Fractures of the femoral diaphysis

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Anatomy

5 cm
Anatomy

Femoral neck is anteverted

Linea aspera

Anterolateral bow
Compartments
Muscular forces: determine fracture displacement

Proximal 1/3: flexed, abducted

Middle 1/3: distal fragment extended, adducted

Distal 1/3: proximal fragment adducted
Blood Supply

- 2/3 endosteal
- Centrifugal flow
- 1/3 periosteal
- Soft tissue
- Fracture: reversal → centripetal flow
Historical:
Cast Bracing 1901
Steinman pin traction 1907
Thomas splint added in WWI
History: IMN

- Introduced in 1939 by Gerhard Kuntscher
- Nonreamed
- Small diameter
- Nail breakage common
Classification: Comminution

Winquist and Hansen, 1980
Classification: AO/OTA

Diaphyseal types

Diaphyseal groups

A1  A2  A3

B1  B2  B3

C1  C2  C3

>30°  <30°
Classification

- Proximal 1/3
- Middle 1/3
- Distal 1/3
- Open vs Closed (Gustillo classification)
Mechanism of Injury

- High-energy trauma
  - Young patients
  - MVA, MCA, GSW, fall from height
- Low-energy trauma
  - Older patients
  - Pathologic fracture
  - Osteoporosis, tumor, metabolic bone disease
Presentation

- Not usually subtle
- Pain
- Deformity
- Shortening
- Assess for soft tissue injury, NV injury, multisystem injury
- ATLS protocol
Associated injuries

- Ligaments of the knee (up to 50%)
- Meniscal injuries (up to 30%)
- Vascular injuries (rare, <2%)
- Neurologic injuries (rare, <1%)
- Blood loss (avg. 1200 cc)
Associated vascular injuries

- Distal 1/3 in adductor hiatus
- 8-13 cm from adductor tubercle
- Associated with penetrating trauma
- Angiogram
Associated fractures

- Ipsilateral femoral neck fracture
- 5-10%
- 30% initially missed
- ‘floating knee’- assoc. tibial shaft fracture
Treatment options

1. Cast brace
2. Traction
3. External fixation (WW II)
4. Internal fixation
   - Flexible nails
   - Plating (1960’s-1970’s)
   - Intramedullary nailing
Nonoperative management: Casting or traction

- Rarely indicated
- Severely injured and unstable multitrauma patients, nonoperative candidates
Timing of surgical treatment

- Blunt trauma thought to produce pulmonary failure state that lasts several days
- ‘Classical’ management of multi-trauma patient involved 5-7 days of patient stabilization before operative treatment
Early vs. delayed surgery

• 1977: Riska et al, *J Trauma*,
  – primary osteosynthesis of long bone fractures
  – Eliminated cases of fat embolism syndrome
  – Earlier mobilization

• 1982, Goris et al., *J Trauma*
  – Decreased incidence of ARDS, death with early osteosynthesis and mechanical ventilation
Early vs. delayed surgery

• 1989, Bone et al. *JBJS*
  – Prospective, randomized early vs. delayed
  – 178 patients, 2-year period
  – ISS < 18 (isolated femur fracture)
    • Delayed fixation increased cost, no difference in pulmonary complications
  – ISS > 18
    • Delayed fixation- increases ICU days and incidence of ARDS (16% vs. 2%)
**CHI**

- McKee et al, *JOT* 1997
- 46 patients with CHI and femur fx
- 99 matched patients with CHI
- Femur fixed by reamed IMN within 24 hours
- No difference in mortality or neurologic disability
- Maintain intraop cerebral perfusion pressure
Surgical stabilization within 24 hours
External fixation

- Unstable patient
- Grade IIIB or IIIC open fractures
- Rarely used as definitive management
  - Malunion
  - Nonunion
  - Pin site infection
External fixation
External fixation: Bridge to IMN

- Scalea et al, *J Trauma* 2000
  - 43 unstable trauma patients, acute ex-fix
  - 35 minute OR time, 90 EBL
  - Avg 4.8 days (2.5-6) exchange IMN
  - One incidence of infection
External fixation: Bridge to IMN

- Nowotarski et al, *JBJS* 2000
  - 54 patients delayed (avg 7 days)
  - One-stage procedure – no draining pin sites
  - At 12 months 1.7% infection rate
  - 1 infected non-union
  - 1 aseptic non-union
Flexible nailing: primary use is for pediatric fractures
Plate Fixation

• Popularized by the AO group in the 1960’s
• Load-bearing vs. load-sharing
• Special situations: ipsilateral femoral neck and shaft fracture
Ipsilateral femoral neck and shaft fracture
Plate vs. Nail biomechanics

Bending moment

Load sharing

Load Bearing

\[ B = \text{distance from force to implant} \]

\[ \text{Bending moment} = F \times D \]
Plate fixation: outcomes

- Wagner et al, *Unfallchirurg* 1994
- 199 femoral shaft fractures treated with plate fixation
- 21% aseptic complications
  - Loss of reduction
  - Implant failure
  - Delayed union
  - Nonunion
- 3% infection
Plate fixation: outcomes

- Riemer et al, *Orthopaedics* 1992
- 150 polytrauma patients with femur fracture stabilized with plate fixation
- 7% delayed/non-union
- 2% infection in open fractures
Locked intramedullary nailing

- Treatment of choice in most cases
- Load-sharing
- Maintains soft-tissue envelope
- Earlier weight-bearing
- Union rates close to 100%
Locked intramedullary nailing: ISSUES

1. Reamed vs. non-reamed (pulmonary)
2. Patient positioning
3. Insertion point, hoop stresses
4. Static vs. dynamic interlocking
5. Antegrade vs. retrograde
Issue #1: Reamed vs. nonreamed

- **Advantages** of reaming
  - Larger nail
  - Accurate nail sizing
  - Bone graft

- (Theoretical) **disadvantages** of reaming
  - Compromise endosteal blood supply
  - Marrow emboli exacerbate pulmonary injury
Basic science: pulmonary injury

• Duwelius et al, *JBJS* 1997
• Sheep model: IMN femur with or without reaming +/- pulmonary contusion
• Fat emboli increased in lung in both reamed and non-reamed
• Reamed: transient increase in PVR
Duwelius et al

- Intravascular ultrasound: emboli
  - Opening femoral canal
  - First and second pass of reamer
  - Inserting nail
Duwelius et al

• “...With regard to their effect on pulmonary function, there was no distinct advantage either to nailing with reaming or to nailing without reaming for fractures of the femoral shaft.”
Norris et al, *JBJS* 2001

- Prospective study
- Peri-operative alveolar dead space
- 50 femurs reamed, 30 femurs ‘minimally reamed’
- No significant difference in alveolar dead space or postop pulmonary dysfunction
- Alveolar dead space predicted postop pulmonary dysfunction
Basic science: cortical blood flow

• Schemitsch et al, *JOT* 1994
• Cortical blood flow in sheep tibia fx model
• Cortical perfusion decreased to a significantly greater extent in reamed vs. non-reamed tibia (time 0 to 6 weeks)
Perfusion returned to normal by 12 weeks
Schemitsch et al, *JOT* 1995

- Same model: blood flow in fracture callus reamed vs. non-reamed
- Significantly less cortical blood flow but no difference in fracture callus blood flow or strength of union
- Reaming increased extracortical blood flow
Muller et al, *JOT* 1998

- Lower canal pressures associated with:
  - Sharp edges, Deep flutes,
  - Short length of cutting flute,
  - Large reamed head with small shaft diameter
  - Lower speed of traversing the canal
Bosse et al, *JBJS* 1997

- Two trauma centers: one is standard IMN (229), second standard is plate fixation (206)
- Patients with thoracic injury and femur fracture (well-matched)
- Outcome: no difference in ARDS, PE, multiple organ failure, death
Tornetta and Tiburzi, *JOT* 2000

- Prospective, randomized study, 170 patients
- Two matched groups: reamed and non-reamed
- No statistical difference in hypoxic episodes
- Reaming: increased blood loss and significantly decreased time to union (80 vs. 109 days)
- Difference most drastic in distal femur
Anwar, Olson et al, AAST 1998

- Prospective randomized study 82 patients
- Matched groups: reamed and non-reamed
- ABG, PaO$_2$/FiO$_2$, A-a gradients, pulmonary complications, length of mech. ventilation
- No difference in pulmonary physiologic response or clinical outcome*

*power 80% to detect difference of 20%
Intramedullary nailing with reaming is recommended, even in the face of thoracic injury

- Many Uncontrolled Variables
  - Degree of Pulmonary Injury
  - Adequacy of Fluid Resuscitation
  - Associated Abnormalities - ie Coagulopathy
Issue #2: patient positioning

- Supine vs lateral on fracture table
Lateral position-fracture table

- Entry site easier, esp. in obese patients
- Skeletal traction for knee flexion
- Pelvis will flex forward \rightarrow internally rotate to realign
Supine position-fracture table

- Polytrauma patient (lateral position not feasible)
- More difficult to obtain entry site
- Pudendal neuropraxia with prolonged traction

Brumback et al, *JBJS* 1992
Supine-fracture table

- Avoid foot plate traction
- Skeletal traction allows knee flexion
- Flex/adduct thigh and adduct torso
Incision often too anterior
Incorrect incision

- Lateral femoral shaft
- Greater trochanter
- Anterior femur
Correct incision

Lateral femoral shaft

Greater trochanter

Anterior femur
Anterior incision: inaccurate entry portal
Supine vs lateral, fracture table vs radiolucent flat table: Based on individual patient factors
Issue #3: entry portal
Hoop stresses minimal at central piriformis fossa

100 kPA

1 kPa

Johnson et al, 1987
Johnson et al, *JOT* 1987

- Cadaveric study
- **Anterior starting hole >6 mm** from neutral axis of femoral medullary canal
- Hoop stresses at fracture site and bursting of proximal femoral component by lifting off anterior cortex
Issue #4: Interlocking

- Helps prevent shortening and malrotation of fracture fragments
- How many?
- Dynamize?
- How close to fx?
Dynamization: adequate stability?

- Brumback et al, *JBJS* 1988
- 133 Dynamically Locked Femoral Fractures
- 14 Fractures - Loss of Reduction
  - Shortening & Rotation
  - Comminution 7 Type I, 4 Type II, 3 Type III
- Recommend routine static interlocking
Dynamizing required for union?

- Brumback et al, *JBJS* 1988
- 87 Statically Locked Femoral Fractures
- 70% Winquist and Hansen III or IV (comminuted)
- 85 Fractures Healed Without Dynamization
  - Average Time to Union - 19 Weeks
  - Loss of Reduction < 1%
- Do not recommend routine dynamization
Does locked nail allow early WB?

• Brumback et al, *JBJS* 1999
• Clinical and biomechanical study
• 28 patients with comminuted femur fx stabilized with statically locked IMN
• Immediate post-op WBAT
• No cases of hardware failure, 100% union
• Recommend early WBAT
How many distal interlocks?

• Grover and Wiss, Ortho Clin NA, 1995
  • 178 Femur Fractures
    – 74 Single Proximal & Single Distal Locking Screws
    – 104 Single Proximal & Two Distal Locking Screws
  • Proximal Third / Middle Third Fractures
    No Difference
  • Distal Third Fractures
    1 Loss of Reduction with Single Distal Screw
• Recommend two interlocks in distal third fractures
Interlocking Femoral Nailing

- Bucholz et al, *JBJS* 1989
- Interlocking Hole Within 5 cm of Fracture
  - Increases Stresses on Nail - Cyclic Fatigue
  - Protected WB in these cases
Techniques for accurate leg lengths

• Obtain a scanogram of the opposite leg pre-op
• Maintain distraction until crosslocks are in
• Examine the patient post-op
Interlock summary

- Dynamizing not routinely recommended
- Two distal interlocks in distal 1/3 fractures
- WBAT, even with comminuted fractures
- Stay within 5 cm of fracture
Issue #5: antegrade vs retrograde

Indications:

- Polytrauma, Bilateral Femoral Shaft Fx’s
- Ipsilateral Neck-Shaft Femur Fx
- Ipsilateral Femur-Tibia Shaft Fx’s
- Obese patient
- Multisystem injuries, pelvis, spine
- Pregnancy
Retrograde Entry Site

Entry site in line with axis of femoral shaft
Nail left prominent in the intercondylar notch will increase stresses within the PF joint, and can lead to pain and stiffness
AP proximal interlock

- Tornetta et al, *JOT* 1998
- Cadaveric study
- Safe placement of AP interlock?
- **Above** lesser trochanter
  - Avoid injury to femoral vessels
  - Minimizes possible injury to small branches of femoral nerve
Retrograde IMN

• Moed et al, *JBJS* 1995:
  – Retrograde IMN, non-reamed
  – Union rate 89%

• Ostrum et al, *OTA* 1997:
  – Retrograde IMN, reamed (not over-reamed)
  – Union rate 90%
Antegrade vs retrograde

- Tornetta and Tiburzi, *JBJS* (Br), 2000
- Prospective randomized study
- 38 antegrade, 31 retrograde
- Matched for age, ISS, location/stability of fx, associated injuries
- Over-reaming technique
12-month follow-up

- 100% union rate both groups
- No difference in time to union
- **Rotational deformity:**
  - Antegrade: 17%
  - Retrograde: 33%
- **Significant shortening**
  - Antegrade: 0
  - Retrograde: 5 patients
- No difference in knee, hip ROM or pain
Retrograde IMN

- Specific indications
- Technical aspects still being developed
- Not first-line treatment at this time
Postop assessment/management

- WBAT
- Abductor strengthening
  - Bain et al, JOT 1997: thigh pain, weakness and limp present in up to 40% patients
- Check rotation and length in OR
- Groin pain → be alert for femoral neck fx
Sickness Impact Profile

Physical impairment
Summary

- Multisystem injury common: ATLS
- Associated injuries (fem neck, tibia)
- Classification based on comminution, stability, location
- Operative fixation within 24 hours
- Ex-fix for IIIB or IIIC open fx, unstable pt
- Reamed, statically locked, antegrade IMN is treatment of choice
Summary

- Close to 100% union rate
- No indication at this time that reaming affects pulmonary outcome or fx healing
- Pitfalls: inaccurate entry portal, malrotation, shortening, abductor weakness
- Retrograde nailing: evolving indications and techniques
- Expect functional impairment
A patient reports groin pain and has painful range of motion of the hip 3 weeks after undergoing locked intramedullary nailing of a comminuted femoral shaft fracture. The first step in assessment should consist of obtaining which of the following imaging studies?

1. Radiographs of the femur
2. Radiographs of the femoral neck
3. Radiographs of the acetabulum
4. MRI
5. Bone Scan
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To prevent abnormal patellofemoral contact loading after insertion of a retrograde femoral nail through an intra-articular starting portal, the surgeon should:

1. Seat the nail beneath the articular surface.
2. Use a patellar-tendon splitting approach.
3. Use an unreamed technique.
4. Perform a lateral release.
5. Perform a medial parapatellar arthrotomy.
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OITE

In the treatment of femoral shaft fractures, the lowest union rate has been reported after which of the following types of nailing?

1. Reamed antegrade locked
2. Reamed antegrade unlocked
3. Reamed retrograde locked
4. Unreamed antegrade locked
5. Unreamed retrograde locked
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OITE

What is the most common complication at a minimum of 1 year after treatment with a reamed antegrade nail for a femoral shaft fracture?

1. Nonunion
2. Malunion
3. Trendelenburg gait
4. Hip discomfort
5. Osteonecrosis of the femoral head
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5. Osteonecrosis of the femoral head
Use of a retrograde femoral nail is best indicated for which of the following injuries?

1. An isolated femoral shaft fracture from a low-velocity gunshot
2. A subtrochanteric femoral fracture
3. A femoral shaft fracture with an associated unstable spinal injury
4. A femoral shaft fracture with a contaminated open knee wound
5. A femoral shaft fracture with a prior meniscectomy
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Thank You!