation rings
 - distal fixation



- determined by the configuration of the fracture and the soft-tissue injury
 - rings placed at the level of the plafond or calcaneus to distract and reduce the fracture
 - pins should be placed at least 1-2 cm from the joint line in order to avoid possible septic arthritis
 - safe zones for wire placement form a 60-degree arc in the medial-lateral plane



- can include limited internal fixation if soft tissues permit
 - consider the need for soft tissue coverage with position of the fixator
 - hydroxyapatite coated pins
 - provides better fixation and decreases frequency of loosening

- Open reduction and rigid internal fixation (ORIF)

- timing to definitive surgery
 - once skin wrinkles present, blister epithelization, and ecchymosis resolution (10-14 days)

- approach(es)
 - single or multiple incisions based on fracture pattern and goals of fixation
 - keep full thickness skin bridge >7cm between incisions
 - positioning of patient dependent on approach(es) being utilized
 - direct anterior approach to ankle
 - anterolateral approach to ankle
 - useful with fractures impacted in valgus or with an intact fibula
 - puts the deep peroneal nerve at risk during exposure and dissection in the anterior compartment
 - superficial peroneal nerve at risk during superficial dissection in the lateral compartment
 - anteromedial approach to ankle
 - medial approach
 - posteromedial approach
 - posterolateral approach
 - lateral approach
- technique
 - reduction and fixation
 - goal is for anatomic reduction of articular surface
 - location of plates/screws are fracture and soft-tissue dependent
 - restore alignment
 - <5-10 degrees varus/valgus
 - <5-10 degrees procurvatum/recurvatum
 - restore length
 - consider provisionally leaving the external fixator in place
 - reconstruct metaphyseal shell
 - bone graft (if warranted)
 - reattach metaphysis to diaphysis
 - fibula fixation if needed
 - can be with intramedullary screw/wire or plate/screw construct
 - postoperative care
 - ankle ROM exercises beginning 2 weeks post-op
 - non-weightbearing for ~6-12 weeks depending on radiographic evidence of fracture consolidation
- **Primary ankle arthrodesis**
 - approach
 - direct anterior
 - technique
 - plate and screw fixation
 - debride fibrous tissue, fracture callous, and cartilage
 - small comminuted articular fragments are removed
 - remove talar dome cartilage
 - pack metaphyseal defects and the tibiotalar joint with autologous or allograft bone graft
 - iliac crest
 - demineralized bone matrix
 - optimal position
 - neutral dorsiflexion
 - 5-10° of external rotation
 - 5° of hindfoot valgus
 - 5 mm of posterior talar translation
 - fixation with an anterior plate and screw construct
 - post-op care
 - apply cast or splint for 8 weeks
 - progress weight bearing between 8 and 12 weeks in removable boot
 - full weight bearing with ankle brace at 12 weeks post-op
 - CT at 3 months to assess for successful fusion
 - tibiotalocalcaneal (TTC) fusion with retrograde intramedullary nail
 - sacrifices subtalar joint motion
 - accelerates transverse tarsal joint arthritis
 - immediate weightbearing permissible

- Complications

- Wound slough and dehiscence
 - incidence
 - 9-30%
 - wait for soft tissue edema to subside before ORIF (1-2 weeks)
 - treatment
 - free flap for postoperative wound breakdown
- Infection
 - incidence
 - 5-15%
 - risk factors
 - significant soft tissue swelling at time of definitive surgery
 - treatment
 - irrigation and debridement, antibiotics, possible hardware removal
- Malunion
 - incidence
 - 6-14%
 - treatment
 - joint-preserving correction with secondary anatomic reconstruction
 - corrective ankle fusion
- Nonunion
 - incidence
 - 5% of patients undergoing ORIF
 - usually at the metaphyseal junction
 - risk factors
 - metaphyseal comminution
 - open fractures
 - bone loss
 - tobacco use
 - NSAID use
 - treatment
 - must rule out infected non-union (labs to obtain CRP, ESR, WBC)
 - other non-union labs (PTH, calcium, total protein, serum albumin, vitamin D, TSH)
 - rigid fixation with bone grafting
- Post-traumatic arthritis
 - incidence
 - chondrocyte cell death at fracture margins is a contributing factor
 - IL-6 is elevated in the synovial fluid following an intra-articular ankle fracture
 - most commonly begins 1-2 years postinjury
 - risk factors
 - sequelae of cartilage trauma
 - non-anatomic articular reduction
 - mal-alignment
 - treatment
 - first line is conservative management (bracing, injections, NSAIDs, activity modification)
 - total ankle arthroplasty
 - ankle arthrodesis
- Chondrolysis
- Stiffness

- Prognosis

- Poor outcomes and lower return to work associated with
 - lower level of education
 - pre-existing medical comorbidities
 - male sex
 - work-related injuries

- lower income levels
- Outcomes correlate with severity of the fracture pattern and the quality of reduction
 - at 2 year follow-up, the majority of type C pilon fractures report lower SF-36 scores than patients with pelvic fractures, AIDS, or coronary artery disease
 - clinical improvement seen for up to 2 years after injury
- Return of vehicle braking response time
 - 6 weeks after initiation of weight bearing

57- Talar Neck Fractures

Images



• Summary

- Talar neck fractures are high energy injuries to the hindfoot that are associated with a high incidence of talus avascular necrosis.
- Diagnosis is made with radiographs of the foot but frequently require CT scan for full characterization.
- Treatment is emergent reduction of the talus following by internal fixation in an acute or delayed fashion.

• Epidemiology

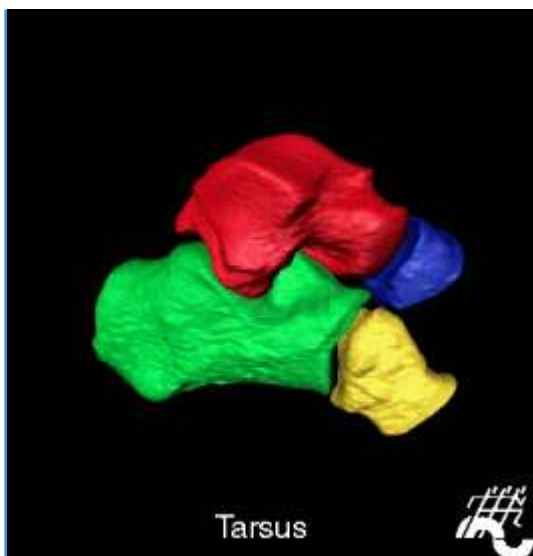
- Incidence
 - common
 - most common fracture of talus (50%)

• Etiology

- Mechanism
 - a high-energy injury
 - is forced dorsiflexion with axial load
- Associated conditions
 - ipsilateral lower extremity fractures common

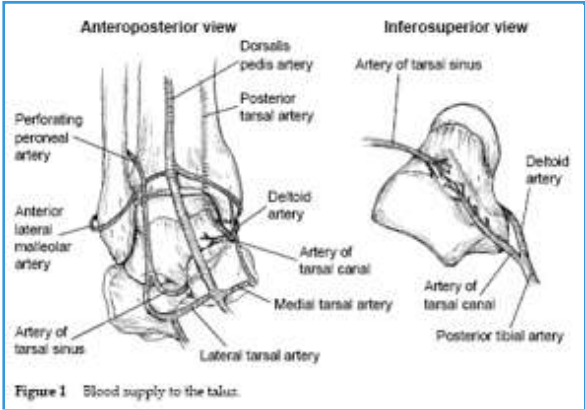
• Anatomy

- Articulation



- inferior surface articulates with posterior facet of calcaneus
- talar head articulates with
 - navicular bone
 - sustentaculum tali
 - navicular bone
 - sustentaculum tali
- navicular bone
- sustentaculum tali
- lateral process articulates with

- posterior facet of calcaneus
 - lateral malleolus of fibula
- posterior process consist of medial and lateral tubercles separated by groove for FHL
- Navicular bone
- Sustenaculum tali
- Blood supply
 - talar neck supplied by three sources



- posterior tibial artery
 - via artery of tarsal canal (dominant supply)
 - supplies majority of talar body
 - deltoid branch of posterior tibial artery
 - supplies medial portion of talar body
 - may be only remaining blood supply with a displaced fracture
 - anterior tibial artery
 - supplies head and neck
 - perforating peroneal artery via artery of tarsal sinus
 - supplies head and neck

Classification

- Hawkins Classification			
Type	Description	AVN risk	
- Hawkins I	- Nondisplaced	0-13%	
- Hawkins II	- Subtalar dislocation	20-50%	
- Hawkins III	- Subtalar and tibiotalar dislocation	20-100%	
- Hawkins IV	- Subtalar, tibiotalar, and talonavicular dislocation	70-100%	

Imaging

- Radiographs
 - recommended views
 - AP

- lateral
- Canale view



- best view to demonstrate talar neck fractures
- technique is maximum equinus, 15 degrees pronated, xray 75 degrees cephalad from horizontal



- CT scan
 - best study to determine degree of displacement, comminution and articular congruity
 - CT scan also will assess for ipsilateral foot injuries (up to 89% incidence)

• Treatment

- Nonoperative
 - **emergent reduction in ER**
 - indications
 - all cases require emergent closed reduction in ER
 - **short leg cast for 8-12 weeks (NWB for first 6 weeks)**
 - indications
 - nondisplaced fractures (Hawkins I)
 - CT to confirm nondisplaced without articular stepoff
- Operative
 - **open reduction and internal fixation**
 - indications
 - all displaced fractures (Hawkins II-IV)
 - Talus extrusion
 - techniques
 - extruded talus should be replaced and treated with ORIF
 - ~63% of reimplanations do not require secondary procedure
 - low incidence of infection with adequate I&D and antibiotic therapy
 - high incidence of AVN without collapse
 - complications
 - post-traumatic arthritis
 - mal-union
 - non-union
 - infection
 - wound dehiscence

• Techniques

- **ORIF**
 - approach
 - two approaches recommended
 - visualize medial and lateral neck to assess reduction
 - typical areas of comminution are dorsal and medial
 - anteromedial

- between tibialis anterior and posterior tibialis
 - preserve soft tissue attachments, especially deep deltoid ligament (blood supply)
 - medial malleolar osteotomy to preserve deltoid ligament
- anterolateral
 - between tibia and fibula proximally, in line with 4th ray
 - elevate extensor digitorum brevis and remove debris from subtalar joint
- technique
 - anatomic reduction essential
 - variety of implants used including mini and small fragment screws, cannulated screws and mini fragment plates
 - medial and lateral lag screws may be used in simple fracture patterns
 - consider mini fragment plates in comminuted fractures to buttress against varus collapse

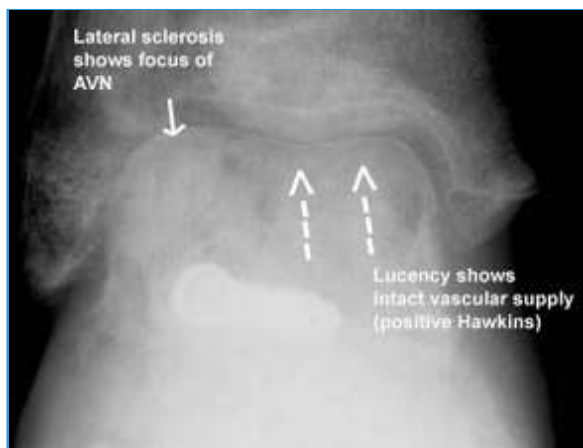


- postoperative
 - non-weight-bearing for 10-12 weeks

• Complications

○ Osteonecrosis

- 31% overall (including all subtypes)
- radiographs
 - hawkins sign



- subchondral lucency best seen on mortise Xray at 6-8 weeks
 - indicates intact vascularity with resorption of subchondral bone
- associated with talar neck comminution and open fractures
- delayed internal fixation is not associated with avascular necrosis
- Posttraumatic arthritis
 - subtalar arthritis (50%) is the most common complication
 - tibiotalar arthritis (33%)
- Varus malunion (25-30%)
 - can be prevented by anatomic reduction
 - treatment includes medial opening wedge osteotomy of talar neck
 - leads to
 - decreased subtalar eversion
 - decreased motion with locked midfoot and hindfoot
 - weight bearing on the lateral border of the foot

58- Subtalar Dislocations

- Summary

- Subtalar Dislocations are hindfoot dislocations that result from high energy trauma.
- Diagnosis is made clinically and confirmed with orthogonal radiographs of the foot.
- Treatment is a trial of closed reduction but may require open reduction given the several anatomic blocks to reduction.

- Epidemiology

- Incidence
 - rare
 - accounts for 1% of all dislocations
 - < 1 per 100,000 per year
- Demographics
 - more common in young or middle-aged males

- Pathophysiology

- Mechanism
 - typically result from a high-energy mechanism
 - 25% may be open



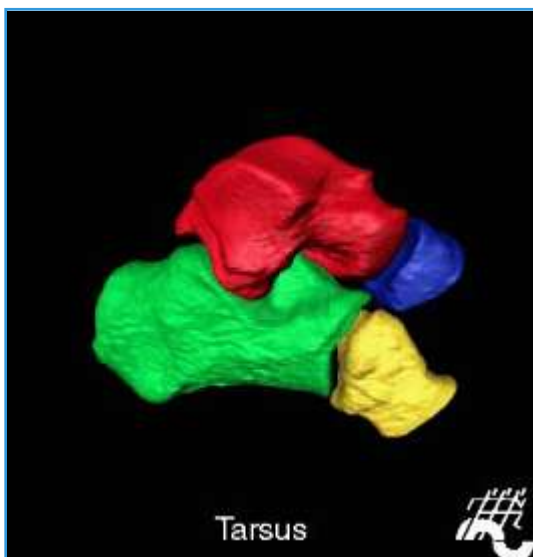
- lateral dislocations more likely to be open
- Associated conditions
 - associated dislocations
 - talonavicular
 - associated fractures (up to 44%)
 - with medial dislocation
 - dorsomedial talar head
 - posterior process of talus



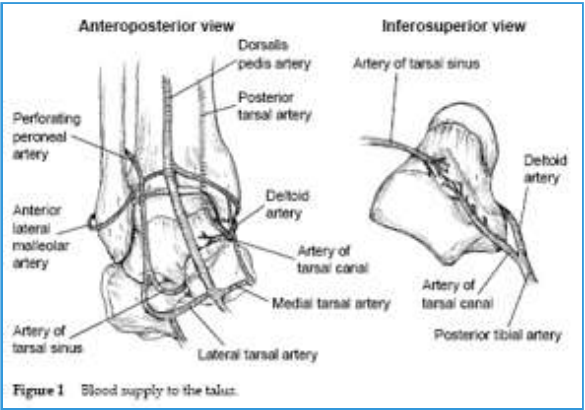
- navicular
- with lateral dislocation
 - cuboid
 - anterior calcaneus
 - lateral process of talus
 - fibula

• Anatomy

◦ Articulation



- inferior surface articulates with posterior facet of calcaneus
- talar head articulation
 - navicular bone
 - sustentaculum tali
- navicular bone
- sustentaculum tali
- lateral process articulates with
 - posterior facet of calcaneus
 - lateral malleolus of fibula
- posterior process consist of medial and lateral tubercles separated by groove for FHL
- Muscles
 - talus has no muscular or tendinous attachments
- Blood Supply



- posterior tibial artery
 - via artery of tarsal canal (most important and main supply)
 - supplies most of talar body
 - via calcaneal braches
 - supplies posterior talus
- anterior tibial artery
 - supplies head and neck
- perforating peroneal arteries via artery of tarsal sinus
 - supplies head and neck
- deltoid artery (located in deep segment of deltoid ligament)
 - supplies body
 - may be only remaining blood supply with a talar neck fracture

• Classification

○ Anatomic

■ Anatomic ○ (based on dislocation direction of midfoot/forefoot)		
■ Medial dislocation	■ most common (65-80%) , due to lateral malleolus acting as strong buttress, preventing lateral dislocation ■ results from inversion force on plantarflexed foot ■ S ustentaculum tali acts as fulcrum for the neck of the talus to pivot around ■ foot becomes locked in supination ■ associated with posterior process of talus, dorsomedial talar head, and navicular fracture ■ reduction blocked by peroneal tendons, EDB, talonavicular joint capsule ■	■ 
■ Lateral dislocation	■ more likely to be open ■ results from eversion force on plantarflexed foot ■ anterior process of calcaneus acts as fulcrum for the anterolateral corner of the talus to pivot around ■ foot becomes locked in pronation ■ associated with lateral process of talus, anterior calcaneus, cuboid, and fibula fractures ■ reduction blocked by PT tendon, FHL, FDL ■	■ 
■ Anterior dislocation	■ rare	■ 
■ Posterior dislocation	■ rare	■ 
■ Total dislocation	■ talus is completely dislocated from ankle and subtalar and talonavicular joints ■ results from continuation of forces required for medial or lateral dislocation with disruption of talocrural ligaments and extrusion of talus from ankle joint ■ usually open	■ 

• Presentation

○ Physical exam

- foot will be locked in supination with medial dislocation



- known as "acquired clubfoot"
- foot will be locked in pronation with lateral dislocation



- known as "acquired flatfoot"

• Imaging

◦ Radiographs

- recommended views
 - AP
 - lateral
- findings
 - medial dislocation
 - talar head will be superior to navicular on lateral view



- lateral dislocation
 - talar head will be collinear or inferior to navicular on lateral view



◦ CT scan

- indications
 - perform following reduction
- findings
 - look for associated injuries or subtalar debris



• Treatment

◦ Nonoperative

- **closed reduction and short leg non-weight bearing cast for 4-6 weeks**

- indications
 - first line of treatment
 - 60-70% can be reduced by closed methods

- Operative

- **open reduction**

- indications
 - open dislocations
 - failure of closed reduction
 - up to 32% require open reduction
 - medial dislocation reduction blocked by lateral structures including
 - peroneal tendons
 - extensor digitorum brevis
 - talonavicular joint capsule
 - lateral dislocation reduction blocked by medial structures including
 - posterior tibialis tendon is the most common



- flexor hallucis longus
- flexor digitorum longus

- Techniques

- **Closed reduction**

- sedation
 - requires adequate sedation
- reduction
 - typical maneuvers include knee flexion and ankle plantarflexion
 - followed by distraction and hindfoot inversion or eversion depending on direction of dislocation
- post-reduction
 - perform a post-reduction CT to look for associated injuries

- **Open reduction**

- anesthesia
- approach
 - dictated by direction of dislocation and associated fractures
 - medial dislocation
 - sinus tarsi approach to remove incarcerated lateral structures (EDB, etc.)
 - lateral dislocation
 - medial approach between tibialis anterior and posterior tibial tendon to remove medial structures (posterior tibialis tendon, etc.)
 - may still require sinus tarsi/lateral approach to remove subtalar debris
- post-op care
 - if joint stable
 - place in short leg cast with non-weightbearing for 4-6 weeks
 - if joint remains unstable
 - place temporary transarticular pins or spanning external fixator

- Complications

- Post-traumatic arthritis
 - long-term follow up of these injuries show degenerative changes
 - subtalar joint most commonly affected with up to 89% of patients demonstrating radiographic arthrosis (63% symptomatic)
- Stiffness

- most common complication

- Prognosis

- Post-traumatic arthritis is common
- Poor outcomes associated with
 - high-energy mechanisms
 - lateral dislocation s
 - result from higher energy mechanisms
 - open dislocations
 - high risk of infection due to
 - lack of muscle coverage
 - poor vascularity of soft tissues
 - difficulty cleaning contaminated joints
 - concomitant fractures involving the subtalar joint

59- Ankle Fractures

Images



- Summary

- Ankle fractures are very common injuries to the ankle which generally occur due to a twisting mechanism.
- Diagnosis is made with plain radiographs of the ankle.
- Treatment can be nonoperative or operative depending on fracture displacement, ankle stability, presence of syndesmotic injury, and patient activity demands.

- EPIDEMIOLOGY

- Incidence
 - 187 per 100,000 adults annually
- Demographics
 - bimodal distribution
 - young, active
 - highest incidence in male is between 15-24 years of age
 - elderly
 - highest incidence in females is 75-84 years of age
- Location
 - breakdown by fracture type
 - isolated malleolus fracture 70%
 - bimalleolar 20%
 - trimalleolar 7%
- Risk Factors
 - male
 - younger age
 - obesity
 - smoking
 - alcohol consumption

- Etiology

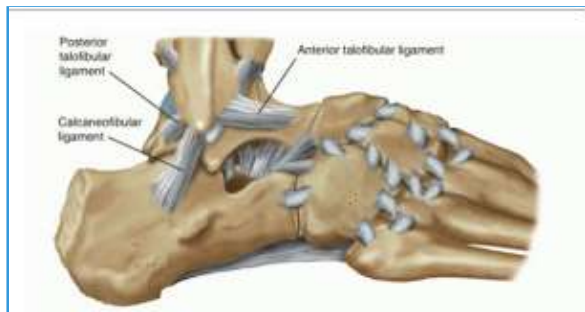
- Pathophysiology
 - mechanism of injury
 - twisting injury
- Associated conditions
 - orthopedic
 - open fractures (2%)
 - syndesmotic injury (10%)
 - chondral injury
 - peroneal tendon tears (4%)

- Anatomy

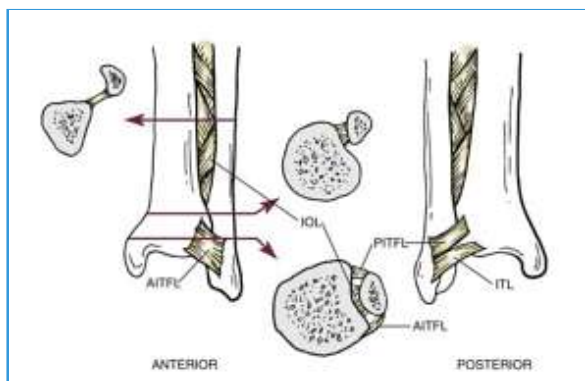
- Osteology
 - modified hinge joint consisting of tibia, fibula, and talus
 - tibial plafond and talus are broader anteriorly and wider laterally
- Ligaments
 - 3 ligamentous complex stabilize ankle
 - deltoid



- 2 components
 - superficial
 - extends from medial malleolus to broad insertion onto navicular, sustentaculum tali, and talus
 - resists hindfoot eversion
 - deep
 - extends from medial malleolus to talus
 - resists ER of talus
- lateral ligament complex



- 3 components
 - anterior talofibular ligament (ATFL)
 - primary restraint to anterior displacement, IR, and inversion of talus
 - most frequently injured lateral ligament
 - calcaneofibular (CFL)
 - deep to peroneal tendons
 - 2nd most commonly injured
 - posterior talofibular ligament (PTFL)
 - strongest ligament of lateral complex and least likely to be disrupted
- syndesmosis



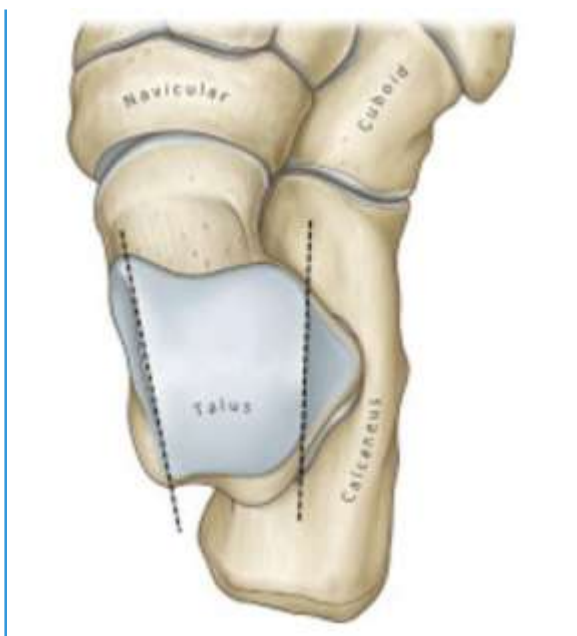
- 5 components
 - anterior inferior tibiofibular ligament (AITFL)
 - originates from anterolateral tubercle of distal tibia (Chaput)
 - inserts anteriorly onto lateral malleolus (Wagstaffe)
 - posterior inferior tibiofibular ligament (PITFL)
 - broad origin from posterior tibia (Volkman's fragment)
 - inserts onto posterior aspect of lateral malleolus
 - strongest component of syndesmosis
 - intraosseous ligament (IOL)
 - distal continuation of intraosseous membrane
 - intraosseous membrane
 - inferior transverse ligament (ITL)

○ Tendons

- peroneal tendons
 - peroneus longus and brevis pass along posterior groove of lateral malleolus
 - at risk with posterolateral fibular plating
- posterior tibial tendon
 - located posterior and inferior at the level of the medial malleolus
 - at risk with posterior placement of medial malleolus screws

○ Neurovascular structures

- anterior tibial artery and deep peroneal nerve
 - course over anterior ankle between EDL and EHL
 - at risk with anterior approach
- posterior tibial artery and tibial nerve
 - course posterior to medial malleolus between FDL and FHL
 - at risk with posteromedial approach
- superficial peroneal nerve
 - crosses anteriorly over fibula about distal 1/3
 - at risk with posterolateral and direct lateral approach to fibula proximally and with anterior/anterolateral approaches
- sural nerve
 - at risk with posterolateral and direct lateral approach to fibula
- Biomechanics
 - deltoid ligament (deep portion)
 - primary restraint to anterolateral talar displacement
 - fibula
 - acts as buttress to prevent lateral displacement of talus
 - trapezoidal shape of talus



- dorsiflexion results in fibula ER and lateral translation, accommodating anteriorly wider talus
- plantarflexion results in narrower, posterior aspect of the talus leading to IR of talus

• Classification

- Lauge-Hansen
 - based on combination of foot position and direction of force applied at the time of injury
 - has been shown to predict the observed (via MRI) ligamentous injury in less than 50% of operatively treated fractures

■ Lauge-Hansen Classification		
■ Supination - Adduction (SAD)	■ 1. Talofibular sprain or distal fibular avulsion 2. Vertical medial malleolus and impaction of anteromedial distal tibia	■ 
■ Supination - External Rotation (SER)	■ 1. Anterior tibiofibular ligament sprain 2. Lateral short oblique fibula fracture (anteroinferior to posterosuperior) 3. Posterior tibiofibular ligament rupture or avulsion of posterior malleolus 4. Medial malleolus transverse fracture or disruption of deltoid ligament	■ 
■ Pronation - Abduction (PAB)	■ 1. Medial malleolus transverse fracture or disruption of deltoid ligament 2. Anterior tibiofibular ligament sprain 3. Transverse comminuted fracture of the fibula above the level of the syndesmosis	■ 
■ Pronation - External Rotation (PER)	■ 1. Medial malleolus transverse fracture or disruption of deltoid ligament 2. Anterior tibiofibular ligament disruption 3. Lateral short oblique or spiral fracture of fibula (anterosuperior to posteroinferior) above the level of the joint 4. Posterior tibiofibular ligament rupture or avulsion of posterior malleolus	■ 

- Danis-Weber (location of fibular fracture)
 - A - infrasyndesmotic (generally not associated with ankle instability)
 - B - transsyndesmotic
 - C - suprasyndesmotic
- AO / OTA
 - 44A - infrasyndesmotic
 - 44B - transsyndesmotic
 - 44C - suprasyndesmotic
- Anatomic / Descriptive
 - isolated medial malleolar
 - isolated lateral malleolar
 - isolated posterior malleolar
 - bimalleolar-equivalent
 - bimalleolar
 - trimalleolar
- Variants
 - Bosworth fracture-dislocation
 - hyperplantarflexion injury (6%)
 - curbstone fracture

- avulsion fracture of posterior tibia resulting from tripping
- LeFort-Wagstaffe fracture
 - AITFL avulsion off anterior fibular tubercle usually seen with SER-type fracture patterns
- Tillaux-Chaput fracture
 - AITFL avulsion of anterior tibial margin (tibial counterpart of LeFort-Wagstaffe fracture)

- PRESENTATION

- Symptoms
 - severe ankle pain
 - difficulty or inability to ambulate
- Physical exam
 - inspection and palpation
 - ecchymosis and swelling around the ankle
 - medial sided swelling, tenderness, and ecchymosis not sensitive for medial stability
 - deformity with displaced fractures
 - palpate proximal fibula for Maisonneuve fracture
 - soft tissue assessment
 - soft tissue injury
 - fracture blisters
 - skin tenting
 - open wounds
 - motion
 - ankle motion generally limited
 - neurovascular
 - peripheral vascular disease
 - diabetic neuropathy

- Imaging

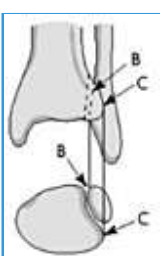
- Radiographs
 - recommended views
 - ankle series
 - AP
 - lateral
 - mortise
 - dynamic stress views
 - manual stress view



- most appropriate stress radiograph to assess competency of deltoid ligament
 - assess on mortise view
 - foot dorsiflexed and ER with tibia stabilized
 - more sensitive to injury than medial tenderness, ecchymosis, or edema
- gravity stress radiograph is equivalent to manual stress radiograph



- full-length tibia radiographs
 - rule out Maisonneuve-type fracture
- optional
 - comparison view of contralateral ankle
 - weight bearing views
 - difficult for patients to tolerate in acute setting
- findings
 - syndesmotic injury
 - decreased tibiofibular overlap



- measure at point of maximum overlap
- normal >6 mm on AP view
- normal >1 mm on mortise view

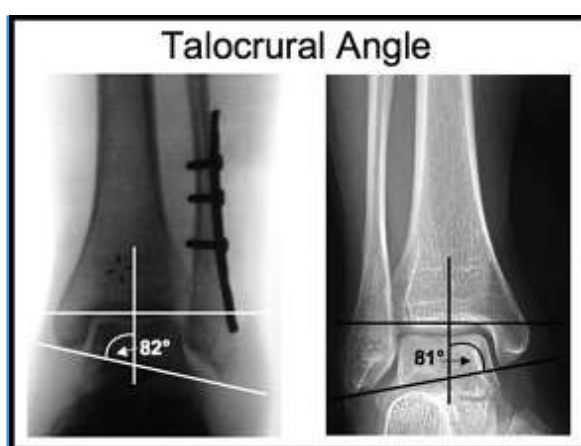
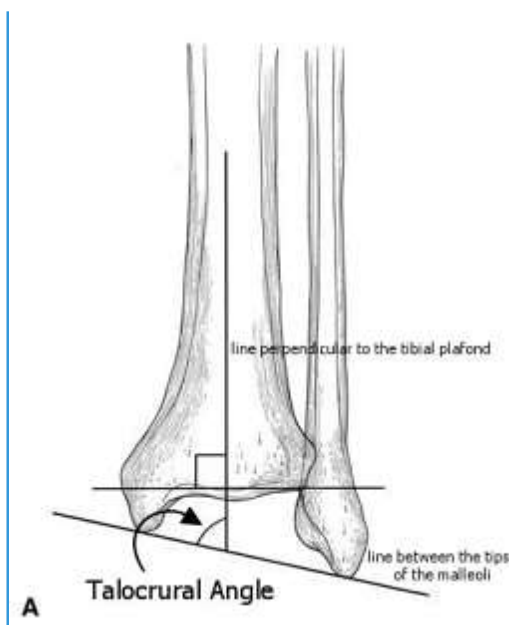
- it has also been reported that there is no actual correlation between syndesmotic injury and tibiofibular clear space or overlap measurements
- increased medial clear space



- normal ≤ 4 mm on mortise or stress view
- medial clear space of >5 mm with external rotation stress applied to a dorsiflexed ankle is predictive of deep deltoid disruption
- increased tibiofibular clear space



- measure clear space 1 cm above joint
- normal <6 mm on both AP and mortise views
- lateral malleolus fractures
- talocrural angle



- bisection of line through tibial anatomical axis and line through tip of both malleoli
- shortening of lateral malleoli fractures can lead to increased talocrural angle
- talocrural angle is not 100% reliable for estimating restoration of fibular length
- can also utilize realignment of the medial fibular prominence with the tibiotalar joint
- posterior malleolus fractures
- double contour sign



- misty mountains sign



- spur sign

○ CT scan

- indications
 - trimalleolar ankle fracture
 - operative planning
 - 25% of surgeons would change operative technique after CT
 - assess morphology of posterior malleolus
 - supination-adduction injury
 - assess for anteromedial impaction of tibial plafond and talar articular cartilage injury
- views
 - axial and sagittal views most useful to assess posterior malleolus
- findings
 - size and shape of posterior malleolus fragment
 - entrapped loose fragments
 - impaction
 - comminution

○ MRI

- Indications
 - evaluate for soft tissue or cartilaginous injuries
- findings
 - deltoid injury
 - syndesmotic injury
 - lateral ankle ligament complex
 - peroneal tendon injury
 - chondral lesions of talus

• DIFFERENTIAL

○ Ankle sprain

- may be able to bear weight
- positive anterior drawer or talar tilt test
- radiographs without fracture

- Syndesmotic injury
 - positive Hopkin's squeeze test
 - increased medial clear space or tibiofibular diastasis on stress view
 - lambda sign on MRI
- Achilles tendon rupture
 - palpable gap over achilles
 - inability or weakness with plantar flexion
 - increased resting dorsiflexion when prone with knees bent
 - positive Thompson's test
- Pilon fracture
 - high energy, axial load
 - significant articular involvement
 - CT showing 4 common components of pilon
 - Chaput fragment, Volkmann fragment, medial malleolus, central impaction
- Subtalar dislocation
 - high energy with extensive soft tissue injury, 25% open
 - x-ray shows dislocation of talus from calcaneous or navicular bone
- Treatment
 - Nonoperative
 - indications
 - stable ankle fracture
 - isolated stable medial malleolus fracture
 - isolated stable lateral malleolus fracture
 - avulsion tip fractures of medial or lateral malleolus
 - posterior malleolar fracture with < 25% joint involvement or < 2mm step-off
 - unfit for surgery
 - modalities
 - short-leg AO splint
 - short-leg cast
 - CAM boot
 - Operative
 - **open reduction internal fixation**
 - indications
 - any talar displacement
 - bimalleolar or bimalleolar-equivalent fracture
 - posterior malleolar fracture with > 25% or > 2mm step-off
 - Maisonneuve fracture
 - Bosworth fracture-dislocations
 - open fractures
 - symptomatic malleolar nonunions
 - technique
 - goal of treatment is stable anatomic reduction with restoration of mortise
 - see fracture patterns below for specific treatment
 - positioning
 - supine
 - direct reduction of medial and lateral malleolus fractures
 - indirect reduction of posterior malleolus
 - syndesmotic fixation
 - prone or lateral
 - facilitates direct reduction of posterior malleolus
 - approach
 - direct lateral approach to fibula
 - common approach for fibula ORIF syndesmotic fixation
 - syndesmotic fixation
 - posterolateral approach to ankle

- concomitant access to posterior fibula and posterior malleolus
 - prone or lateral
 - posteromedial approach to ankle
 - access to medial malleolus and posterior malleolus
 - direct medial approach to ankle
 - common approach for medial malleolus ORIF
- outcomes
 - overall success rate of 90%
 - prolonged recovery expected (2 years to obtain final functional result)
 - anatomic reduction is considered most important factor for satisfactory outcome
 - 1 mm shift of talus leads to 42% decrease in tibiotalar contact area
 - worse outcomes associated with:
 - decreased level of education
 - smoking
 - alcohol use
 - presence of medial malleolar fracture
 - ORIF superior to closed treatment of bimalleolar fractures
 - restoration of marginal impaction of tibial plafond in SA ankle fracture leads to optimal functional outcomes
 - improved incisional perfusion with Allgöwer-Donati sutures
- postoperative rehabilitation
 - proper braking response time (driving) returns to baseline at 9 weeks after surgery
 - braking travel time is significantly increased until 6 weeks after initiation of weight bearing in both long bone and periarticular fractures of lower extremity
- **external fixation**
 - indications
 - staging procedure
 - severe open fractures with gross contamination
 - poor soft tissue requiring close monitoring
 - unstable reduction
 - modalities
 - ankle-spanning external fixator
 - circular frame
 - hybrid
 - outcomes
 - lower risk of redislocation and skin complication in ankle fracture dislocation vs splint

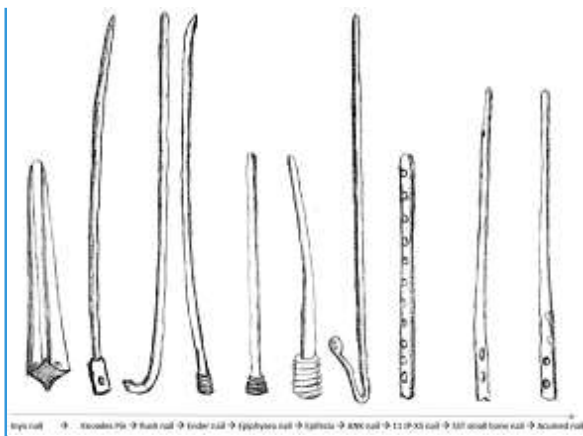
• Isolated Medial Malleolus Fracture

- Nonoperative
 - indications
 - isolated medial malleolus fracture without talar shift
 - avulsion tip fracture
 - deep deltoid inserts on posterior colliculus
 - technique
 - NWB for 4-6 weeks
 - outcomes
 - good outcomes with >95% union rate for isolated injury
- Operative
 - **ORIF**
 - indications
 - any talar shift (static or stress view)
 - technique
 - lag screw fixation
 - lag screw fixation stronger if placed perpendicular to fracture line
 - antilide plate with lag screw
 - best for vertical shear fractures

- tension band fixation
 - fragment too small
 - poor bone quality
- outcomes
 - bicortical 3.5 mm fully-threaded screw (lag by technique) superior to unicortical 4.0 mm partially-threaded screw (lag by design)

- Isolated Lateral Malleolus Fracture

- Nonoperative
 - indications
 - stable mortise with no talar shift
 - > 4-5 mm of medial clear space widening on stress views considered unstable
 - recent studies show deep deltoid intact with 8-10 mm of widening on stress view
 - technique
 - immediate WBAT in CAM boot
 - brief period of immobilization in splint
- Operative
 - **open reduction and internal fixation (ORIF)**
 - indications
 - presence of talar shift on static or stress view (bimalleolar equivalent)
 - >3 mm displacement
 - technique
 - plate
 - lateral
 - one-third tubular or anatomic distal fibular plate
 - stiffest fixation construct for the fibula is a locking plate
 - posterolateral
 - one-third tubular plate (antiglide mode)
 - posterior antiglide plating is biomechanically superior to lateral plate
 - disadvantage of peroneal tendon irritation if plate too distal
 - retrograde intramedullary fixation



- several implant choices
 - newer implants have improved axial and rotational control with distal/proximal fixation
 - useful for poor soft-tissue envelopes or high risk for wound-healing complication
- outcomes
 - similar outcomes with operative and non-operative treatment if stable mortise

- Bimalleolar-Equivalent Fracture (deltoid ligament tear with fibular fracture)

- Nonoperative
 - indications
 - low demand and unable to tolerate surgery
- Operative
 - **ORIF of lateral malleolus +/- syndesmotic fixation**
 - indications
 - lateral malleolus fracture with talar shift (static or stress view)
 - technique
 - assess syndesmotic stability after fixation of lateral malleolus
 - not necessary to repair medial deltoid ligament

- explore medially if unable to reduce mortise and deltoid ligament potentially interposed
- outcomes
 - lower rate of nonunion and fracture displacement with operative treatment

• Bimalleolar (MEDIAL AND LATERAL) Fracture

- Nonoperative
 - indications
 - low demand and unable to undergo surgical intervention
- Operative
 - **ORIF**
 - indications
 - any displacement or talar shift (static or stress view)
 - fibula technique
 - lateral plate
 - posterolateral plate
 - retrograde intramedullary fixation
 - medial malleolus technique
 - antiglide plate
 - tension band wiring
 - lag screws
 - screws perpendicular to fracture plane

• Posterior Malleolar Fracture

- Nonoperative
 - indications
 - < 25% of articular surface involved
 - size should be calculated on CT since plain radiographs are unreliable
 - < 2 mm articular stepoff
 - stable syndesmosis
- Operative
 - **ORIF**
 - indications
 - > 25% of articular surface
 - > 2 mm articular stepoff
 - syndesmotic instability
 - posterior subluxation of talus
 - technique
 - approach
 - posterolateral approach
 - interval between FHL and peroneal tendons
 - common approach since posterior malleolus fractures are frequently posterolateral
 - posteromedial approach
 - percutaneous
 - decision of approach will depend on location of fracture, degree of displacement, and need for fibular fixation
 - fixation methods
 - antiglide plate
 - percutaneous A to P lag screws
 - fix fibula first
 - must be well reduced
 - syndesmosis injury
 - stiffness of syndesmosis restored to 70% normal with isolated fixation of posterior malleolus vs 40% with isolated syndesmosis fixation
 - PITFL may remain attached to posterior malleolus and syndesmotic stability may be restored with isolated posterior malleolar fixation
 - stress examination of syndesmosis still required after posterior malleolar fixation

- 40-90% of distal third spiral tibia fractures have an associated posterior malleolus fracture

- Bosworth Fracture-Dislocation

- Overview

- rare fracture-dislocation of ankle where fibula is entrapped behind tibia and is irreducible
 - posterolateral ridge of the distal tibia hinders reduction of the fibula
 - open reduction of fibula and internal fixation is required

- Hyperplantarflexion Variant

- Overview

- fracture-dislocation of the ankle due to hyperplantarflexion
 - main feature is a vertical shear fracture of the posteromedial tibial rim
 - "spur sign" is pathognomonic



- double cortical density at the inferomedial tibial metaphysis
 - 79% sensitive, 100% specific
 - ORIF of posterior malleolus with antiglide plating

- Open Ankle Fracture

- Operative

- **emergent operative debridement and ORIF**
 - indicated if soft tissue amenable
 - primary closure at index procedure can be performed in appropriately-selected grade I, II, and IIIA open fractures in otherwise healthy patients without gross contamination
 - **external fixation**
 - indications
 - significant soft tissue compromise
 - unstable fracture in splint/cast

- Associated Syndesmotic Injury

- Overview

- 10% of all ankle fractures



- higher incidence with higher fibula fractures
 - Weber A fracture <10%
 - Weber B fractures ~40-50%
 - Weber C fracture patterns (>80%)
- fixation usually not required when fibula fracture within 4.5 cm of plafond

○ Evaluation

- static views
 - tibiofibular clear space
 - measure tibiofibular clear space 1 cm above joint
 - tibiofibular overlap
 - medial clear space
- dynamic views
 - manual external-rotation stress
 - abduction/external rotation stress of dorsiflexed foot
 - lateral stress radiograph has greater interobserver reliability than an AP/mortise stress film
 - instability of the syndesmosis is greatest in the anterior-posterior direction
 - gravity-stress
 - patient placed in lateral decubitus position
 - similar effectiveness to manual ER stress test
 - Cotton/hook test
 - intraoperative assessment
 - bone hook around fibula used to pull while placing counter traction on tibia

○ Treatment

- **syndesmotic screw or suture fixation**
 - indications
 - widening of medial clear space
 - tibiofibular clear space (AP) greater than 5 mm
 - tibiofibular overlap (mortise) narrowed
 - technique
 - length and rotation of fibula must be accurately restored
 - "Dime sign"/Shenton's line to determine length of fibula



- fixing lateral and/or posterior malleolus first may obviate need for syndesmotic fixation
- outcomes are strongly correlated with anatomic reduction
 - placing reduction clamp on middle medial tibial ridge and the lateral fibular ridge at the level of the syndesmosis (1-2 cm proximal to mortise) will achieve reliable anatomic reduction
 - maximum dorsiflexion not required during screw placement (over-tightening)
 - open reduction required if closed reduction unsuccessful or questionable
- one or two cortical screw(s) or suture-button devices 2-4 cm above joint
 - angled posterior to anterior 20-30 degrees (fibula posterior to tibia)

- controversies
 - number of screws
 - 1 or 2 most commonly reported
 - number of cortices
 - 3 or 4 most commonly reported
 - size of screws
 - 3.5 mm or 4.5 mm screws
 - implant
 - suture button has lower rate of malreduction and reoperation rate than screws
- hardware removal with screws
 - no difference in outcomes seen with hardware maintenance (breakage or loosening) or removal at 1 year
 - outcome may be worse with maintenance of intact screws
- postoperative
 - screws should be maintained in place for at least 8-12 weeks
 - must remain non-weight bearing, as screws are not biomechanically strong enough to withstand forces of ambulation
 - any postoperative malalignment or widening should be treated with open debridement, reduction, and fixation

• Diabetic Ankle Fractures (with or without Neuropathy)

- Pathophysiology
 - poor circulation impairs wound and fracture healing
 - loss of protective sensation
 - poor bone quality
- Nonoperative treatment
 - Stable unimalleolar ankle fractures
 - Poor outcomes and increased risk for:
 - loss of reduction (greatest risk)
 - Charcot arthropathy
 - malunion
 - nonunion
- Operative treatment
 - Risks
 - prolonged healing
 - high risk of hardware failure
 - high risk of infection
 - lower functional outcomes
 - need for future amputation
 - Enhanced fixation
 - multiple quadricortical syndesmotic screws (even in the absence of syndesmotic injury)
 - tibiotalar Steinmann pins or hindfoot nailing
 - ankle spanning external fixation
 - augment with intramedullary fibula K-wires
 - stiffer, more rigid fibular plates (instead of 1/3 tubular plates)
 - compression plates
 - small fragment locking plates
 - Delay weightbearing
 - maintain non-weightbearing postop for 8-12 weeks (instead of 4-8 weeks in normal patients)

• Complications

- Nonoperative
 - ulceration from cast
 - delayed union or nonunion
 - malunion
 - post-traumatic arthritis

- DVT (5%)
 - ankle stiffness
 - Operative
 - wound problems (~5%)
 - deep infections (1-2%)
 - up to 20% in diabetic patients
 - largest risk factor for diabetic patients is presence of peripheral neuropathy
 - malunion
 - articular impaction of tibial plafond in SAD injuries should be addressed at time of surgery
 - corrective osteotomy requires obtaining anatomic fibular length and mortise correction for optimal outcomes
 - post-operative stiffness
 - Loss of dorsiflexion with posterior fixation
 - post-traumatic arthritis
 - rare with anatomic reduction and fixation
 - very common in "log-splitter" type injuries (trans-syndesmotic fracture-dislocations in which the talus is driven into the distal tibiofibular articulation)
 - neurologic injury
 - superficial peroneal nerve injury (10-15%)
 - At risk with lateral approach to distal fibula, posterolateral, and anterior/anterolateral approaches
 - Two terminal nerve branches that innervate dorsum of the foot
 - hardware irritation
 - hardware removal ~20%
 - risk factors
 - younger age
 - women
 - longer operative time
 - peroneal tendonitis (5-40%)
 - posterolateral plating of fibula
 - risk factors
 - distal placement of fibula plate
 - protruding screw head in most distal hole of fibula plate
 - posterior tibial tendonitis
 - at risk with posterior medial malleolus screw placement
 - complex regional pain syndrome
- PROGNOSIS
 - Excellent for stable ankle fractures treated nonoperatively
 - Outcomes following operative treatment generally very favorable
 - 90% mild/no ankle pain with minimal limitations and near full functional recovery at 1 yr
 - Positive predictors for good outcomes
 - age <40
 - male
 - ASA 1 or 2
 - absence of diabetes
 - Risk factors for adverse outcomes
 - older age
 - osteoporosis
 - diabetes
 - peripheral vascular disease
 - female
 - higher ASA
 - smoking
 - alcohol use
 - lower level of education

60- Calcaneus Fractures

- Summary

- Calcaneus fractures are the most common fractured tarsal bone and are associated with a high degree of morbidity and disability.
- Diagnosis is made radiographically with foot radiographs with CT scan often being required for surgical planning.
- Treatment is nonoperative versus operative based on fracture displacement and alignment, associated soft tissue injury, and patient risk factors.

- Epidemiology

- Incidence
 - common
 - most frequent tarsal fracture
 - 60-75% of injuries are intra-articular fractures
 - 1-3% are calcaneal tuberosity fractures
- Anatomic location
 - 17% are open fractures
 - no significant increase in infection rates
 - increased risk for wound complications
 - calcaneal tuberosity fractures
 - peak incidence in women in seventh decade of life

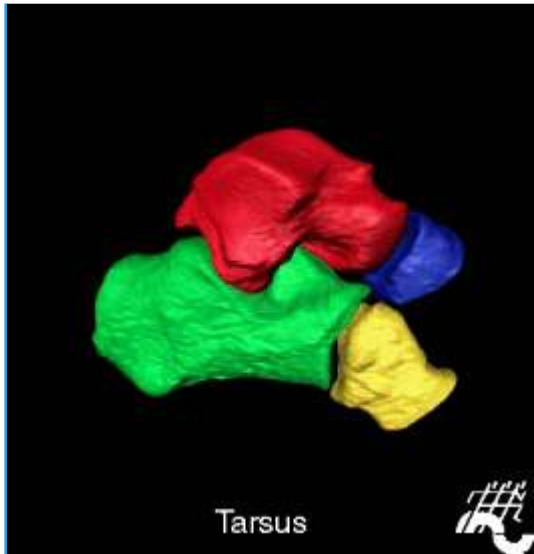
- Etiology

- Pathophysiology
 - mechanism
 - intra-articular fractures
 - traumatic axial loading is the primary mechanism of injury
 - fall from height
 - motor-vehicle accidents
 - calcaneal tuberosity fractures
 - poor bone quality/osteoporosis
 - violent contact of the triceps surae with forced dorsiflexion
 - strong concentric contact of the triceps surae with knee in full extension
 - intrinsic tightness of the gastrocnemius and achilles tendon
 - peripheral neuropathy leading to decreased pain sensation and proprioception resulting in recurrent microtrauma
 - calcaneal stress fractures
 - increased physical activity in the setting of relative energy deficiency
 - anterior process fractures
 - twisting injury mechanism
 - avulsion injury of the bifurcate ligament
 - pathoanatomy
 - intra-articular fractures
 - primary fracture line results from oblique shear and leads to the following two primary fragments
 - superomedial fragment (constant fragment)
 - includes the sustentaculum tali and is stabilized by strong ligamentous and capsular attachments
 - superolateral fragment
 - includes an intra-articular aspect through the posterior facet
 - secondary fracture lines
 - dictate whether there is joint depression or tongue-type fracture
 - extra-articular fractures
 - strong contraction of gastrocnemius-soleus with concomitant avulsion at its insertion site on calcaneus

- more common in osteopenic/osteoporotic bone
 - anterior process fractures
 - inversion and plantar flexion of the foot cause avulsion of the bifurcate ligament
- Associated injuries
 - orthopaedic
 - extension into the calcaneocuboid joint occurs in 63%
 - vertebral injuries in 10%
 - contralateral calcaneus in 10%

• Anatomy

- Osteology
 - articular facets



- superolateral fragment contains the articular facets
 - superior articular surface contains three facets that articulate with the talus
 - posterior facet is the largest and is the major weight bearing surface
 - the flexor hallucis longus tendon is medial to the posterior facet and inferior to the medial facet and can be injured with errant drills/screws that are too long
 - middle facet is anteromedial on sustentaculum tali
 - anterior facet is often confluent with middle facet
- sinus tarsi
 - between the middle and posterior facets lies the interosseous sulcus (calcaneal groove) that together with the talar sulcus makes up the sinus tarsi
- sustentaculum tali
 - projects medially and supports the neck of talus
 - FHL passes beneath it
 - represented by the constant fragment
 - deltoid and talocalcaneal ligament connect it to the talus
 - contained in the anteromedial fragment, which remains "constant" due to medial talocalcaneal and interosseous ligaments
- bifurcate ligament
 - connects the dorsal aspect of the anterior process to the cuboid and navicular

• Classification

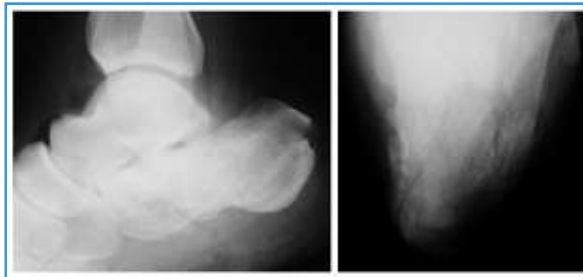
- Extra-articular (25%)
 - avulsion injury of
 - anterior process by bifurcate ligament



- sustentaculum tali
- calcaneal tuberosity (Achilles tendon avulsion)



- Intra-articular (75%)
 - Essex-Lopresti classification
 - the primary fracture line runs obliquely through the posterior facet forming two fragments
 - the secondary fracture line runs in one of two planes
 - the axial plane beneath the facet exiting posteriorly in tongue-type fractures

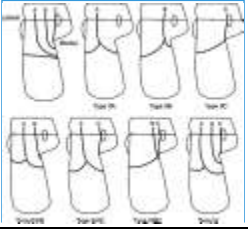
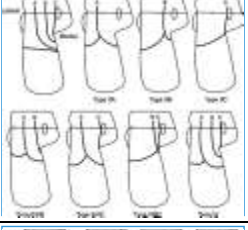
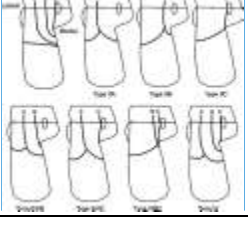


- when the superolateral fragment and posterior facet remain attached to the tuberosity posteriorly
- behind the posterior facet in joint depression fractures



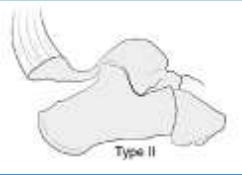
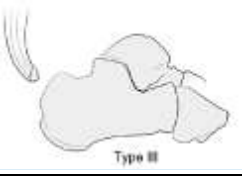
■ Sanders classification

- based on the number of articular fragments seen on the coronal CT image at the widest point of the posterior facet

■ Sanders classification		
■ Type I	■ Nondisplaced posterior facet (regardless of number of fracture lines)	■ 
■ Type II	■ One fracture line in the posterior facet (two fragments)	■ 
■ Type III	■ Two fracture lines in the posterior facet (three fragments)	■ 
■ Type IV	■ Comminuted with more than three fracture lines in the posterior facet (four or more fragments)	■ 

■ Beavis classification

- based on fracture morphology of the calcaneus tuberosity

- Beavis Classification (based on fracture of tuberosity)		
Type 1	Sleeve fracture - small shell of cortical bone avulses from the tuberosity	 
Type 2	Beak fracture - oblique fracture line runs posteriorly from most superior portion of the posterior facet	 
Type 3	Infrabursal fracture from the middle of the tuberosity	

• Presentation

- Symptoms
 - pain
 - swelling
 - inability to bear weight
 - gross deformity
 - open fracture
- Physical exam
 - inspection
 - ecchymosis and swelling
 - shortened and widened heel
 - may have apparent varus deformity
 - open skin lesions or fractures
 - posterior heel skin compromise
 - tenting, ecchymosis, or lack of skin blanching with tuberosity fractures



- neccessitates urgent sugical reduction and fixation to avoid posterior heel skin necrosis

- fracture blisters
 - must be debrided and epithelialized prior to surgical intervention
- palpation
 - diffuse tenderness to palpation
 - lack of heel cord continuity in avulsion fractures
 - lack of posterior heel skin blanching with tenting fractures
 - assess for compartment syndrome secondary to swelling
 - rare
 - presence of Langer's lines and skin wrinkles suggests skin is appropriate for surgical intervention
- strength
 - decreased ankle plantarflexion strength with avulsion fractures
- neurologic
 - assess for neurologic compromise due to swelling
- vascular
 - assess peripheral pulses
 - severe peripheral vascular disease may preclude surgical treatment due to poor wound healing potential

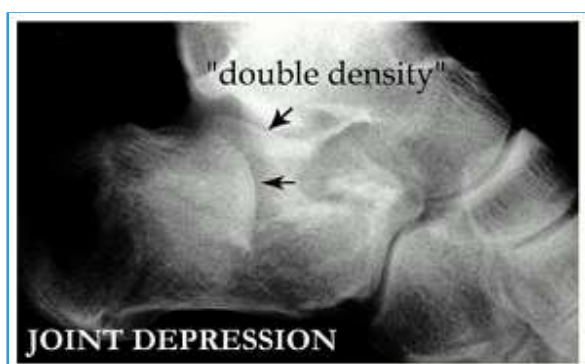
• Imaging

◦ Radiographs

- recommended views
 - AP
 - lateral
 - oblique
- optional views
 - Broden
 - allows visualization of posterior facet
 - useful for evaluation of intraoperative reduction of posterior facet
 - with ankle in neutral dorsiflexion and ~45 degrees internal rotation, take x-rays at 40, 30, 20, and 10 degrees cephalad from neutral
 - Harris



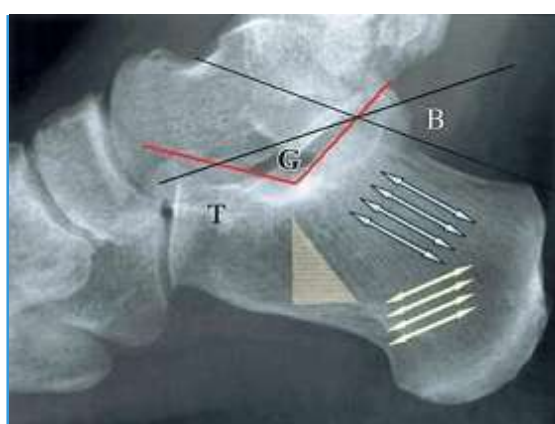
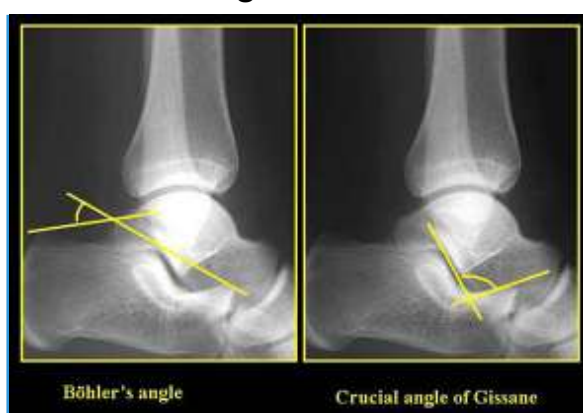
- visualizes tuberosity fragment widening, shortening, and varus positioning
 - place the foot in maximal dorsiflexion and angle the x-ray beam 45 degrees
- AP ankle
 - demonstrates lateral wall extrusion causing fibular impingement
- findings
 - double-density sign



- represents subtalar incongruity
- indicates partial separation of facet from sustentaculum
 - lateral portion of the posterior facet
- calcaneal shortening
- varus tuberosity deformity
- decreased Böhler's angle



- angle between line from highest point of anterior process to highest point of posterior facet + line tangential to superior edge of tuberosity
- measured on lateral view
- normal 20-40°
- represents collapse of the posterior facet
- increased angle of Gissane



- angle between line along lateral margin of posterior facet + line anterior to beak of calcaneus
- measured on lateral view
- normal 120-145°
- represents collapse of the posterior facet

○ CT

- indications
 - gold standard
 - should perform 2-3 mm cuts
- views
 - 30-degree semicoronal
 - demonstrates posterior and middle facet displacement
 - axial
 - demonstrates calcaneocuboid joint involvement
 - sagittal
 - demonstrates tuberosity displacement

○ MRI

- indications

- used only to diagnose calcaneal stress fractures in the presence of normal radiographs and/or uncertain diagnosis

- Treatment

- Nonoperative

- **cast immobilization with nonweightbearing for 6 weeks**

- indications
 - calcaneal stress fractures

- **cast immobilization with nonweightbearing for 10 to 12 weeks**

- indications
 - small extra-articular fracture (<1 cm) with intact Achilles tendon and <2 mm displacement
 - Sanders Type I (nondisplaced)
 - near normal Böhler's angles (20-40°)
 - anterior process fracture involving <25% of calcaneocuboid joint
 - comorbidities that preclude good surgical outcome (smoker, diabetes, PVD)
 - avoids the high wound complications seen with these fractures
 - minimally displaced tuberosity fractures (<1 cm of displacement) without threatened soft-tissue envelope in elderly patients with reduced function or physical capacity
- techniques
 - begin early range of motion exercises once swelling allows

- Operative

- **closed reduction with percutaneous pinning**

- indications
 - minimally displaced tongue-type fxs or those with mild shortening
 - large extra-articular fractures (>1 cm)
 - early reduction prevents skin sloughing and need for subsequent flap coverage
 - ideal in patients with severe peripheral vascular disease or severe soft-tissue compromise
- techniques
 - lag screws from posterior superior tuberosity directed inferior and distal

- **ORIF**

- indications
 - displaced tongue-type fractures
 - >1 cm displacement
 - threatened soft tissue
 - require urgent reduction and fixation to avoid skin necrosis (disastrous consequence)
 - open fractures
 - open reduction allows for sufficient debridement of contaminated tissue
 - inability to participate in closed treatment
 - large extra-articular > 2 mm displacement
 - Sanders Type II and III
 - posterior facet displacement >2 to 3 mm, flattening of Bohler angle, or varus malalignment of the tuberosity
 - anterior process fracture with >25% involvement of calcaneocuboid joint
 - displaced sustentaculum fractures
- timing
 - wait 10-14 days until swelling and blisters resolve and wrinkle sign present 10-14 days
 - no benefit to early surgery due to significant soft tissue swelling



- displaced tuberosity fractures with posterior skin compromise should be addressed urgently

■ outcomes

- surgical outcome correlates with the number of intra-articular fragments and the quality of articular reduction
- surgical treatment decreases the risk of post-traumatic arthritis
- factors associated with a poor outcome
 - age > 50 (similar outcomes with surgical and nonsurgical treatment)
 - obesity
 - initial Böhler's angle < 0° (these injuries do poorly regardless of treatment)
 - lower Böhler angles suggest greater energy absorbed
 - manual labor
 - open fractures (significant soft tissue injury and energy absorbed)
 - workers comp
 - smokers (poor wound healing)
 - bilateral calcaneal fractures (significant gait problems following bilateral injuries)
 - multiple trauma
 - vasculopathies
 - men do worse with surgery than women
- factors associated with most likely need for a secondary subtalar fusion
 - male worker's compensation patient who participates in heavy labor work with an initial Böhler angle less than 0 degrees

■ **primary subtalar arthrodesis**

- indications
 - Sanders Type IV
- techniques
 - combined with ORIF to restore height

■ Techniques

✧ **Cast immobilization with nonweightbearing for 6 weeks**

- techniques:
 - standard short-leg cast for calcaneal stress fractures
 - nonweight bearing cast
 - well-padded heel

✧ **Cast immobilization with nonweightbearing for 10-12 weeks**

- techniques:
 - standard short-leg cast applied with mild equinus
 - windowed over posterior heel to allow for frequent skin checks



- requires close follow-up to determine if pull of gastrocnemius-soleus displaces fracture
- weekly cast changes are necessary due to high incidence of skin complications

- high incidence of vascular insufficiency and diabetes in this population

□ **Closed reduction and percutaneous pinning**

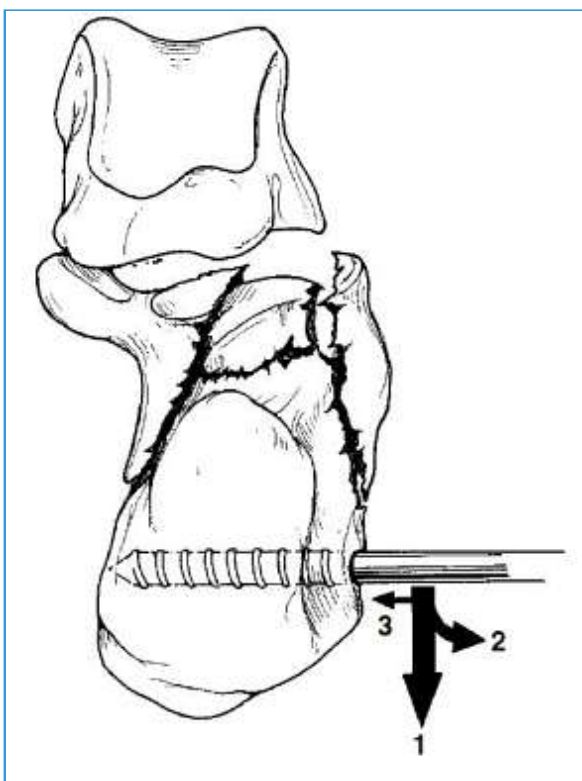
- ideal for poor soft tissue coverage or patients with peripheral vascular disease
- techniques:
 - Steinmann pin placed into the fracture site anteromedially-to-posterolateral to leverage fragments into place
 - additional K-wires and Steinmann pins are placed from posterior-to-anterior and lateral-to-medial to secure remaining bone fragments
 - calcaneal transfixin pin can be used to distract fracture
 - percutaneous tamps and elevators can be used to raise the articular surface
 - pins are cut flush with the skin and removed 8-10 weeks post-op
 - can be combined with distracting external fixator
 - pins placed in calcaneal tuberosity, cuboid, and distal tibia
 - restore calcaneal height, width, and alignment
 - can be combined with percutaneous cannulated screws

☆ **ORIF**

- extensile lateral or medial approach
- techniques:
 - extensile lateral L-shaped incision is most popular
 - vertical portion inbetween posterior fibula and achilles tendon



- horizontal portion in line with 5th metatarsal base
 - a more inferior incision protects the sural nerve
 - high rate of wound complications
 - provides access to the calcaneocuboid and subtalar joints
- full-thickness skin, soft tissue, and periosteal flaps are developed
 - flap supplied by lateral calcaneal branch of peroneal artery
 - superior flap contains the calcaneofibular ligaments and peroneal tendon sheath
- sural nerve and peroneal tendons are retracted superiorly
- lateral calcaneal wall visualized
- fracture opened and medial wall reduced going medial to lateral
 - reduction confirmed indirectly via fluoroscopy
- tuberosity reduction is done under direct visualization
 - manual traction, Schanz pins, and minidistractors
 - pin in tuberosity aids with reduction

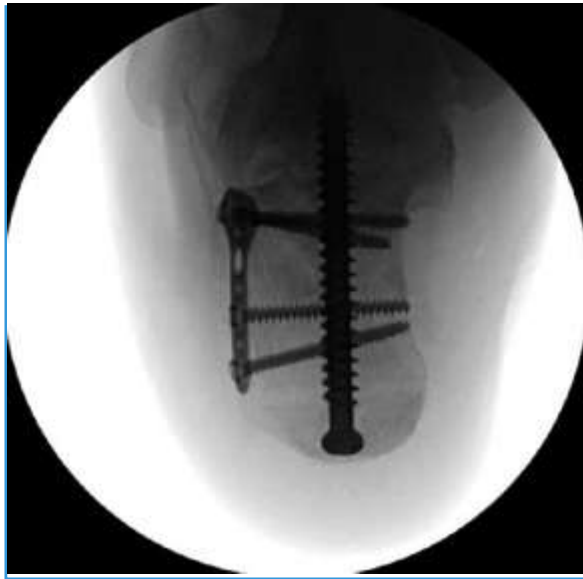


- height and length of tuberosity is recreated
 - quality of reduction affects outcomes
- provisional fixation was K-wires
- definitive fixation with plates and screws

- bone grafting provided no added benefit
- goals:
 - restore congruity of subtalar joint
 - restore Böhler's angle and calcaneal height
 - restore width
 - correct varus malalignment
- sinus tarsi approach
 - minimally invasive incision that minimizes soft tissue dissection
 - reduces wound complications associated with extensile lateral incision
 - allows direct visualization of the posterior facet, anterolateral fragment, and lateral wall
 - lower incidence of sural nerve neuralgia
 - same incision can be utilized for secondary subtalar arthrodesis or peroneal tendon debridement
 - decreased surgical time
 - techniques:
 - patient placed in lateral decubitus position
 - incision made in line with the tip of the fibula and the base of the 4th metatarsal



- 2-4 cm in length
- extensor digitorum brevis retracted cephalad to expose sinus tarsi and posterior facet
- peroneal tendons retracted posteriorly
- Schanz pin inserted percutaneously in posteroinferior tuberosity going from lateral to medial
 - provides distraction and aids with reduction
- fibrous debris and fat removed from sinus tarsi
- small elevator or lamina spreader placed under posterior facet fragment to aid in reduction
- K-wires inserted for provisional fixation aimed towards the sustentaculum
- two screws are placed lateral-to-medial to engage sustentaculum and support facet
- one large fully threaded screw from posterior-to-anterior to support axial length of calcaneus
- low-profile plate is applied underneath a well developed soft tissue envelope with screws engaging anterolateral and tuberosity fragments



- nonweight bearing for 6-8 weeks post-op with ankle range-of-motion exercises beginning 2 weeks post-op
- Essex-Lopresti maneuver
 - manipulate the heel to increase the calcaneal varus deformity
 - plantarflex the forefoot
 - manipulate the heel to correct the varus deformity with a valgus reduction
 - stabilize the reduction with percutaneous K-wires or open fixation as described above
- arthroscopic-assisted reduction and internal fixation
 - benefits:
 - decreased soft-tissue dissection
 - preservation of local blood supply
 - removal of loose bone fragments
 - improved visualization of articular surface and cartilage lesions
 - cons:
 - increased set-up
 - increased swelling from fluid extravasation
 - technically challenging
 - can be combined with sinus tarsi approach
 - techniques:
 - patient positioned in lateral decubitus position
 - fluoroscopy unit positioned posterior and oblique to patient
 - allows for axial hindfoot views
 - anterolateral and posterolateral portals are used to visualize posterior facet



- 2.4 mm 0° arthroscope
- interosseous ligament is preserved



- hematoma is irrigated
- loose bodies and cartilage fragments are removed with a shaver
- Freer elevator is introduced into one of the portal sites and used to elevate the posterior facet
 - reduction can be visualized directly



- Schanz pin to control tuberosity fragment
- cannulated screws from the posterior aspect of the calcaneal tuberosity to the anterior aspect of the calcaneus
 - restores and stabilizes length
- lateral-to-medial screws placed in sustentaculum
- buttress screw from the posterior aspect of the calcaneal tuberosity to the subchondral bone of the posterior facet
- posterior approach for calcaneal tuberosity fractures
 - techniques:
 - patient positioned prone on table
 - posterior midline incision
 - fracture fragment is mobilized and debrided



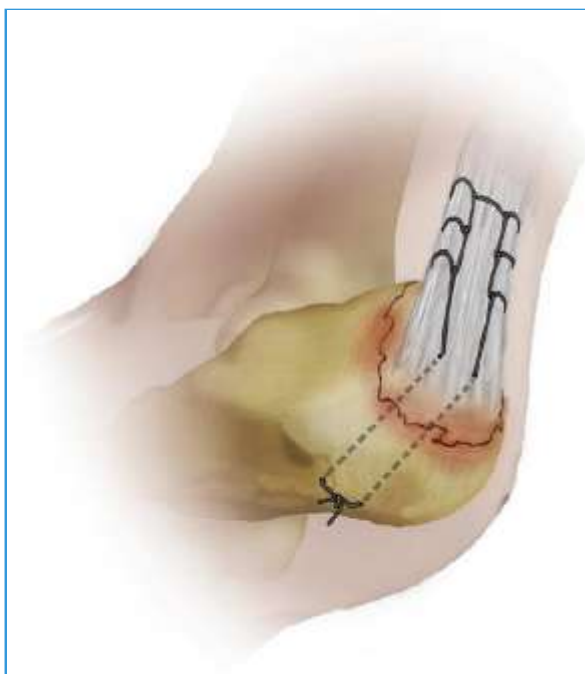
- plantar flexion of foot aids with reduction
 - presence of gastrocnemius tightness may preclude reduction
 - Strayer procedure may be performed to aid in reduction



- provisional fixation with K-wires
- final fixation with either
 - lag screws
 - tension-band constructs
 - figure-of-8 tension-band wire passed around ends of K-wires or cannulated screws



- suture fixation



- Krackow sutures passing through bone tunnels
- restricted weight bearing for 6 weeks followed by progression of weight bearing an additional 6 weeks

✦ **Primary subtalar arthrodesis**

- performed in highly comminuted Sanders IV intraarticular fractures



- high rate of secondary fusion after ORIF with these injuries
- avoids added treatment costs and decreases time off from work
- techniques:
 - can be performed through an extensile lateral or sinus tarsi approach
 - fracture reduction is performed in a similar fashion as ORIF
 - articular cartilage of the subtalar joint denuded to bleeding subchondral bone
 - cannulated compression screws are placed from the posterior calcaneal tuberosity to the talar dome



- lateral fixation plate applied to hold reduction

✧ Wound complications (10-25%)

- increased risk in smokers, diabetics, and open injuries
 - may consider nonoperative treatment in these patients
- tongue type fractures at high risk (>20%) for posterior skin necrosis
 - should be splinted in 30 degrees of planarflexion to relieve soft tissue tension
- keep all hardware away from the corner of the incision
- delayed wound healing is the most common complication

☐ Subtalar arthritis



- increased with nonoperative management
- can be addressed with ankle bracing (gauntlet type), NSAIDs, injections, and physical therapy
- may require bone block subtalar arthrodesis to address loss of calcaneal height
 - important when there are symptoms of anterior ankle impingement
- in-situ arthrodesis with preserved calcaneal height

☐ Lateral impingement with peroneal irritation

☐ Sural nerve neuroma

☐ Damaged FHL

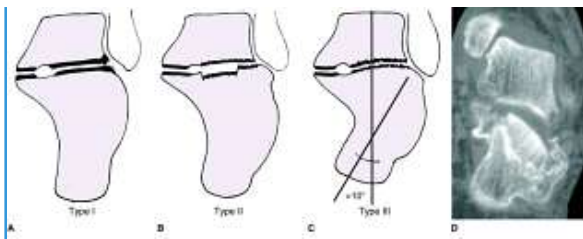
- at risk with placement of lateral to medial screws, especially at level of sustentaculum tali (constant fragment)

✧ Compartment syndrome (10%)

- results in claw toes

✧ Malunion

- introduction
 - loss of height, widening, and lateral impingement
- physical exam
 - limited ankle dorsiflexion
 - due to dorsiflexed talus with talar declination angle <20
- classification (see below)



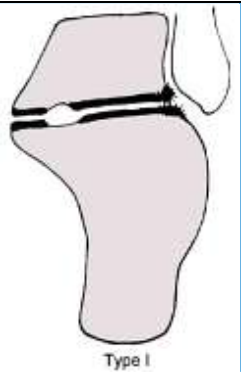
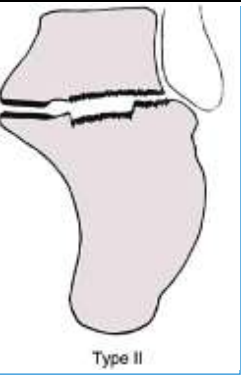
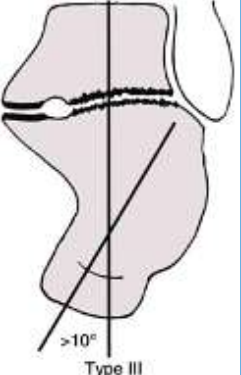
■ treatment

■ **distraction bone block subtalar arthrodesis**

- indications
 - chronic pain from subtalar joint
 - incongruous subtalar joint/post-traumatic DJD
 - loss of calcaneal height
 - mechanical block to ankle dorsiflexion
 - results from posterior talar collapse into the posterior calcaneus

■ technique

- goal is to correct
 - hindfoot height
 - ankle impingement
 - subfibular impingement
 - subtalar arthritis

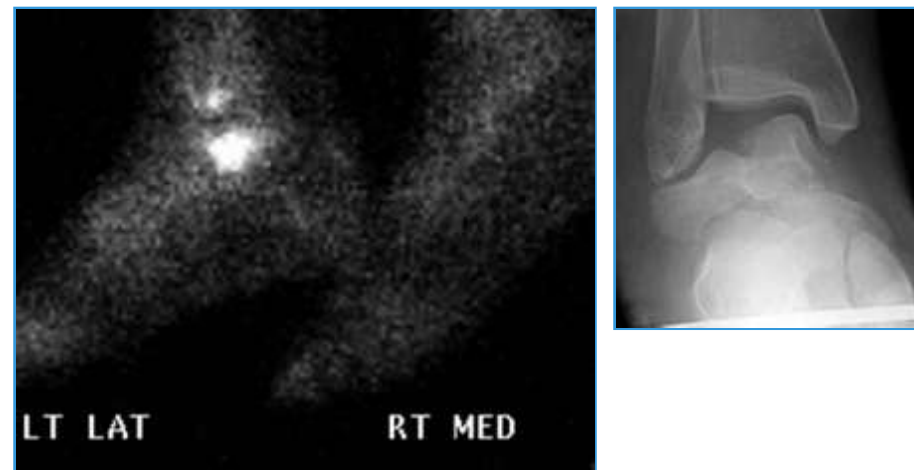
Malunion CT Classification & Treatment		
Type I	- Lateral exostosis with no subtalar arthritis - Treat with lateral wall resection	 Type I
Type II	- Lateral exostosis with subtalar arthritis - Treat with lateral wall resection and subtalar fusion	 Type II
Type III	- Lateral exostosis, subtalar arthritis, and varus malunion - Treat with lateral wall resection, subtalar fusion , and +/- valgus osteotomy (controversial)	 Type III

Prognosis

- Poor with 40% complication rate
 - increased due to mechanism (fall from height), smoking, and early surgery
 - lateral soft tissue trauma increases the rate of complication

61- Talus Fracture Other Than Neck

Images



Summary

- ✚ Talus fractures (other than neck) are rare fractures of the talus that comprise of talar body fractures, lateral process fractures, posterior process fractures, and talar head fractures.
- ✚ Diagnosis is made radiographically with foot radiographs but CT scan is often needed for full characterization of the fracture.
- ✚ Treatment is generally nonoperative with immobilization for minimally displaced injuries and surgical reduction and fixation for displaced and intra-articular fractures.

Epidemiology

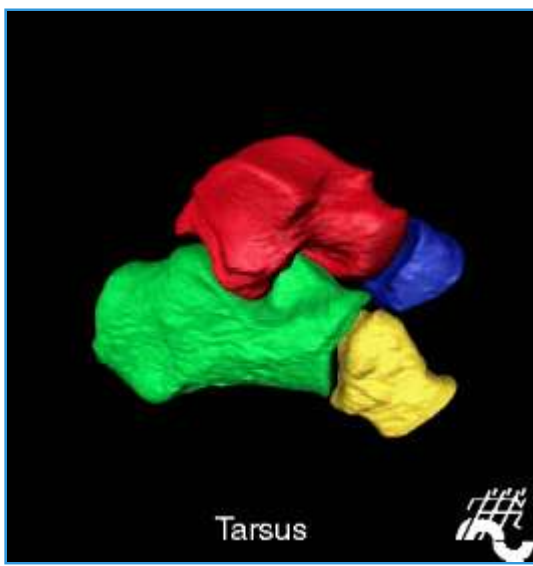
- ✚ Incidence
 - rare
 - less than 1% of all fractures
 - second most common tarsal fractures after calcaneus fxs
- ✚ Anatomic location
 - talar body fractures
 - account for 13-23% of talus fractures
 - lateral process fractures
 - account for 10.4% of talus fractures
 - talar head fracture
 - least common talus fracture

Etiology

- ✚ Mechanism
 - talar body
 - injuries often result from high energy trauma, with the hindfoot either in supination or pronation
 - lateral process of talus
 - injuries result from forced dorsiflexion, axial loading, and inversion with external rotation
 - often seen in snowboarders

Anatomy

- ✚ 3D Anatomy of talus



✧ Talus has no muscular or tendinous attachments

✧ Articulation

- there are 5 articulating surfaces
 - seventy percent of the talus is covered by cartilage
 - inferior surface articulates with posterior facet of calcaneus
- talar head articulates with
 - navicular bone
 - sustentaculum tali
- lateral process articulates with
 - posterior facet of calcaneus
 - lateral malleolus of fibula
 - this forms the lateral margin of the talofibular joint
- posterior process consist of medial and lateral tubercle separated by groove for FHL

✧ Blood supply

- because of limited soft tissue attachments, the talus has a direct extra-osseous blood supply
- sources include

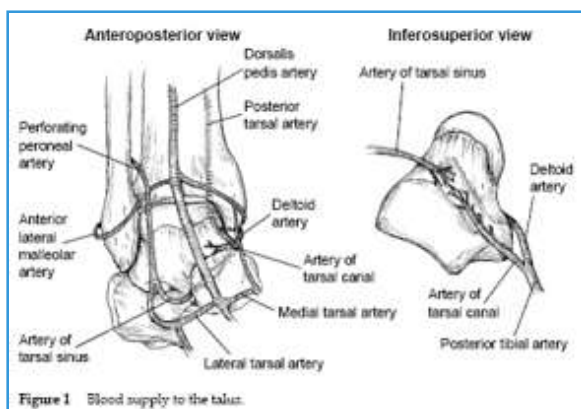


Figure 1 Blood supply to the talus.

- posterior tibial artery
 - via artery of tarsal canal (most important and main supply)
 - supplies most of talar body
 - via calcaneal braches
 - supplies posterior talus
- anterior tibial artery
 - supplies head and neck
- perforating peroneal arteries via artery of tarsal sinus
 - supplies head and neck
- deltoid artery (located in deep segment of deltoid ligament)
 - supplies body
 - may be only remaining blood supply with a talar neck fracture

■ Classification

✧ Anatomic classification

Anatomic classification		
Lateral process fracture		
Type 1	Fractures do not involved the articular surface	
Type 2	Fractures involve the subtalar and talofibular joint	
Type 3	Fractures have comminution	
Posterior process		
Posteromedial tubercle	Avulsion of the posterior talotibial ligament or posterior deltoid ligament	
Posterolateral tubercle	Avulsion of the posterior talofibular ligament	
Talar head fracture		
Talar body fracture		



Physical Exam

Symptoms

- pain
 - lateral process fractures often misdiagnosed as ankle sprains

Physical exam

- provocative tests
 - pain aggravated by FHL flexion or extension may be found with a posterolateral tubercle fractures

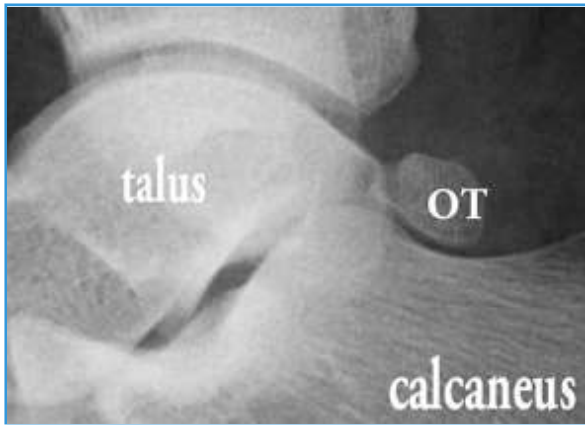
Imaging

Radiographs

- recommended views
 - AP and lateral
 - lateral process fractures may be viewed on AP radiographs
- Canale View



- optimal view of talar neck
- technique
 - maximum equinus
 - 15 degrees pronated
 - Xray 75 degrees cephalad from horizontal
- careful not to mistake os trigonum (present in up to 50%) for fracture



- may be falsely negative in talar lateral process fx

CT scan

- indicated when suspicion is high and radiographs are negative
 - best study for posterior process fx, lateral process fx, and posteromedial process fx
 - helpful to determine degree of displacement, comminution, and articular congruity

MRI

- can be used to confirm diagnosis when radiographs are negative

Treatment

Nonoperative

- **SLC for 6 weeks**
 - indications
 - nondisplaced (< 2mm) lateral process fractures
 - nondisplaced (< 2mm) posterior process fractures
 - nondisplaced (< 2mm) talar head fractures
 - nondisplaced (< 2mm) talar body fractures
 - technique
 - cast molded to support longitudinal arch

Operative

ORIF/Kirshner wire Fixation

- indications
 - displaced (> 2mm) lateral process fractures
 - displaced (> 2mm) talar head fractures
 - displaced (> 2mm) talar body fractures
 - medial, lateral or posterior malleolar osteotomies may be necessary
 - displaced (> 2mm) posteromedial process fractures
 - may require osteotomies of posterior or medial malleoli to adequately reduce the fragments
- **fragment excision**
 - indications
 - comminuted lateral process fractures
 - comminuted posterior process fractures
 - nonunions of posterior process fractures

Technique

ORIF/Kirshner Wires

- approaches
 - lateral approach
 - for lateral process fractures
 - incision over tarsal sinus, reflect EDB distally
 - posteromedial approach
 - for medial tubercle of posterior process fracture or for entire posterior process fracture that has displaced medially
 - between FDL and neurovascular bundle
 - posterolateral approach
 - for lateral tubercle of posterior process fractures
 - between peroneal tendons and Achilles tendon (protect sural nerve)
 - beware when dissecting medial to FHL tendon (neurovascular bundle lies there)
- combined lateral and medial approach

- required for talar body fractures with more than 2 mm of displacement

□ **Fragment excisions**

- incompetence of the lateral talocalcaneal ligament is expected with excision of a 1 cm fragment
 - this is biomechanically tolerated and does not lead to ankle or subtalar joint instability

■ **Complications**

✦ **AVN**

- Hawkins sign (lucency) indicates revascularization



- lack of Hawkins sign with sclerosis is indicative of AVN



✦ **Talonavicular arthritis**

- posttraumatic arthritis is common in all of these fractures
- this can be treated with an arthrodesis of the talonavicular joint

✦ **Malunion**

✦ **Chronic pain from symptomatic nonunion**

- may have pain up to 2 years after treatment

□ **Subtalar arthritis**

- found in 45% of patients with lateral process fractures, treated either non-operatively or operatively
 - anatomic reduction of the articular surface can decrease incidence

■ **Prognosis**

- ✦ Lateral process injuries have a favorable outcomes with prompt diagnosis and immediate treatment

62- Head Trauma

■ Epidemiology

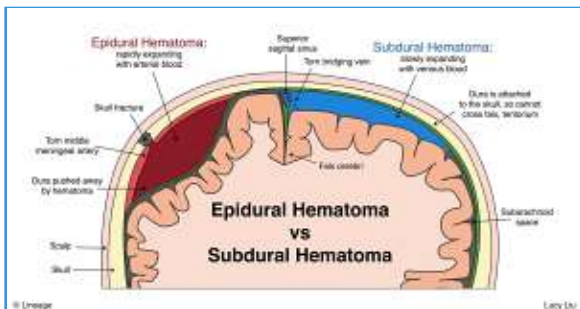
- ✚ Incidence
 - 1.5 million in the US each year
- ✚ Mechanisms
 - 41% in falls
 - 14% in motor vehicle accidents
 - 11% in assaults
- ✚ Death after head injury (bimodal distribution)
 - 10-30 year olds
 - > 70 years of age
- ✚ Demographics
 - males affected 2x more than females

■ Etiology

- ✚ Conditions include
 - epidural hematoma (below)
 - subdural hematoma (below)
 - subarachnoid hemorrhage (below)
 - intraparenchymal hemorrhage (below)
 - stroke
 - transient ischemic attack
 - concussion (mild traumatic brain injury)

✚ Epidural Hematoma

✚ Introduction



- a traumatic intracranial hemorrhage which can follow a temporal bone skull fracture resulting in tearing of the middle meningeal artery
 - the middle meningeal artery passes through the foramen spinosum of the sphenoid bone
 - resultant rapid expansion of the hematoma with high arterial pressure can lead to transtentorial herniation
- prognosis
 - better than for subdurals
- ✚ Presentation
 - symptoms
 - momentary loss of consciousness
 - lucid period up to 48 hours
 - headache, nausea, hemiparesis
 - physical exam
 - CN III palsy (if tentorial herniation present)
- ✚ Imaging
 - CT
 - lens-shaped , biconvex hyperdensity not crossing sutures

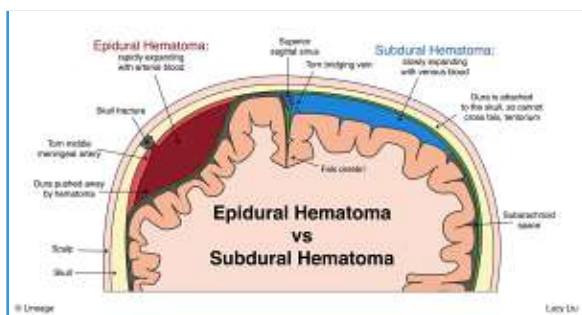


☆ Treatment

- nonoperative
 - **medical management of increased intracerebral pressure**
 - mannitol
 - hyperventilate
 - steroids/ventricular shunt
- operative
 - **evacuate hematoma**

■ Subdural Hematoma

✧ Introduction



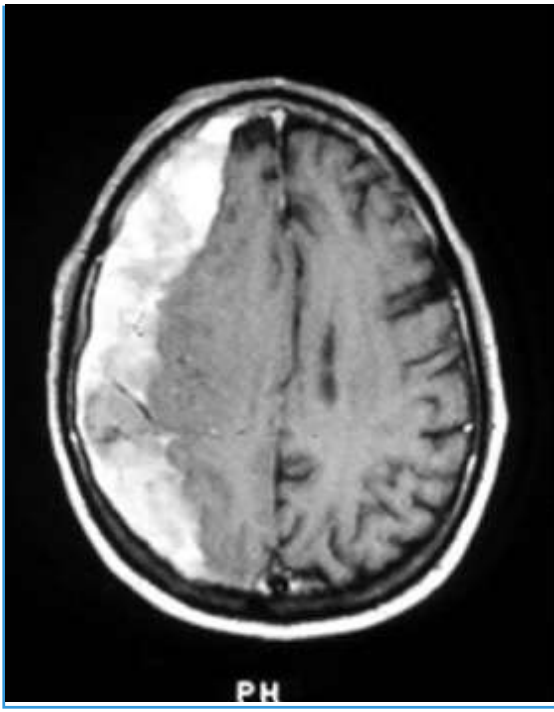
- occurs with head trauma + / - coagulopathy
- results from rupture of cortical bridging veins
- especially common in elderly and alcoholics
- prognosis
 - worse than epidurals due to concurrent brain damage.

☆ Presentation

- symptoms
 - may begin immediately, or from days to weeks after trauma.
 - headache
 - contralateral hemiparesis
- may look like a chronic change, with a past history of a fall
 - can be easily confused with dementia.
- other focal changes.

📖 Imaging

- CT shows crescent shaped, concave hyperdensity that can extend across suture line



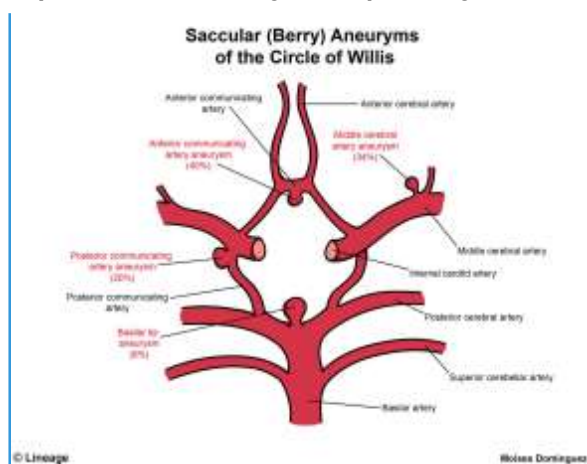
☞ Treatment

- nonoperative
 - **medical management for increased ICP**
 - mannitol
 - hyperventilate
 - steroids/ventricular shunt
- operative
 - **evacuation via burr holes**
 - indications
 - increased ICP
 - clinical neuro decline

■ Subarachnoid Hemorrhage

✦ Introduction

- commonly caused by
 - ruptured aneurysm (Berry Aneurysm)



- most common site of berry aneurysm development is the anterior communicating artery
- stroke
- AVM
- trauma
- blood accumulates between arachnoid and pia mater



☞ Presentation

- symptoms

- intense headache
- neck stiffness
- fever
- nausea
- vomiting
- fluctuating level of consciousness
- possible seizure activity
- can resemble meningitis because both cause menigeal irritation
- physical exam
 - berry aneurysm presents with severe, sudden headache and CN III palsy

□ Imaging

- immediate head CT without contrast
 - look for blood in the subarachnoid space
- if CT is negative and there is no papilledema or focal signs, proceed with an LP
 - RBC in CSF
 - CSF xanthoma (CSF protein > 150 mg/dL or serum bilirubin > 6 mg/dL)
- once an SAH has been confirmed, move to four vessel angiography

🔔 Treatment

- nonoperative
 - **medical management to prevent elevation of ICP**
 - raise the head of bed
 - limit fluids
 - treat HTN
 - giving calcium channel blockers (nimodipine)
 - prevent vasospasms
 - prophylax with anti-seizure medications (phenytoin)
- surgical
 - **clip ping or coiling of aneurysm or AVM**

■ Intraparenchymal Haemorrhage

□ Introduction

- a hemorrhage within the brain parenchyma



- common bleeding sites include:
 - basal ganglia
 - internal capsule
 - thalamus
 - cerebellum
- causes include:
 - HTN
 - leads to hemorrhage in the basal ganglia, thalamus, cerebellum, and pons .
 - trauma
 - AVM
 - coagulopathy
 - tumors
 - amyloid angiopathy in the elderly
 - leads to lobar hemorrhage

🔔 Presentation

- symptoms
 - lethargy
 - headache

- obtundation
- physical exam
 - focal motor and sensory deficits

📖 Imaging

- immediate head CT/MRI without contrast
 - hypodensity
 - look for mass effect or focal edema that may predict a herniation

📖 Treatment

- nonoperative
 - **prevent elevation of ICP**
 - raise the head of the bed
 - limit IV fluids
 - treat HTN
 - give calcium channel blockers (Nimodipine)
 - **if ICP increased**
 - mannitol
 - hyperventilate
 - steroids
 - ventricular shunt

63- Adult Respiratory Distress Syndrome

- Summary
- Adult respiratory distress syndrome (ARDS) is a pulmonary condition that can arise after polytrauma and long bone fractures leading to acute lung injury and progressive respiratory distress, refractory hypoxemia and pulmonary edema.
 - Diagnosis is made in the polytrauma patient by calculation of hypoxemia defined by $\text{PaO}_2 / \text{FIO}_2$ ratio < 200 mm Hg with chest x-ray revealing diffuse bilateral pulmonary infiltrates with pulmonary edema.
 - Treatment is focused on prevention with early stabilization of long bone fractures and PEEP ventilation when ARDS develops.

- Etiology
- Pathophysiology
 - acute endothelial damage resulting from
 - aspiration
 - infection
 - pancreatitis
 - multiple blood transfusions
 - lung injury
 - sepsis or shock
 - major trauma
 - large surface area burns
 - fat emboli
 - thromboembolism
 - multi-system organ failure
 - pathoanatomy
 - injury cascade leads to
 - non-cardiogenic pulmonary edema
 - respiratory distress
 - refractory hypoxemia
 - decreased lung compliance

- Classification
- ARDS is represented by three phases
- | | | | |
|---------------------|-----------|--|---|
| 3 phases of ARDS | | | |
| Exudative phase | Initially | Hyaline membrane comprised of fibrin form |  |
| Proliferative phase | 3 days | Alveolar exudate resolves or organizes | |
| Fibrotic phase | 3-4 weeks | Alveolar ducts and spaces undergo fibrosis | |

- Presentation
- Symptoms
 - acute onset (12-48 hours) of
 - dyspnea
 - fever
 - mottled or cyanotic skin
 - Physical exam
 - resistant hypoxia
 - intercostal retractions

- rales/crackles and ronchi
- tachypnea

■ Evaluation

- Hypoxemia is refractory to O₂
 - 3 different categories of ARDS based on degree of hypoxemia
 - PaO₂ / FIO₂ ratio < 300 mm Hg= mild
 - classified as acute lung injury (ALI)
 - PaO₂ / FIO₂ ratio < 200 mm Hg= moderate
 - values below 200 classified as ARDS
 - PaO₂ / FIO₂ ratio < 100 mm Hg= severe
- 📌 Chest xray
 - shows patchy pulmonary edema (air space disease)
 - diffuse bilateral pulmonary infiltrates
 - normal sized heart
 - makes CHF less likely
- 📖 Respiratory compliance (<40 mL/cm H₂O)
- 📖 Positive end-expiratory pressure (>10cm H₂O)
- 📖 Corrected expired volume per minute (>10L/min)

■ Differential

- 📖 Cardiogenic pulmonary edema (i.e. CHF or MI), bilateral pneumonia, SARS

★ Treatment

- 📖 Nonoperative
 - **PEEP ventilation and steroids**
 - treat the underlying pathology/disease
- ✦ Operative
 - **early stabilization of long bone fractures** (femur)
- 📌 Prevention
 - closely monitor PEEP in patients at-risk of ARDS
 - serial X-rays in concerning patients can assist in early identification and intervention

+ Complications

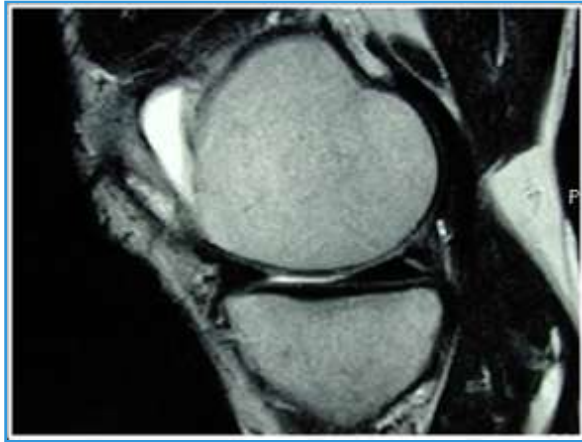
- 📖 Pneumothorax
 - secondary to ventilator with high PEEP

■ Prognosis

- 📖 High mortality rate (50% overall) is associated with ARDS even in setting of ICU

64- Flail Chest

Images



summary

- ✧ Flail Chest is a traumatic chest injury defined as segmental fractures of 3 or more ribs and is often associated with pulmonary injuries such as hemothorax and pneumothorax.
- 📖 Diagnosis is made with radiographs of the chest.
- 📖 Treatment can be nonoperative or operative depending on the presence of respiratory compromise, the number of consecutive rib fractures, and the presence of open fractures.

Epidemiology

- ✧ Bimodal distribution
 - younger patients involved in trauma
 - older patients with osteopenia

Etiology

- 📖 Mechanism
 - blunt forces
 - deceleration injuries
- 📖 Associated Injuries
 - scapula fractures
 - clavicle fractures
 - hemo/pneumothorax

Prognosis

- 📖 Varies depending on underlying pulmonary injury or other concomitant injuries

Anatomy

- ✧ Osteology
 - 12 ribs per side
 - the first seven pairs are connected with the sternum
 - the next three are each articulated with the lower border of the cartilage of the preceding rib
 - the last two have pointed extremities
 - can have an accessory clavicular rib
 - anterior ribs articulate with the sternum via the costal cartilage
- 📖 Blood Supply
 - derived from intercostal vessels

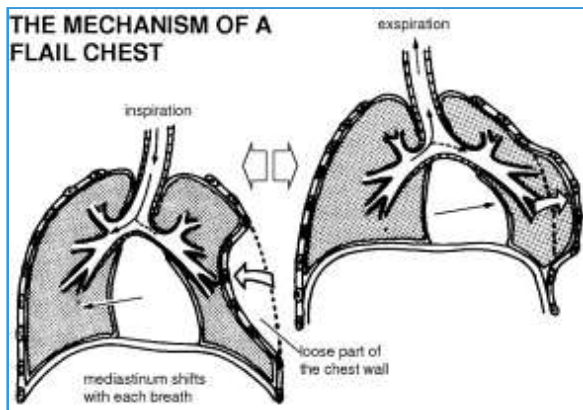
Presentation

- ✧ Symptoms

- pain
- respiratory difficulty
- hemopneumothorax

✧ Exam

- paradoxical respiration



- area of injury "sinks in" with inspiration, and expands with expiration (opposite of normal chest wall mechanics)
- chest wall deformity can be seen



- bony or soft-tissue crepitus is often noted

■ Imaging

✧ Radiographs

- may be hard to distinguish non- or minimally-displaced rib fractures
- may see associated hemothorax



✧ CT

- improved accuracy of diagnosis with CT (vs. radiographs)

■ Treatment

✧ Nonoperative

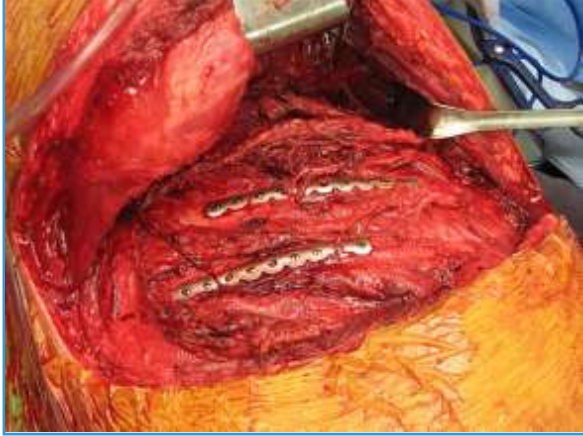
■ **observation**

- indications
 - no respiratory compromise
 - no flail chest segment (>3 consecutive segmentally fractured ribs)
- techniques
 - pain control
 - systemic narcotics or local anesthetics
 - positive pressure ventilation

✧ Operative

- **open reduction internal fixation**

- indications
 - displaced rib fractures associated with intractable pain
 - flail chest segment (3 or more consecutive ribs with segmental injuries)
 - rib fractures associated with failure to wean from a ventilator
 - open rib fractures
- technique
 - approach
 - full thoracotomy approach
 - limited exposure approach
 - open reduction and internal fixation
 - plate and screw constructs



- intramedullary splinting
- postop
 - early shoulder and periscapular range of motion

- **Complications**

- ⌘ Intercostal neuralgia
- ⌘ Periscapular muscle weakness
- ⌘ Pneumonia
- ⌘ Restrictive type pulmonary function

65- Gas Gangrene

■ Introduction

✧ Definition

- also called clostridial myonecrosis

✧ Epidemiology

📖 Demographics

- male:female ratio
 - no sexual predilection

✦ Anatomic location

- buttocks, thigh, perineum

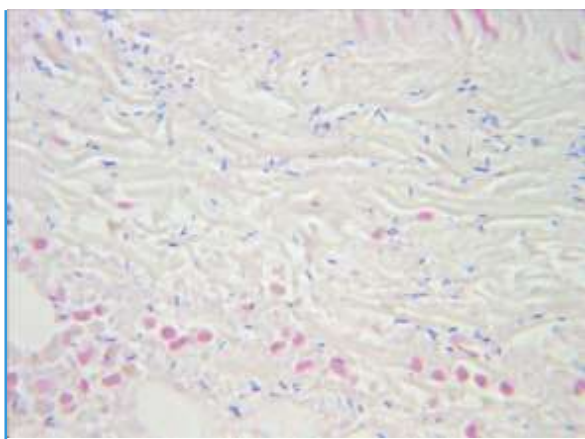
✧ Risk factors

- posttraumatic (associated with *C. perfringens*)
 - car accidents (most common)
 - crush injuries
 - gunshot wounds with foreign bodies
 - burns and frostbite
 - IV drug abuse
- postoperative
 - bowel resection or perforation
 - biliary surgery
 - premature wound closure
- spontaneous
 - colon cancer (associated with *C. septicum*)
 - neutropenia

+ Etiology

☆ Pathophysiology

- Clostridial species
 - *Clostridium perfringens* (most common), *Clostridium novyi*, *Clostridium septicum*
 - found in soil and gut flora
 - gram-positive obligate anaerobic spore-forming rods that produce exotoxins (e.g. *C. perfringens* alpha toxin)



- causes muscle necrosis and vessel thrombosis
 - can cause hemolysis and shock
- incubation period <24h
- gas produced by fermentation of glucose
 - main component is nitrogen
- other bacteria include *E. coli*, *Pseudomonas aeruginosa*, *Proteus* species, *Klebsiella pneumoniae*

■ Presentation

📖 History

- recent surgery to GI or biliary tract

□ Symptoms

- triad
 - sudden progressive pain out of proportion to injury
 - from thrombotic occlusion of large vessels
 - tachycardia not explained by fever
 - feeling of impending doom

✦ Physical exam

- sweet smelling odor
- swelling, edema, discoloration and ecchymosis
- blebs and hemorrhagic bullae
- "dishwater pus" discharge
- crepitus
- altered mental status

■ Imaging

✦ Radiographs

- findings
 - linear streaks of gas in soft tissues



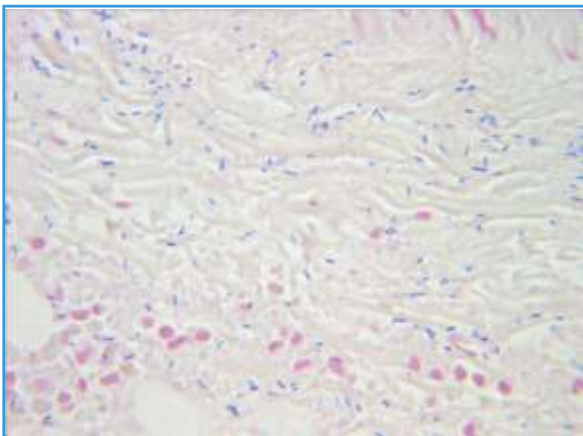
■ Studies

🔍 Labs

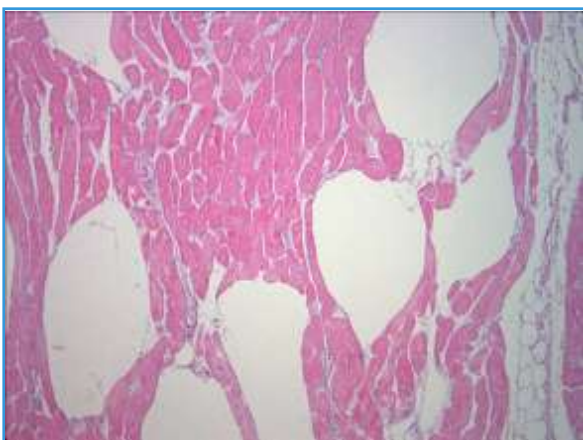
- Elevated LDH
- Elevated WBC
- Metabolic acidosis and renal failure

□ Histology

- Gram stain reveals Gram-positive bacilli



- absence of neutrophils



- lack of acute inflammatory response is hallmark of gas gangrene

□ Culture

- blood culture rarely grows Clostridial species

■ Differential

- ✦ Necrotizing fasciitis

■ Treatment

▣ Nonoperative

- **high dose IV antibiotics**
 - 1st line is penicillin G and clindamycin
 - alternative treatment is erythromycin, tetracycline or ceftriaxone
 - clindamycin and tetracycline inhibit toxin synthesis
- **hyperbaric O2**
 - indications
 - useful adjunct
 - outcomes
 - effectiveness of HBO2 is inconclusive

▣ Operative

- **radical surgical debridement with fasciotomies**
 - indications
 - 1st line treatment is surgical

■ Complications

✦ Shock

✧ Renal failure

- both mediated by TNF alpha, IL-1, IL-6

✦ Prognosis

▣ Overall 25% mortality

- 50% mortality if bacteremic
- 100% mortality if treatment is delayed

✦ Poorer prognosis for older patients with comorbidities

66- Hand And Forearm Compartment Syndrome

Images



summary

- Hand & Forearm Compartment Syndrome are devastating upper extremity conditions where the osseofascial compartment pressure rises to a level that decreases perfusion to the hand or forearm and may lead to irreversible muscle and neurovascular damage.
- ✧ Diagnosis is made with the presence of severe and progressive hand or forearm pain that worsens with passive finger or wrist motion, respectively. Firmness and decreased compressibility of the compartments is often present. Needle compartment pressures are diagnostic in cases of inconclusive physical exam findings and in sedated patients.
- ✧ Treatment is emergent fasciotomies.

Epidemiology

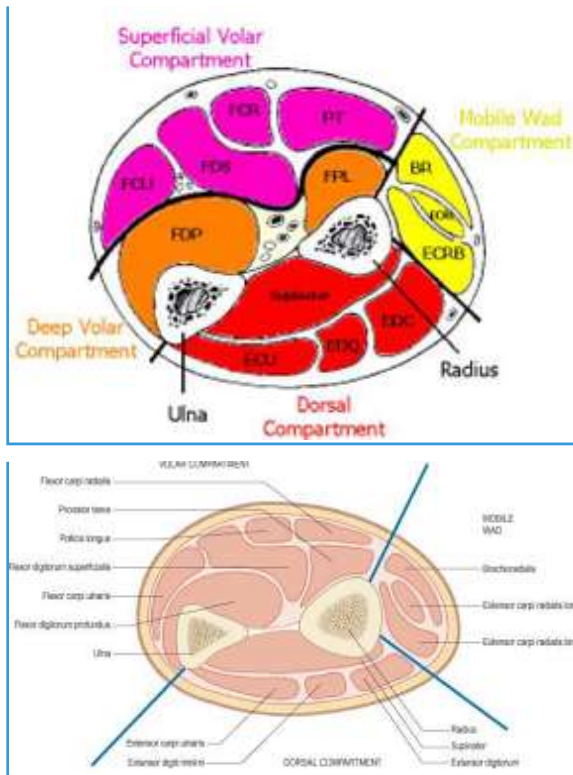
- Anatomic location
 - May occur anywhere that skeletal muscle is surrounded by fascia, but most commonly
 - leg
 - forearm (details below)
 - hand (details below)
 - foot
 - thigh
 - buttock
 - shoulder
 - paraspinous muscles

Etiology

- ✧ Pathophysiology
 - local trauma and soft tissue destruction > bleeding and edema > increased interstitial pressure > vascular occlusion > myoneural ischemia
- ✧ Causes
 - trauma
 - fractures (most common)
 - distal radius fractures in adults
 - supracondylar humerus fracture in children
 - crush injuries
 - contusions
 - gunshot wounds
 - tight casts, dressings, or external wrappings
 - extravasation of IV infusion
 - burns
 - postischemic swelling
 - bleeding disorders
 - arterial injury

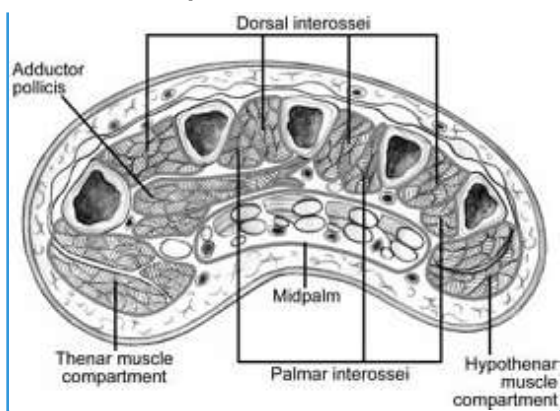
- Anatomy

📖 Forearm compartments



- 3 in total
 - volar
 - most commonly affected
 - dorsal
 - mobile wad (lateral)
 - rarely involved
 - muscles
 - brachioradialis
 - extensor carpi radialis longus
 - extensor carpi radialis brevis

- ✦ Hand compartments



- 10 in total
 - hypothenar
 - thenar
 - adductor pollicis
 - dorsal interosseous (x4)
 - volar (palmar) interosseous (x3)

- Presentation

Symptoms

- pain out of proportion to clinical situation is usually first symptom
 - may be absent in cases of nerve damage
 - difficult to assess in
 - polytrauma
 - sedated patients
 - children

- 📌 Physical exam

- pain w/ passive stretch of fingers
 - most sensitive finding
- paraesthesia and hypoesthesia
 - indicative of nerve ischemia in affected compartment

- paralysis
 - late finding
 - full recovery is rare in this case
- palpable swelling
 - tense hand in intrinsic minus position
 - most consistent clinical finding
- peripheral pulses absent
 - late finding
 - amputation usually inevitable in this case

★ Evaluation

📖 Radiographs

- obtain to rule-out fracture

📌 Compartment pressure measurements

- indications
 - polytrauma patients
 - patient not alert/unreliable
 - inconclusive physical exam findings
- relative contraindication
 - unequivocally positive clinical findings should prompt emergent operative intervention without need for compartment measurements
- threshold for decompression
 - controversial, but generally considered to be
 - within 30 mm Hg of diastolic blood pressure (delta p)
 - intraoperatively, diastolic blood pressure may be decreased from anesthesia
 - if delta p is less than 30 mmHg intraoperatively, check preoperative diastolic pressure and follow postoperatively as intraoperative pressures may be low and misleading

★ Treatment

📖 Nonoperative

- **observation**
 - indications
 - exam not consistent with compartment syndrome
 - delta p > 30

✚ Operative

- **emergent forearm fasciotomies**
 - indications
 - clinical presentation consistent with compartment syndrome
 - compartment measurements within 30 mm Hg of diastolic blood pressure (delta p)
 - intraoperatively, diastolic blood pressure may be decreased from anesthesia
 - must compare intra-operative measurement to pre-operative diastolic pressure
- **emergent hand fasciotomies**
 - indications
 - clinical presentation consistent with compartment syndrome
 - compartment measurements within 30 mm Hg of diastolic blood pressure (delta p)
 - intraoperatively, diastolic blood pressure may be decreased from anesthesia
 - must compare intra-operative measurement to pre-operative diastolic pressure

★ Techniques

📖 Forearm

- **emergent fasciotomies of all involved compartments**
 - approach
 - volar incision



- decompresses volar compartment and carpal tunnel
 - incision starts just radial to FCU at wrist and extends proximally to medial epicondyle
 - may extend distally to release carpal tunnel
- dorsal incision



- decompresses mobile wad and dorsal compartment
 - dorsal longitudinal incision 2cm distal to lateral epicondyle toward midline of wrist

■ technique

- volar incision
 - open lacertus fibrosus and fascia over FCU
 - retract FCU ulnarly, retract FDS radially
 - open fascia over deep muscles of forearm
- dorsal incision
 - dissect interval between EDC and ECRB
 - decompress mobile wad and dorsal compartment

■ post-operative

- leave wounds open

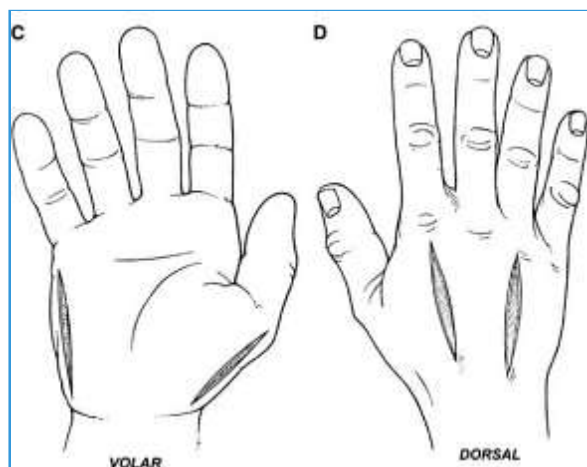


- wound VAC
 - sterile wet-to-dry dressings
- repeat irrigation and debridement 48-72 hours later
 - debride all dead muscle
 - possible delayed primary wound closure
 - VAC dressing when closure cannot be obtained
 - follow with split-thickness skin grafting at a later time



□ Hand

- **emergent fasciotomies of all involved compartments**
 - approach



- two longitudinal incisions over 2nd and 4th metacarpals



- decompresses volar/dorsal interossei and adductor compartment
- longitudinal incision radial side of 1st metacarpal



- decompresses thenar compartment
- longitudinal incision over ulnar side of 5th metacarpal
 - decompresses hypothenar compartment
- technique
 - first volar interosseous and adductor pollicis muscles are decompressed through blunt dissection along ulnar side of 2nd metacarpal
- post-operative
 - wounds left open until primary closure is possible
 - if primary closure not possible, split-thickness skin grafting is used

■

Complications

- 📖
- Volkman's ischemic contracture
- irreversible muscle contractures in the forearm, wrist and hand that result from muscle necrosis
 - contracture positioning
 - elbow flexion
 - forearm pronation
 - wrist flexion
 - thumb adduction
 - MCP joints in extension
 - IP joints in flexion
 - classification
 - Tsuge Classification (see table below)

■ Tsuge classification (Stages & Treatment of Volkman's Ischemic Contracture of Hand)		
■ <i>Stage</i>	■ <i>Affected Muscle</i>	■ <i>Treatment</i>
■ Mild	■ Finger flexors	■ Dynamic splinting, tendon lengthening
■ Moderate	■ Wrist and finger flexors	■ Excision of necrotic tissue, median and ulnar neurolysis BR to FPL and ECRL to FDP tendon transfers, distal slide of viable flexors
■ Severe	■ Wrist/finger flexors and extensors	■ Same as above (moderate) with possible free muscle transfer

📌

Prognosis

- 📖
- May lead to
- loss of function
 - Volkmann ischemic contracture
 - neurologic deficit
 - infection
 - amputation

67- Foot Compartment Syndrome

Images



■ summary

- 📌 Foot Compartment Syndrome is a devastating lower extremity condition where the osseofascial compartment pressure rises to a level that decreases perfusion to the foot and may lead to irreversible muscle and neurovascular damage.
- 📌 Diagnosis is made with the presence of severe and progressive foot pain that worsens with the passive motion of the toes. Firmness and decreased compressibility of the compartments is often present. Needle compartment pressures are diagnostic in cases of inconclusive physical exam findings and in sedated patients.
- 📌 Treatment is usually emergent fasciotomies.

■ Epidemiology

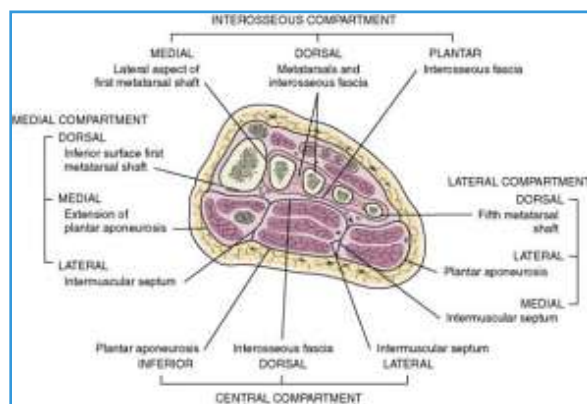
- 📌 Anatomic location
 - May occur anywhere that skeletal muscle is surrounded by fascia, but most commonly
 - leg
 - forearm
 - hand
 - foot (details below)
 - thigh
 - buttock
 - shoulder
 - paraspinous muscles

■ Etiology

- 📌 Pathophysiology
 - local trauma and soft tissue destruction > bleeding and edema > increased interstitial pressure > vascular occlusion > myoneural ischemia
- 📌 Causes
 - trauma
 - fractures (69% of cases)
 - 5-17% of calcaneus fractures result in compartment syndrome
 - crush injuries
 - severe ankle sprains
 - gunshot wounds
 - tight casts, dressings, or external wrappings
 - burns
 - postischemic swelling
 - bleeding disorders
 - vascular injury

■ Anatomy

- 📌 9 main compartments (controversial)



- medial
 - abductor hallucis
 - flexor hallucis brevis
- lateral
 - abductor digiti minimi
 - flexor digiti minimi brevis
- interosseous (x4)
- central (x3)
 - superficial
 - flexor digitorum brevis
 - central
 - quadratus plantae
 - deep
 - adductor hallucis
 - posterior tibial neurovascular bundle

Presentation

⚠ Symptoms

- pain out of proportion to injury

✦ Physical exam

- pain with dorsiflexion of toes (MTPJ)
 - places intrinsic muscles on stretch
- tense swollen foot
- loss of two-point discrimination
- pulses
 - presence of pulses does not exclude diagnosis

■ Imaging

✦ Radiographs

- obtain to rule-out fracture

■ Studies

☐ Compartment pressure measurements

- indications
 - polytrauma patients
 - patient not alert/unreliable
 - inconclusive physical exam findings
- relative contraindication
 - unequivocally positive clinical findings should prompt emergent operative intervention without need for compartment measurements
- technique
 - central compartment
 - base of first metatarsal
 - direct needle lateral and plantar through abductor hallucis
 - medial compartment
 - base of first metatarsal advancing 2cm into abductor hallucis
 - interosseous
 - second, third, and fourth webspaces

- advance plantar 2cm to puncture extensor fascia
- lateral
 - midshaft of fifth metatarsal
 - advance 1cm medial and plantar
- threshold for decompression
 - within 30 mm Hg of diastolic blood pressure (delta p)
 - intraoperatively, diastolic blood pressure may be decreased from anesthesia
 - must compare intra-operative measurement to pre-operative diastolic pressure
 - absolute value of 30-45 mm Hg (controversial, historic)

✦ Treatment

📖 Nonoperative

- **observation**
 - indications
 - delta p > 30
 - exam not consistent with compartment syndrome

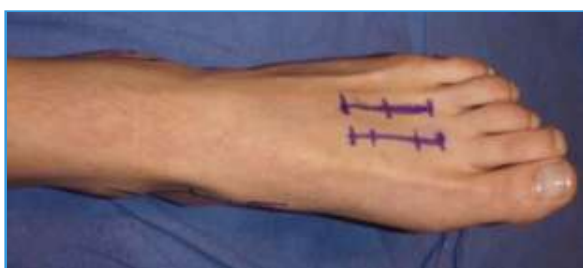
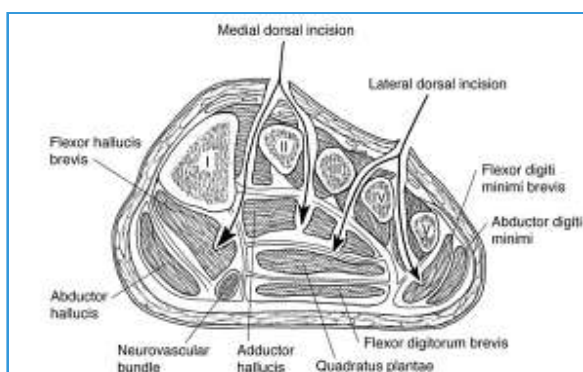
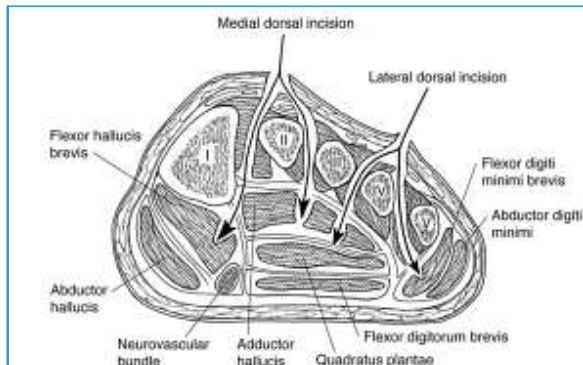
🔧 Operative

- **emergent foot fasciotomies**
 - indications
 - clinical presentation consistent with compartment syndrome
 - compartment measurements with absolute value of 30-45 mm Hg
 - compartment measurements within 30 mm Hg of diastolic blood pressure (delta p)
 - intraoperatively, diastolic blood pressure may be decreased from anesthesia
 - must compare intra-operative measurement to pre-operative diastolic pressure

▪ Technique

🔧 Emergent fasciotomies of all compartments

- dual dorsal incisions (gold standard)



- approach
 - dorsal medial incision
 - medial to 2nd metatarsal
 - releases 1st and 2nd interosseous, medial, and deep central compartment
 - dorsal lateral incision
 - lateral to 4th metatarsal
 - releases 3rd and 4th interosseous, lateral, superficial and middle central compartments
- technique

- dorsal fascia of each interosseous compartment opened longitudinally
- strip muscle from medial fascia in first interosseous compartment
- split adductor compartment
- may add medial incision for decompression of calcaneal compartment
- post-operative
 - delayed wound closure with possible skin grafting
- pros
 - direct access to all compartments
 - provides exposure for Chopart, Lisfranc, or tarsometatarsal fractures
- cons
 - does not provide access for fixation of calcaneus fractures
- single medial incision
 - technique



- single medial incision used to release all nine compartments
 - incision is made within the arch of the foot, along the muscle body of the abductor hallucis
 - dissection is continued both dorsal and plantar to the abductor hallucis muscle, which also serves to disrupt the superficial and deep components of the central compartment and allows access to the adductor muscle belly
- cons
 - technically challenging

★ Complications

- 📖 Chronic pain and hypersensitivity
 - difficult to manage
- 👉 Fixed flexion deformity of digits (claw toes)



- release flexor digitorum brevis and longus at level of digits

68- Neonatal Forearm Compartment Syndrome

Images



summary

- Neonatal Forearm Compartment Syndrome is a devastating upper extremity condition in neonates where the osseofascial compartment pressure rises to a level that decreases perfusion to the forearm and may lead to irreversible muscle and neurovascular damage.
- ☆ Diagnosis is different from compartment syndrome in adults with the primary finding in neonates being skin lesions such as bullae, eschars, ulcers, with the presence of digital and hand ischemia/edema.
- ✧ Treatment is usually emergent fasciotomies.

Epidemiology

- Incidence
 - rare
 - limited to case reports, largest series is 24 cases over 20 years
- ☆ Demographics
 - age bracket
 - neonates during first 24 hours of life
- ✧ Anatomic location
 - forearm, wrist, hand (equal R:L distribution)
 - unilateral
 - dorsum more common than volar
- Risk factors
 - hypercoagulable states
 - polycythemia
 - prematurity
 - oligohydramnios
 - maternal diabetes
 - multiple gestation
 - abnormal lie
 - neonatal respiratory distress

Etiology

- Pathophysiology
 - mechanism of injury
 - possible birth trauma (see below)
 - idiopathic is most common
 - pathophysiology
 - exact mechanism unknown, although both extrinsic and intrinsic factors are believed to be involved
 - extrinsic (mechanical compression with forearm being trapped between structures)
 - fetal posture
 - oligohydramnios
 - umbilical cord loops
 - amniotic band constriction
 - direct birth trauma
 - intrinsic (clotting)

- hypercoagulable state producing arterial/venous compression

■ Presentation

- ▢ History
 - idiopathic (no obvious cause) is most common cause
- ▢ Symptoms
 - common symptoms
 - all patients present with skin lesion (wide spectrum)
 - bullae
 - erythema
 - ulcerative
 - distal digital/hand edema
 - eschar
 - fingertip gangrene
 - duration
 - presents at birth
- ▢ Physical exam
 - inspection
 - skin lesion
 - bullous swelling, erythema
 - nerve involvement (radial nerve and PIN > ulnar = median)
 - may have lack of spontaneous limb movement

■ Imaging

- ▢ Radiographs
 - recommended views
 - AP and lateral forearm radiographs
 - findings
 - skeletal changes happen late (more evident when the child grows)
 - physeal distortion (widening, flaring, premature closure, angular deformity, shortening)
 - limb length discrepancy
- ▢ MRI
 - indications
 - late-presenting cases without edema, but with extensive full-thickness necrosis and extreme contractures (where fasciotomy is likely to be futile)
 - may help delineate full extent of underlying necrosis and guide muscle debridement

■ Studies

- ✦ Labs
 - indications
 - to rule out infection, cellulitis
 - findings
 - CBC, ESR, CRP within normal values
- ▢ Compartment pressure
 - indications
 - is NOT done in neonates because
 - no standards for acceptable pressure gradients (delta value)
 - neonate's DBP at birth is <40mmHg and a small increase in compartment pressure rapidly impairs muscle perfusion

■ Differential

- ▢ Cellulitis
 - distinguishing features
 - mother does not show signs of infection, has negative cultures
- ▢ Necrotizing fasciitis
 - most easily mistaken for compartment syndrome, and only diagnosed/confirmed at operation

- distinguishing features
 - only involves skin, subcutaneous tissue
 - treated with excision, not fasciotomy

🔖 Vascular injuries

- associated with brachial plexus lesions
- distinguishing features
 - absent pulses and Doppler studies

■ Treatment

📁 Nonoperative

- **anticoagulants and thrombolytics**
 - indications
 - hypercoagulable states

🔖 Operative

- **emergency immediate fasciotomy**
 - indications
 - emergent surgery is usually indicated
 - diagnosis of compartment syndrome
 - technique
 - release volar, dorsal and mobile wad compartments
 - release carpal tunnel
 - may need split thickness skin graft
 - outcomes
 - best outcomes if diagnosed and treated within first 24 hours of life
- **salvage surgery**
 - indications
 - late sequelae
 - techniques
 - neurolysis
 - debridement of dead muscle
 - contracture release
 - soft tissue resurfacing
 - angular correction
 - limb lengthening
 - staged flexor/extensor tendon reconstruction
 - outcomes
 - outcomes are inferior to early fasciotomy

■ Complications

📁 Most common complications:

- Ischemic muscle contracture
 - muscle debridement and contracture release
- Fingertip gangrene
- Physeal distortion
 - limb lengthening
 - angular correction
- Nerve dysfunction
 - neurolysis

+ Prognosis

🔖 Natural history of disease

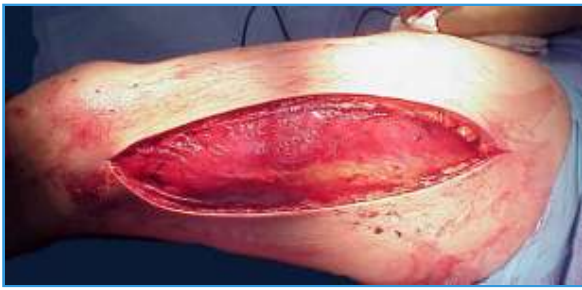
- usually missed initially, detected only after complications ensue
- prognostic variable
 - negative
 - missed diagnosis has worst prognosis

🔖 Outcomes with treatment

- prognostic variable
 - favorable
 - early fasciotomy has best prognosis

69- Thigh Compartment Syndrome

Images



summary

- ✦ Thigh Compartment Syndrome is a devastating lower extremity condition where the osseofascial compartment pressure rises to a level that decreases perfusion to the thigh and may lead to irreversible muscle and neurovascular damage.
- 📖 Diagnosis is made with the presence of severe and progressive thigh pain that worsens with passive knee motion. Firmness and decreased compressibility of the compartments is often present. Needle compartment pressures are diagnostic in cases of inconclusive physical exam findings and in sedated patients.
- Treatment is usually emergent fasciotomies of all 3 compartments.

Epidemiology

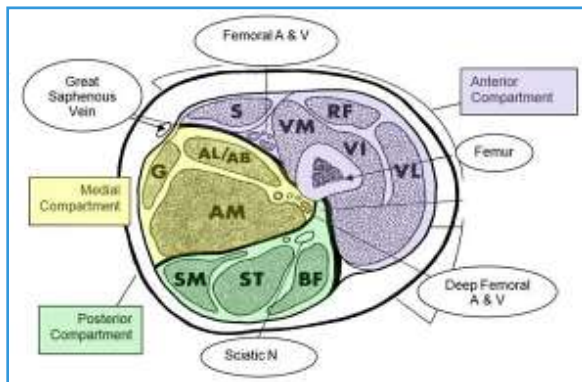
- ✦ Anatomic location
 - May occur anywhere that skeletal muscle is surrounded by fascia, but most commonly
 - leg
 - forearm
 - hand
 - foot
 - thigh (details below)
 - buttock
 - shoulder
 - paraspinous muscles

Etiology

- 📖 Pathophysiology
 - local trauma and soft tissue destruction >
 - bleeding and edema >
 - increased interstitial pressure >
 - vascular occlusion >
 - myoneural ischemia
- ☆ Causes
 - trauma (most common)
 - ipsilateral femur fractures
 - increased incidence with open fractures
 - crush injuries
 - contusions
 - gunshot wounds
 - tight casts, dressings, or external wrappings
 - extravasation of IV infusion
 - burns
 - postischemic swelling
 - bleeding disorders
 - arterial injury

Anatomy

✦ 3 thigh compartments



- anterior compartment
 - muscles
 - quadriceps
 - sartorius
 - nerves
 - femoral nerve
- posterior compartment
 - muscles
 - hamstrings
 - nerves
 - sciatic nerve
- adductor compartment
 - muscles
 - adductors
 - nerves
 - obturator nerve

■ Presentation

📖 Symptoms

- pain out of proportion to clinical situation is usually first symptom
 - may be absent in cases of nerve damage
 - pain is difficult to assess in a polytrauma patient and impossible to assess in a sedated patient
 - difficult to assess in children (unable to verbalize)

📖 Physical exam

- pain w/ passive stretch
 - is most sensitive finding prior to onset of ischemia
 - must test each compartment separately
 - anterior compartment
 - pain with passive flexion of knee
 - posterior compartment
 - pain with passive extension of knee
 - medial compartment
 - pain with passive abduction of hip
- paraesthesia and hypoesthesia
 - indicative of nerve ischemia in affected compartment
- paralysis
 - late finding
 - full recovery is rare in this case
- palpable swelling
- peripheral pulses absent
 - late finding
 - amputation usually inevitable in this case

■ Imaging

✦ Radiographs

- obtain to rule-out fracture

■ Studies

- ☐ Compartment pressure measurements
 - indications
 - polytrauma patients
 - patient not alert/unreliable
 - inconclusive physical exam findings
 - relative contraindication
 - unequivocally positive clinical findings should prompt emergent operative intervention without need for compartment measurements
 - technique
 - should be performed within 5cm of fracture site or area of maximal swelling
 - must test each compartment separately

+ Diagnosis

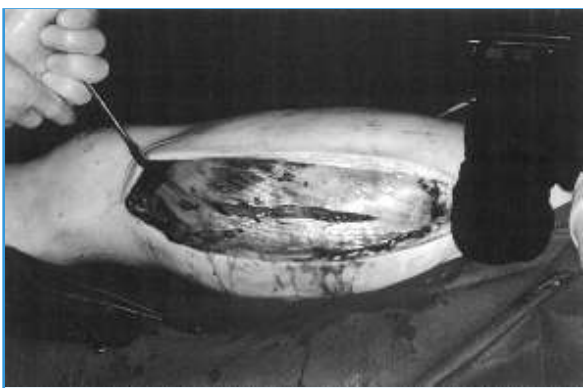
- ☆ Clinical
 - based primarily on physical exam in patient with intact mental status

■ Treatment

- ☐ Nonoperative
 - **observation**
 - indications
 - $\Delta p > 30$, and
 - presentation not consistent with compartment syndrome
- ☆ Operative
 - **emergent fasciotomy of all affected compartments**
 - indications
 - clinical presentation consistent with compartment syndrome
 - compartment pressures within 30 mm Hg of diastolic blood pressure (Δp)
 - intraoperatively, diastolic blood pressure may be decreased from anesthesia
 - must compare intra-operative measurement to pre-operative diastolic pressure
 - contraindications
 - missed compartment syndrome

■ Techniques

✦ Thigh fasciotomies



- approach
 - anterolateral incision over length of thigh
- technique
 - single incision technique for anterior and posterior compartments
 - incise fascia lata
 - expose and decompress anterior compartment
 - retract vastus lateralis medially to expose lateral intermuscular septum
 - incise lateral intermuscular septum to decompress posterior compartment
 - may add medial incision for decompression of adductor compartment

■ Complications

- ☐ Associated with significant long-term morbidity
 - over 50% will experience functional deficits including
 - pain

- decreased knee flexion
- myositis ossificans
- sensory deficits
- decreased strength

70- Morel Lavallee Lesion

Summary

- ▣ A Morel-Lavallee Lesion (MLL) is a closed traumatic soft tissue degloving injury characterized by separation of the dermis from the underlying fascia due to a shearing force.
- ✧ Diagnosis requires high a index of suspicion with presence of an area of ecchymosis, swelling, fluctuance and skin hypermobility in the polytrauma patient with underlying fractures.
- ✧ Treatment is generally operative irrigation and debridement for most lesions given the proximity to planned surgical incisions and increased risk of infection.

Epidemiology

- ▣ Incidence
 - present in up to 8% of acetabulum fractures
- ✧ Anatomic location
 - most often along proximal lateral thigh, in the peritrochanteric region
 - to a lesser extent gluteal, lumbosacral, and abdominal areas
 - due to hypermobility of skin in these regions
- ✧ Risk factors
 - high-energy, shearing trauma

Etiology

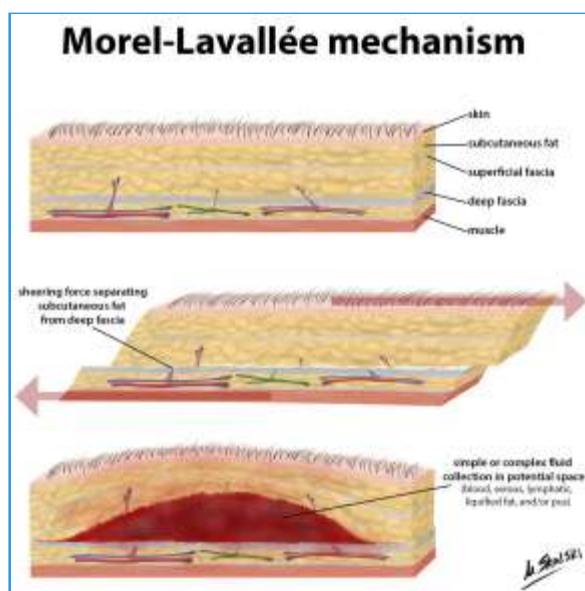
- ▣ Pathophysiology
 - divided into 4 stages:
 - shearing forces to soft-tissue envelope lead to separation of the dermis from the underlying fascia
 - injured lymphatics and vasculature from the injured subdermal plexus produce



- these components are then replaced by serosanguinous fluid as the lesion enlarges
 - finally, if left untreated during the acute stage, local inflammation leads to pseudocapsule formation and lesion maturation as the body attempts to sequester the space
 - bacterial colonization of the fluid occurs in up to 46% of lesions
 - ▣ Associated conditions
 - orthopaedic conditions
 - pelvic and acetabular fractures
 - proximal femur fractures

Anatomy

- ✧ Anatomy of soft tissues (order of layers from superficial to deep)
 - epidermis
 - dermis
 - subcutaneous fat



- MLL develops deep to subcutaneous fat and superficial to deep fascia
- deep fascia
- muscle

Presentation

History

- there should be high clinical suspicion for a MLL in a polytrauma patient with a high-energy mechanism

Symptoms

- often minimally symptomatic or marginalized due to underlying distracting injuries or patient body habitus
 - up to 33% of lesions are missed at the time of index evaluation
- chronic lesions may lead to cosmetic issues

Physical exam

- inspection



- ecchymosis, swelling, fluctuance and skin hypermobility



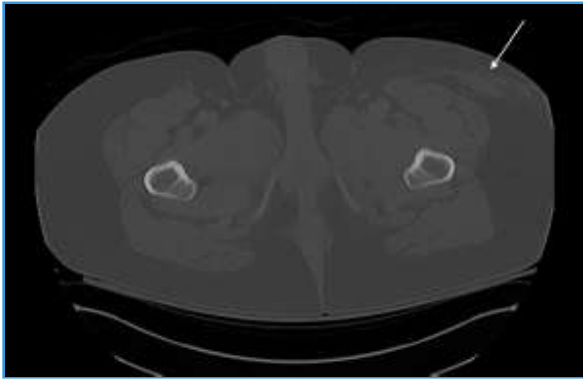
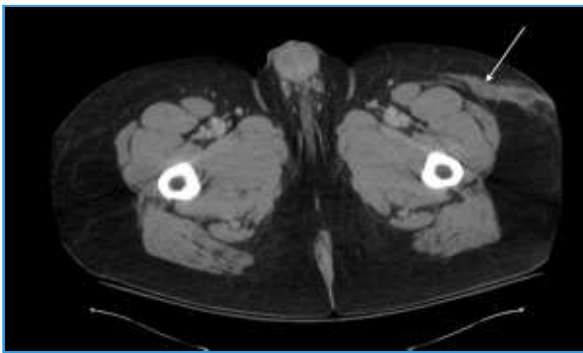
- skin discoloration may not be apparent until several days later
- neurovascular
 - key indicator is paresthesias of overlying skin

Imaging

Radiographs

- indications
 - evaluate underlying proximal femur, acetabulum or pelvis fractures
- findings
 - may show soft tissue swelling

CT



- indications
 - CT of the area of interest often obtained due to high-energy nature of the injury, underlying fracture, or abdominal/pelvic injury
- findings
 - used to measure size of lesion to determine management
 - soft tissue windows will show slice of fluid within fascial plane
- ✦ Ultrasound
 - indications
 - can be used to localize lesion for percutaneous treatment
 - findings
 - hypoechoic space superficial to fascial layer
- ☐ MRI
 - indications
 - generally not required for diagnosis but will best demonstrate extent of the lesion
 - findings
 - average size reported to be 30 x 12 cm
 - fluid-filled space is often identifiable on T1- and T2-weighted MRI sequences.
 - acute lesions are hypointense on T1-weighted images and hyperintense on T2-weighted sequences
 - subacute lesions are homogeneously hyperintense on T1- and T2-weighted sequences, with a peripheral capsule that is hypointense on both T1- and T2-weighted sequences

★ Treatment

- ☐ Nonoperative
 - **compressive therapy**
 - indications
 - small lesions ($< 50 \text{ cm}^3$)
 - outcomes
 - resolution of smaller lesions can be successful with compressive therapy but this requires high patient compliance
 - **percutaneous drainage with drain placement**
 - indications
 - small lesions ($< 50 \text{ cm}^3$)
 - outcomes
 - considered inferior to open debridement given inability to perform an adequate debridement of necrotic tissue
- ☐ Operative
 - **Single-incision irrigation and debridement (I&D)**
 - relative indications
 - large lesions ($> 50 \text{ cm}^3$) or persistent MLL having failed non-operative management
 - lesion is not in the way of surgical approach for fracture
 - outcomes

- successful resolution of lesion in up to 75% of cases with single I&D
 - more than I&D may be required for very large lesions
- **Dual-incision I&D**
 - relative indications
 - lesion overlies surgical approach for fracture management
 - MLL discovered intra-operatively during surgical approach
 - outcomes
 - lesions near a surgical approach have a higher rate of infection and may require serial I&Ds prior to definitive management of underlying fracture
- **Open debridement with resection of the fibrous capsule**
 - relative indication
 - chronic MLLs with pseudocyst formation
 - outcomes
 - mixed, often requires multiple surgeries for eradication

Techniques

- ▢ **Compressive therapy**
 - technique
 - most common modalities are ace wraps, compression bandages, bike shorts (for proximal thigh lesions)
- ✦ **Percutaneous drainage with drain placement**
 - technique
 - use ultrasound to localize lesion then make 1-2 cm incision overlying lesion
 - insert a suction tip into the lesion to remove hemorrhagic fluid
 - irrigate with normal saline
- ▢ **Single incision I&D**
 - approach
 - incision centered over MLL
 - technique
 - aggressive debridement of cavity performed with scrub brush, Cobb and/or other instruments
 - placement of a drain exiting away from lesion (consider using 15 Fr or larger drain)
 - recommend leaving drain until minimal output (< 20-30 cc/day)
 - primary closure of lesion versus delayed closure
 - controversial
 - depends on size of lesion
 - delayed closure would involve wound vacuum placement and repeat I&D and closure in 48-72 hours
- ▢ **Dual-incision I&D**
 - approach
 - incision over most proximal aspect of lesion
 - counter incision over most distal aspect of lesion
 - technique
 - similar to single incision for rest of treatment EXCEPT
 - primary closure of most proximal incision during first I&D
 - delayed closure of distal incision with wound vacuum (VAC)
 - return in 48-72 hours for repeat I&D through distal incision and closure

Complications

- ▢ **Recurrence**
 - incidence
 - most common complication
 - up to 56% in patients with non-operative management and 15-20% in those with open debridements
 - risk factors
 - inadequate debridement, larger lesions
 - treatment
 - repeat I&D and placement of drain
 - use of VAC and secondary healing (requires delayed skin graft)
 - use of sclerotherapy with talc or other sclerosing compound

- ▣ Pseudocyst formation
 - risk factors
 - chronic, untreated MLL
 - treatment
 - open debridement with resection of the fibrous capsule
- ✦ Skin necrosis
 - risk factors
 - delay in treatment, loss of epidermal blood supply due to inciting event or several repeat I&Ds of large MLL lesions
 - treatment
 - skin grafting
- ▣ Peri-operative infection
 - risk factors
 - presence of a MLL has been cited as an independent risk factor for postoperative surgical site infection following pelvic and acetabular surgery

■ Prognosis

- ✦ MLL cited as an independent significant risk factor for postoperative surgical site infection following pelvic and acetabular surgery
- ▣ Overall prognosis varies with lesion chronicity and size
 - improved prognosis with smaller, acute lesions and discontinuous with surgical incisions

71- Tscherne Classification

Closed Fractures

The Oestern and Tscherne classification for closed fractures

Oestern and Tscherne classification of soft tissue injury in closed fractures		
Grade 0	- Minimal soft tissue damage - Indirect injury to limb (torsion) - Simple fracture pattern	
Grade 1	- Superficial abrasion or contusion - Mild fracture pattern	
Grade 2	- Deep abrasion - Skin or muscle contusion - Severe fracture pattern - Direct trauma to limb	
Grade 3	- Extensive skin contusion or crush injury - Severe damage to underlying muscle - Compartment syndrome - Subcutaneous avulsion	

Open Fractures

The Oestern and Tscherne classification for open fractures

uses wound size, level of contamination, and fracture pattern to grade open fractures

The Oestern and Tscherne classification for open fractures		
Grade I	- Open fractures with a small puncture wound without skin contusion - Negligible bacterial contamination - Low-energy fracture pattern	
Grade II	- Open injuries with small skin and soft tissue contusions - Moderate contamination - Variable fracture patterns	
Grade III	- Open fractures with heavy contamination - Extensive soft tissue damage - Often, associated arterial or neural injuries	
Grade IV	Open fractures with incomplete or complete amputations	

72- Adult Ankle Radiographs

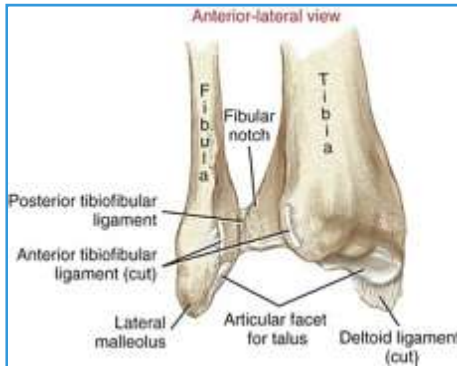
NORMAL ANATOMY

Osteology & Attachments

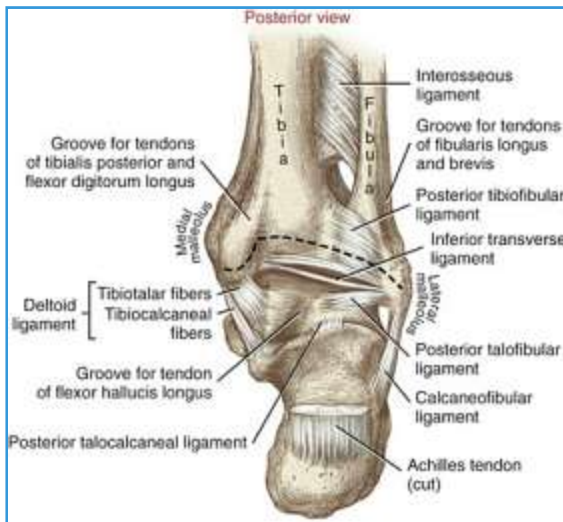
Anterior view



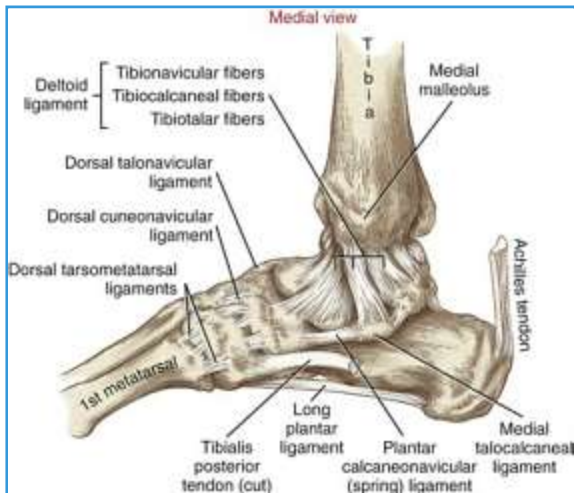
Anterolateral view



Posterior view



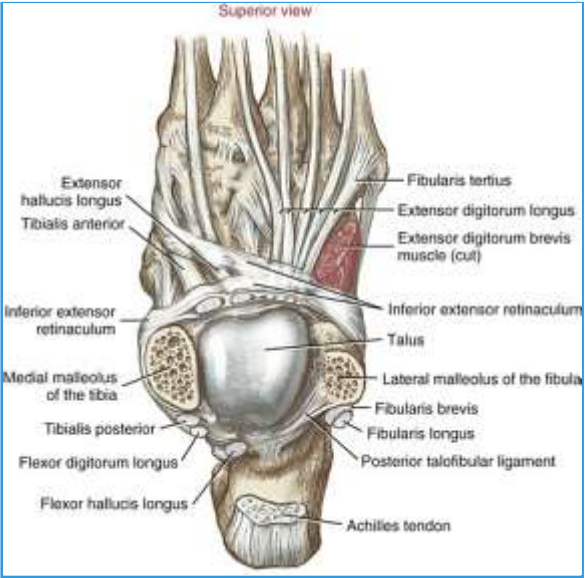
Medial view



Lateral view



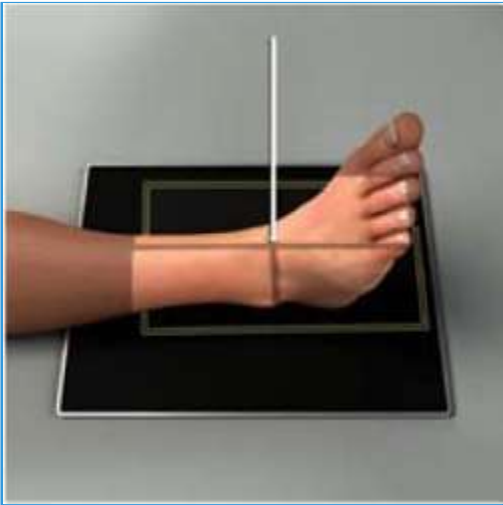
Superior view



RADIOGRAPHIC VIEWS

AP view

■ Positioning



- ✧ patient
 - supine
 - knee extended + foot dorsiflexed
- ✧ beam
 - aim at mid-tibiotalar joint

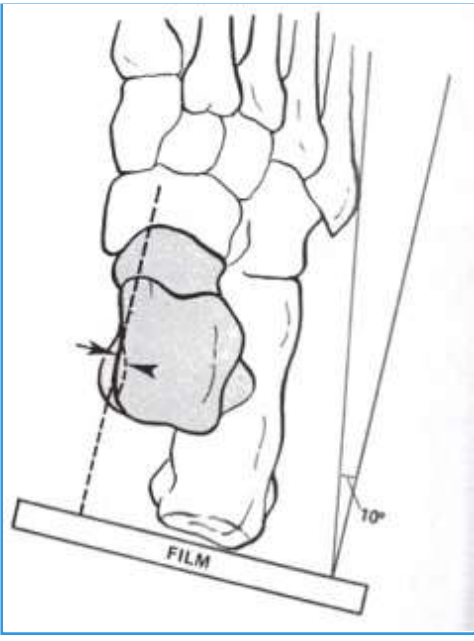
■ Critique



- ✧ lateral malleolus closer to plate
- ✧ open medial joint space + tibiotalar joint
- ✧ closed lateral joint space
- ✧ slight superimposition of talus + fibula
 - increased by ER + decreased by IR

Mortise view

■ Positioning



- ❑ patient
 - supine
 - knee extended + leg IR 15° + foot dorsiflexed
- ❑ beam
 - aim at mid-tibiotalar joint

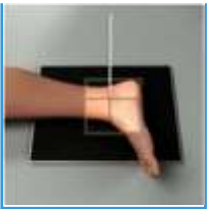
✦ Critique



- ❑ slight superimposition of fibula + tibia
- ❑ open lateral joint space + tibiotalar joint
- ❑ closed medial joint space
- ❑ no visualization of sinus tarsi
 - too much IR if visible

Lateral view

✦ Positioning



- ✧ patient
 - supine
 - knee extended + leg/ankle ER 90° + foot dorsiflexed
- ✧ beam
 - aim at medial malleolus

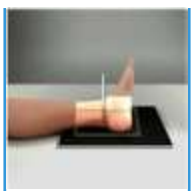
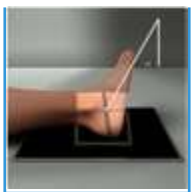
■ Critique



- superimposition of medial + lateral malleoli
- superimposition of talar domes
 - superoinferior plane = lateral dome moves more proximal if proximal tibia higher than distal tibia
 - AP plane = lateral dome moves posterior if too much ER
- ✧ superimposition of fibula + tibia
 - fibula on posterior half of tibia but not superimposing posterior malleolus
 - fibula moves anteriorly if too much IR
- ✧ open tibiotalar joint
- ✧ visualization of pre-talar fat pad
 - requires foot dorsiflexion

Oblique view

■ Positioning



- ✧ patient
 - supine
 - knee extended + foot IR/ER 45°
- ✧ beam
 - aim at mid-tibiotalar joint

■ Critique

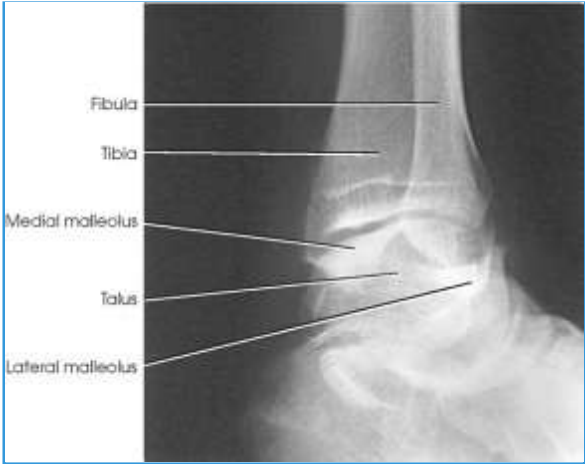
- medial/IR



- open lateral mortise + tibiotalar joint
 - mortise closes with too much IR
- closed medial mortise
- slight superimposition of fibula + tibia

- no superimposition of talus + fibula
- no visualization of sinus tarsi
 - too much IR if visible

☞ lateral/ER

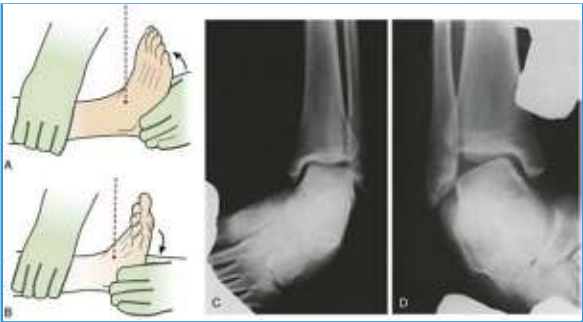


- superimposition of fibula + tibia

Stress view

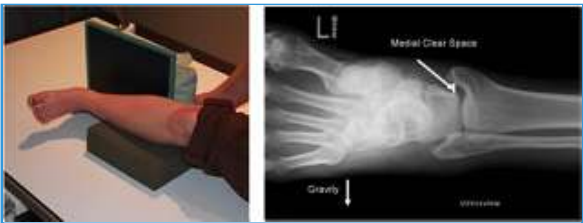
+ Positioning

- ☛ patient
 - manual stress



= supine + knee extended + ankle inverted/everted

- gravity stress



= supine + hip ER + knee flexed + ankle placed on bump

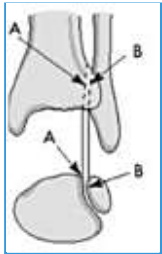
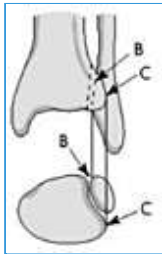
☞ beam

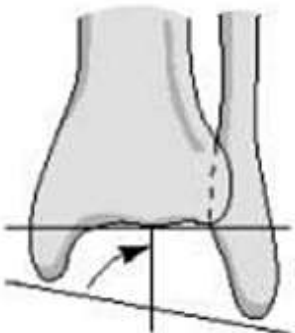
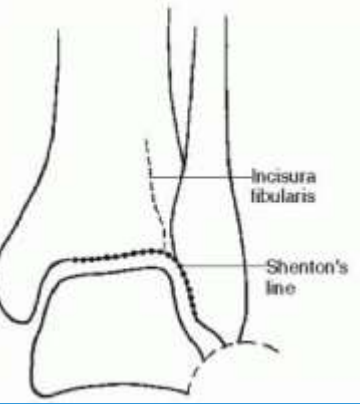
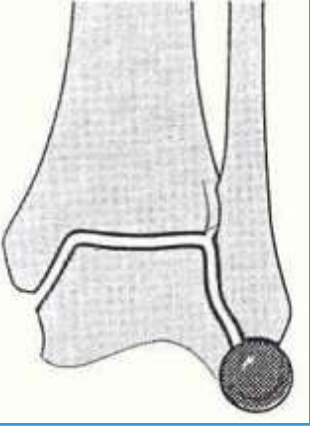
- aim at tibiotalar joint

+ Uses

- ☛ joint stability = < 5° difference between ipsilateral + contralateral ankles
- ☞ ER stress = evaluates syndesmotic/deep deltoid ligament injury
- ☞ IR stress = evaluates LCL injury

NORMAL FINDINGS

	VIEW	MEASUREMENT TECHNIQUE	NORMAL FINDINGS	
Tib-fib clear space	AP/mortise	measure 1 cm above joint	< 6mm	
Tib-fib overlap	AP/mortise	measure at maximum overlap	> 6mm or 42% fibular width on AP view; > 1mm on mortise view	
Talar tilt	AP/mortise	difference in width of superior clear space	< 2mm or < 2° on AP view, < 2mm or 0° on mortise view	
Talocrural angle	mortise	angle between intermalleolar line + line perpendicular to tibial articular surface	< 83 ° ± 4 °	

				 Talo crural angle (83° ± 4°)
Medial clear space	mortise	distance between lateral medial malleolus + medial talus	≤ 4mm	 Medial clear space (≤ 4 mm)
Shenton's line	mortise	line along lateral plafond	continuous	 Incisura fibularis Shenton's line
Dime test	mortise	line along lateral talus + lateral malleolus	continuous	
Hawkin's sign	mortise	subchondral radiolucent band in talar dome seen 6-8 wks post-injury, results from revascularization of talar body	present (absence indicates AVN)	
Heel-pad thickness	lateral	shortest distance between plantar calcaneus + skin	23mm in females, 25mm in males (increased in acromegaly)	
Achilles tendon thickness	lateral	measure 1-2cm above calcaneus	4-8mm	

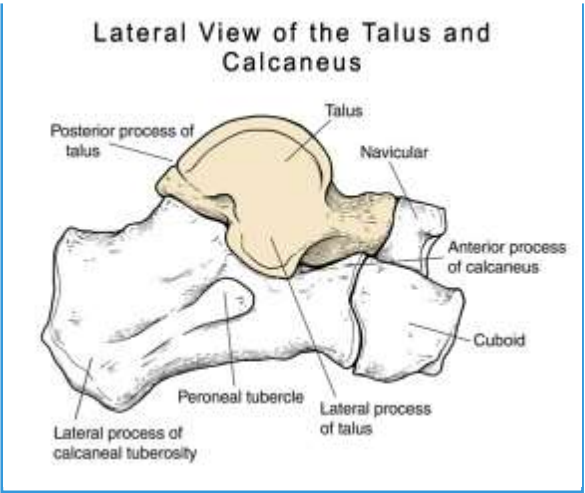


73- Adult Hindfoot Radiographs

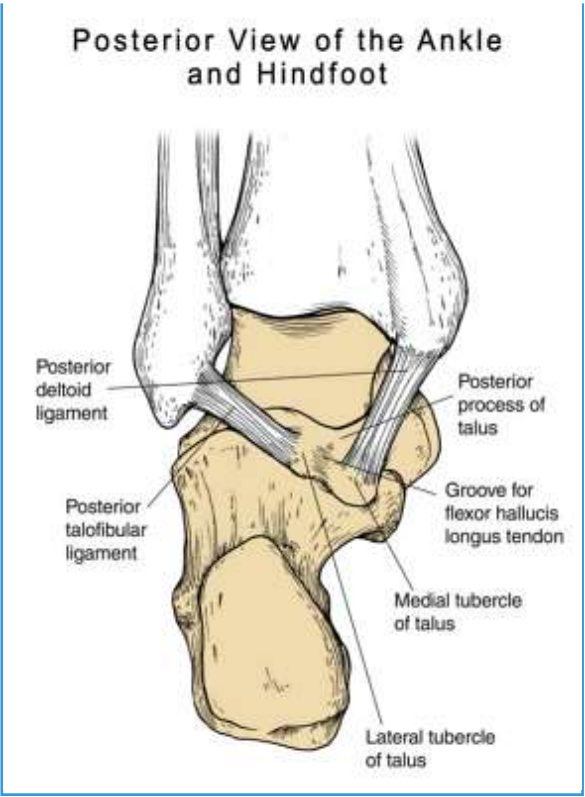
NORMAL ANATOMY

Osteology

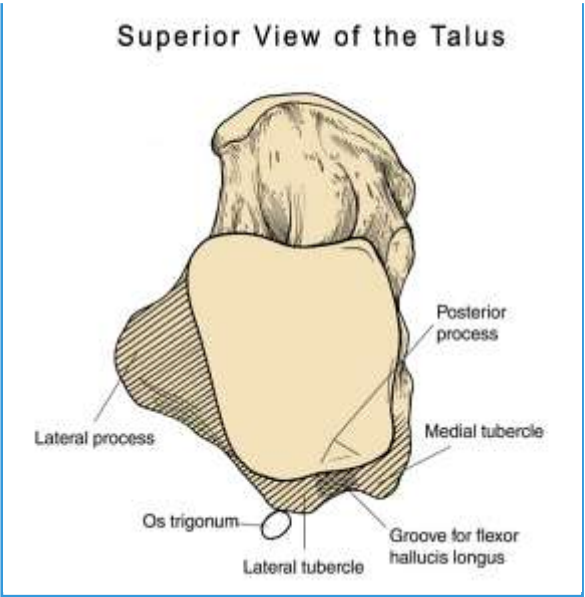
■ Lateral view



+ Posterior view

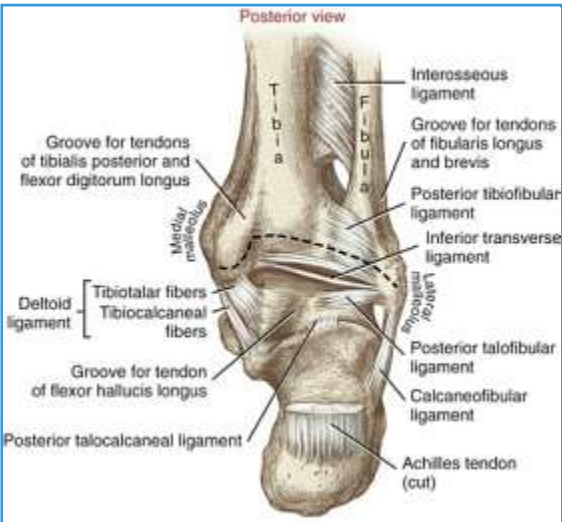


■ Superior view



Attachments

■ Posterior view



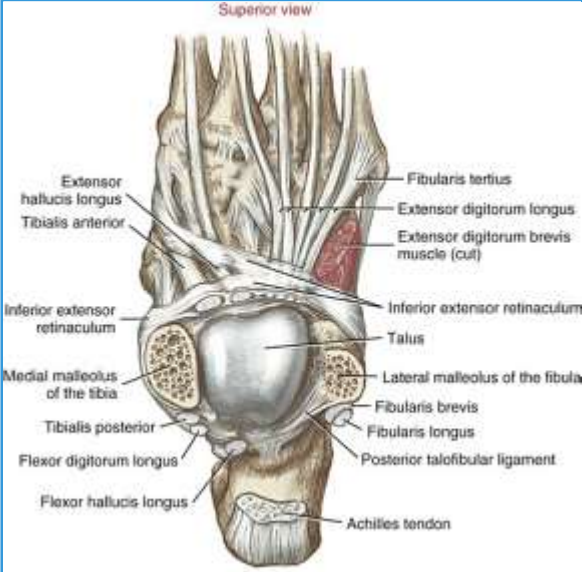
■ Medial view



■ Lateral view



+ Superior view



RADIOGRAPHIC VIEWS

Lateral View

■ Positioning



✧ patient

- lateral decubitus on ipsilateral side
- knee flexed 45° + foot dorsiflexed

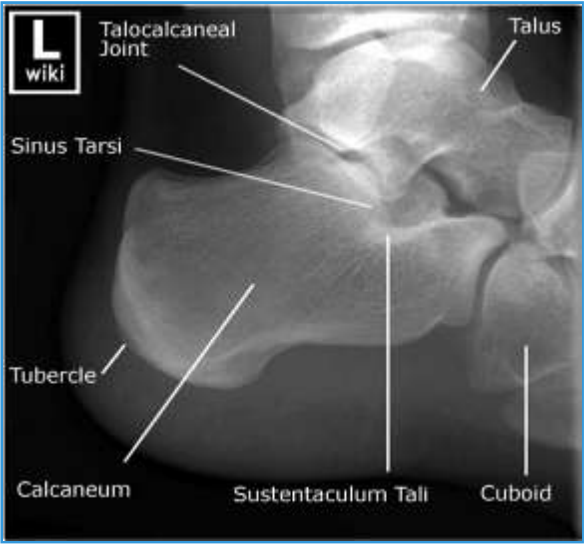
✧ beam

- aim 2.5cm below medial malleolus

■ Indications

- ✦ Bohler's angle
- ✦ angle of Gissane

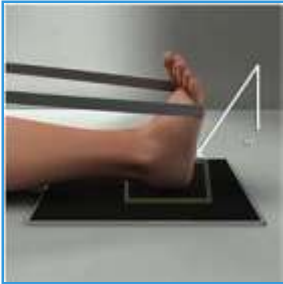
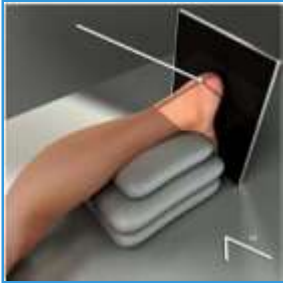
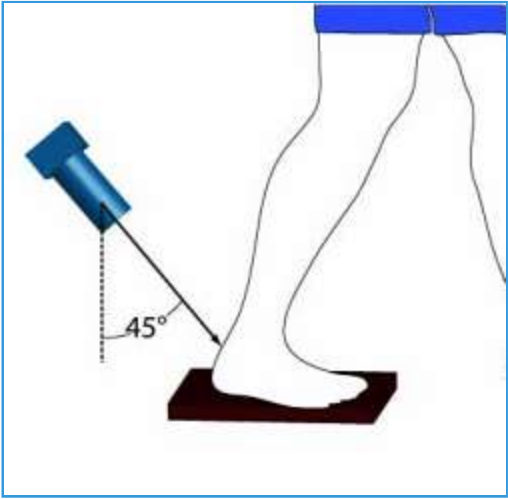
■ Critique



- ✦ superimposition of fibula + posterior tibia
- ✦ superimposition of talar domes
- ✦ open tibiotalar joint + talonavicular joint + tarsal sinus

Axial View

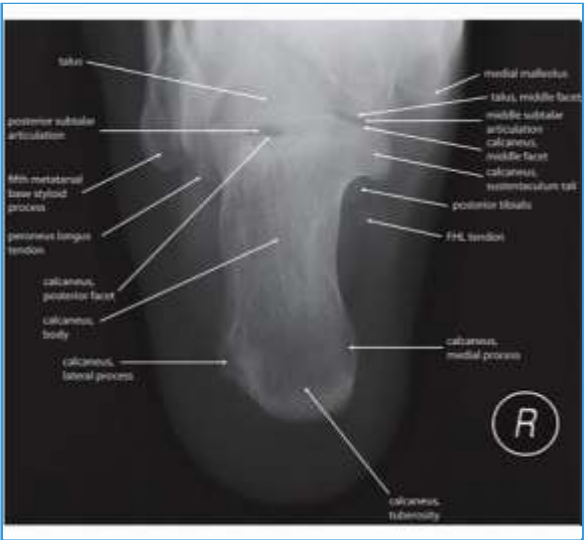
✦ Positioning

	METHOD	PATIENT		BEAM	
	Plantodorsal/Harris	supine vs. seated		knee extended + leg slightly IR + foot dorsiflexed	base of 3rd metatarsal 40° cephalad
	Dorsoplantar	prone		ankle elevated + foot dorsiflexed	proximal anterior calcaneus 40° caudad
	Dorsoplantar/Harris	erect		foot dorsiflexed	mid-calcaneus 45° cephalad

■ Indications

- ✦ anterior + posterior calcaneus

■ Critique



- ✦ visualization of entire calcaneus
- ✦ visualization of sustentaculum tali

Canale View

■ Positioning



- ✦ patient
 - supine
 - foot with max plantarflexion + pronated 15°
- beam
 - aim at talar neck + 15° cephalad

■ Indications

- ✦ talar neck

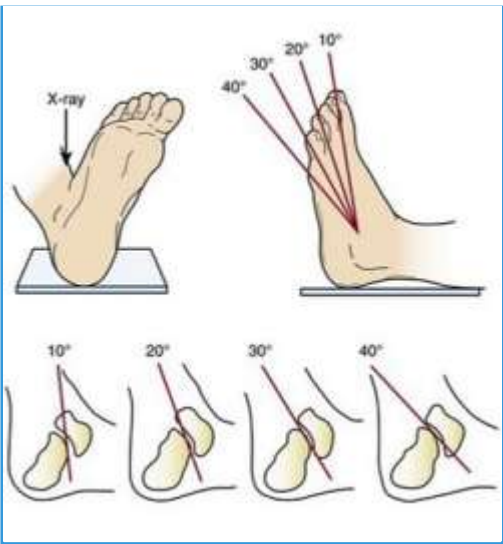
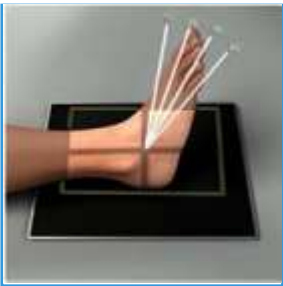
+ Critique



- ✦ visualization of talar neck

Broden View

■ Positioning



- ✦ patient
 - supine
 - leg IR 10/20/30/40° + foot dorsiflexed

- ✧ beam
 - aim at lateral malleolus + 10/20/30/40° cephalad

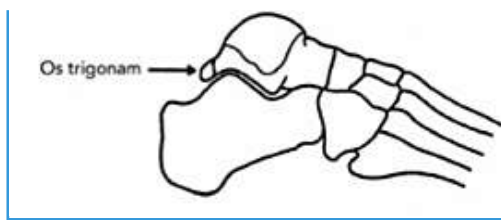
✧ Indications

- ✧ posterior facet of talus = 10° shows posterior aspect, 40° shows anterior aspect
- ✧ sustentaculum tali/middle facet of talus = 20-30° view
- ✧ subtalar joint

NORMAL FINDINGS

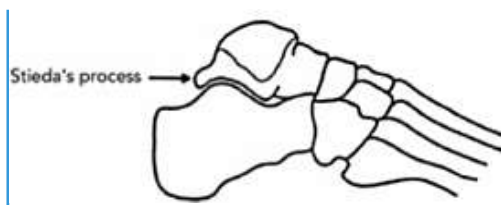
✧ Notable normal variants

✧ os trigonum



- sesamoid bone located posterior to posterior process of talus, usually unilateral

✧ Steida's process



- elongated posterior process of talus

✧ oblique talus

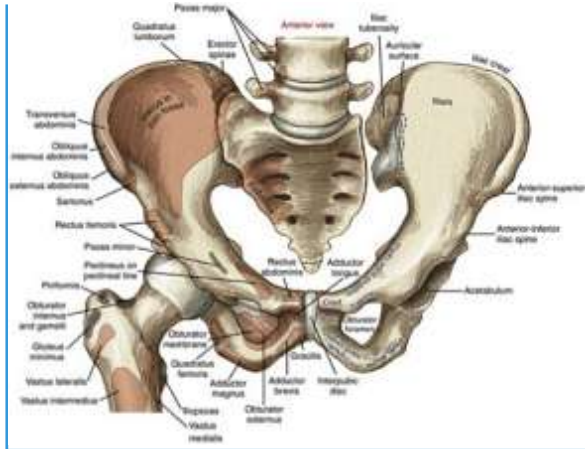


- talonavicular subluxation that reduces with forced plantarflexion

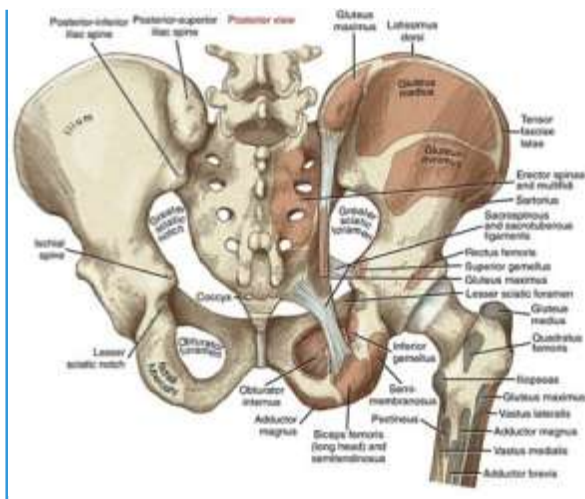
74- Adult Hip Radiographs

Osteology & Attachments

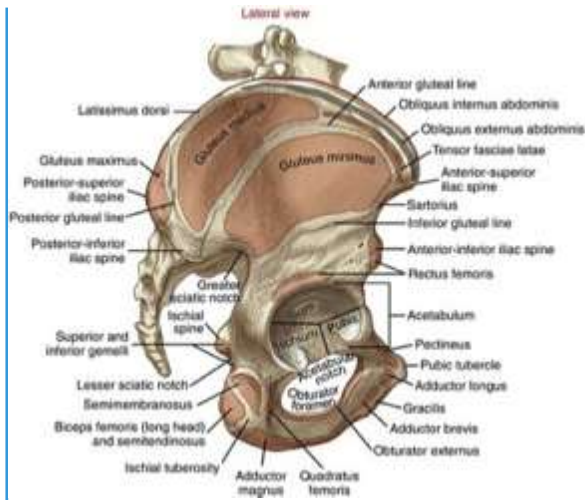
Anterior view



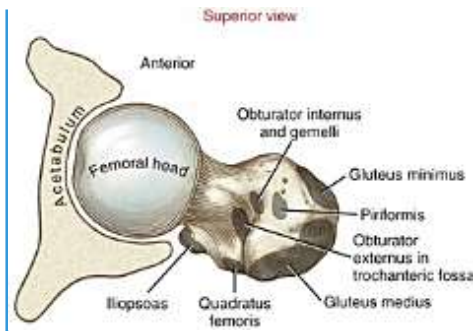
Posterior view



- ✦ Lateral view



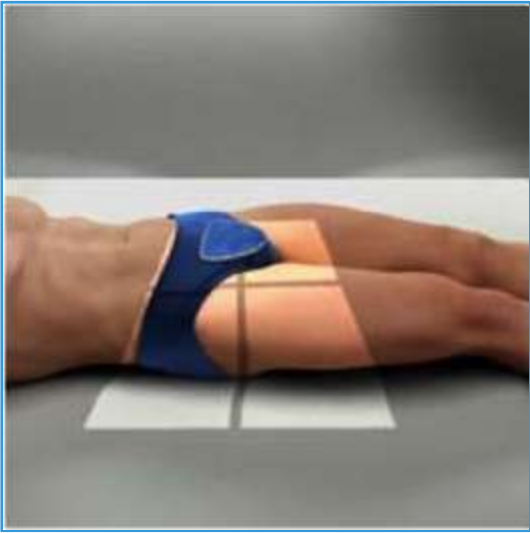
- Superior view



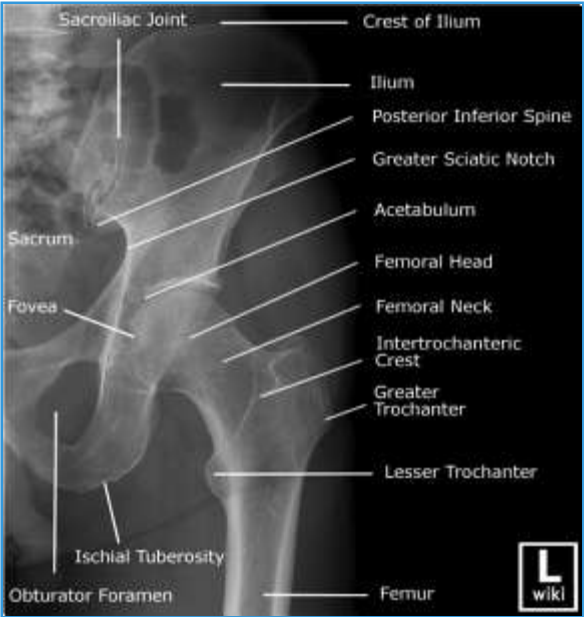
RADIOGRAPHIC VIEWS

AP view

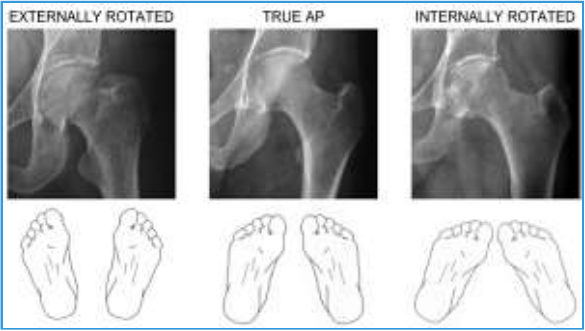
- Positioning



- patient
 - supine
 - leg IR 15-20°
- beam
 - aim between ASIS + symphysis pubis
- Critique



- no rotation of pelvis
 - superimposition of ischial spine with pelvic brim
 - open obturator foramen
- no visualization of lesser trochanters
 - too much external rotation of leg leads to increased visualization of lesser trochanter

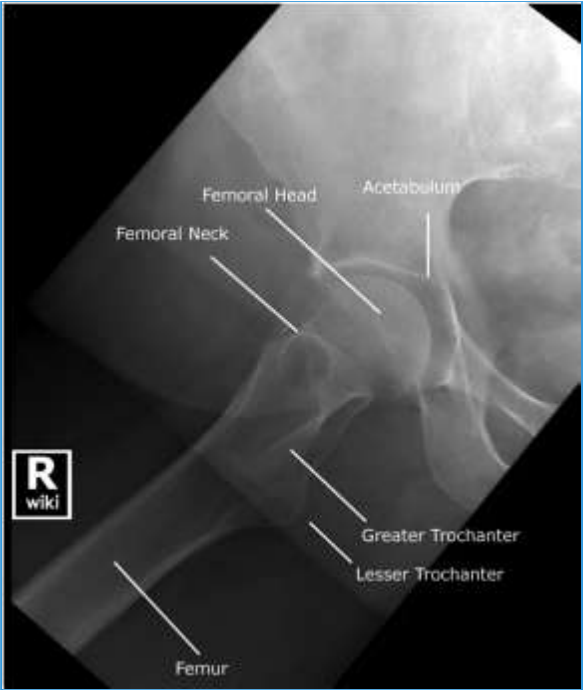
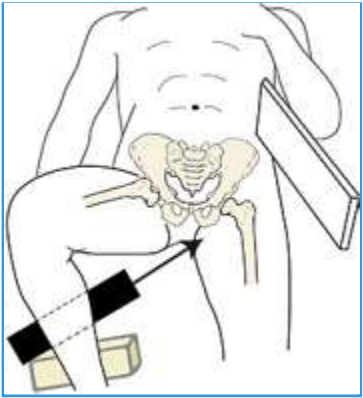
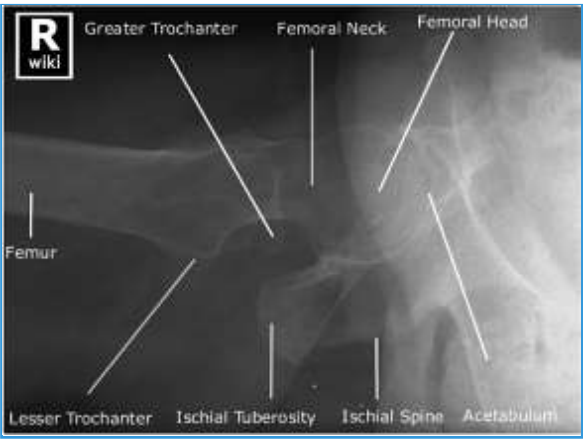
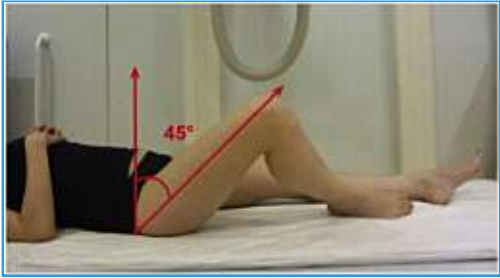


- superimposition of ischial spine with pelvic brim

Lateral view

- Positioning

METHOD	PATIENT		BEAM		
Rolled lateral	supine	hip abducted 45 ° + knee flexed 90°	mid-femoral neck	n/a	
					

					
Horizontal ray/cross-table	supine 	contralateral hip flexed 90° + ipsilateral hip IR 15-20 °	femoral head	45° cephalad	
Modified Dunn	supine 	hip flexed 45° + abducted 20 °	2.5 cm above pubic symphysis	n/a	
Frog leg	supine 	hip abducted 45° + knee flexed 30-40 °	2.5 cm above pubic symphysis	n/a	
Lowenstein	semi-lateral 45 ° on ipsilateral side 	hip flexed 90°	mid-femoral neck	20-25° cephalad	
False profile	erect	hip flexed 90° pelvis ER 65° toward ipsilateral side	femoral head	n/a	

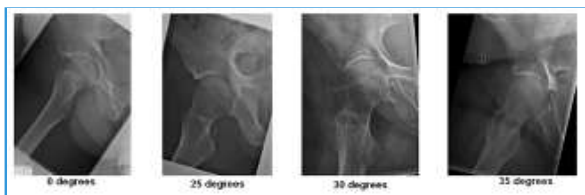


+ Indications

- + horizontal ray/cross-table
 - useful in trauma patients where positioning is limited by pain
- ⌘ modified dunn
 - better demonstrates relationship of femoral head with acetabulum
 - useful for confirming femoroacetabular impingement (alpha angle)
- frog leg
 - better demonstrates shape of femoral head + head/neck transition
 - useful for confirming epiphysiolysis, SCFE, Perthes disease
- ☆ lowenstein
 - useful as alternative to frog leg view, as it is technically easier to obtain
- + false profile
 - provides true lateral projection of femoral head/neck and oblique view of acetabulum
 - demonstrates anterior acetabular coverage of femoral head
 - useful for determining anterior center-edge angle

■ Critique

- horizontal ray/cross-table
 - visualization of greater trochanter
 - increased cephalad angle leads to increased visualization of greater trochanter off femoral neck but will distort/elongate femoral neck



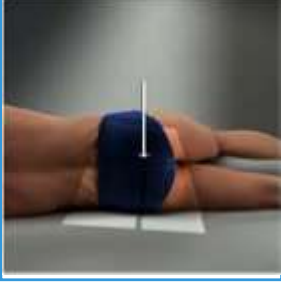
- no obstructing soft tissue artifact via adequate elevation of contralateral leg
- + modified dunn
 - no overhang of greater trochanter over posterior margin
 - visualization of lesser trochanter
- ⌘ frog leg/lowenstein
 - symmetrical obturator foramen + iliac wing concavity
 - superimposition of greater trochanter + femoral neck
- false profile
 - visualization of lesser trochanter
 - too much ER leads to nonvisualization of lesser trochanter
 - demonstration of bullet sign



= superimposition of ischial tuberosity

Oblique view

■ Positioning

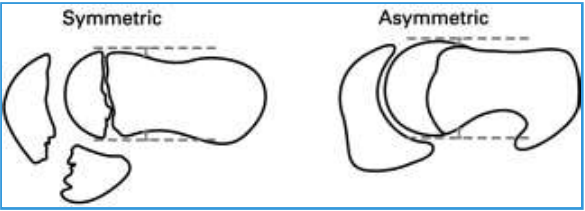
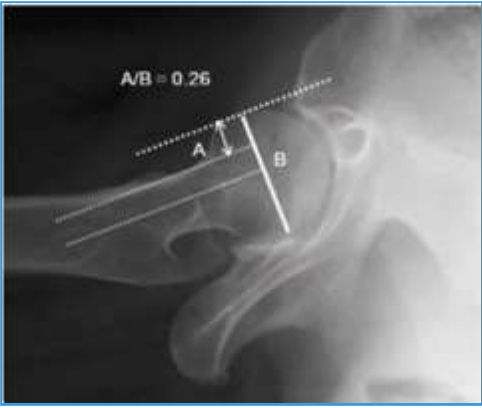
METHOD	PATIENT		BEAM	
Hsieh	semi-prone 	contralateral hip elevated 40-45°	femoral head	n/a
Lillenfeld	lateral decubitus on ipsilateral side 	pelvis tilted anteriorly 15°	greater trochanter	n/a
Teufel	semi-prone 	c ontralateral hip elevated 38°	2 cm above greater trochanter	12° cephalad

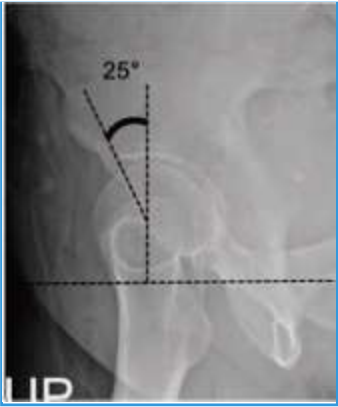
- ★ Indications
 - ✦ hsieh = posterior hip dislocation
 - ✦ lillenfeld = posterolateral pelvis
 - ✦ teufel = fovea capitis
- Critique



NORMAL FINDINGS

	VIEW	MEASUREMENT TECHNIQUE	NORMAL FINDINGS	SIGNIFICANCE	
Leg-length discrepancy	AP	line along inferior ischial tuberosity + line along superior aspect of lesser trochanter	0 cm		
Neck-shaft angle	AP	angle between femoral neck + femoral shaft	125-140 °	coxa vara < 120 °; coxa valga > 140 °	
Lateral center-edge angle/angle of wiberg	AP	angle between vertical line through femoral head + line along lateral acetabulum	25-40 °	assesses superolateral coverage: dysplasia < 20 °; overcoverage > 40 °	
Femoral head extrusion index	AP	% of femoral head not covered by acetabulum	< 25%	dysplasia > 25%	
Acetabular depth	AP	relationship of ilioischial line with acetabular floor vs. femoral head	lateral	coxa profunda = acetabular floor touches/medial to ilioischial line; protrusion acetabuli = femoral head touches/medial to ilioischial line	

					
Acetabular inclination/acetabular roof angle of tonnis	AP	angle between line through inferior sourcil parallel to inter-teardrop line + line from inferior to lateral sourcil	0-10 °	hip instability > 10°; pincer-type FAI < 0 °	
Acetabular version	AP	crossover/figure-of-8 sign = relationship of anterior + posterior rim before reaching lateral sourcil	5-25 ° anteverted	anteverted = no crossover; retroverted = crossover, also deficient posterior wall (femoral head lateral to posterior acetabulum) + prominent ischial spine, increased by increased pelvic tilt/rotation	
Hip center position	AP	distance from medial femoral head to ilioischial line	< 10 mm	lateralized > 10 mm	
Joint space width	AP weight bearing	minimum distance between femoral head + acetabulum	4 mm	OA < 4 mm	
Head-neck offset	AP vs. lateral	relationship of anterior + posterior femoral head-neck junction	symmetric radius of curvature	decreased = anterior concavity > posterior; increased = anterior convexity	
Head-neck offset ratio	lateral	distance between line parallel to femoral neck through anterior femoral neck + anterior femoral head divided by diameter of femoral head	> 0.15	cam lesion < 0.15	
Alpha angle	lateral	angle between line from femoral head to anterolateral head-neck junction (where radius of femoral head becomes larger than neck) + line through femoral head/neck	< 42 °	Cam lesion > 50-55°	

					
Head sphericity	AP + lateral	displacement of femoral head from reference circle	< 2 mm	aspherical > 2 mm	
Anterior center-edge angle/angle of lequesne	false profile	angle between vertical line through femoral head + line along femoral head/anterior acetabulum	> 20°	assesses anterior coverage; can have crossover sign but no posterior wall deficiency	

75- Adult Knee Radiographic Views

✦ NORMAL ANATOMY

📖 Osteology

■ Distal femur

■ anterior/posterior view



■ lateral view



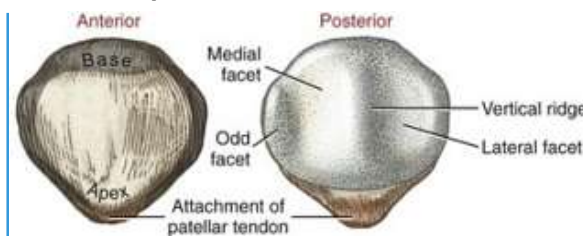
■ Proximal tibia

■ anterior/posterior view



■ Patella

■ anterior/posterior view



✦ Attachments

■ Muscle

■ anterior view



■ posterior view



- lateral view



- Ligament/tendon

- anterior/posterior view



- lateral view

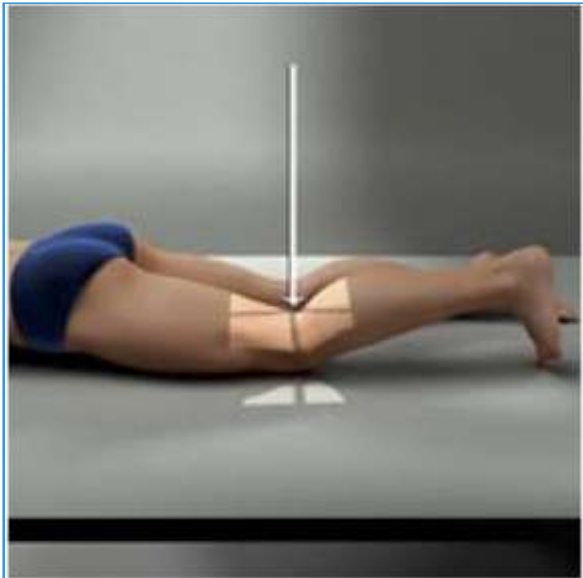
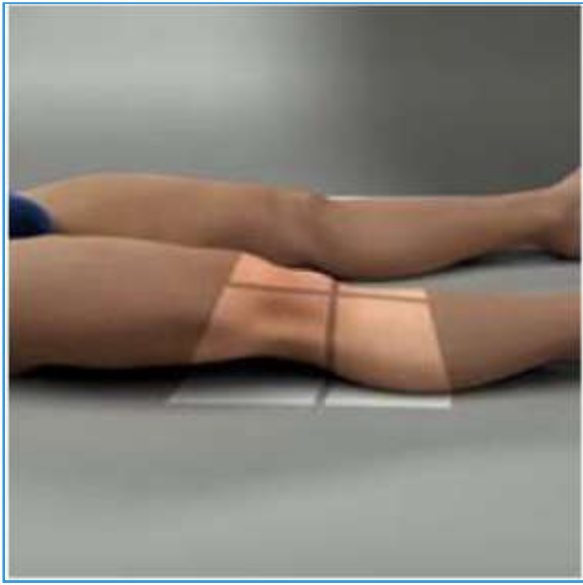


- AP/PA view

- Positioning

- patient

- supine (AP) vs. prone (PA)



- knee extended + leg IR 3-5°
- beam
 - aim 1.5cm distal to apex of patella

✦ Indications

- fracture
- joint alignment
- OA
 - PA view preferred over AP view
 - weightbearing view preferred over non-weightbearing view

📖 Critique



- symmetrical femoral + tibial condyles
- fibular head should be bisected by the tibia
- visualization of intercondylar eminence in intercondylar fossa

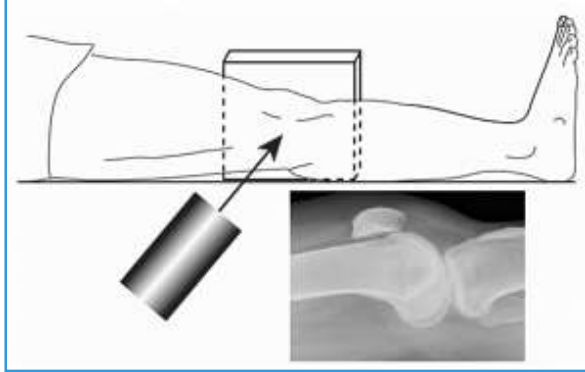
■ Lateral view

✦ Positioning

- patient
 - rolled lateral (mediolateral) = lateral decubitus on ipsilateral side + knee flexed 20-30°



- horizontal ray (lateromedial) = supine + knee extended



- beam
 - aim 2.5cm distal to medial epicondyle
 - tilt 5-7° cephalad (if rolled lateral)

▣ Indications

- patella fracture = horizontal ray view to avoid displacement
- patella alta/baja = requires knee in 30° flexion
- trochlear dysplasia
- OA
- joint effusion

✦ Critique

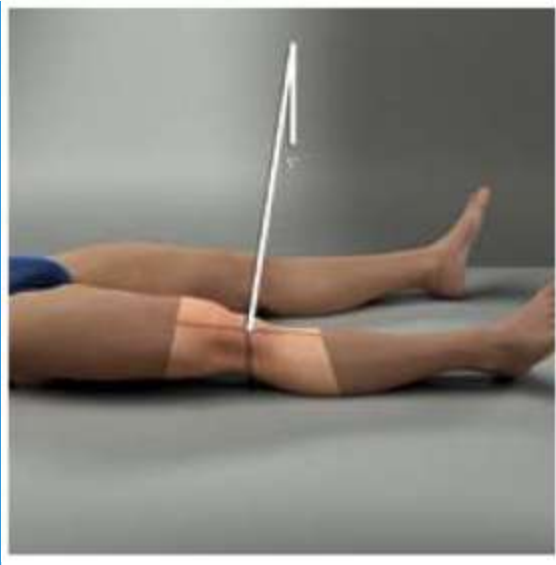
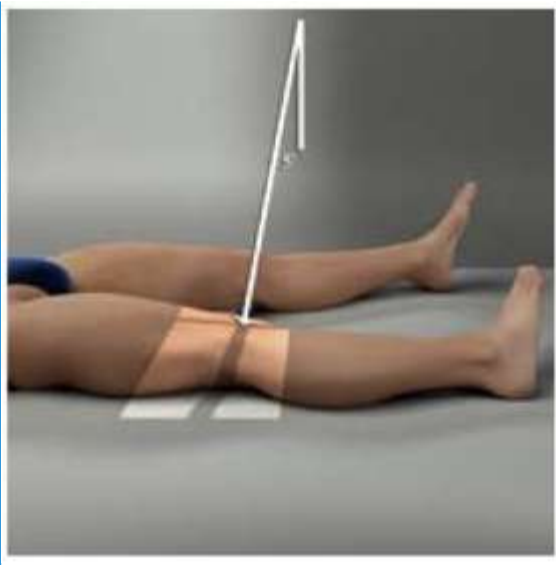


- visualization of suprapatellar fat pad = via knee flexion < 30°
- appropriate IR/ER
 - superimposition of posterior aspect of femoral condyles
 - superimposition of fibular head + tibia
 - open patellofemoral joint
 - no visualization of adductor tubercle
- appropriate cephalad angulation = open tibiofemoral joint

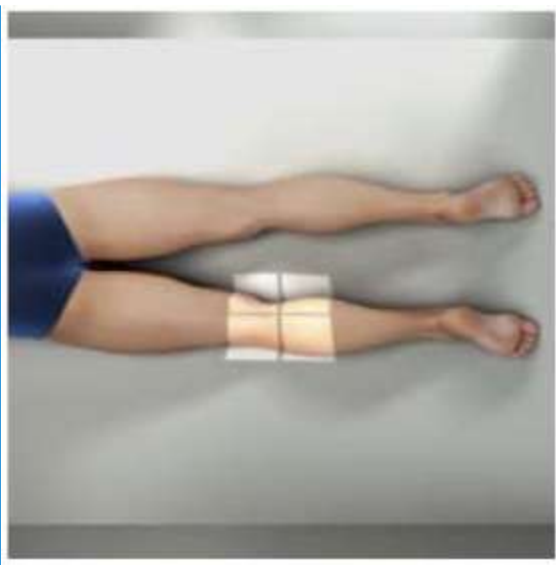
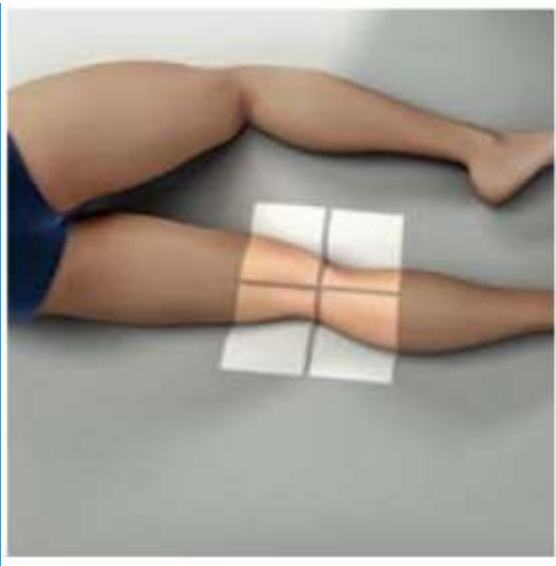
✦ Oblique view

✦ Positioning

- patient
 - AP = supine + knee extended + leg IR/ER 45°



- PA = prone + knee flexed 10° + leg IR/ER 45°



- beam
 - aim 1.5cm distal to apex of patella

⚙ Indications

- fracture = femoral condyle, patella
- OA
- intercondylar fossa pathology = loose bodies

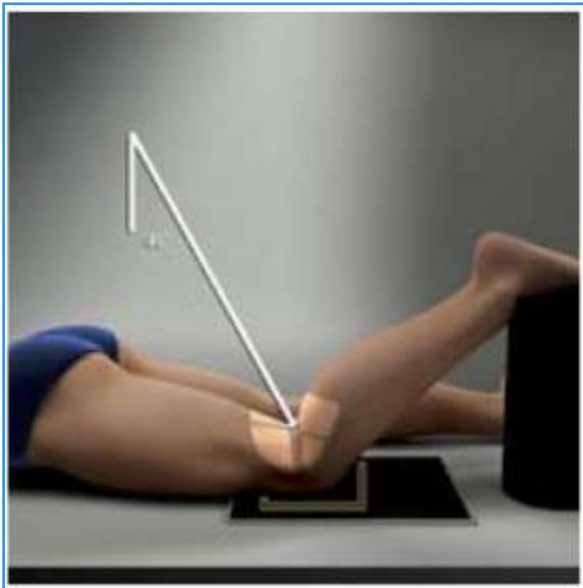
□ Critique

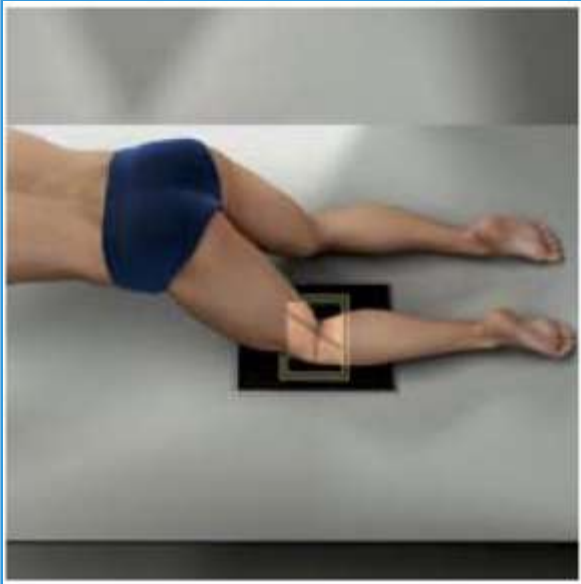
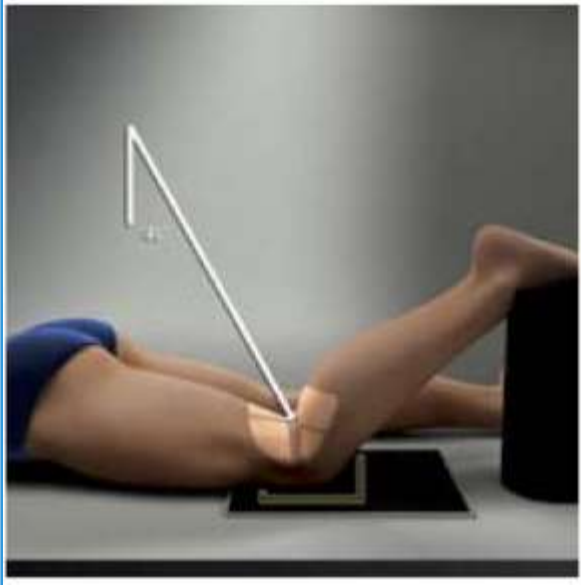
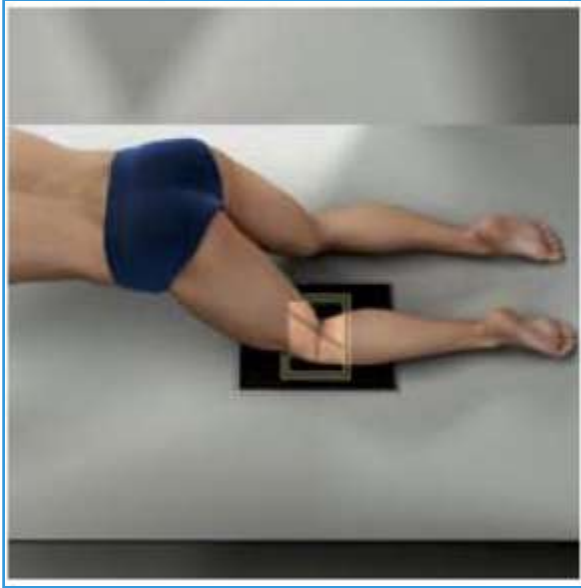


- superimposition of patella + ipsilateral femoral condyle
- asymmetrical tibiofemoral joint spaces

■ Intercondylar view

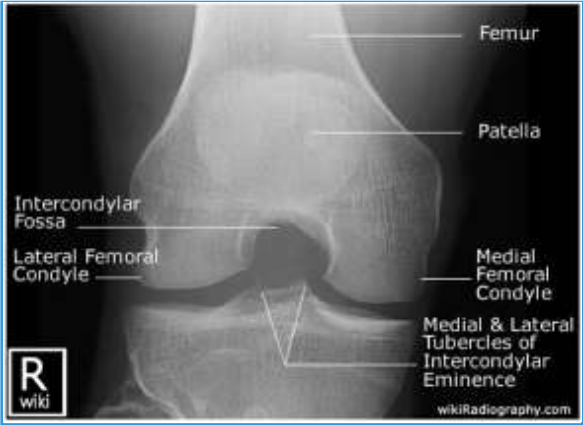
+ Positioning

METHOD	PATIENT		BEAM	
Beclere	supine		knee flexed 40°	AP 40° cephalad
Camp Coventry/Tunnel	prone		knee flexed 40°	PA 40° caudad
Holmblad	erect		knee flexed 70°	PA 0°
	vs. kneeling			



- ✦ Indications
 - OCD = displaced cartilage
 - congenital slipped patella = flattening/underdevelopment of lateral femoral condyle
 - hemophilia = intercondylar widening
 - intercondylar fossa pathology = loose bodies

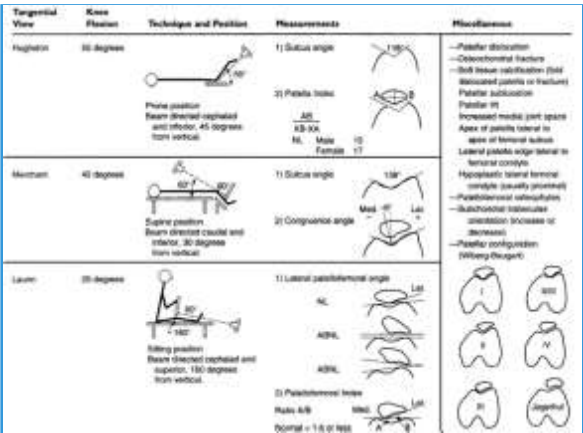
❑ Critique



- superimposition of patella + ipsilateral femoral condyle
- asymmetrical tibiofemoral joint spaces

■ Tangential view

✦ Positioning



METHOD	PATIENT	BEAM
Sunrise/Settegast vs. prone	supine 	knee flexed 90° inf-sup 10-20° cephalad
	prone 	
Hughston	prone 	knee flexed 50-60° inf-sup 45° cephalad
Merchant	supine 	knee flexed 40° sup-inf 30°

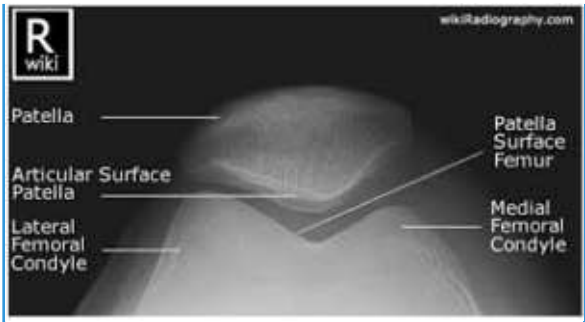
				caudad
Laurine	semi-recumbent	knee flexed 30°	inf-sup	30° cephalad



📌 Indications

- patellar malalignment
- trochlear groove depth
- OA
- vertical patella fracture

📌 Critique

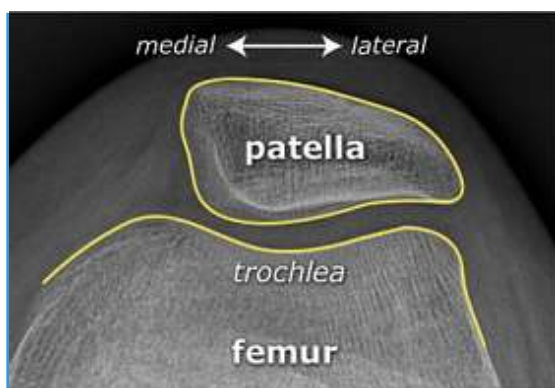


- visualization of femoral condyles + trochlear groove
- no superimposition of patella + femur
- open patellofemoral joint

■ NORMAL FINDINGS

📖 Normal anatomy

	Medial	Lateral
Femoral condyles	Larger + posterior Adductor tubercle	Proximal + anterior Lateral femoral notch = junction between tibiofemoral + patellofemoral curves
Tibial plateau	Concave + distal	Convex + proximal
Patellar facets	Shorter	Longer



📖 Normal variants

■ fabella



- sesamoid bone in lateral head of gastrocnemius
- best seen on lateral view
- cyamella



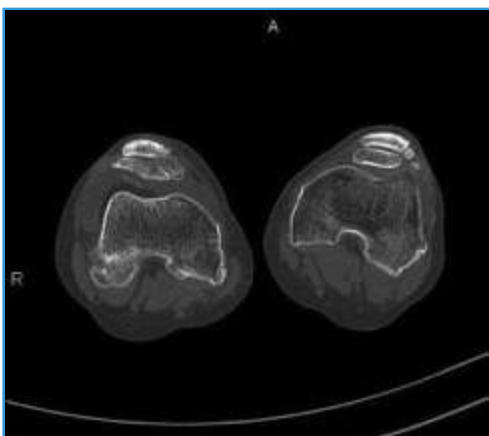
- sesamoid bone in popliteus tendon
- usually present in lateral aspect of distal femur in popliteal groove
- best seen on AP view
- cortical desmoid



- cortical lucency in posteromedial aspect of distal femur
- represents origin of medial head of gastrocnemius + insertion of adductor magnus
- seen in adolescents (10-15 yo)
- bipartite/tripartite patella



- usually superolateral with smooth margins
- double-layered patella



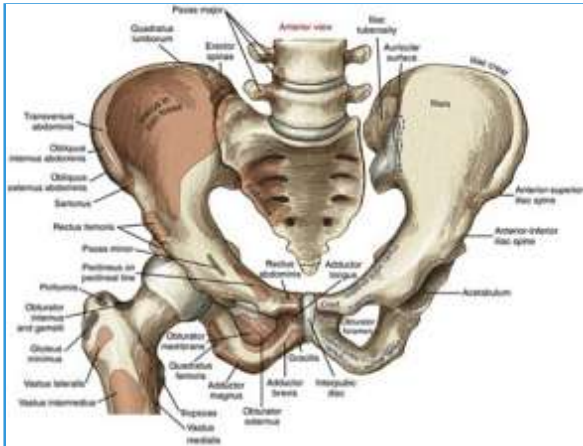
- rare form of bipartite patella
- multiple fragmented patella with smooth well-corticated borders
- pathognomonic for multiple epiphyseal dysplasia

76- Adult Pelvis Radiographs

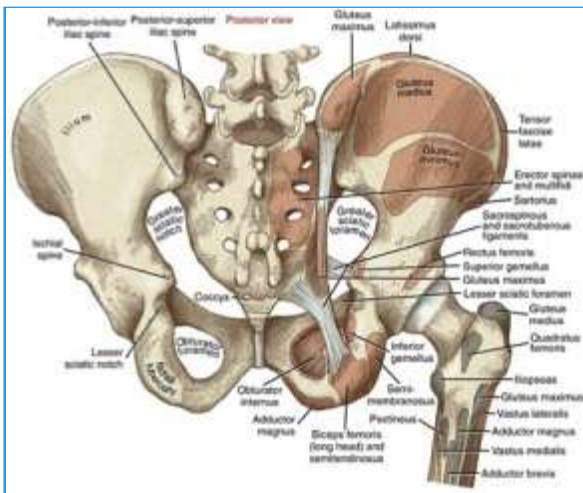
NORMAL ANATOMY

Osteology & Attachments

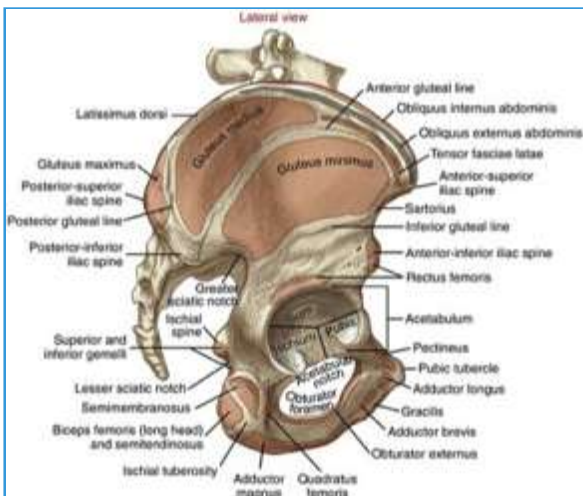
Anterior view



Posterior view



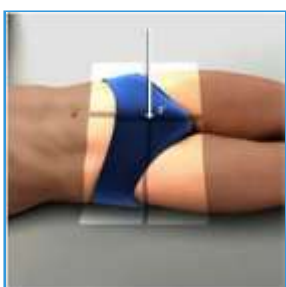
Lateral view



RADIOGRAPHIC VIEWS

AP view

Positioning



patient

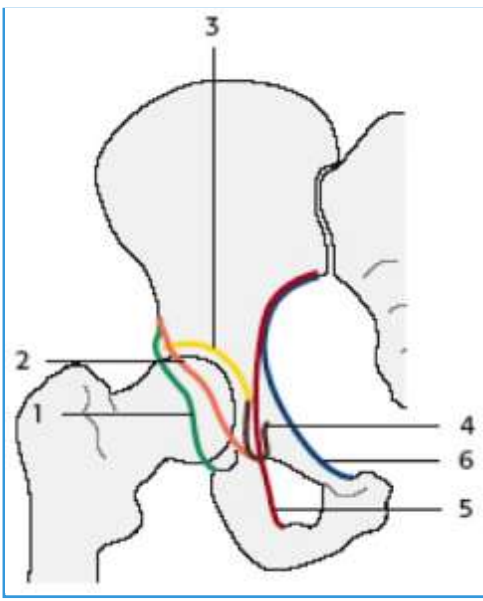
- supine
- legs IR 15-20°

beam

- aim midway between ASIS + pubic symphysis

Indications

- ▣ pelvic/acetabular fractures
- assess 6 lines

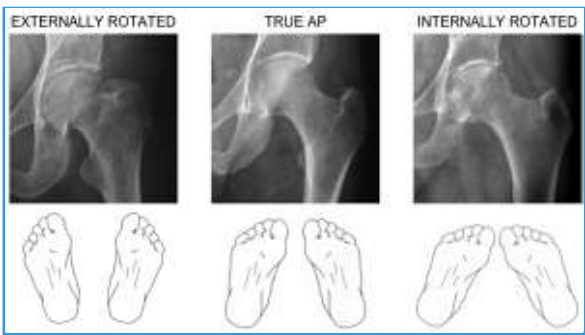


- **posterior rim (1)** = posterior wall/column
 - posterior horn of acetabulum
 - more lateral + horizontal line
- **anterior rim (2)** = anterior wall/column
 - inferior margin of superior pubic ramus
 - more medial + horizontal line
- **sourcil (3)** = anterior/posterior column
 - acetabular roof = superior weight-bearing portion
 - normal 45-60° arc
- **teardrop (4)** = anterior/posterior column
 - external/lateral limb = inferior anterior acetabular wall + outer cotyloid fossa
 - lower border = ischiopubic/acetabular notch + superior obturator foramen
 - internal/medial limb = outer wall of obturator canal + quadrilateral surface
 - internal + external limbs = not in same coronal plane but usually parallel + forms U
- **ilioischial line (5)** = posterior column
 - pelvic brim + quadrilateral surface + posterior obturator foramen + ischiopubic ramus
 - always superimposed on teardrop = disruption 2/2 rotation vs. quadrilateral surface Fx
- **iliopectineal line (6)** = anterior column
 - anterior $\hat{A}^{3/4}$ = pelvic brim, pubic symphysis to ilioischial line
 - posterior $\hat{A}^{1/4}$ = lower $\hat{A}^{1/2}$ of sciatic buttress to roof of greater sciatic notch

■ Critique



- ❏ no pelvic tilt
 - coccyx located 2cm above pubic symphysis
- ❏ no rotation of pelvis
 - sacrum in midline
 - symmetrical greater trochanters + obturator foramen
- ❏ no visualization of lesser trochanters
 - too much external rotation of leg leads to increased visualization of lesser trochanter



- if lesser trochanters are visible, they should be of symmetrical size and shape

Lateral view

+ Positioning



- patient
 - supine vs. lateral decubitus
- beam
 - aim 5cm above greater trochanters

✦ Critique



- no superimposition of femurs + pubic arch
 - achieve via leg extension
- ✦ superimposition of femurs + acetabulum
- ✦ superimposition of posterior ischium/ilium

Axial/Chassard-Lapine view

✦ Positioning



- ✦ patient
 - seated + leaning forward
 - pelvis tilted anteriorly 45° + hips abducted
- beam
 - aim between greater trochanters

■ Indications

- assess relationship of femoral head + acetabulum
- measurement of horizontal/bi-ischial diameter

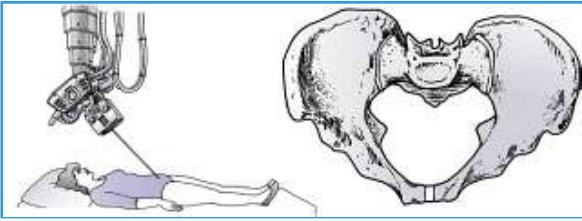
✦ Critique



- ✦ symmetrical greater trochanters
- ✦ equal distance between greater trochanters + sacrum

Inlet view

Positioning



- ✦ patient
 - supine
 - legs IR 15-20°
- ✦ beam
 - aim at ASIS + 40° caudad

Indications

- ✦ AP displacement + IR/ER of hemipelvis
- ✦ rotational stability of pelvis
- ✦ SI joint widening
- ✦ sacral Fx

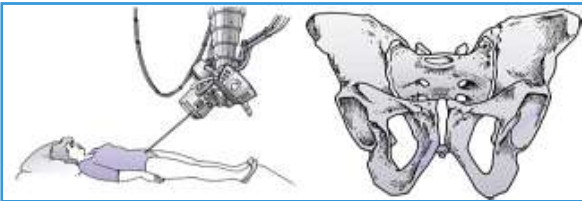
Critique



- ✦ superimposition of S1 + S2 body

Outlet view

Positioning



- ✦ patient
 - supine
 - legs IR 15-20°
- ✦ beam
 - aim 5cm below pubic symphysis
 - til 20-35° cephalad if male, 30-45° cephalad if female

Indications

- ✦ vertical displacement + flexion/extension of hemipelvis
- ✦ SI joint widening
- ✦ sacral Fx

Critique

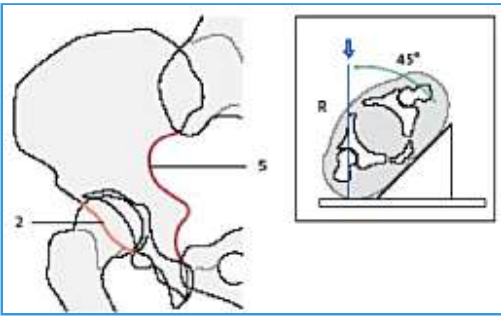


- ❑ superimposition of pubic symphysis + S2 body
- ❑ open obturator foramen

Judet view

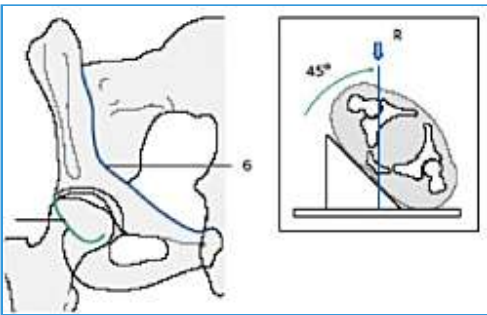
■ Positioning

- ❑ patient
 - iliac oblique



= semi-lateral 45° on ipsilateral side

■ obturator oblique



= semi-lateral 45° on contralateral side

❑ beam

- aim 5cm medial + inferior to ASIS

■ Indications

- ❑ iliac oblique = anterior wall + posterior column
- ❑ obturator oblique = posterior wall + anterior column

✦ Critique



- ❑ iliac oblique = visualization of iliac wing
- ❑ obturator oblique = open obturator foramen

NORMAL FINDINGS

■ Normal anatomy

- ❑ female pelvis



- wider in the mediolateral dimension
- suprapubic angle $> 90^\circ$

☐ male pelvis



- wider in AP dimension
- suprapubic angle $< 90^\circ$

✦ Normal variants

✦ phleboliths



- calcifications in walls of veins
- usually found laterally around bladder
- can be symmetrical
- can occur in clusters

☐ os acetabuli



- located at anterosuperior margin of acetabulum
- round in shape with concave lateral border and convex medial border
- may be bilateral and partially fused to the acetabulum

✦ paraglenoid sulcus



- groove at insertion of anterior SI ligament
- commonly seen in multiparous females
- associated with osteitis condensans ilii

77- Other Trauma Topics

Triage and transfer of trauma patients

- Factors associated with transfer to Level 1 trauma center
 - ✧ African-American race
 - ✧ presence of medical comorbidity
 - ✧ medicaid insurance
 - ✧ male gender

