Femur Fractures

• Common injury due to major violent trauma
• 1 femur fracture/10,000 people
• More common in people < 25 yo or > 65 yo
• Femur fracture leads to reduced activity for 107 days, the average length of hospital stay is 25 days
• Motor vehicle, motorcycle, auto-pedestrian, aircraft, and gunshot wound accidents are most frequent causes
Anatomy

- Long tubular bone, anterior bow, flair at femoral condyles
- Blood supply
  - Metaphyseal vessels
  - Single nutrient artery in diaphysis enters through the linea aspera
  - Nutrient artery communicates with medullary arteries in intramedullary canal
  - Medullary arteries supply 2/3 of endosteal blood supply
Blood Supply

- Reaming destroys intramedullary endosteal blood supply
- Periosteal blood flow increases
- Medullary blood supply is re-established over 8-12 weeks if spaces left in canal by implant
- Unreamed intramedullary nailing decreases blood flow less; restoration of endosteal blood flow earlier but equal to reamed canal at 12 weeks
Femur Fracture Classification

AO/OTA Femur Diaphysis - Bone segment 32

- A1: Simple fx, spiral
- A2: Simple fx, oblique ($\geq 30^\circ$)
- A3: Simple fx, transverse ($< 30^\circ$)
- B1: Wedge fx, spiral wedge
- B2: Wedge fx, bending wedge
- B3: Wedge fx, fragmented wedge
- C1: Complex fx,
- C2: Complex fx, segmental
- C3: Complex fx, irregular
Femur Fracture Classification

- Type 0 - No comminution
- Type 1 - Insignificant butterfly fragment with transverse or short oblique fracture
- Type 2 - Large butterfly of less than 50% of the bony width, > 50% of cortex intact
- Type 3 - Larger butterfly leaving less than 50% of the cortex in contact
- Type 4 - Segmental comminution
  - Winquist and Hansen 66A, 1984

Axial and rotational stability
Femur Fracture Management

- Piriformis fossa intact, lesser trochanter intact
- Can you nail this?
- Should you nail this?
Femur Fracture Management

• Initial traction with portable traction splint or transosseous pin and balanced suspension
• Evaluation of knee to determine pin placement
• Timing of surgery is dependent on:
  – Resuscitation of patient
  – Other injuries - abdomen, chest, brain
  – Isolated femur fracture
Bending moment = F x D

The bending moment for the plate is greater due to the force being applied over a larger distance.
Femur Fracture Management

• Diaphyseal fractures are managed by intramedullary nailing through an antegrade or retrograde insertion site.

• Proximal or distal 1/3 fractures MAY be managed best with a plate or an intramedullary nail depending on the location and morphology of the fracture.
Hare traction splint for initial reduction of femur fractures prior to OR or skeletal traction
Femoral IM Nailing
To Ream?

Hypothesis:
Femoral reaming increases fatty emboli to the lungs and potentially increases pulmonary complications.
Femur Fracture
Reaming

• Reaming advantages:
  – Nail will not get incarcerated
  – Higher union rates
  – More durable fracture/nail construct
  – Earlier weight bearing

• Unreamed nails - still generate fat embolism with opening of piriformis fossa and probably higher pressure with unreamed nail insertion
Femur Fracture Reaming

- Reaming of the femoral shaft fracture
  - Multiple studies demonstrate that the thoracic injury is the major determinant of pulmonary complications, **NOT** the use of a reamed IM nail
    - Charash J Trauma 1994
    - Van Os J Trauma 1994
    - Ziran J Trauma 1997
    - Bone Clin Orthop 1998
    - Bosse JBJS 79A 1997
Femur Fracture
Reaming

• Reaming of the femoral shaft fracture
  – Only Pape (J Trauma 1993) has shown a deleterious pulmonary effect to immediate reamed intramedullary nailing in acute femur fracture patients with pulmonary trauma
  – In both a retrospective analysis and multiple animal studies (Pape, J Trauma 1992)
  – However, other animal studies refute these results
    • Wolinsky, J Orthop Tr 1998
    • Duwelius, JBJS 79A 1997
Femur Fracture
Reaming Pressures

- Muller, Injury 1993

No difference in pressures generated by head design

NO increase pressure with nail insertion

9mm reaming guide pin

9.5mm first reamer

13mm reamer with larger shaft

awl
Injury + Patient


1. Incidence of ARDS increased with increased ISS and delay in fracture stabilization

2. The more severe the injury, the more significant fracture stabilization was in preventing ARDS

3. Pts with ISS > 40 had an increased mortality assoc with a delay in fracture stabilization
Select group of critically injured or “borderline” patients may not tolerate extensive procedures or blood loss
External Fixator for Femoral Shaft Fracture

Exchange Nailing in the femur is safe and yields high union and low infection rates

Nowotarski JBJS 2000
Injury + Patient

Practice management guidelines
Recommendations-Polytrauma

• Level II-no improvement in survival
  - some patients fewer complications
  - no detrimental effect of early fixation
  - early fixation preferable

Dunham J Trauma 2001
Head Injury + Femur Fx

• Early fixation of long bone fractures does NOT promote secondary brain injury which may increase mortality, **BUT** hypoxia, hypotension, and increased ICP **DO**

Poole J Trauma 1992
Schmeling CORR 1995
McKee J Trauma 1997
Scalea J Trauma 1999
Chest Injury + Femur Fx

CHEST INJURY

Thoracic trauma ITSELF is the major determinant of morbidity and mortality, NOT IM NAILING

Bone CORR 1995
Bosse JBJS 1997
Timing of femur fracture fixation: effect on outcome in patients with thoracic and head injuries

Brundage SI, J Trauma 2002

Data showed 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 IM Nailing of Femur Fractures Reduces Mortality

- 3069 patients, ISS ≥ 15
- Serious abdominal injury (AIS >3) had most benefit from resuscitation
- Delay > 12 hours DECREASED mortality by 50% in multisystem trauma patients

- Morshed, JBJS 2009
Comparison of Reamed vs Unreamed IM Nails

224 patients multiply injured patients
Risk of nonunion was 5x greater in unreamed group
80% of nonunions could have been prevented by reaming

NO increase in ARDS with reaming!!

Conclusion: REAM

Powell and COA, JOT 2006
Femoral Nailing
Course # 101

1. Femoral Nail Design
2. Ream vs Unreamed
3. Nails available, treatment options
Gerhard Kuntscher
Technik der Marknagelung, 1945

Straight nail with 3 point fixation

First IM nailing but not locking
Klemm K, Schellman WD: Verriegelung des marnagels, 1972

Locking IM nails in the 1980’s

Kempf I, Grosse A: Closed Interlocking Intramedullary Nailing. Its Application to Comminuted fractures of the femur, 1985
IM Nail Variables

- Stainless steel vs Titanium
- Wall Thickness
- Cannulation
- Slotted vs Non-slotted
- Radius of Curvature
- ? To Ream
Stiffness
Modulus of Elasticity

Metallurgy less important than other parameters for stiffness of IM Nail
Wall Thickness

Large determinant of stiffness
Slotted vs Non-slotted

Anterior slot - improved flexibility

Posterior slot - increased bending strength

Non-slotted - increased torsional stiffness, increased strength in smaller sizes, ? comminution
Radius of Curvature of femur averages 120 cm

- Current femoral nails radius of curvature ranges from 150-300 cm
- IM nails are straighter (larger radius) than the femoral canal
Femur Fracture Management

• Antegrade nailing is still the gold standard
  – Highest union rates with reamed nails
  – Extraarticular starting point
  – Refined technique

• Antegrade nailing problems:
  – Varus alignment of proximal fractures
  – Trendelenburg gait
  – Can be difficult with obese or multiply injured patients
Antegrade Femoral Nailing: piriformis fossa starting point

Caution !! Anterior starting point leads to increased proximal femur stresses
Minimally Invasive Nail Insertion Technique (MINIT)

Courtesy T.A. Russell, M.D.
Antegrade Femoral Nailing
starting point

Posterior - loss of proximal fixation

Piriformis fossa - proper starting point

Anterior - generates huge forces, can lead to bursting of proximal femur
Femur Fractures

Iliopsoas leads to flexion of the proximal fragment

Adductor muscles shorten the femur

Gluteal muscles

These muscle forces must be overcome to reduce and intramedullary nail the femur
Static Locking of All Femoral IM Nails !!!

- Brumback- 1988
  - 98% union with Statically Locked Rod
Immediate Weight Bearing

- Mythical 70 Kg Man
  - Axial Load to Failure 300%
    - 75% Stiffness in Bending
    - 50% Stiffness in torsion
  - Withstand 500,000 cycle at loads of 3X body
  - 28 Winquist type 4 fractures
    - 27 Healed primarily
    - No Locking Bolt or Rod Fatigue
      » Brumback JBJS 1999
Antegrade Nailing
Fracture Table or Not?

Supine - better for multiply injured patients, tough starting point
Lateral - easier piriformis fossa starting point, difficult set up, ? rotation
Without a fracture table, length, distal lock first and slap nail

Lateral
Supine with bolster under torso
Manual traction and rotation
Femur Fracture Management

• Retrograde nailing has advantages
  – Easier in large patients to find starting point
  – Better for combined fracture patterns (ipsilateral femoral neck, tibia, acetabulum)
  – Union approaching antegrade nails when reamed

• Retrograde nailing has its problems:
  – Union rates are slightly lower, more dynamizing with small diameter nails
  – Intra-articular starting point
Femur Fracture Technique

• Retrograde Intramedullary Nailing
  – Supine - flex the knee 50° to allow access to Blumensaat’s line

Percutaneous with fluoro OR
Limited open technique
Center guide pin on AP and Lateral
Especially important for distal 1/3 fractures
Above Blumensaat’s Line
Retrograde Femoral Nailing
Starting Point
Mean Contact Area

- Control
- In
- Flush
- Out

90 degrees

120 degrees
Only with the nail 1 mm prominent were the patellofemoral pressures increased
Retrograde Femoral Nailing

- A cadaveric study using Fuji film demonstrated NO deleterious effects on the patello-femoral joint with a properly inserted retrograde IM nail.
- The orthopaedic literature does NOT support decreased knee motion or increase knee pain with a retrograde nail.
Bilateral femur fractures nailed retrograde

Less comminuted fracture nailed first to assess length for segmental fracture
• 42 yo male C2 femur, Gr 2 open ipsilateral tibia fx
• Immediate post-op with treatment through a limited 4cm knee incision
Femur Fracture Management

• Retrograde Nailing
  – Union rates lower with unreamed nails
  – Higher dynamization with non canal sized nails
  – Better union rates equal to antegrade with reamed canal sized nails
    • Moed JBJS 1995, J Orthop Trauma 1998
    • Ostrum J Orthop Trauma 1998, 2000
  – Advantages for ipsilateral acetabulum or femoral neck and shaft fracture, floating knees, obese patients, supracondylar fractures including those around total knee replacements
Retrograde Nailing is Beneficial for Floating Knee Injuries
Shortening after Retrograde Nail Insertion

Backslap after distal locking
Retrograde Nail: Long or Short?

- 9 human matched cadaver femurs, gap model
- 36 cm vs 20 cm
- Coronal and sagittal testing
- 75 Newtons applied in 3 point bending
- Locked with 1 or 2 proximal screws
Retrograde Nail: Long or Short?

<table>
<thead>
<tr>
<th></th>
<th>20cm</th>
<th>36cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 prox, sagittal</td>
<td>7.2*</td>
<td>1.8*</td>
</tr>
<tr>
<td>2 prox, coronal</td>
<td>6.3</td>
<td>4.3</td>
</tr>
<tr>
<td>1 prox, sagittal</td>
<td>7.6*</td>
<td>2.2*</td>
</tr>
<tr>
<td>1 prox, coronal</td>
<td>13.6*</td>
<td>4.4*</td>
</tr>
</tbody>
</table>

Longer nails provide improved stability !!!

* statistically significant at p<0.05
Femur Fracture Technique

• Antegrade Intramedullary Nailing
  – Supine - better for multiply injured patients
  – Lateral - easier piriformis fossa starting point, difficult set up, rotation concerns
  – Without a fracture table

• Retrograde Intramedullary Nailing
  – Supine - flex the knee 50° to allow access to Blumensaat’s line
Antegrade v Retrograde Comparisons

Equal union rates

Tornetta, JBJS (B), 2000
Ricci, JOT, 2001
Ostrum, JOT, 2000

• ANTEGRADE
  – More hip and proximal thigh pain
  – Greater incidence of Trendelenburg gait

• RETROGRADE
  – More symptomatic distal hardware
  – Higher dynamization rates with small diameter nails
## Obesity

**Antegrade v Retrograde**

<table>
<thead>
<tr>
<th></th>
<th>Obese BMI &gt;30</th>
<th>Non-Obese BMI &lt;30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ante OR Time</td>
<td>94</td>
<td><strong>Retrograde nailing is easier in obese patients!!</strong></td>
</tr>
<tr>
<td>Retro OR Time</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Ante Fluoro</td>
<td>247</td>
<td>135</td>
</tr>
<tr>
<td>Retro Fluoro</td>
<td>76</td>
<td>63</td>
</tr>
</tbody>
</table>

Tucker M. JOT 2007
Comparison of Knee function after Antegrade and Retrograde IM Nailing with Isokinetic Evaluation

No differences in:

- knee range of motion
- Lysholm Scores
- isokinetic knee evaluation
- time to union
- secondary surgeries (including hardware removal)  

- Daglar, JOT 2009
Antegrade Femoral Nailing: Piriformis vs Trochanteric

- Reduction and starting point are still the keys !!
- Problems arise with subtrochanteric fractures
- Inappropriate starting point leads to malreduction
Piriformis Nail: Poor Technique
Piriformis Screw: Poor Technique

Illustration 80.
Place of the incision in relation to the tip of the trochanter.
three different starting points were used

Tip of Trochanter

2-3 mm medial to tip

2-3 mm lateral to tip
Recommendations

The tip of the trochanter or slightly medial is the entry site of choice for antegrade trochanteric nailing of subtrochanteric fractures

The lateral starting point, even 2-3 mms from the tip of the trochanter, is to be avoided

Ostrum R, JOT 2005
Lateral to tip of GT is OK for shaft fractures

Medial to the tip of the GT for subtrochanteric fractures

Lateral starting point with varus!
Reduction with **medial** tip starting point
Medial Trochanteric Portal

Perez E, Russell TA. JOT 2007
Starting point

Reduction
• Assessing rotation in the lateral position
• Without changing rotation of the C-arm
• A true AP of the hip and knee
• 17 mm entry hole in trochanter
• 15-50% disruption of gluteus medius tendon
• ? Functional sequelae

- McConnell T, Clin Orthop 2003
A prospective, randomized comparison of trochanteric vs piriformis fossa entry portal for high energy proximal femur fractures

- 34 pts
- Fx table, supine or lateral
- FAN or Gamma
- EBL
- incision length,
- duration of surgery
- ease of device
- adequacy of reduction
- patient positioning

No difference

Starr AJ, J Orthop Trauma 2006
A prospective, randomized comparison of trochanteric vs piriformis fossa entry portal for high energy proximal femur fractures

- NO difference in: Hip Scores, RTW, Ambulation, Hip/Knee ROM

- Varus $\geq 5$ degrees
  - Recon = 2
  - Gamma = 4

- BMI significantly linked to duration of OR and length of incision, NOT EBL

Starr AJ, J Orthop Trauma 2006
Femur Fracture
Complications

• Hardware failure
• Nonunion - less than 1-2%
• Malunion - shortening, malrotation, angulation
• Infection
• Neurologic, vascular injury
• Heterotopic ossification
Femur Fracture
Nonunion

Femoral nonunion with broken IM Nail

Union after exchange, reamed IM nail
Hypertrophic Nonunion

- Problem with smaller diameter nails
- Don’t Dynamize  EXCHANGE !!
- Has a blood supply, WANTS MORE STABILITY
Plating of femoral nonunions after IM Nail

- 23 pts, nonunion of femur after IM nail
- nail removal, PLATING, soft tissue preservation
- 21/23 healed, avg 12 weeks
- avg OR time 164 minutes (120-240)
- avg EBL = 340 ml (200-700)

-Bellabarba, JOT 2001
Exchange Nailing of femoral Nounions

- 42 pts, closed exchange nailing
- 7 positive cultures
- 36 (86%) healed, avg 4 mos after OR
- Lack of immediate weight bearing, open fractures assoc with nonunion after 1st OR
- Atrophic/oligotrophic nonunions, and infection were associated with treatment failure after exchange nail
- A second nail larger by 2 mm or more than the original nail was associated with a higher success rate
  - Shroeder, JOT 2009
Femur Fracture
Subtrochanteric Fracture Management

- Possible to perform intramedullary nail if the piriformis fossa is intact
- Choice of nail type depends on if the lesser trochanter is intact
- Varus seen with proximal femur intramedullary nailing
- Plating is also an option with/without an intact starting point
Subtrochanteric fractures are from the base of the lesser trochanter to 5 cm distal.
Low Subtroch Fx’s

Most low subtrochanteric fractures with an intact piriformis fossa can be treated with a 1st gen IM Nail.
When piriformis fossa is not involved and the lesser trochanter is fractured, a 2nd generation nail may be used.
Nail or... Plate
Indirect Reduction: Technique
Indirect Reduction

Step 1 - Approximate closed reduction with fracture table in BOTH planes

Step 2 - Percutaneous insertion of guide pins
Step 3 - Placement of lag screw and percutaneous plate placement
Indirect Reduction

Step 4 - Final reduction with percutaneous screw placement

Push up to prevent sag
Screw Placement
Final films after percutaneous **Indirect Reduction** of a Subtrochanteric femur fracture
Ipsilateral Femoral Neck & Shaft Fractures

- Optimum fixation of the femoral neck should be the goal
- Varus malunion of the femoral neck is not uncommon, osteotomies can lead to poor results
- Vertical femoral neck fracture seen in 26-59% of cases (Pauwel’s angle > 70°)
- Rate of avascular necrosis is low, 3%, even when missed
Ipsilateral Femoral Neck & Shaft Fractures

- **Type 1** - nondisplaced femoral neck/hip fractures
- When found prior to nailing can be treated with screws or a sliding hip screw then retrograde or antegrade nail.
Ipsilateral Femoral Neck & Shaft Fractures

- Type 2 - missed femoral neck fracture
- Insertion of screws around the nail
- Low AVN rate even when missed
- Vertical fractures not iatrogenic
Ipsilateral Femoral Neck & Shaft Fractures

- Type 3 - displaced femoral neck fractures
- Treat with implant appropriate for neck fracture FIRST
- Treat femoral shaft fracture with retrograde nail
Femoral Shaft Fracture with Vascular Injury

- Quick external fixation with restoration of length
- Fasciotomies
Femoral Shaft Fracture with Vascular Injury

- Exchange femoral nail either in same setting or in a few days
- When found early plating or rodding of femur is rarely possible first
- Do NOT perform IM nailing after arterial repair without initial length restoration
Open Femur Fracture Antegrade IM Nail is Safe

- Reamed, Antegrade Intramedullary Nailing has been shown to be effective
- A high union rate, low complications
- Perhaps stage Grade 3B fractures after debridement and skeletal traction
  - Brumback, JBJS 71A, 1989
  - Lhowe, Hansen JBJS 70A, 198
Open Femur Fracture
Antegrade IM Nail is Safe
IM Nailing of the Femoral Shaft

- Choice **TO** nail depends on fracture configuration, especially at proximal and distal ends
- Choice **OF** nail depends on fracture location, associated musculoskeletal injuries, obesity
- *Think* before IM Nailing of femur

If you would like to volunteer as an author for the Resident Slide Project or recommend updates to any of the following slides, please send an e-mail to ota@ota.org