

Subtrochanteric Femoral Fractures

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Objectives

- **Anatomy**
 - Define unique anatomical considerations of subtrochanteric femur fractures
- **Technique**
 - Describe the important considerations of positioning, starting point, and nail design when treating a subtrochanteric fracture with a medullary nail
- **Controversy**
 - Recognize which subtrochanteric fractures are not appropriately treated with a medullary nail, and describe alternative methods of treatment
- **Clinical application**
 - Identify the important characteristics of an atypical subtrochanteric fracture and their implications for management

Introduction

Subtrochanteric Femur Fractures

Bimodal Incidence and Mechanism

Young patients

- High energy
- Associated limb/life threatening injuries common

“Geriatric” patients

- Low energy – Fall from standing
- Beware of the Atypical subtrochanteric femur fracture

Bimodal Incidence and Mechanism

- Young – High energy
 - Think about...
 - ATLS protocols
 - Associated injuries
 - Temporary stabilization
 - Traction



Bimodal Incidence and Mechanism

- Older - Low energy
 - Think about...
 - Prodromal pain?
 - History of other fragility fractures
 - Medications?
 - Contralateral stress fracture?
 - Endocrine evaluation at follow up



Anatomy

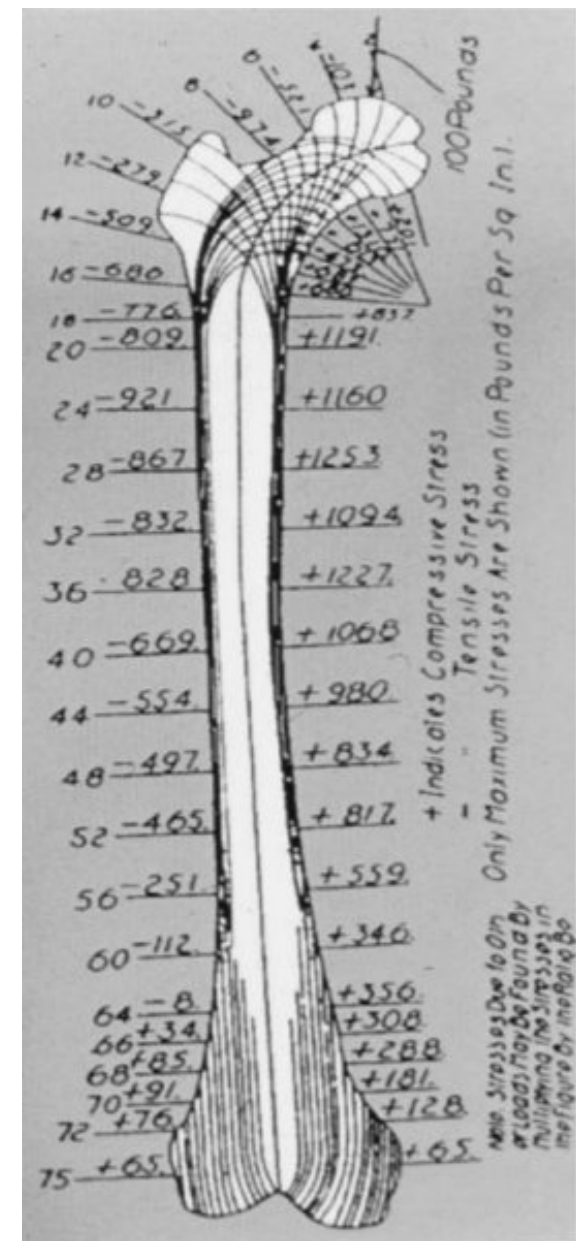
Subtrochanteric Femur Fractures

Anatomy – Proximal femur

- Must understand bony and soft tissue anatomy
 - Critical implications for surgical treatment

Bony Anatomy – Proximal femur

- Region of maximal compressive forces (medially) and tensile forces (laterally)
 - Largest asymmetric difference in load in single long bone in the body



Bony Anatomy – Proximal femur

- Region of maximal compressive forces (medially) and tensile forces (laterally)
 - Largest asymmetric difference in load in single long bone in the body
- Clinical application →
 - Bone heals under compression but lateral cortex is always under tension!
 - Reduction → no lateral cortical gapping (no varus)
 - Fixation → must allow for compression of lateral cortex

Bony Anatomy – Proximal femur

- Fracture isolates short proximal fragment



Bony Anatomy – Proximal femur

- Fracture isolates short proximal fragment



- Clinical application →
 - Presents similar challenges to proximal tibia, proximal humerus fractures
 - Segment is short and thus room for error becomes very small

Soft Tissue Anatomy – Proximal femur

- Multiple large muscles act on proximal segment
 - External rotation
 - Iliopsoas and short external rotators

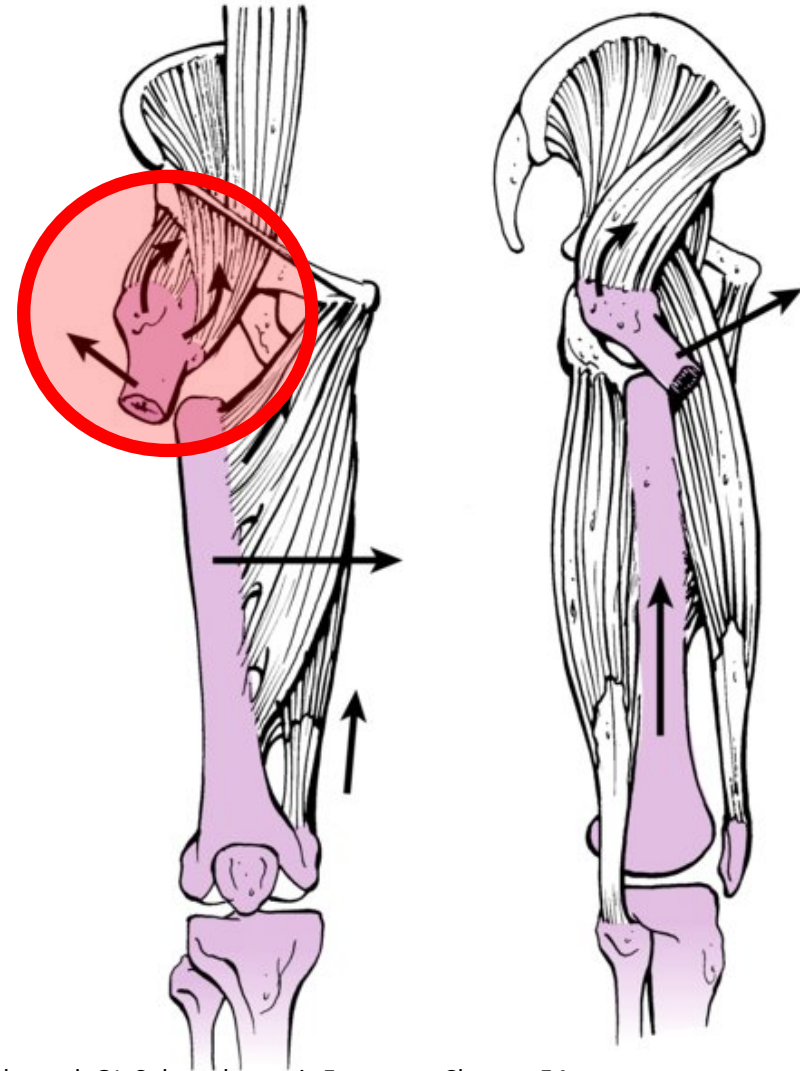


Image: Yoon RS and Haidukewych GJ, Subtrochanteric Fractures, Chapter 54, Figure 54-4. Rockwood and Green's Fractures in Adults, editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019

Soft Tissue Anatomy – Proximal femur

- Multiple large muscles act on proximal segment
 - Flexion
 - Iliopsoas and abductors

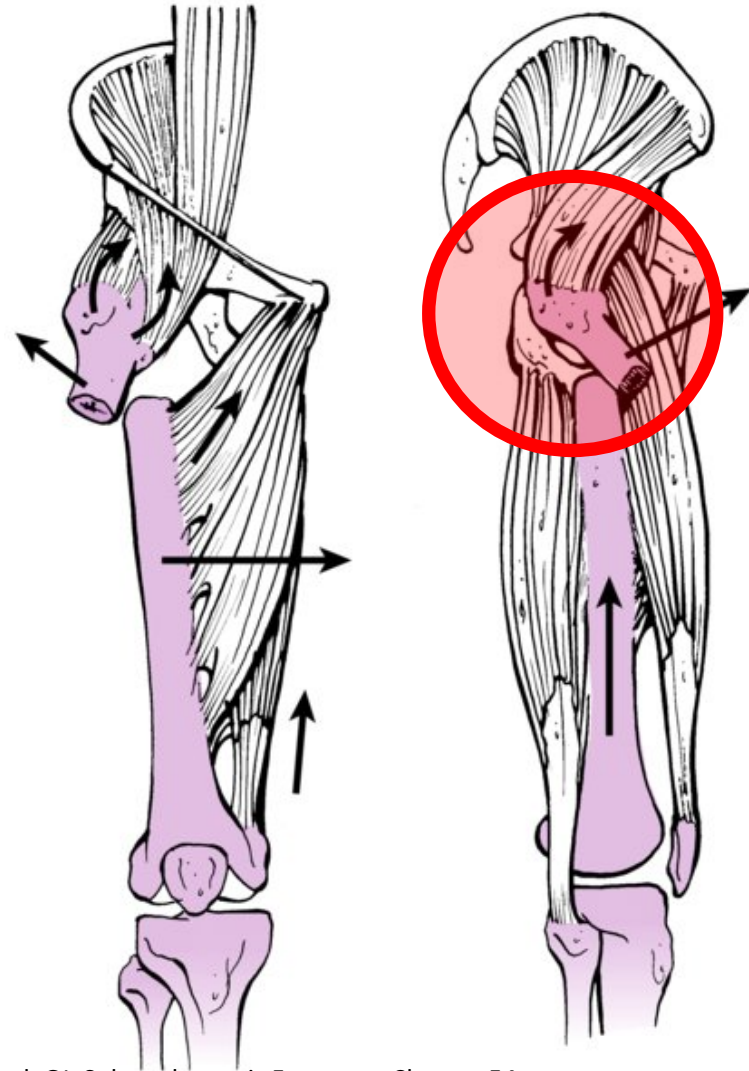


Image: Yoon RS and Haidukewych GJ, Subtrochanteric Fractures, Chapter 54, Figure 54-4. Rockwood and Green's Fractures in Adults, editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019

Soft Tissue Anatomy – Proximal femur

- Multiple large muscles act on proximal segment
 - Abduction (or varus)
 - Abductors

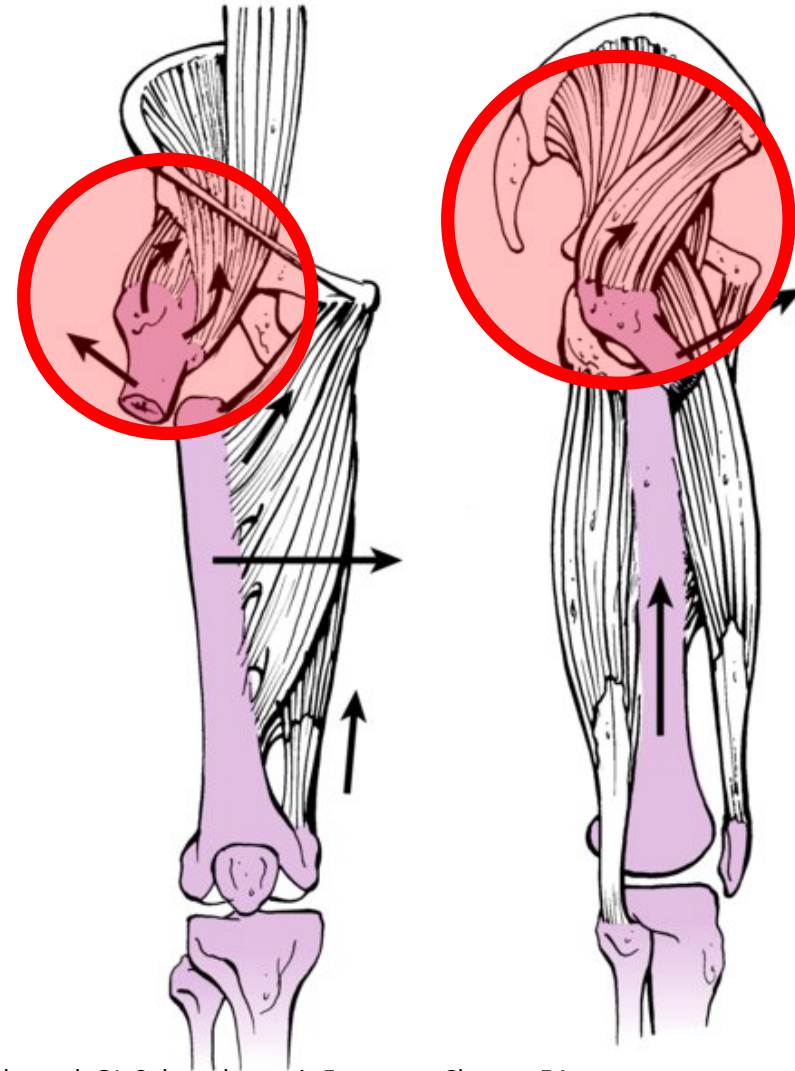


Image: Yoon RS and Haidukewych GJ, Subtrochanteric Fractures, Chapter 54, Figure 54-4. Rockwood and Green's Fractures in Adults, editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019

Soft Tissue Anatomy – Proximal femur

- And distal segment!
 - Adductors → Shortening and medial translation

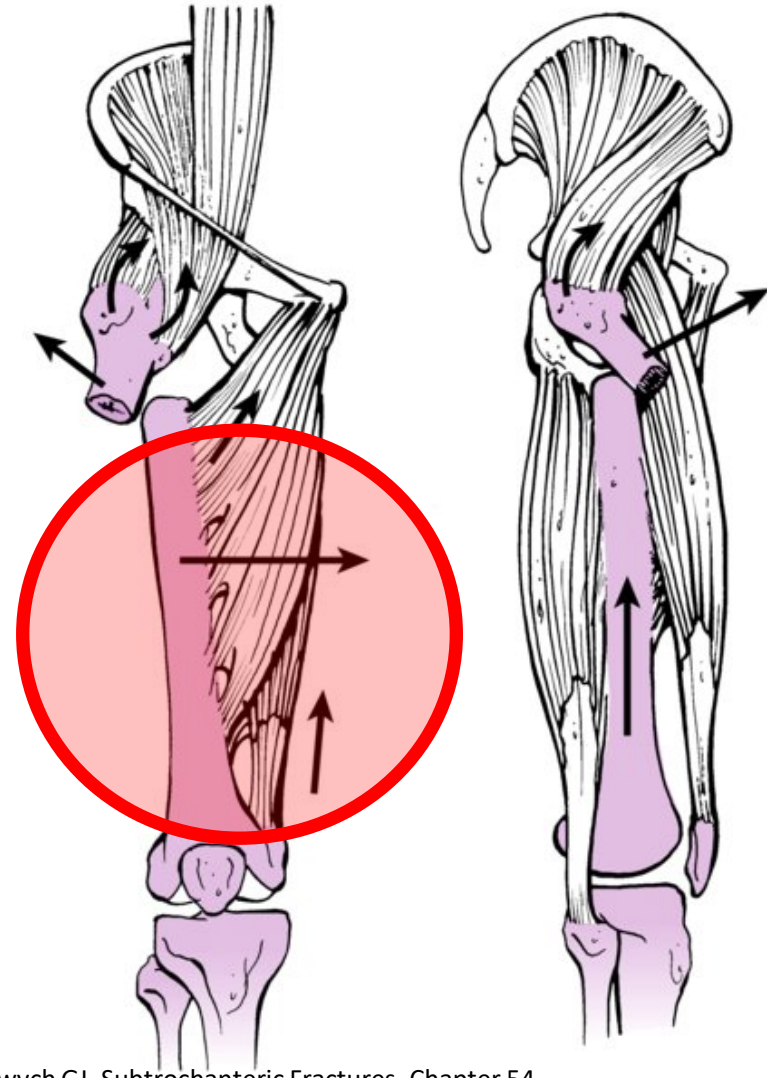


Image: Yoon RS and Haidukewych GJ, Subtrochanteric Fractures, Chapter 54, Figure 54-4. Rockwood and Green's Fractures in Adults, editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019

Soft Tissue Anatomy – Proximal femur

- Multiple large muscles act on proximal (and distal) segment
- Clinical application →
 - Must overcome all forces to obtain reduction

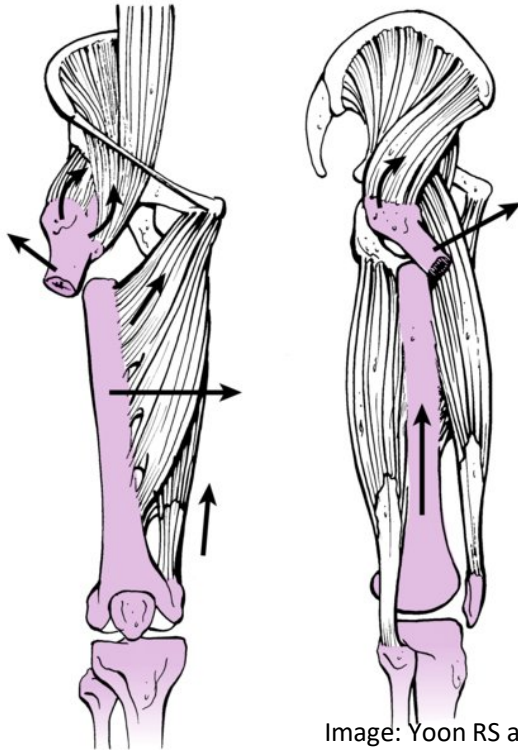
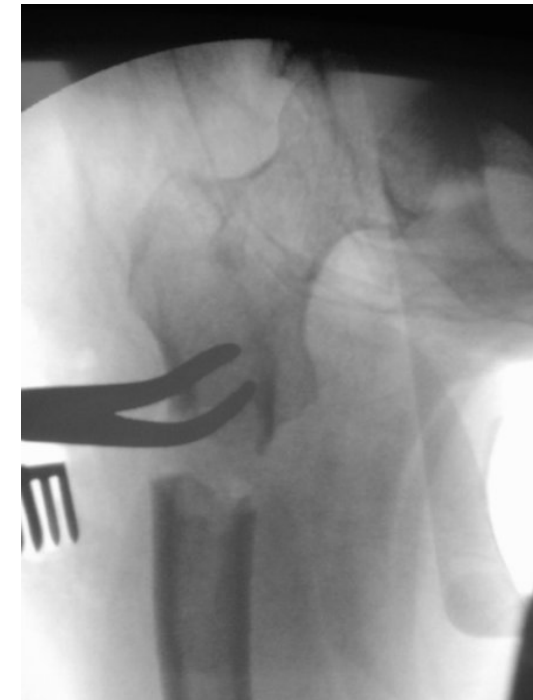


Image: Yoon RS and Haidukewych GJ, Subtrochanteric Fractures, Chapter 54, Figure 54-4 and 54-9. Rockwood and Green's Fractures in Adults, editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019



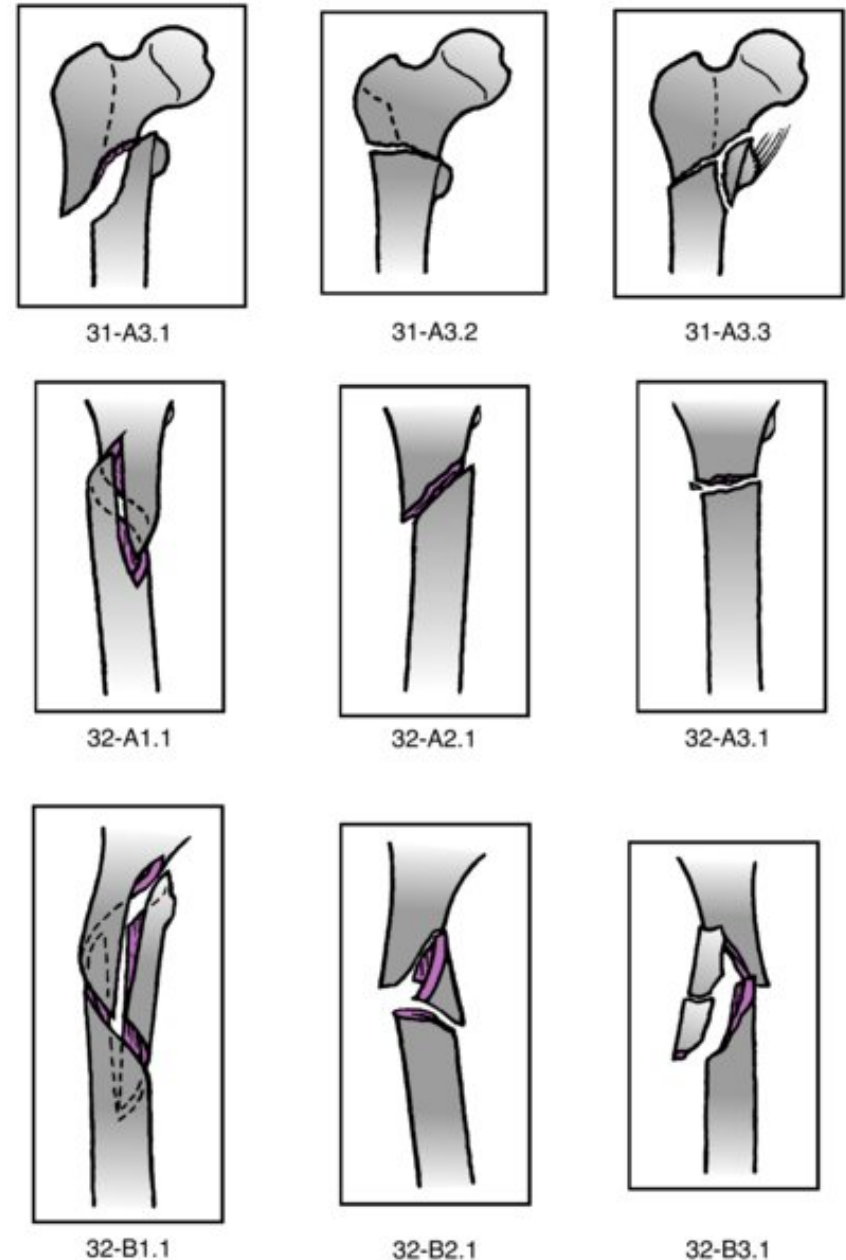
Classification

- Fractures within 5 cm of the lower extent of the lesser trochanter



Classification

- Fractures within 5 cm of the lower extent of the lesser trochanter
- OTA classification
 - Both "31" and "32" sections

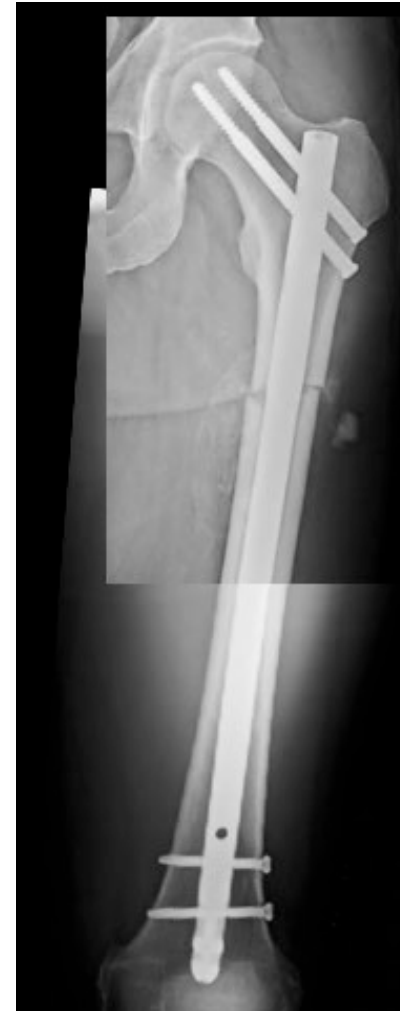


Technique

Surgical fixation of Subtrochanteric Femur Fractures

Technique – Antegrade intramedullary nail

- Majority of cases → Antegrade, locked intramedullary nail
 - Exceptions covered in “Controversy” segment



Technique – Antegrade intramedullary nail

- Majority of cases → Antegrade, locked intramedullary nail
- Biomechanical and clinical data – Nail vs plates:
 - Nails:
 - Greater load to failure
 - Greater number of cycles to failure
 - Higher force at failure



Positioning

- Supine – Free leg
 - Skeletal traction over end of bed
 - Advantages
 - Free control and access to limb by surgeon
 - Ability to maximally adduct limb for access to starting point
 - Supine positioning for polytrauma patient
 - Disadvantages
 - Potential need for additional scrubbed assistant
 - More challenging access for open reduction

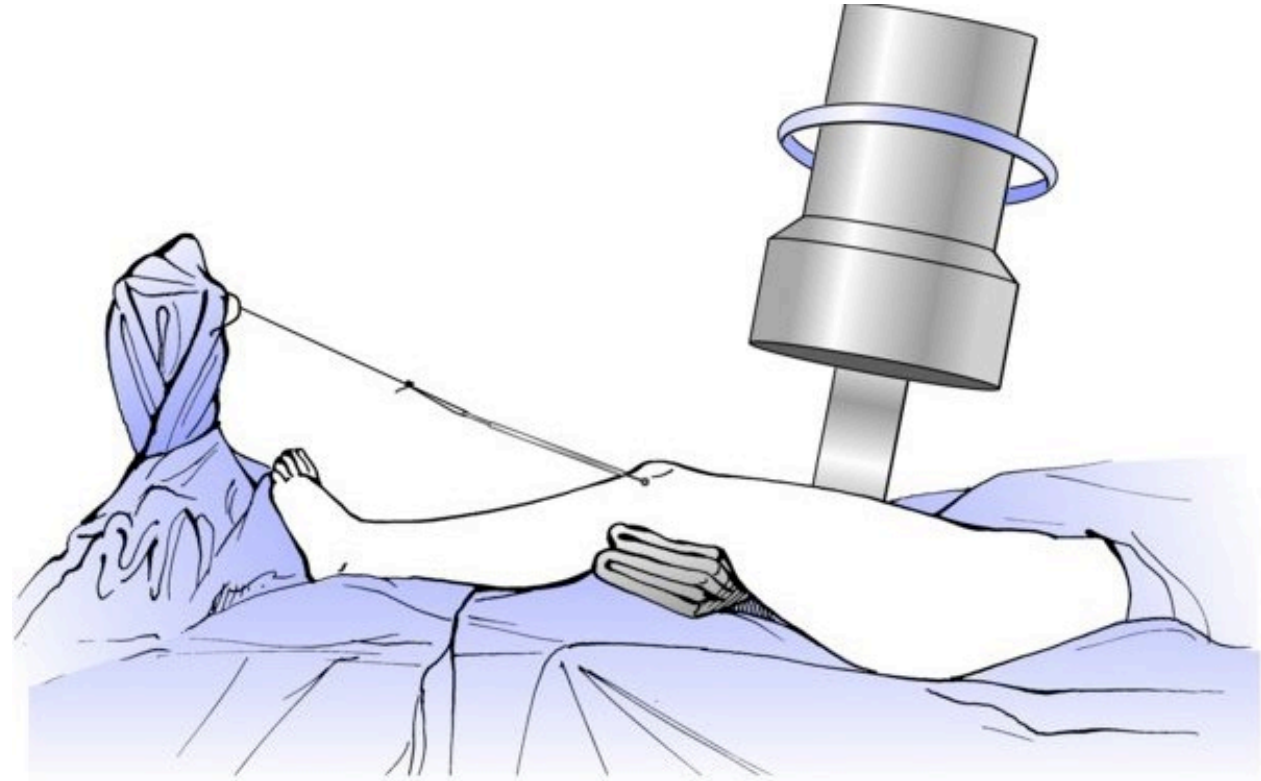
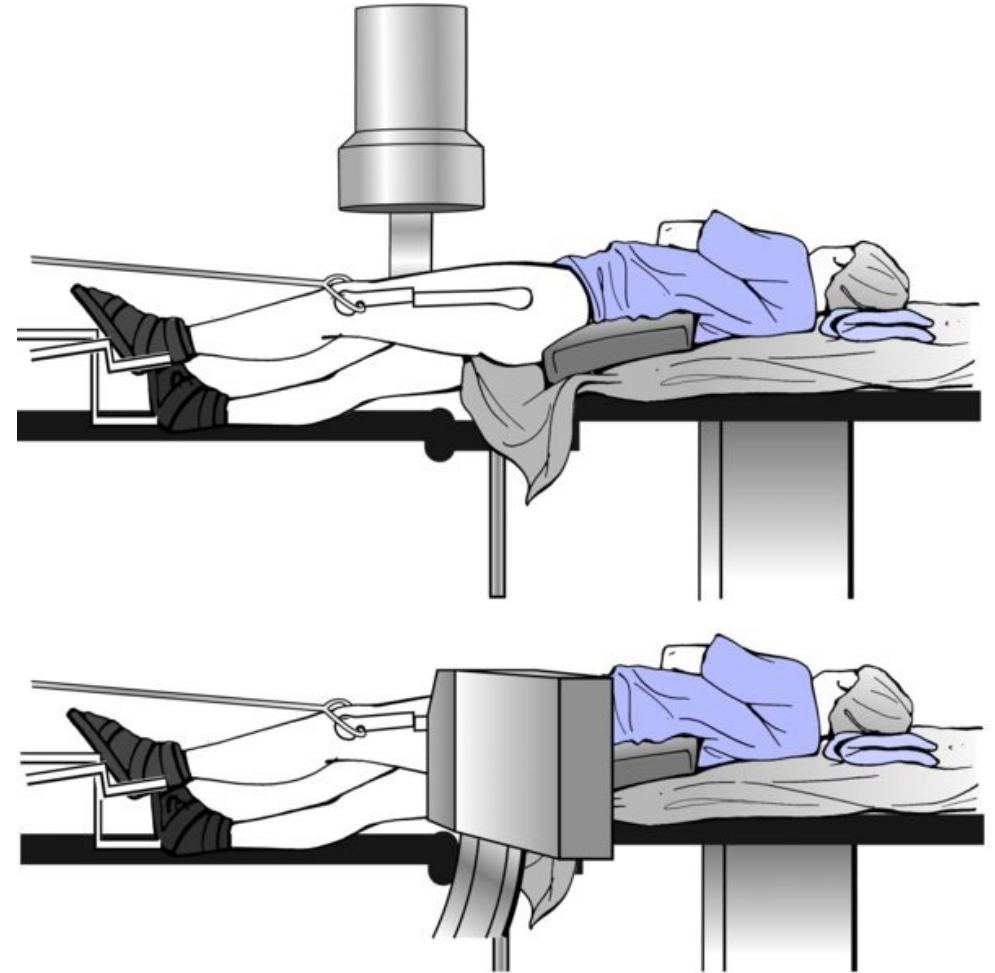


Image: Adams JD and Jeray KJ, Femoral Shaft Fractures, Chapter 56, Figure 56-13. *Rockwood and Green's Fractures in Adults, 9th edition.* Editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019

Positioning

- Supine – Traction table
 - Advantages
 - Ability to hold reduction/traction without need for assistant
 - Supine positioning for polytrauma patient
 - Disadvantages
 - Traction table complications – nerve palsy, skin injury
 - More challenging access for open reduction
 - Sustained traction can accentuate proximal fragment deformity



- OTA Video Link:
 - [Intramedullary Nailing in the Lateral Position without a Traction Table for an Atypical Subtrochanteric Femoral Fracture](#)

Positioning

- Lateral – Free leg
 - Advantages
 - Overcomes abduction of proximal fragment
 - Ability to move distal segment in sagittal plane to match flexion of proximal fragment
 - Improved access for open reduction and to starting point in obese patients
 - Disadvantages
 - Obtaining imaging of proximal femur can be unfamiliar or difficult
 - Contralateral leg less accessible for rotational comparison



Image: OTA PowerPoint, Femoral shaft fracture, revision 11/2009. Slide 41

Reduction

- Medullary nail technique is optimally paired with closed, functional reduction to maximally preserve fracture biology



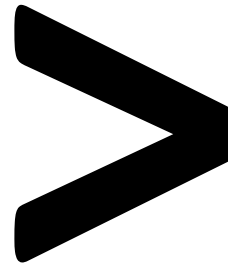
Reduction

- Medullary nail technique is optimally paired with closed, functional reduction to maximally preserve fracture biology
- But...
 - Subtrochanteric femur is not tolerant to malreduction, particularly varus and flexion!
- Thus have a low threshold to perform open reduction to ensure:
 - No Varus
 - Acceptable sagittal plane and rotational reduction



Reduction

Well-aligned fracture via open reduction is always preferable to...



The percutaneous malreduction

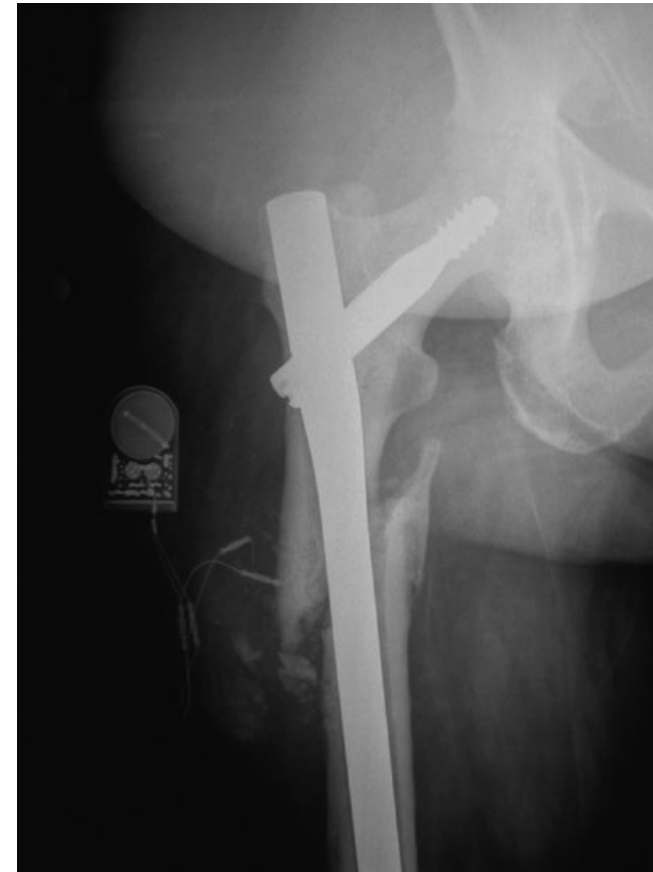


Image: Yoon RS and Haidukewych GJ, Subtrochanteric Fractures, Chapter 54, Figure 54-19. Rockwood and Green's Fractures in Adults, 9th edition. Editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019

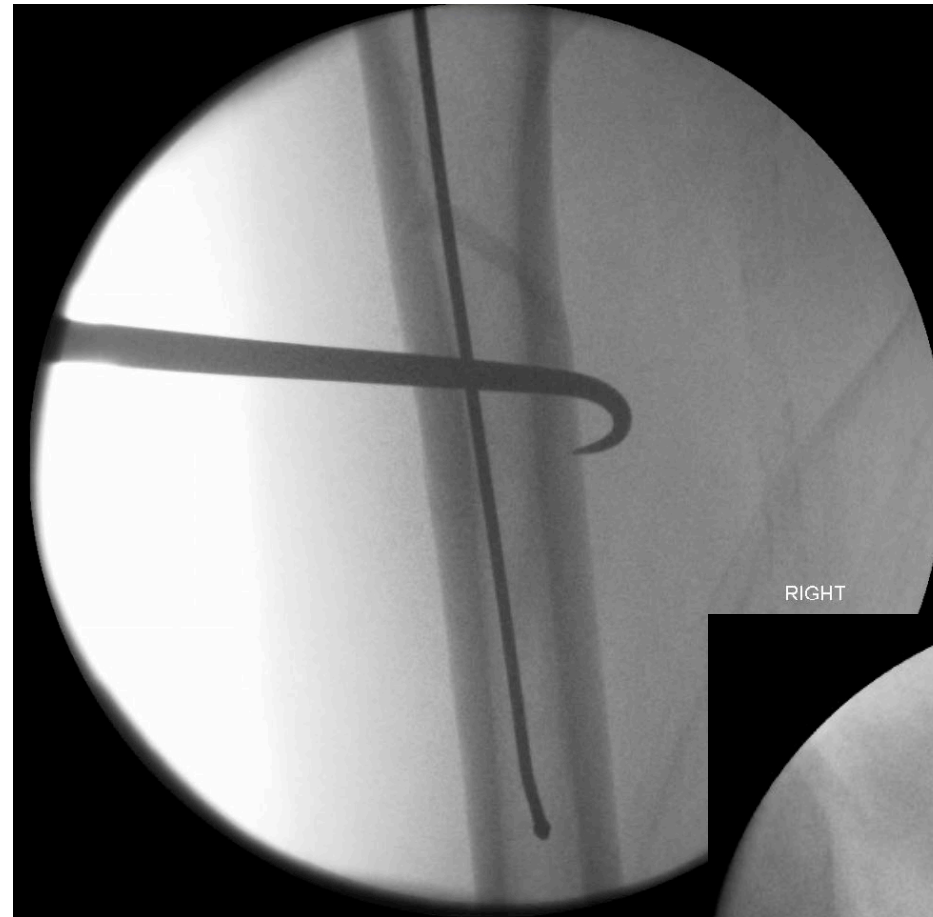
Reduction

- Closed reduction
 - Traction
 - F-tool
 - Intramedullary reduction aid



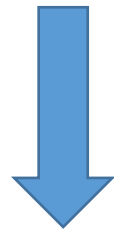
Reduction

- Open reduction
 - Picador/cobb elevator/bone hook/Shanz pins



Reduction

- Open reduction
 - Picador/cobb elevator/Shanz pins

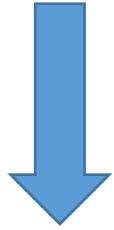


- Reduction clamp/colinear clamp



Reduction

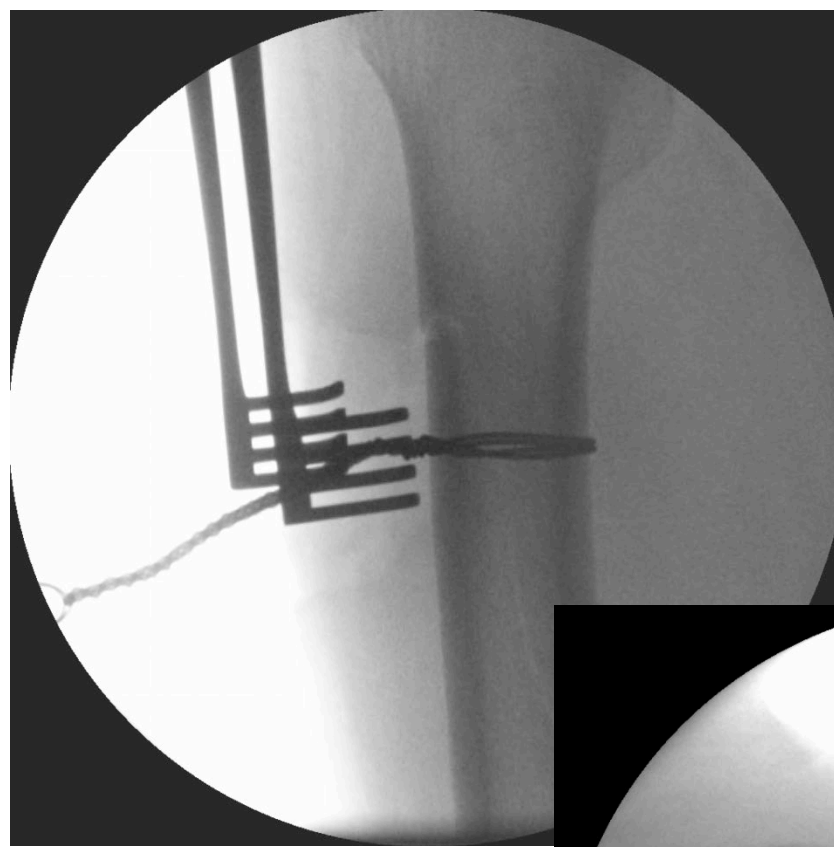
- Open reduction
 - Picador/cobb elevator/Shanz pins



- Clamp/bone hook/colinear clamp



- Cerclage cable/plate assisted reduction



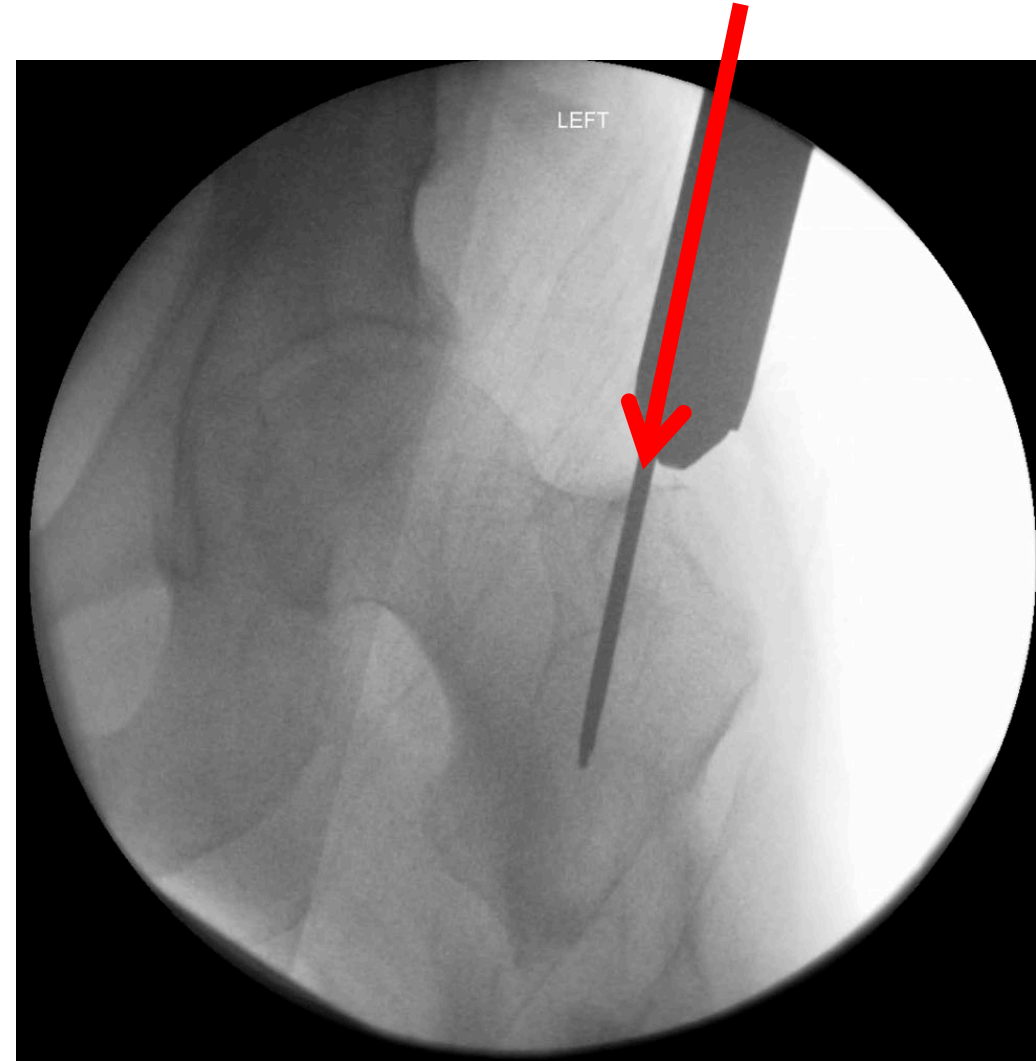
Intramedullary nailing

- Several critical technical points
 - Starting point
 - Nail design
 - Proximal locking



Intramedullary nailing – Starting point

- Error:
 - Too anterior and too lateral
- If using trochanteric start nail:
 - Start medial to the tip of the greater trochanter
 - Will encourage valgus



Intramedullary nailing – Starting point

- Error:
 - Too anterior and too lateral
- If using trochanteric start nail:
 - Start central or even posterior on the greater trochanter
 - Will fight against flexion of proximal fragment



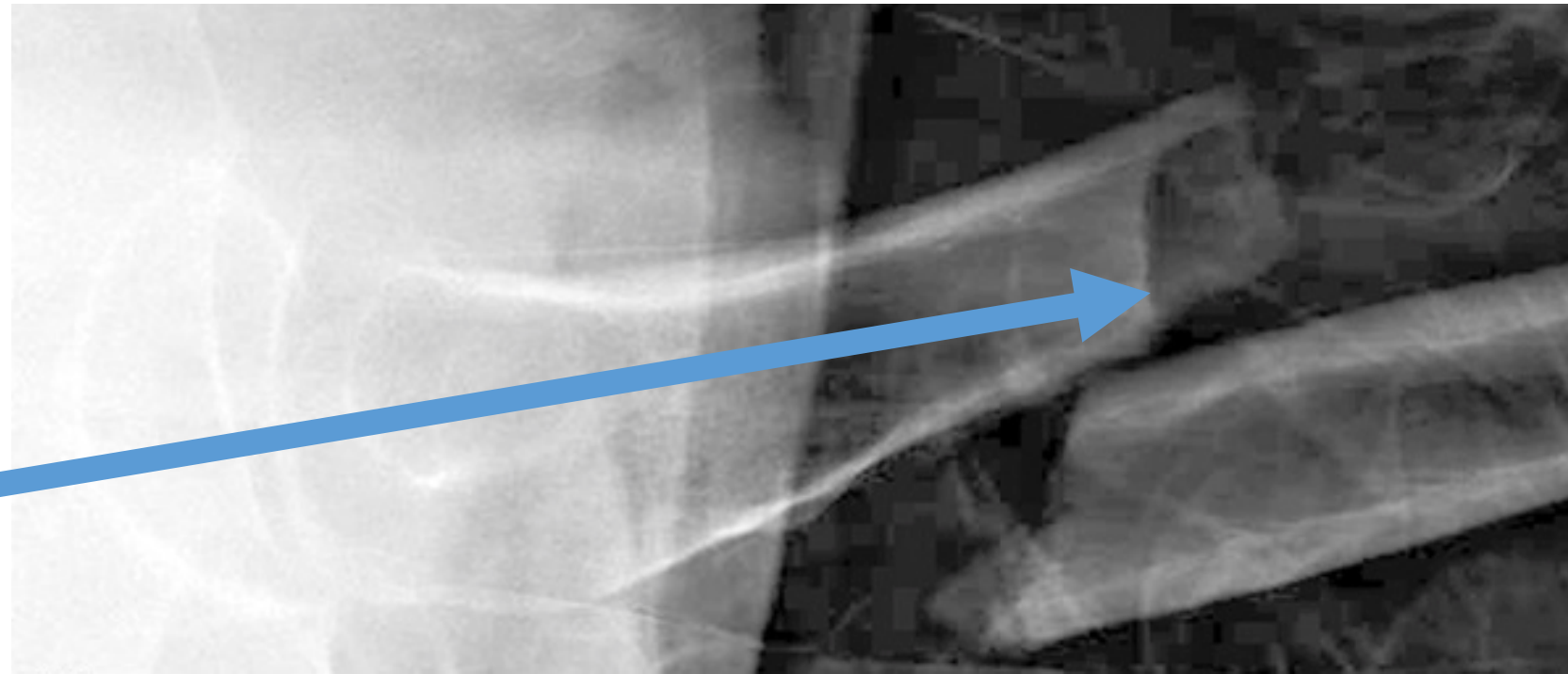
Intramedullary nailing – Starting point

- This relatively anterior starting point...



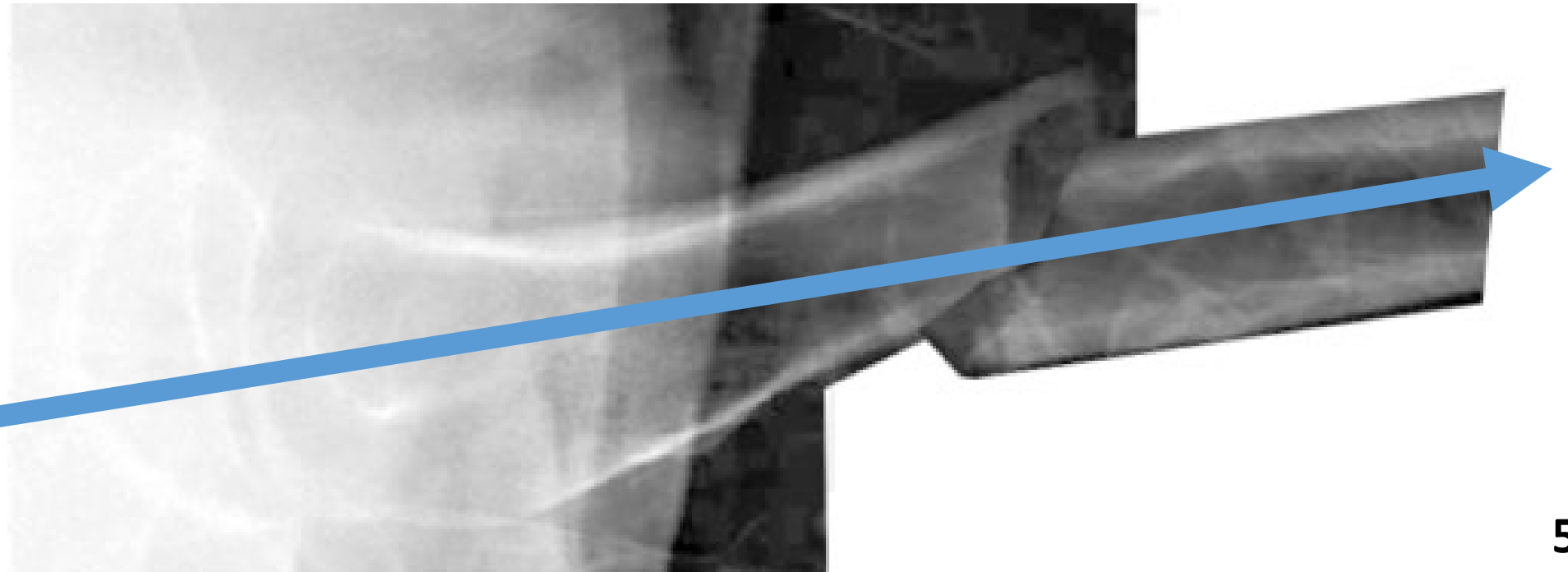
Intramedullary nailing – Starting point

- This relatively anterior starting point...
- Will lead to this entry reamer path...



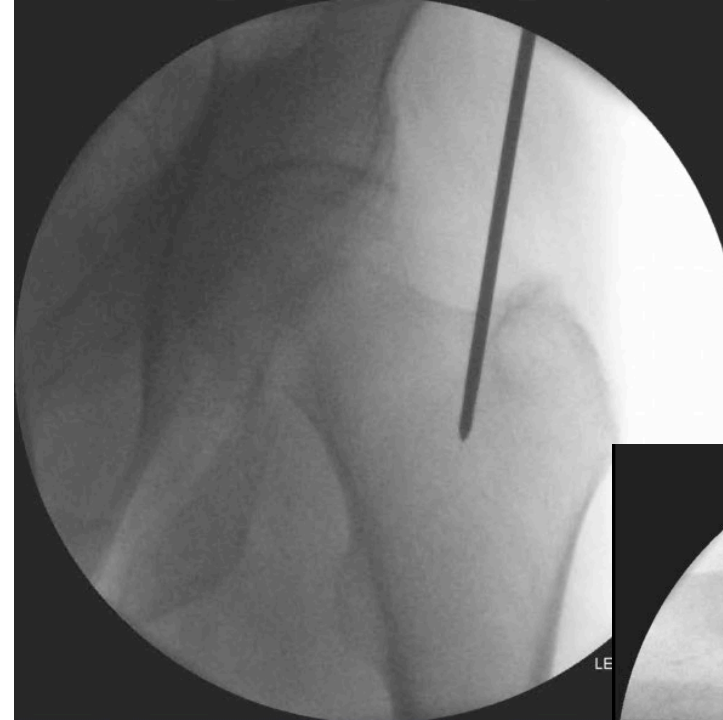
Intramedullary nailing – Starting point

- This relatively anterior starting point...
- Will lead to this entry reamer path...
- And this final reduction in flexion!



Intramedullary nailing – Starting point

- Error:
 - Too anterior and too lateral
- Use piriformis nail
 - Starting point in line with intramedullary pathway in distal segment
 - Starting point is already medial and posterior



Intramedullary nailing – Starting point

Piriformis starting point

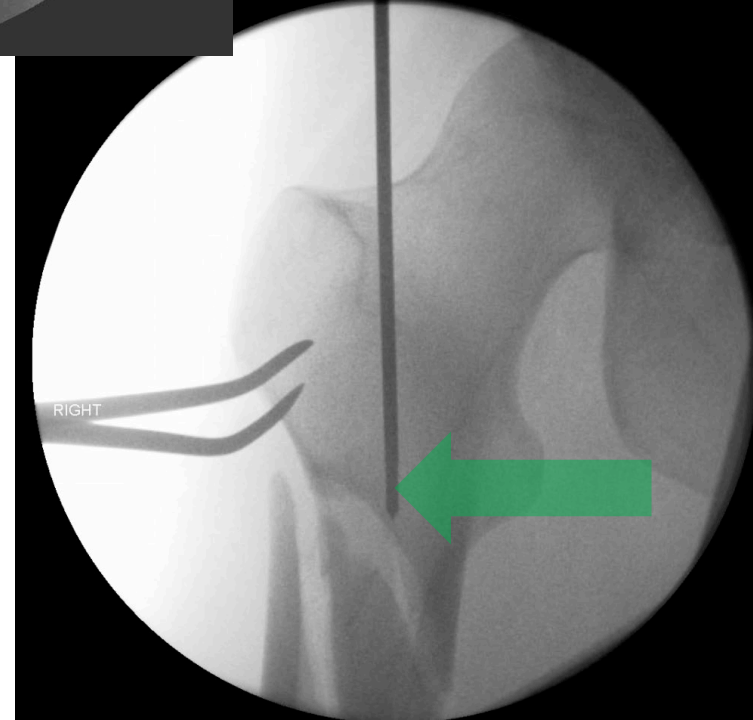
- Advantages
 - In line with anatomic location of femoral shaft
 - Starting point is medial and posterior
- Disadvantages
 - Higher risk of malrotation
 - Piriformis comminution prevents optimal proximal fragment stability

Trochanteric starting point

- Advantages
 - Easier access in larger patients
 - Less risk of malrotation
 - Avoid piriformis fossa if fracture extends there
- Disadvantages
 - Watch out for too anterior starting point → mal-reduction in flexion

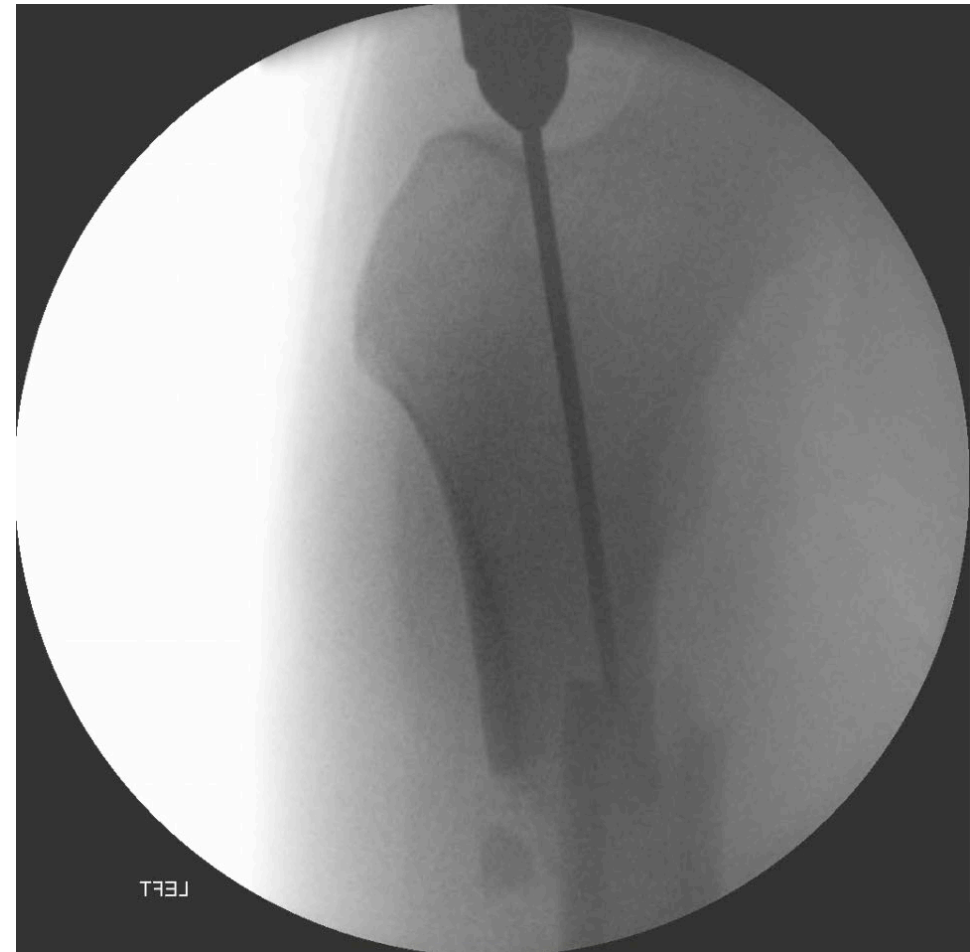
Intramedullary nailing

- Error:
 - Proximal reaming directed too medially distally → will lead to varus



Intramedullary nailing – Reaming

- Error:
 - Proximal reaming directed too medially distally
 - Natural tendency of starting pin to go from lateral proximal to distal medial due to body habitus of patient
 - Often accentuated by medial comminution



Intramedullary nailing – Reaming

- Error:
 - Proximal reaming directed too medially distally
- Fix
 - Ensure proper path of starting guidewire on both views
 - Don't ream the proximal fragment while flexed and abducted
 - Use Cobb/clamp/Shanz pin to reduce deformity prior to reaming



Image: Yoon RS and Haidukewych GJ, Subtrochanteric Fractures, Chapter 54, Figure 54-13. Rockwood and Green's Fractures in Adults, 9th edition. Editors Tornetta, Paul; Ricci, William. Wolters Kluwer, 2019

Intramedullary nailing – Proximal locking

- Potential error:
 - Failure to lock into the femoral head in geriatric patients
- Fix:
 - Consider nail with option to lock into the femoral head in geriatric patients with low energy patterns

Intramedullary nailing – Nail Design



“Reconstruction” style nail

- Smaller proximal body
- Different proximal locking options
 - Two interlocking screws into head
 - Antegrade interlocking bolts
 - Transverse interlocking bolts

Intramedullary nailing – Nail Design

“Hip Fracture” style nail

- AKA “cephalomedullary nail”
- Large proximal body
- Typically one large lag screw/blade → Femoral head
 - Variations with smaller secondary screw



Intramedullary nailing – Nail Design

- No data showing superiority of one type of nail over the other for subtrochanteric fractures of the femur
- However...A reconstruction style nail will remove less overall bone from the proximal femur, which may be beneficial in the young patient, particularly if nail removal is later performed

Controversy

When a nail might not work

- Comminution of the nail starting point
 - Tip of greater trochanter or piriformis fossa



Berkes MB et al., *Ninety-Five Degree Angled Blade Plate Fixation of High-Energy Unstable Proximal Femur Fractures Results in High Rates of Union and Minimal Complications*. J Orthop Trauma, 2019;33(7),335-340. Figure 1

When a nail might not work

- Solution:
 - A plate is still a viable option
 - 95 degree blade plate
- OTA Video link:
 - [Use of the 95 Degree Angled Blade Plate to Treat a High Energy Proximal Femur Fracture](#)



Berkes MB et al., *Ninety-Five Degree Angled Blade Plate Fixation of High-Energy Unstable Proximal Femur Fractures Results in High Rates of Union and Minimal Complications*. J Orthop Trauma, 2019;33(7),335-340. Figure 4

When a nail might not work

- Solution:
 - A plate is still a viable option
 - Proximal femoral locking plate



Medda S et al., *Treatment of Peritrochanteric Femur Fractures With Proximal Femur Locked Plating*. J Orthop Trauma, 2019;33(7),341-345. Figure 3

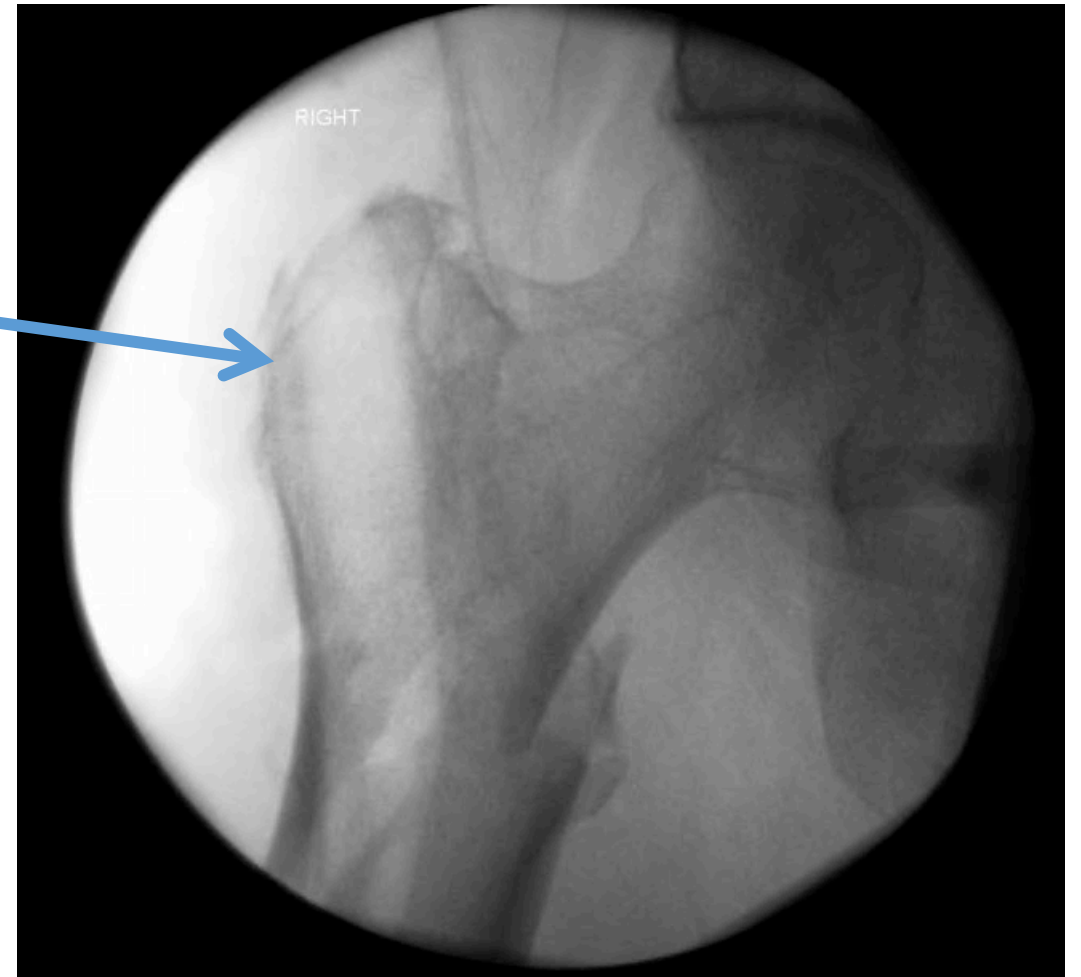
When a nail might not work

- Revision fixation with poor starting point
 - Mal-reduction in varus/flexion with poor starting point and prior nail in place can be next to impossible to correct with nail alone



When a nail might not work

- Revision fixation with poor starting point
 - Note very lateral starting point/nail path
 - Correcting varus with another nail in the short proximal segment is very difficult



When a nail might not work

- Revision fixation with poor starting point
 - Bone grafting old start point/lag screw path
 - Blade plate → correction of varus



Clinical Application

Atypical Femoral fractures

- Atraumatic/low-energy femoral fractures of the subtrochanteric region or femoral shaft
- Atypical Femur fracture = AFF



Image: Bogdan Y, Atypical Femur Fractures, Chapter 55, Figure 55-1.
Rockwood and Green's Fractures in Adults, editors Tornetta, Paul;
Ricci, William. Wolters Kluwer, 2019

Atypical Femur Fractures

- Pathogenesis
 - Likely stress fracture occurring in abnormal underlying bone
 - Remodeling suppression – Occurs with use of bisphosphonates
 - Puts femur at risk for decreased healing of small stress fractures → larger stress reactions → Clinically relevant AFF



Atypical Subtrochanteric and Diaphyseal Femoral Fractures: Second Report of a Task Force of the American Society for Bone and Mineral Research

- Outlined Case definition for AFFs – Revised in 2013
- “Fracture must be located along the femoral diaphysis from just distal to the lesser trochanter to just proximal to the supracondylar flare”
- “In addition, at least four of five Major Features must be present.”
- “None of the Minor Features is required but have sometimes been associated with these fractures.”



Atypical Subtrochanteric and Diaphyseal Femoral Fractures: Second Report of a Task Force of the American Society for Bone and Mineral Research

- Major features (need 4 or 5)
 1. The fracture is associated with minimal or no trauma
 2. The fracture line originates at the lateral cortex and is transverse



Atypical Subtrochanteric and Diaphyseal Femoral Fractures: Second Report of a Task Force of the American Society for Bone and Mineral Research

- Major features (need 4 or 5)
 3. Medial spike
 4. No or minimal comminution
 5. Localized periosteal or endosteal thickening of the lateral cortex is present at the fracture site (“beaking” or “flaring”)



Atypical Subtrochanteric and Diaphyseal Femoral Fractures: Second Report of a Task Force of the American Society for Bone and Mineral Research

- Minor features
 - Increased cortical thickness of diaphysis
 - Prodromal symptoms such as dull or aching pain in the groin or thigh
 - Bilateral incomplete or complete femoral diaphysis fractures
 - Delayed fracture healing



Atypical Femoral fractures – BEWARE!

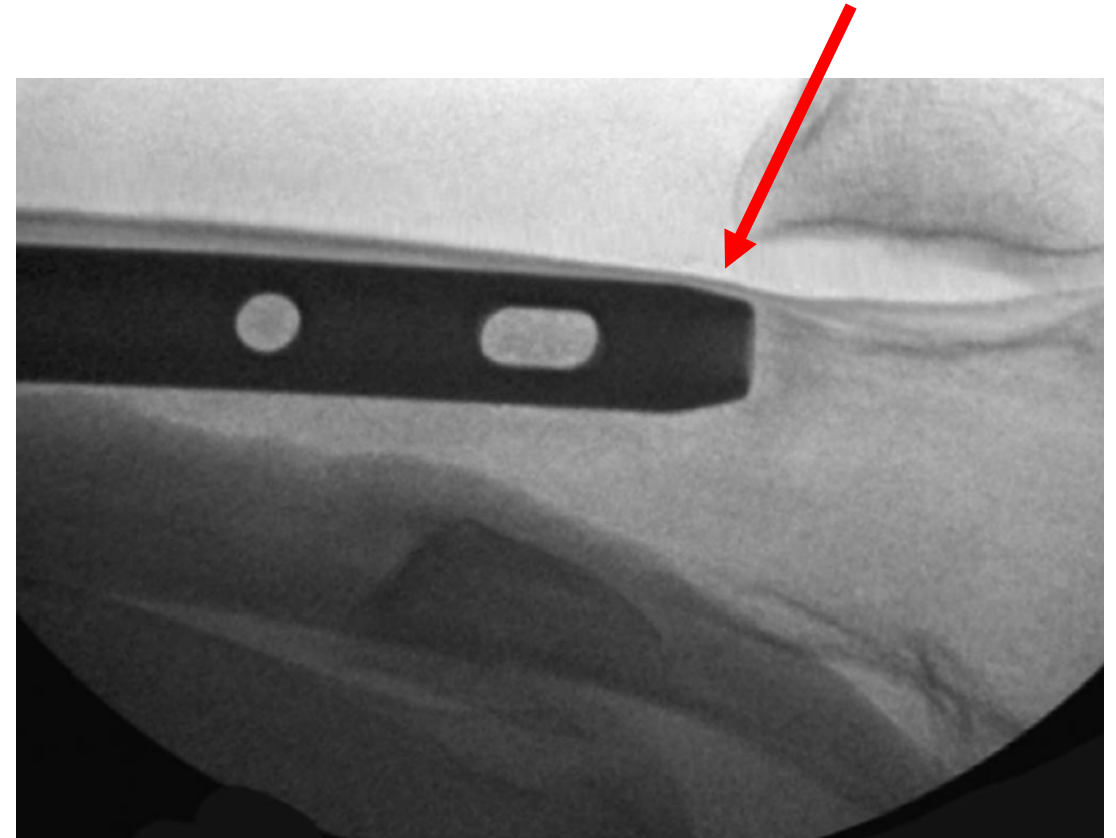
- Nature of the AFF leads to lower healing rates, and abnormal lateral cortex.
- AFF are intolerant to varus!
 - As little as 5 degrees → Failure!
 - Cho et al, JOT 2017



Image: Rollick N et al. *Orthogonal Plating With a 95-Degree Blade Plate for Salvage of Unsuccessful Cephalomedullary Nailing of Atypical Femur Fractures: A Technical Trick.* J Orthop Trauma. 2019;33(6):e246-e250. Figure 1

Atypical Femoral fractures – BEWARE!

- AFF are associated with abnormal femoral geometry
 - Varus and anterior bowing
 - Beware of anterior nail perforation distal!



Atypical Femoral fractures – BEWARE!

- Look for contralateral fractures
 - 28-53% of cases



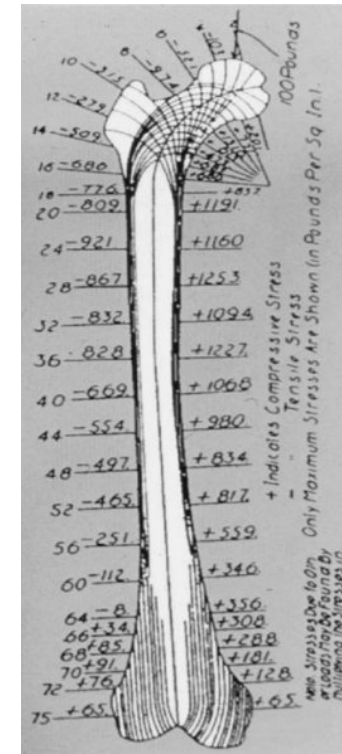
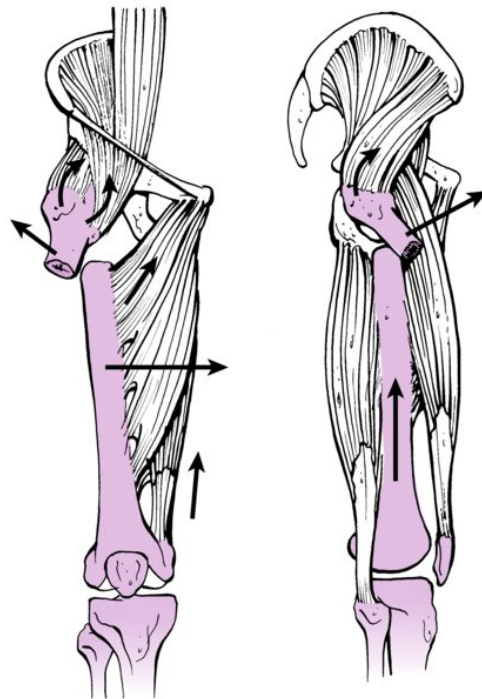
Atypical Femoral fractures – BEWARE!

- Anticipate prolonged healing time
 - 5- 10 months!
 - Bogdan Y. et al., JOT 2016; 30:177-181
- Medical treatment
 - Stop bisphosphonates
 - Ca and Vit D supplementation
 - Consider anabolic agents (ex: teraperatide, etc)



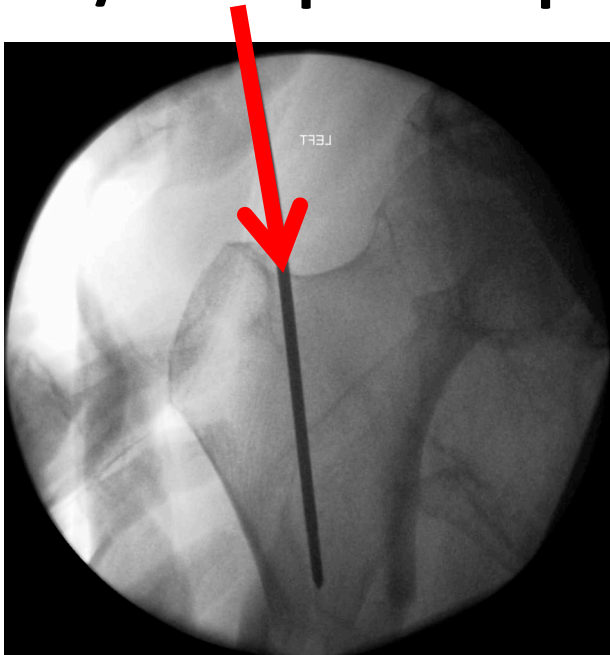
Summary

- **Anatomy**
 - The unique muscular and mechanical forces through the subtrochanteric region have significant implications for fracture reduction and fixation



Summary

- **Technique**
 - **Positioning lateral or supine**
 - **Starting point medial to tip of greater trochanter or piriformis fossa**
 - **Consider options to lock across the femoral neck in geriatric/osteoporotic patients**



Summary

- **Controversy**
 - **Comminution of the starting point of the nail (greater trochanter or piriformis fossa) is a relative indication for use of a plate**
 - **Very lateralized or anterior starting points can be difficult to correct at the time of revision surgery, and may require revision to a plate**



Berkes MB et al., *Ninety-Five Degree Angled Blade Plate Fixation of High-Energy Unstable Proximal Femur Fractures Results in High Rates of Union and Minimal Complications.* J Orthop Trauma, 2019;33(7),335-340.
Figure 1



Figure belongs to Brandon Yuan, MD

Summary

- **Clinical application**
 - **AFF have specific defining characteristics**
 - **Lateral beaking**
 - **Transverse/minimally comminuted fracture line**
 - **Medial beaking**
 - **Low energy/no trauma**



Image: Cho JW et al. Healing of Atypical Subtrochanteric Femur Fractures After Cephalomedullary Nailing: Which Factors Predict Union?. J Orthop Trauma. 2017;31(3):138-145. Figure 1

Summary

- **AFF**
 - **Beware!**
 - **Intolerant to malreduction**
 - **Abnormal femoral geometry**
 - **Contralateral fractures common**
 - **Prolonged healing time**



Image: Cho JW et al. Healing of Atypical Subtrochanteric Femur Fractures After Cephalomedullary Nailing: Which Factors Predict Union?. J Orthop Trauma. 2017;31(3):138-145. Figure 1