

Femoral Shaft Fractures

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Disclosure

All figures belong to Andrew Chen, MD unless otherwise indicated

Objectives

- Review initial management of femoral shaft fractures and possible concomitant injuries
- Discuss multiple options with intramedullary nailing
 - Antegrade/retrograde
 - Starting point
 - Reaming
 - Patient positioning
- Understand commonly associated complications

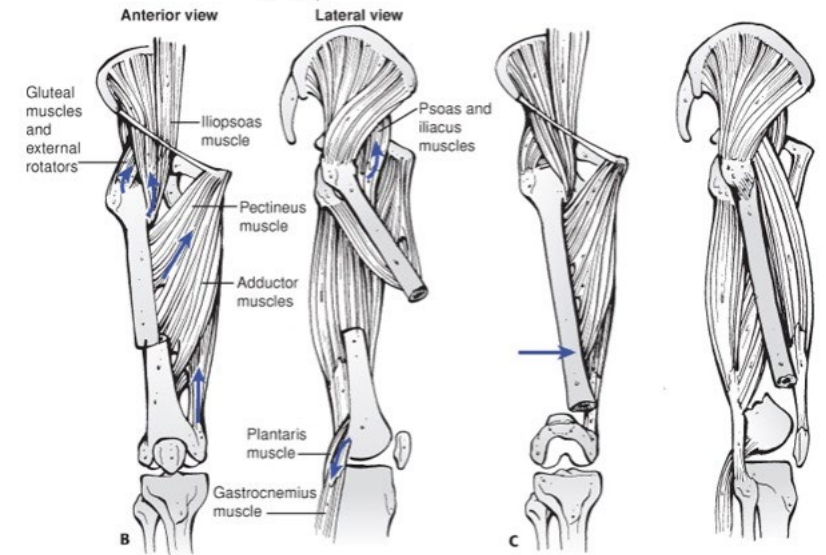
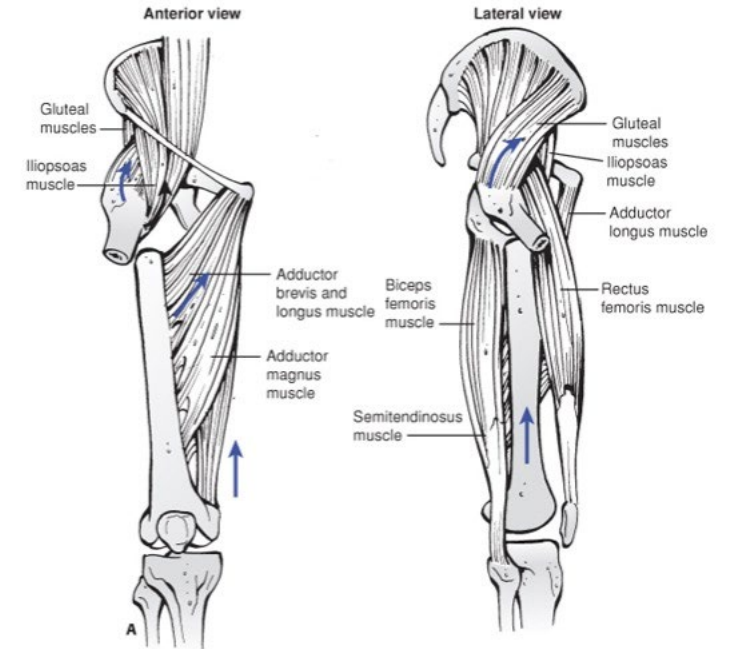
Femoral Shaft Fractures

- Bimodal distribution
 - Young patients after high-energy trauma
 - Elderly patients after falls from standing secondary to osteopenia/osteoporosis
- MVC, MCC, pedestrian struck, fall from height, and gunshot wounds most common mechanisms
- Intramedullary nail as “gold standard” treatment, which has continued to evolve since introduction by Gerhard Küntscher around World War II



Anatomy

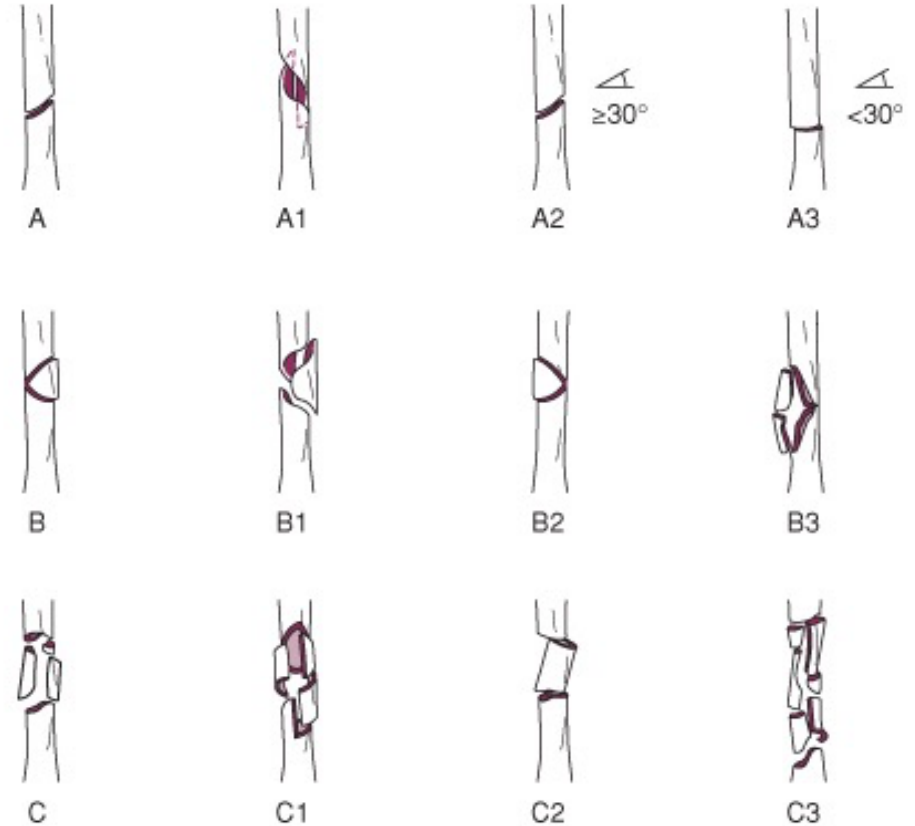
- Largest and strongest bone in body
- Anterior bow with radius of curvature $\sim 120 \text{ cm}^1$
- Blood supply from primary nutrient vessel through linea aspera and small periosteal vessels
- Deformity pattern dependent on attached musculature
 - Proximal fragment
 - Flexed (gluteus medius/minimus on greater trochanter)
 - Abducted (iliopsoas on lesser trochanter)
 - Distal fragment
 - Varus (adductors inserting on medial aspect distal femur)
 - Extension (gastrocnemius attaching on distal aspect of posterior femur)



Courtesy of Rockwood and Green's Fracture in Adults²

Femur Fracture Classification: AO/OTA

- Bone Segment 32
- Type A
 - Simple
- Type B
 - Wedge
- Type C
 - Complex pattern

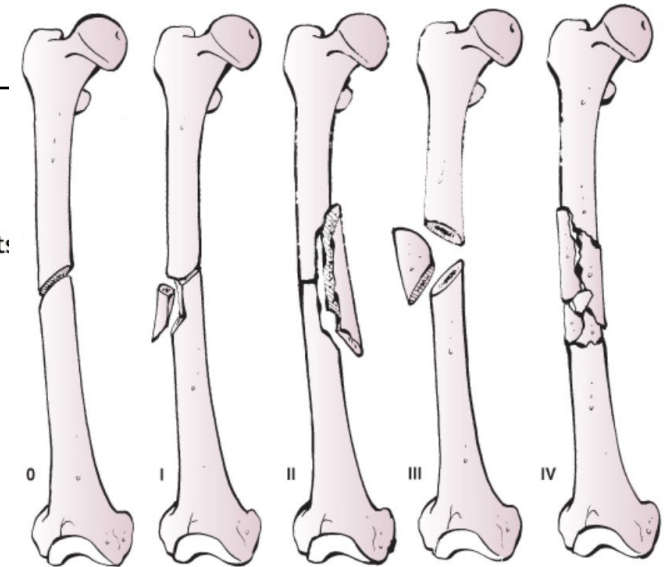


Courtesy of Rockwood and Green's Fracture in Adults²

Femur Fracture Classification: Winquist³

Table 52-1 Winquist and Hansen Classification of Fracture Comminution^{33,34}

Grade	Degree of Comminution
0	No comminution
I	Small butterfly fragment (<25%) or minimally comminuted segment with at least 75% cortical contact remaining between the diaphyseal segment:
II	Butterfly fragment or comminuted segment with (approximately 25-50%) with at least 50% cortical contact between the diaphyseal segments
III	Large butterfly fragment or comminuted segment (approximately 50-75%) with minimal cortical contact between the diaphyseal segments
IV	Complete cortical comminution such that there is no predicted cortical contact between the diaphyseal segments. Segmentally comminuted



Courtesy of Rockwood and Green's Fracture in Adults²

Evaluation and Management

- Circumferential evaluation of thigh for open wounds
- Full length AP/lateral films of femur
- Dedicated hip and knee films
- Average blood loss can be 1250 mL
- Vascular injury as high as 1.6%⁴
- Primary nerve injuries rare
- Open fracture does not preclude compartment syndrome



Associated Injuries

- Do not only focus on obvious shaft fracture
- Concomitant knee injury⁵
 - Easier to diagnose in OR following fixation of femur
 - Ligamentous laxity-49%
 - Medial/Lateral meniscus injury-26%/28%
- Femoral neck/shaft fractures (3-10%)
 - Discussed later in “special situations”

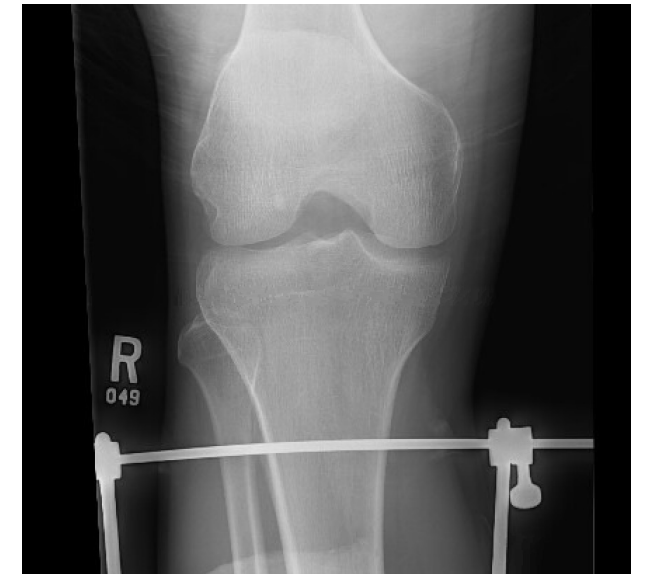
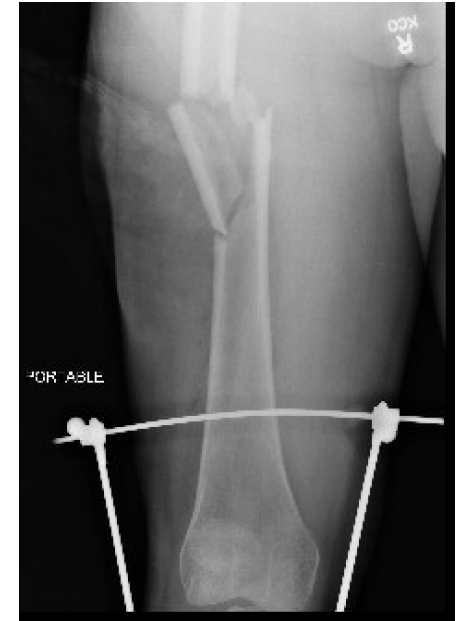


Nonoperative Management

- Historically, traction used with months of bed rest
 - High risk of pressure sores, pin infection, malunion, knee stiffness, muscle wasting, and blood clot
- Now, traction typically used only as temporary measure for pain relief and limit blood loss prior to surgical stabilization

Temporary Traction

- Skin (Buck's traction)
 - Can be utilized with ease and minimal complications if fracture can be stabilized in timely fashion (<24 hours)⁶
- Skeletal
 - Placed at distal femur or proximal tibia with balanced suspension
 - Medial to lateral at distal femur
 - Stay extra-articular
 - Lateral to medial at proximal tibia
 - Bicortical at level of tibial tubercle



Damage Control Orthopaedics

- Select group of patients who are critically ill and not hemodynamically stable for a long procedure
- Rapid temporary skeletal stabilization

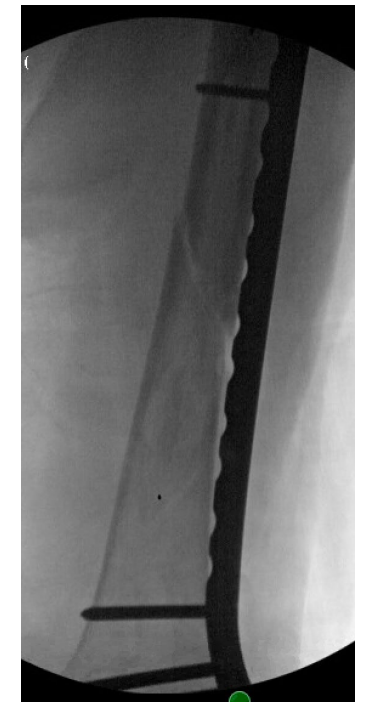
External Fixation

- Quick temporary stabilization as bridge to intramedullary nailing
 - Damage control orthopaedics
 - Severe soft tissue contamination
 - Ipsilateral arterial injury requiring repair
- Typically unilateral frame
- Pins placed anterior, anterolateral, or lateral
- At least 5 mm in size
- Can safely be converted to IMN within 2 weeks without increased risk of deep infection⁷



Plating

- More limited role given predictable results of intramedullary nails
- Load bearing implant
- Considerations
 - If extremely narrow or no canal making IMN difficult or not possible
 - Fracture adjacent to or through previous malunion
 - Fracture adjacent to total arthroplasty stem
 - Fracture extension into pertrochanteric or metaphyseal region
- Fracture pattern can dictate fixation strategy
 - Simple pattern with direct reduction and stable fixation
 - Comminuted pattern with bridge plating using minimally invasive plate osteosynthesis (MIPO)



Intramedullary Nailing

- “Gold standard”
- Minimal disruption to biology of fracture
- Usually achievable with closed reduction
- Multiple options
 - Reamed vs unreamed
 - Antegrade vs retrograde
 - Piriformis vs trochanteric entry point
 - Supine vs lateral position



Reaming

- Potential advantages of reaming
 - Larger implant and more durable construct
 - Increased union
 - Decrease chance of nail getting incarcerated
- Potential disadvantages of reaming
 - Does reaming increase fatty emboli to lungs and increase pulmonary complications?

Reaming

- Reaming increases growth factors that can contribute to healing
- Can cause endosteal thermal damage and disrupt endosteal cortical blood flow
 - Reversed by 12 weeks with reamed nailing and 6 weeks with unreamed nailing based on animal studies⁸
 - However, increased surrounding muscle perfusion and periosteal blood flow allows for healing^{9,10}

Reaming

- Canadian Orthopaedic Trauma Society¹¹
 - Multicenter prospective RCT
 - 224 patients
 - Risk nonunion 4.5 times greater with unreamed femoral nailing
- Bhandari et al¹²
 - Systematic review and meta-analysis
 - Reamed nailing significantly reduces rates of nonunion and implant failure compared to unreamed nailing

Multiply Injured Patients

- Early studies showed benefit of immediate stabilization of long bone fractures in patients with multiple injuries
- Johnson et al¹³
 - 132 patients with ISS of 18 or higher
 - Early operative stabilization of fractures associated with decrease in ARDS
- Bone et al¹⁴
 - Prospective randomized study of 178 patients
 - Early (<24 hours) or delayed stabilization of long bone fractures
 - Incidence of ARDS, fat embolism, and pneumonia were less in patients with immediate femoral stabilization

Chest Injury and Femoral Shaft Fracture

- Early stabilization important, but impact of reaming with chest injury?
- Animal models with mixed results
 - Kropfl et al¹⁵ and Pape et al¹⁶
 - Reaming shown to increase IM pressures and pulmonary artery pressures
 - Reaming associated with fat embolization
 - Wolinsky et al¹⁷ and Duhelius et al¹⁸
 - No adverse affect of reaming
- Clinical studies
 - Pape et al¹⁹
 - Only clinical study to have shown detrimental effects to immediate reamed nailing in patients with pulmonary trauma
 - Retrospective review 106 multiply injured patients
 - Increased incidence of ARDS and and mortality
 - Charash et al²⁰
 - Retrospective study of 138 patients with blunt thoracic trauma and femoral shaft fracture
 - Delayed surgical fixation (≥ 24 hours) associated with higher pulmonary complication rate



Chest Injury and Femoral Shaft Fracture

- Clinical Studies

- Bosse et al²¹

- Center 1: reamed intramedullary nailing (95%)
 - Center 2: plating (92%)
 - Allowed for comparison of effects of reamed nailing
 - ARDS, pneumonia, PE, multiple organ system failure, and death similar regardless of type of treatment
 - Thoracic injury is major determinant of morbidity and mortality, not IMN

- Canadian Orthopaedic Trauma Society²²

- Prospective randomized multicenter study
 - No difference between incidence of ARDS with reamed and unreamed nailing

Head Injury and Femoral Shaft Fracture

- Remains controversial
- Early operative stabilization to limit pulmonary complications, but head injured patients at risk for secondary brain injury
- Appears that early fixation itself does not lead to secondary brain injury, but can result from hypoxemia, hypotension, and decreased cerebral perfusion pressure
 - Starr et al²³
 - Delay did not predict CNS complications, but pulmonary complications 45 times more likely
 - McKee et al²⁴
 - No difference in early mortality, LOS, level neurologic disability, or cognitive testing
- Avoid intraoperative hypotension

Timing of Fracture Fixation

- Brundage et al²⁵
 - “Our data show that early femur fracture fixation (< 24 hours) is associated with an improved outcome, even in patients with coexistent head and/or chest trauma. Fixation of femur fractures at 2 to 5 days was associated with a significant increase in pulmonary complications, particularly with concomitant head or chest trauma, and length of stay. Chest and head trauma are not contraindications to early fixation with reamed intramedullary nailing.”

Delayed IMN and Mortality

- Morshed et al²⁶
 - 3069 patients with ISS \geq 15
 - Decreased mortality by 50% with delay >12 hours
 - Patients with serious abdominal trauma (AIS \geq 3) benefited most with more resuscitation
 - Allow for appropriate resuscitation!

Antegrade Nailing

- Can be used to treat majority of femoral shaft fractures
- Surgical options
 - Starting point
 - Piriformis vs trochanteric entry
 - Positioning
 - Supine or lateral
 - OR table
 - Fracture table or radiolucent flat top



Antegrade Nailing: Piriformis Entry Point

- Colinear trajectory with long axis of femoral shaft
- Reduces risk of iatrogenic fracture comminution and varus malalignment
- Anterior starting point can cause hoop stresses leading to iatrogenic bursting through proximal femur²⁷



Antegrade Nailing: Trochanteric Entry Point

- Potentially easier to identify starting point
- Tip not necessarily appropriate starting point
- Can vary based on patient anatomy, but typically slightly more medial entry point²⁸
- On lateral radiograph colinear with long axis of femur
- Avoid iatrogenic comminution
 - Entry of nail should be rotated 90 degrees with apex medial to help direct nail centrally
 - Then de-rotated gradually once past fracture



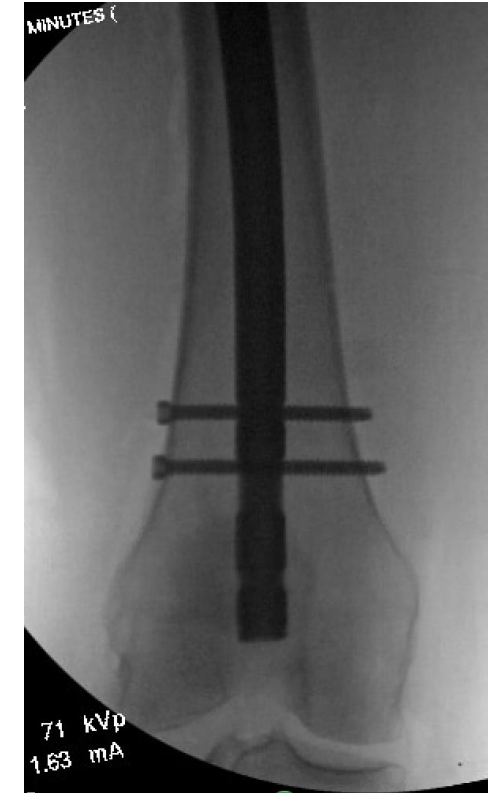
Patient Positioning

- Consider associated injuries such as spine or multiple extremity injuries that can undergo simultaneous surgery
- Supine on fracture table
 - More time consuming, but allows for consistent intraoperative traction
 - Contralateral leg should be monitored to avoid compartment syndrome
 - Potentially higher rate of malrotation
- Supine on radiolucent table
 - +/- skeletal traction with skeletal traction pin
 - Allows access to whole leg
 - Starting point may be slightly more difficult, but can adduct hip to improve access
- Lateral
 - Can improve access to piriformis fossa especially in obese patients
 - Longer setup time
 - Harder to judge rotation



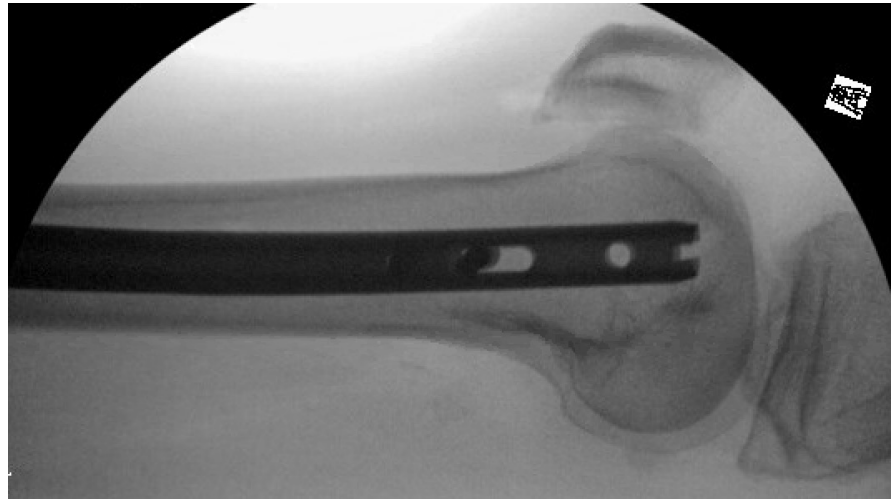
Retrograde Nailing

- Supine on radiolucent table
- Insertion in intercondylar notch at apex of Blumensaat line
 - 1 cm anterior to PCL origin
- Collinear to long axis of femur in both AP and lateral planes
- May be preferred for fractures close to distal metaphysis
- Advocated with “floating knee” with tibial shaft and femoral shaft fracture allowing for fixation for single percutaneous incision



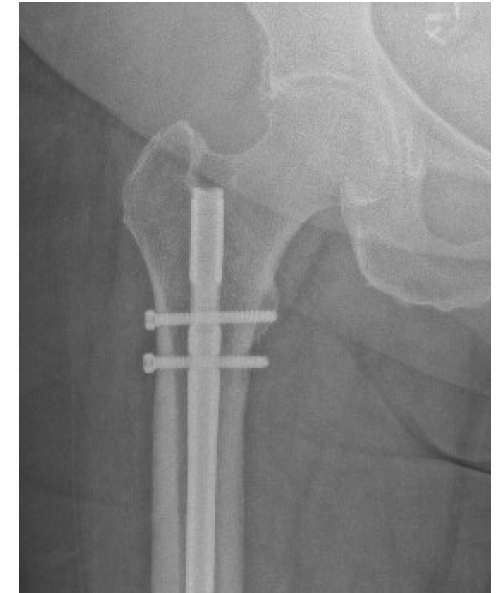
Retrograde Nailing

- Make sure distal end buried under subchondral bone to prevent injury to patella in knee flexion²⁹
 - Only when nail is 1 mm prominent is the patellofemoral pressures increased



Antegrade vs. Retrograde Nailing

- Ricci et al³⁰
 - Retrospective study
 - 134 patients (retrograde) vs 147 (antegrade)
 - Equal union rates: 88% (antegrade) and 89% (retrograde)
 - Antegrade with more hip pain and retrograde with more knee pain
- Ostrum et al³¹
 - Prospective randomized study
 - Higher time to union for retrograde nail group
 - Union rates similar
 - Knee motion similar
 - Increased symptomatic distal locking screws in retrograde group
- Tornetta et al³²
 - Prospective randomized study
 - No difference in OR time, blood loss, technical complications, or nail size
 - Time to union and rate of union same



Knee Function

- No difference between antegrade and retrograde³³
 - Knee ROM
 - Lysholm scores
 - Isokinetic knee eval
 - Secondary surgeries including hardware removal

Static Locking

- Brumback et al³⁴
 - 98% union with statically locked nail
 - Still allows for controlled motion at fracture site while maintaining length and rotation



Post-Operative Weight Bearing

- Guided by multiple factors including other injuries and location of fracture
- Brumback et al³⁵
 - Biomechanical and clinical results of simulated and actual early weight-bearing
 - Immediate weight bearing with segmentally comminuted mid-isthmal fractures with statically locked nail was safe



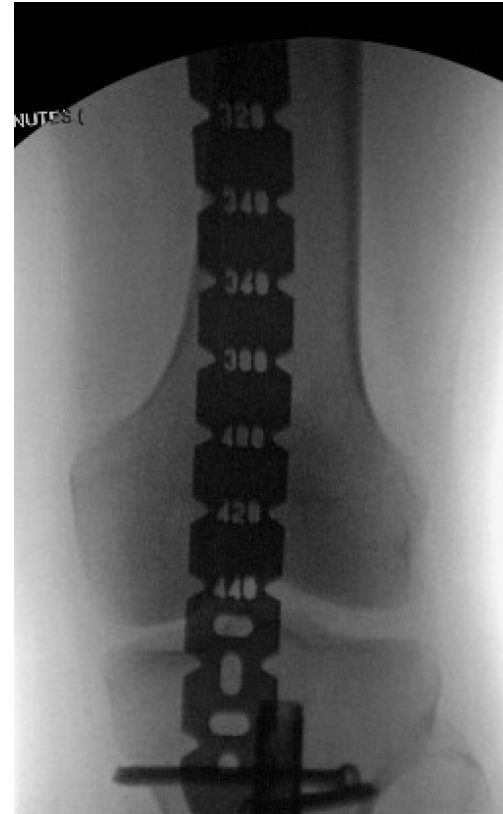
Complications

- Leg length discrepancy
- Nonunion
- Malunion
- Infection
- Heterotopic Ossification
 - At entry site with antegrade nailing
 - Clinically symptomatic 5-10%
- Neurologic injury
 - Usually secondary to patient positioning and intraoperative traction with perineal post (pudendal nerve)



Leg Length Discrepancy

- Can be challenging and discrepancy noted in up to 43% cases³⁶
- Radiographic ruler or bovie cord can be used intraoperatively to compare to uninjured limb
- Compare clinically immediately after nailing



Nonunion

- Largest series of reamed antegrade nailing with <2% nonunion³⁷
- Rule out deep infection
- Dynamization, exchange nailing, plate fixation³⁸, bone grafting, or combination
- Dynamization with limited success and significant shortening^{39,40}



Nonunion

- Exchange Nailing
 - Results vary from retrospective studies⁴¹
 - 54-92.3%
 - Likely better for mid-shaft isthmal region and hypertrophic nonunions that need more stability⁴²
- Plate fixation \pm bone grafting
 - Bellabarba et al⁴³
 - IMN removed, indirect reduction, and plating to correct deformity and compress nonunion site for 23 patients
 - Autologous bone grafting with all atrophic and 73% oligotrophic
 - 91% union rate after initial plating procedure
 - However, need protective weight bearing



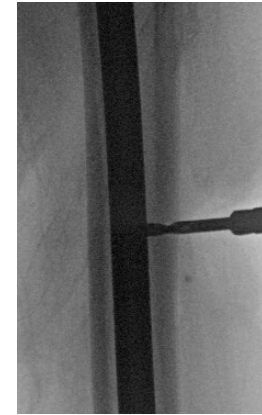
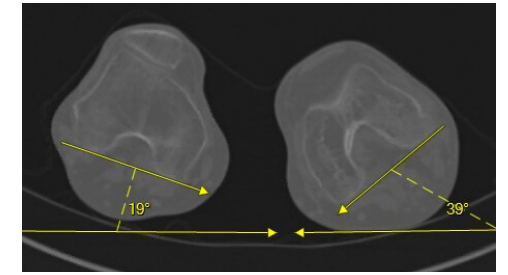
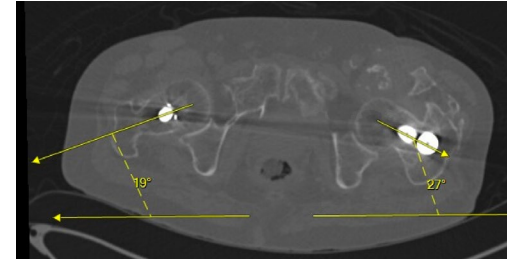
Nonunion

- Augmentation plating around IMN
 - Ueng et al⁴⁴
 - 100% union in 17 patients
 - Early weight bearing allowed
 - Bony union average 7 months
 - Hakeos et al⁴⁵
 - 100% union in 7 patients
 - All had autologous bone grafting
 - Consider in meta-diaphyseal region



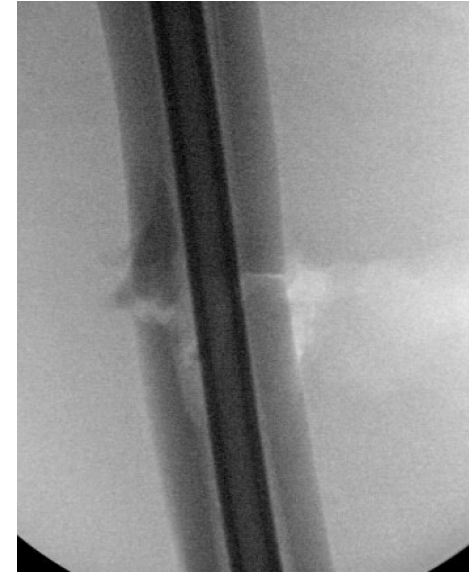
Malunion

- Angular deformity in coronal and sagittal plane more common in proximal (30%) or distal (10%) fractures
 - Nail fit in diaphysis usually helps prevent this in mid-shaft (2%)
- Rotational malalignment
 - Appears to be tolerated up to 15 degrees
 - External deformity more symptomatic
 - Braten et al⁴⁶
 - 110 femurs after IMN
 - 19% with 15 degree deformity or more
 - 38% symptomatic



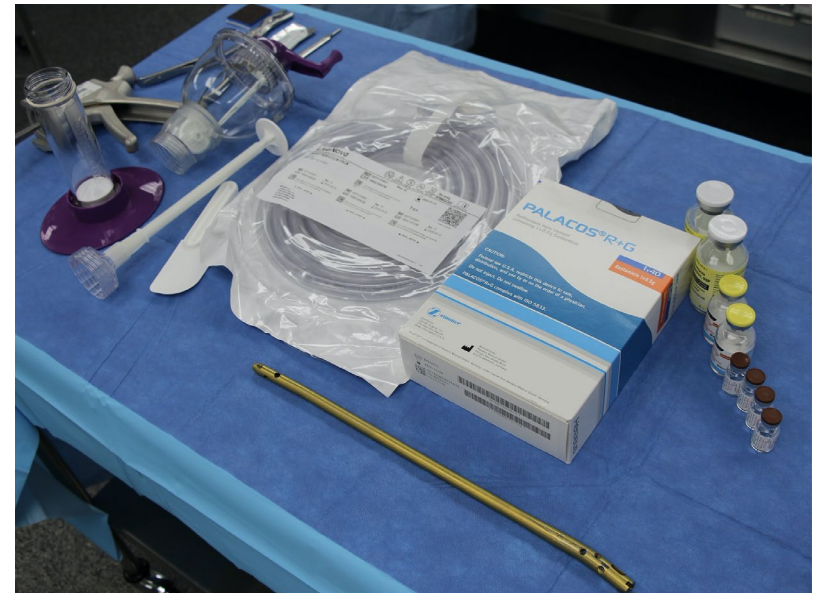
Femoral Rotation Assessment

- Clinical Exam
 - Flex both hips and knees 90 degrees and check IR/ER
 - Only useful after interlocks are placed
- Radiographic Exam
 - Cortical thickness AP/Lateral planes⁴⁷
 - Femoral anteversion compared to uninjured side⁴⁸
 - Lesser trochanter profile compared to uninjured side⁴⁹
 - Inherent nail anteversion⁵⁰
- Bilateral CT scan for accurate assessment post-op if concerned⁵¹
 - Axial cuts at femoral neck and distal femur
- However, must be cautious because of native individual bilateral differences
 - Mean difference in version of 164 uninjured patients was 5.4 degrees⁵²



Infection

- Low rate of infection with IMN (1-3.8%)
- Sinus tract with purulent drainage signifies deep infection
- Labs
 - ESR/CRP/WBC
- Radiographic findings for sequestrum
- Infected nonunion
 - Two stage
 - Debridement with hardware removal followed by temporary fixation with external fixator or antibiotic cement fabricated in chest tube⁵³
 - Return for definitive fixation once infection eradicated
 - Single stage
 - Debridement followed by placement of antibiotic coated interlocking nail⁵⁴



Special Situations

- Obesity
- Ipsilateral neck/shaft fractures
- Open fractures
- Vascular Injury
- Bilateral femur fractures

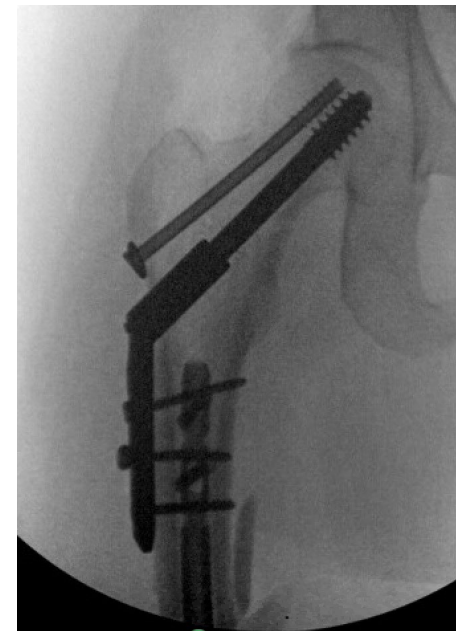
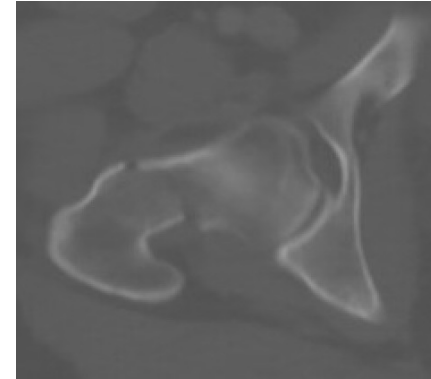
Obesity

- Antegrade nailing can be more difficult
 - Osseous landmarks hard to palpate
 - Femoral adduction limited
 - Better results with trochanteric entry point rather than piriformis entry⁵⁵
- Tucker et al⁵⁶
 - Retrograde nailing
 - Decreased surgical time and radiation exposure



Ipsilateral Femoral Neck and Shaft Fracture

- 3-10% of femoral shaft fractures⁵⁷
- Missed injuries 30-57% cases^{58,59}
- Best-practice protocol⁶⁰
 - Dedicated IR plain radiograph of hip
 - 2 mm fine cut CT scan through femoral neck
 - Fluoroscopic lateral of femoral neck before fixation
 - Postoperative orthogonal hip radiographs in OR
 - Delayed diagnosis of femoral neck fractures reduced by 91%
- Rapid sequence MRI
 - 12% of femoral neck fractures not identified on thin cut CT scan were identified on rapid limited-sequence MRI⁶¹
- Address femoral neck/intertrochanteric fracture FIRST with multiple lag screws or sliding hip screw⁶²
- Femoral shaft then addressed with retrograde nail or lateral plate
- Although sequence of which to fix first – shaft versus neck/intertrochanteric fracture fixation remains controversial



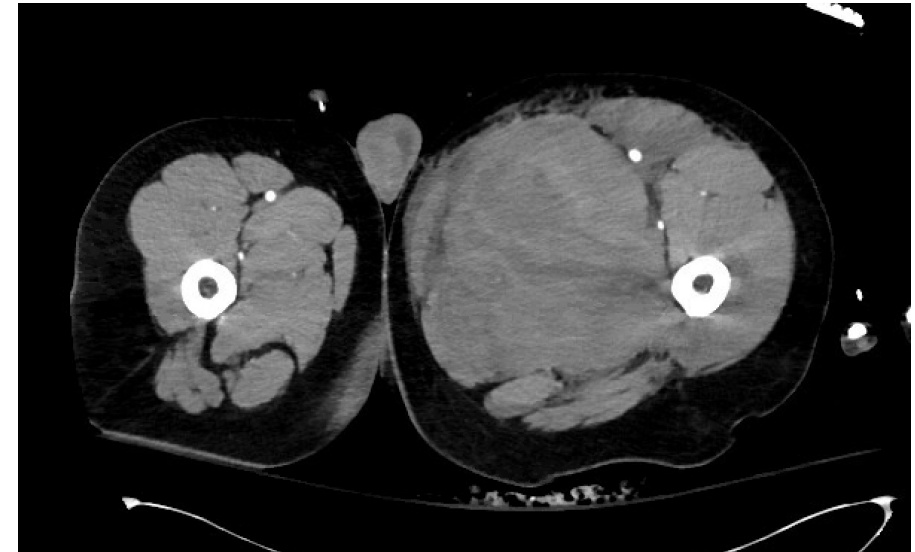
Open Fracture

- Associated with significant soft tissue damage even if just small skin wound
- Unless grossly contaminated, immediate nailing after debridement is acceptable^{63,64}



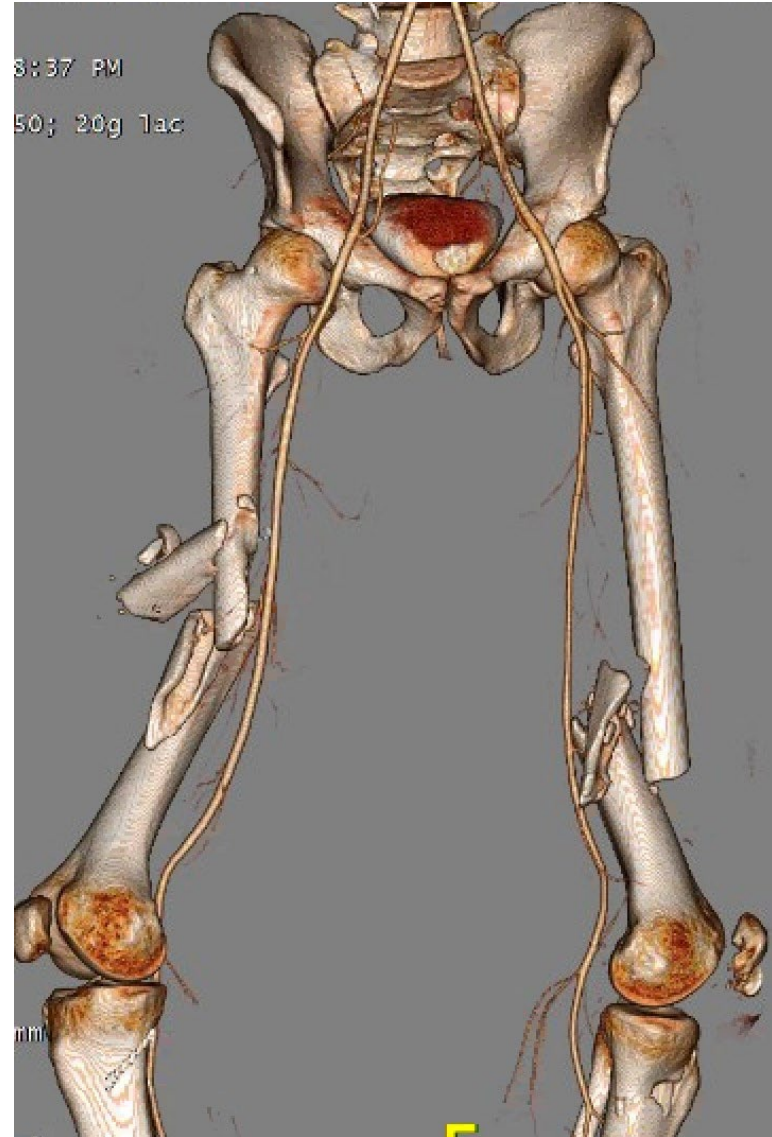
Vascular Injury

- Rare, but usually secondary to penetrating trauma
- Coordination between vascular team and orthopaedic team
- Re-establish blood flow within 6 hours
- If limb perfusion needs to happen first, can consider bony stabilization to obtain proper length or ensure repair is made with sufficient extra length to allow for restoration of limb length
- Usually external fixator
- Early exchange to IMN^{65,66}



Bilateral Fractures

- Worse overall prognosis and higher mortality⁶⁷
- Higher ISS score and lower GCS score⁶⁸
- Nail less comminuted fracture first to assess length/rotation
- Relative indication for retrograde nail fixation



Summary

- Do not miss concomitant injuries including ipsilateral femoral neck/shaft fracture
- IMN is gold standard
- Reaming is safe and has higher union rates
- Multiple options including positioning and antegrade vs retrograde
- Many complications can be prevented!

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