

Femoral Shaft Fractures

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Femur Fractures

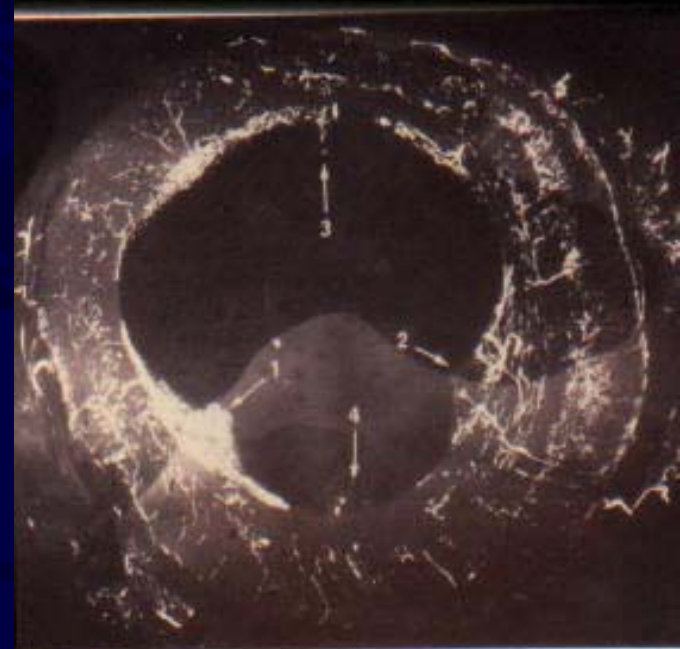
- Common injury due to major violent trauma
- 1 femur fracture/ 10,000 people
- More common in people < 25 yo or >65 yo
- Femur fracture leads to reduced activity for 107 days, the average length of hospital stay is 25 days
- Motor vehicle, motorcycle, auto-pedestrian, aircraft, and gunshot wound accidents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

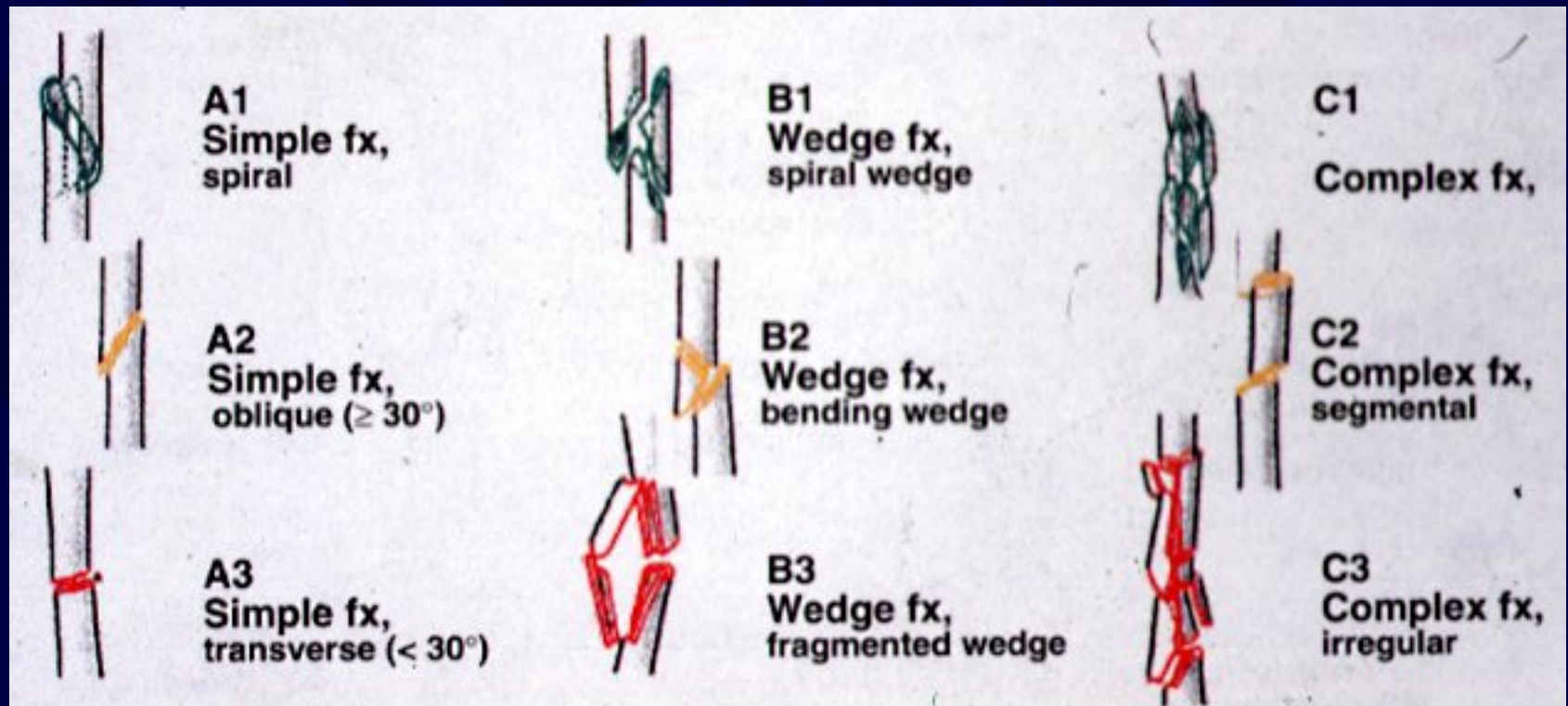
Blood Supply

- 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



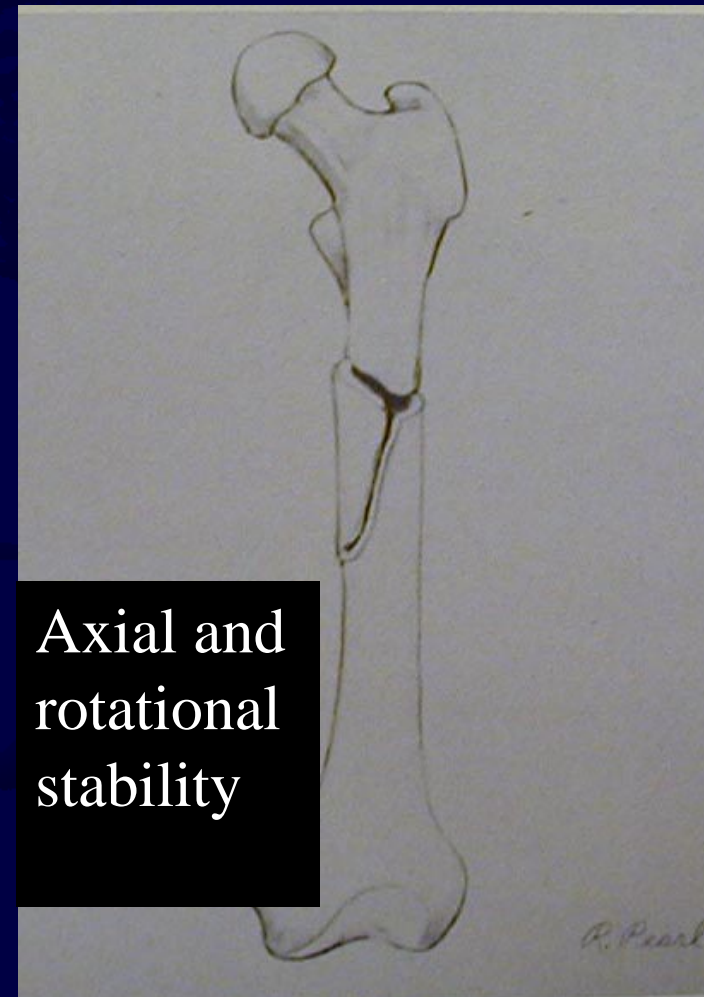
Femur Fracture Classification

AO/OTA Femur Diaphysis - Bone segment 32



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 ?



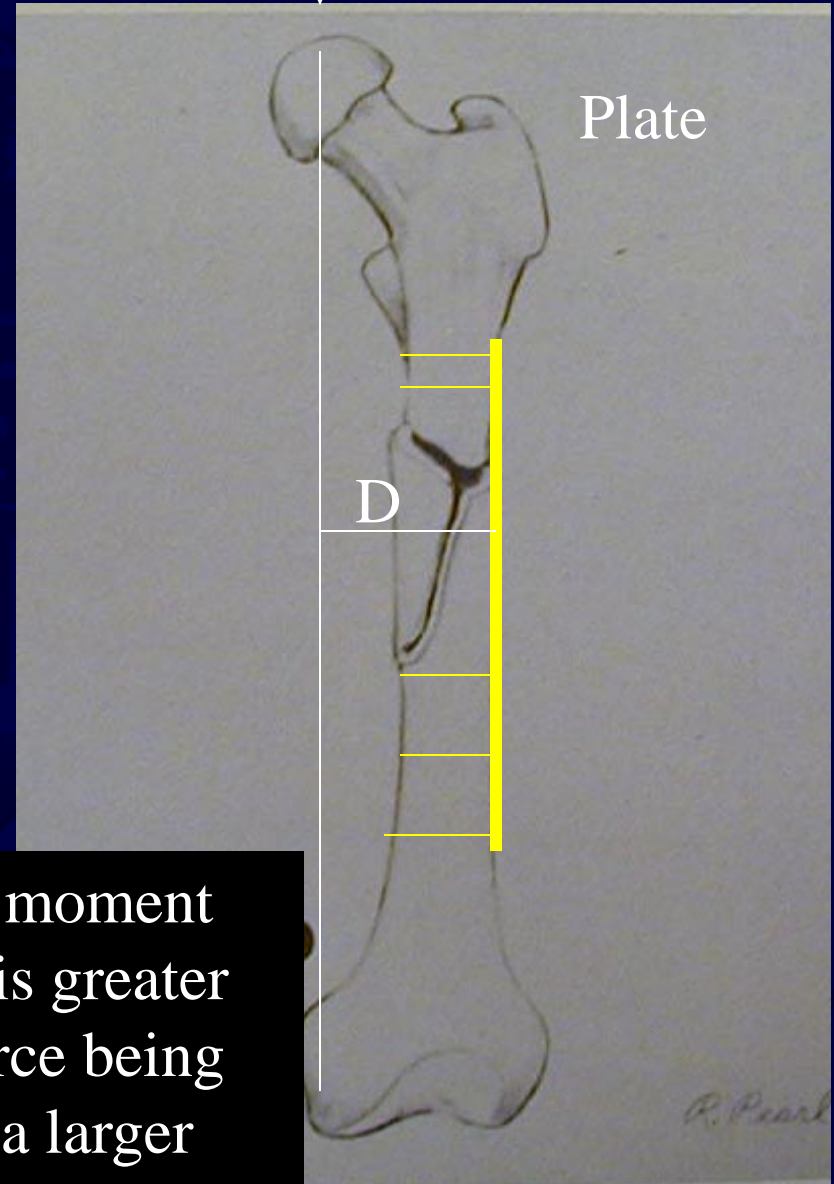
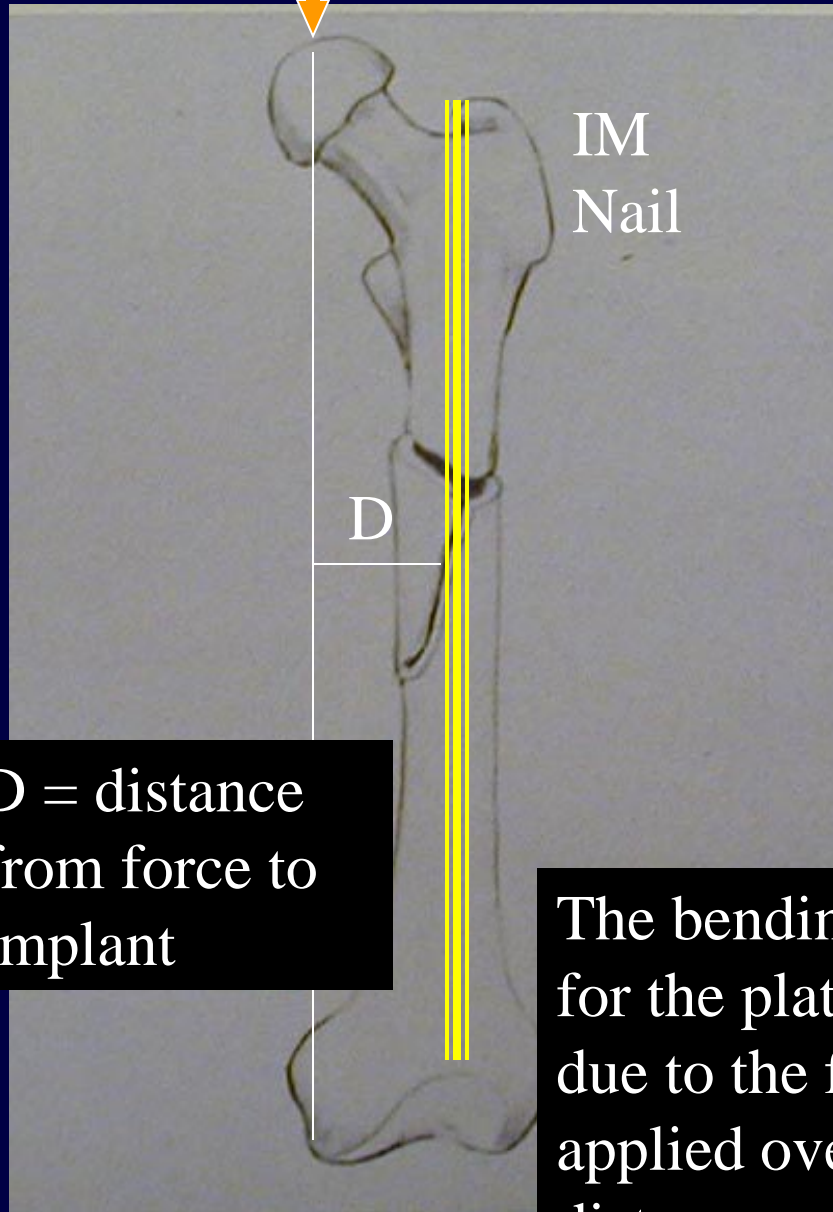
Femur Fracture Management

- 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

F = Force

$$\text{Bending moment} = F \times D$$

F = Force



D = distance
from force to
implant

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



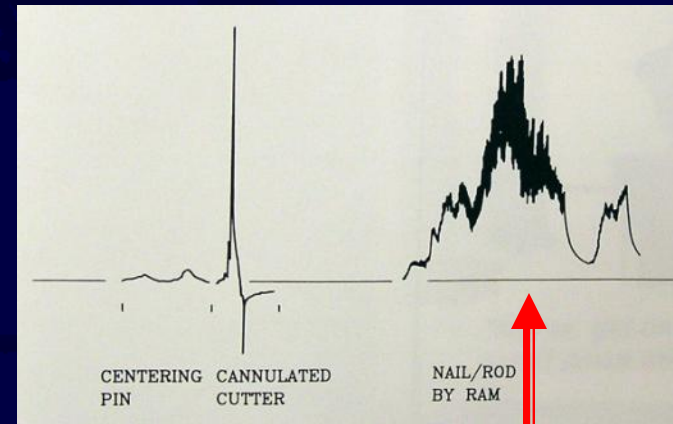
Femoral IM Nailing To Ream ?

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

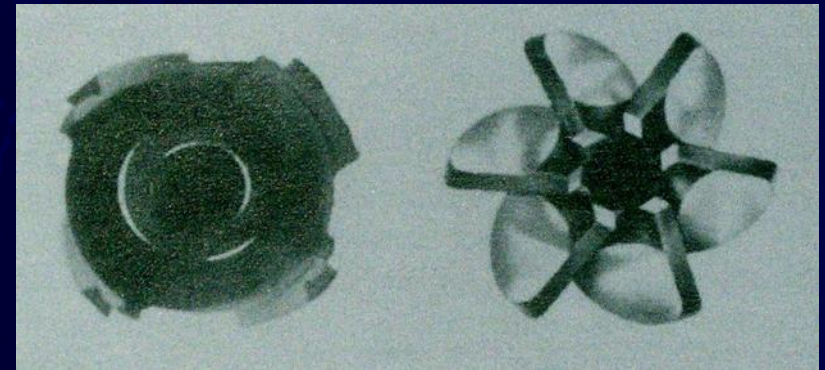
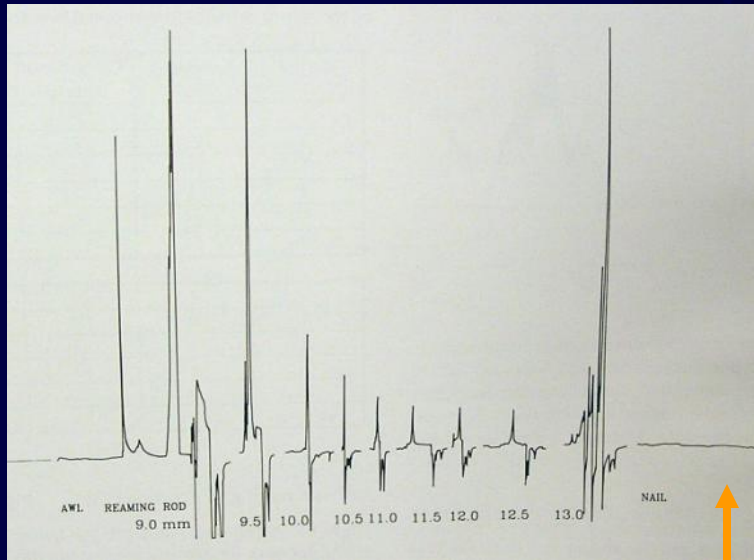
Femur Fracture Reaming

- 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



No difference in pressures generated by head design

- Muller, Injury 1993

awl ↑

9mm reaming guide pin ↑

9.5mm first reamer ↑

13mm reamer with larger shaft ↑

NO increase pressure with nail insertion

Injury + Patient

Johnson KJ, et al :Incidence of ARDS in patients with multiple musculoskeletal injuries: effect of early operative stabilization of fractures. J Trauma 1985

- 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**

Damage Control Orthopaedics



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**

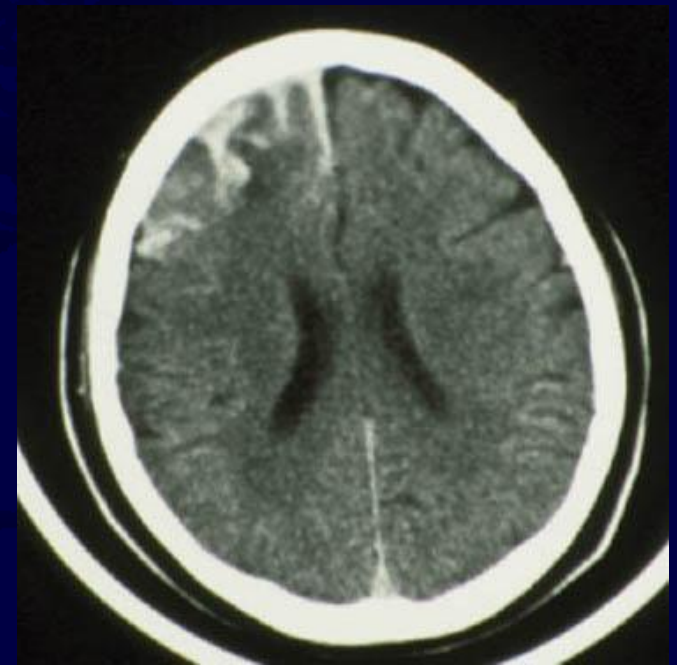
Poole J Trauma 1992

Schmeling CORR 1995

McKee J Trauma 1997

Velmahos Am J Surg 1998

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 \geq 15
- serious abdominal injury (AIS >3) had most benefit from resuscitation
- delay > 12 hours DECREASED mortality by 50% in multisystem trauma patients

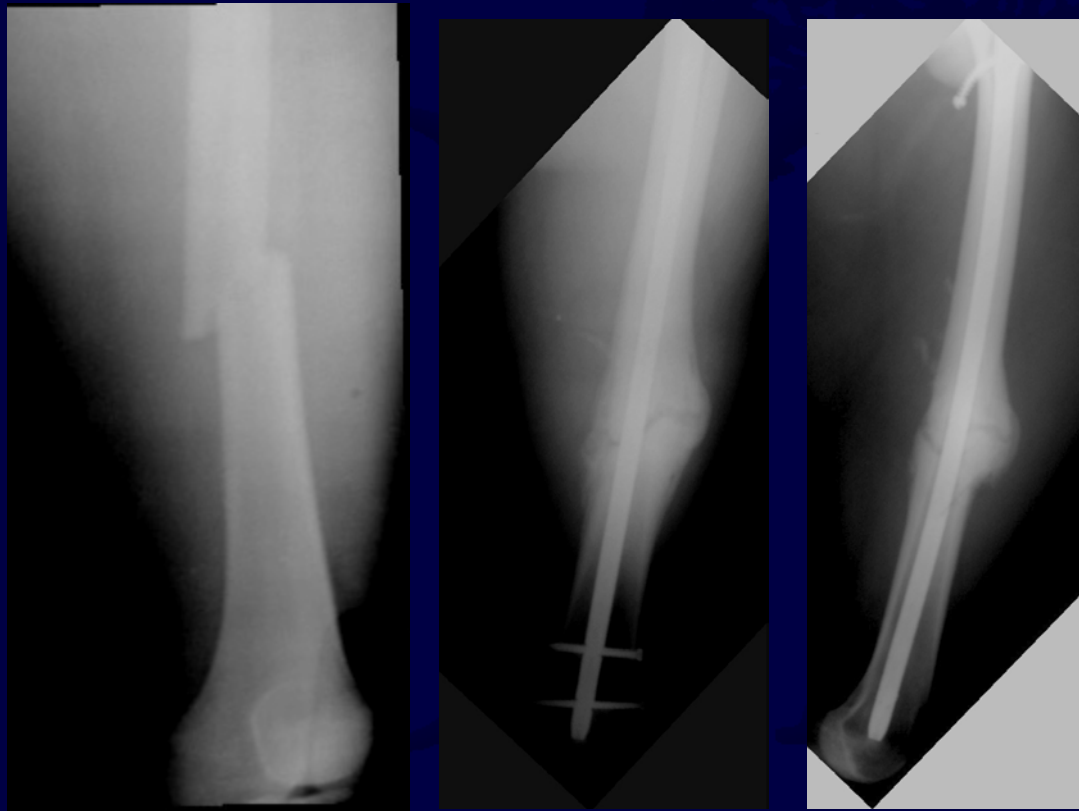
• Morshed, JBJS 2009

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

RAIN AHEAD!
Alligator
The Weekly News Magazine
MARCH 12, 1945

corporation lawyer and onetime U.S. Ambassador to Japan (1924-25). It will be used to establish the Edgar A. and Fred-eric Bancroft Foundation at Columbia.

Bachelors of Mars
How much of what a citizen soldier learns is useful in later life? That depends on a good deal on the soldier, but educators will not admit that it all depends on him. For returning veterans who want to go on with their schooling, educators are now trying to evaluate war's lessons in terms of academic credits.

After World War I, many a school and college adopted an all-thumbs rule-of-thumb which gave veterans too much credit, put them in advanced courses for which they were unprepared. Result: wholesale flunking. Now the American Council on Education, working closely with the armed services, is taking a good long look at each of the training and off-

ROD IN FEMUR (TWO VIEWS)
Ingenious. Satisfactory?

supply and without introducing infection. Surgeons at the hospital cautiously say they "have no opinion one way or another about this case." But they add that they are not quite satisfied with the way the bone is mending around the metal crutch, possibly because of impaired circulation.

MEDICINE

Amazing Thighbone

At England General Hospital in Atlantic City last week was a wounded soldier with a strangely mended femur (thighbone). The man had been treated by the Germans, his captors.

When the broken bone failed to heal after weeks of conventional treatment, the soldier was operated on. He was mystified to find that his only new wound was a 2½-inch incision above the hipbone. Two days later, the German surgeons told him to move his leg; a few days after that, they told him to walk. He did. He has walked ever since.

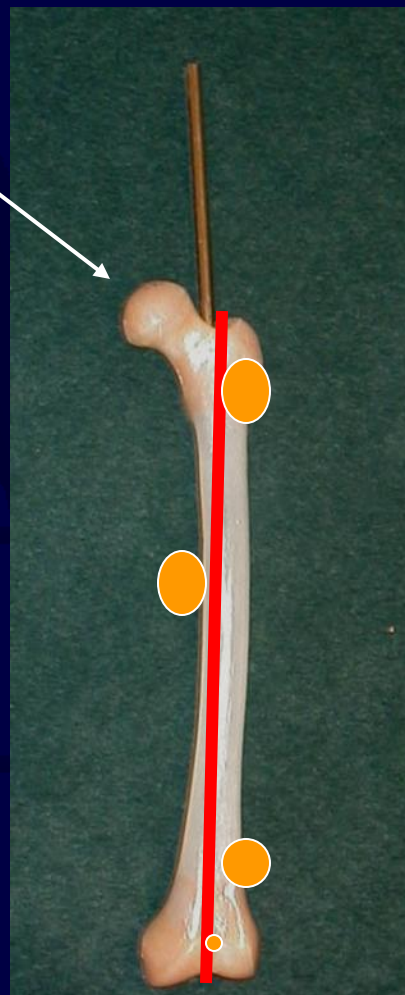
After his exchange, U.S. Army doctors X-rayed the soldier's leg. They were amazed at what they saw: a half-inch metal rod of some kind had been rammed down the thighbone through the marrow for three-quarters of the bone's length, thus supplying a permanent, internal splint.

Mechanically, the surgeons agree, there is no reason such a splint should not work if the lower end of the rod were firmly wedged in hard tissue. But in the past, use of internal splints has been restricted to slim wire to align broken bones in fingers, toes and arms. In such cases, outside splinting is also used and the mended bones are not required to withstand any end-to-end pressure. They call the rod technique "a daring operation" and wonder how their German colleagues insert it

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CORROSION
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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

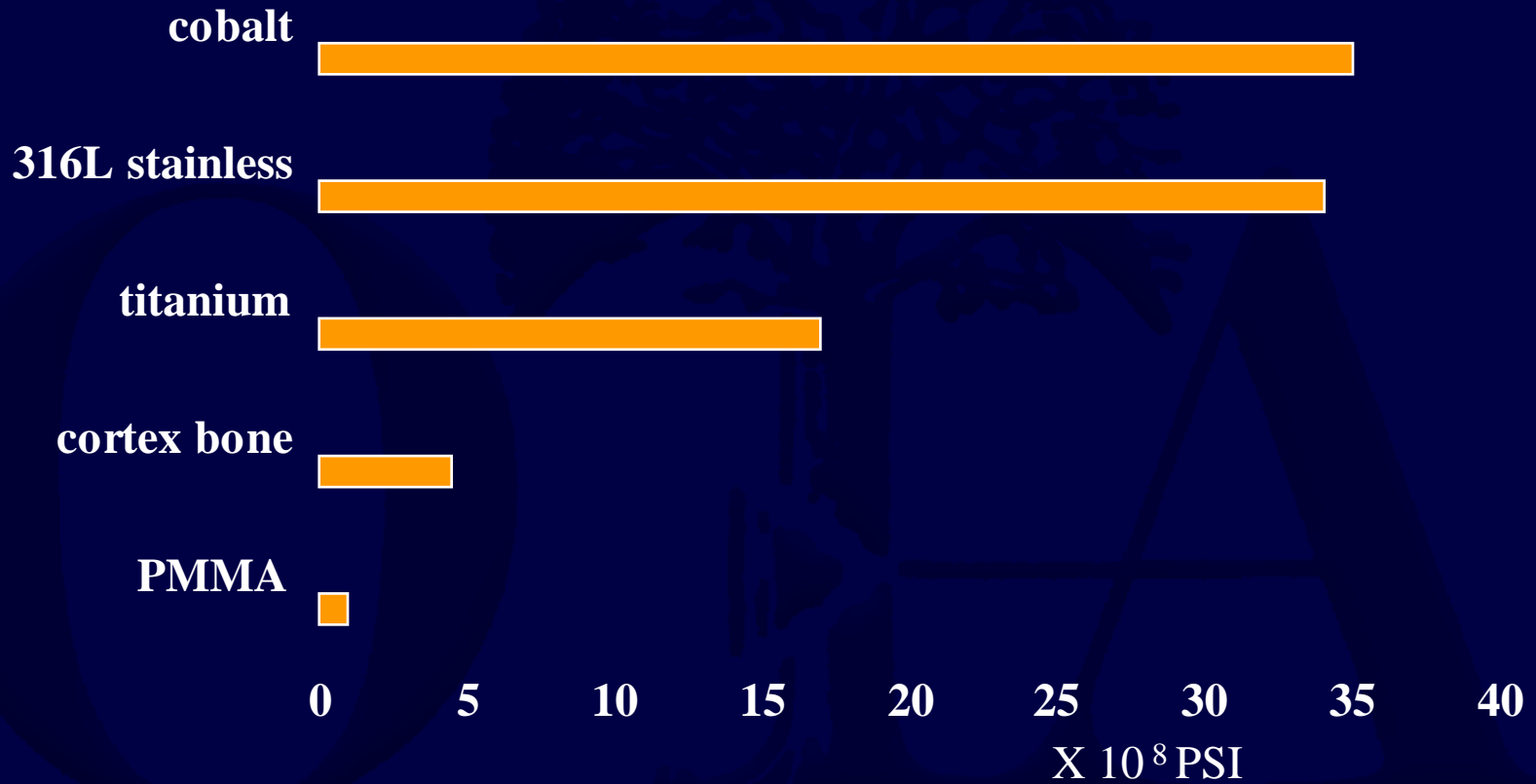


IM Nail Variables

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

Stiffness

Modulus of Elasticity



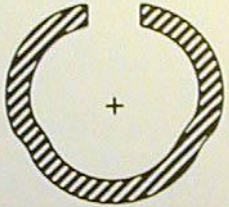
Metallurgy less important than other
parameters for stiffness of IM Nail

Wall Thickness



Large determinant of stiffness

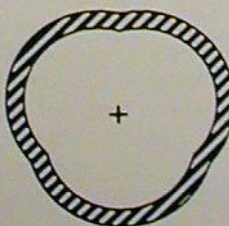
Slotted vs Non-slotted



Anterior slot - improved flexibility

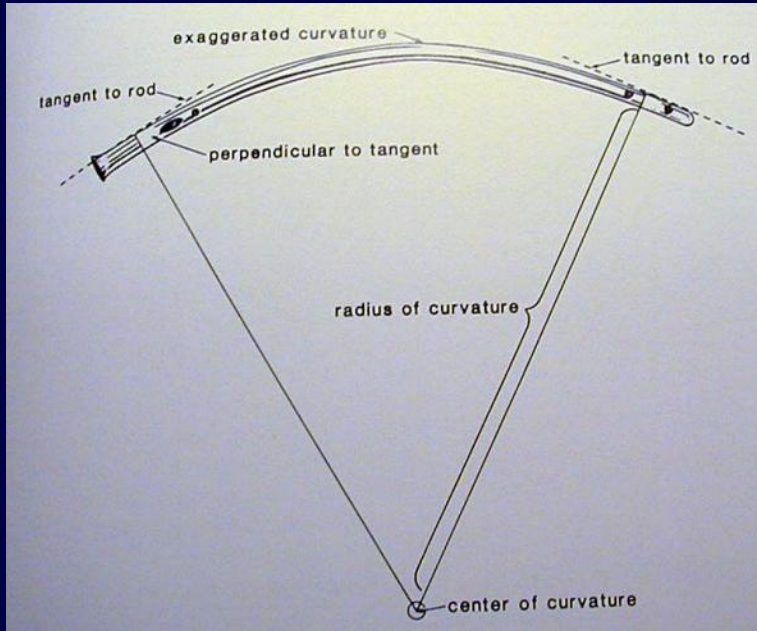


Posterior slot - increased bending strength



Non-slotted - increased torsional stiffness,
increased strength in smaller sizes, ?
comminution

Radius of Curvature of femur averages 120 cm



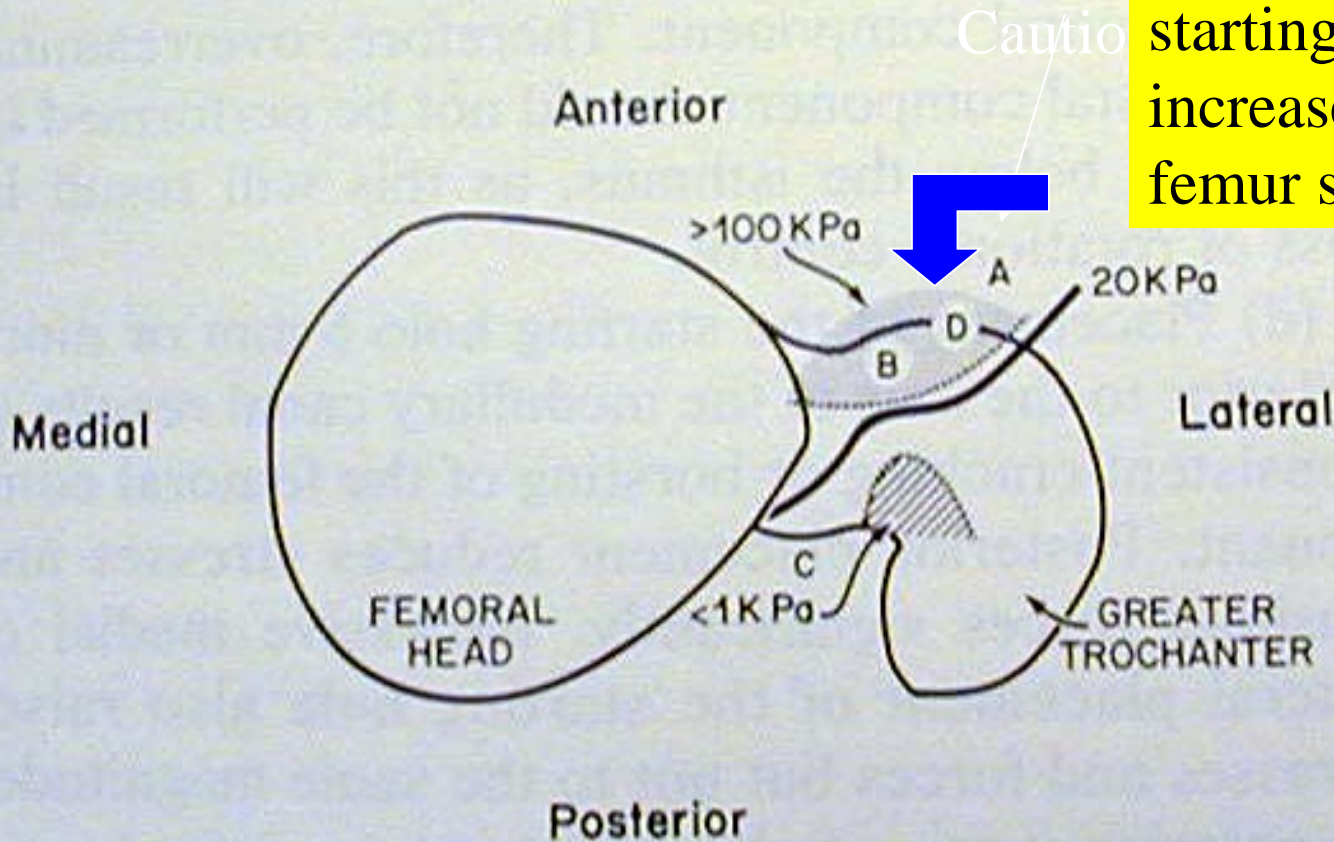
- Current femoral nails radius of curvature ranges from 150-300 cm
- IM nails are straighter (larger radius) than the femoral canal

Femur Fracture Management

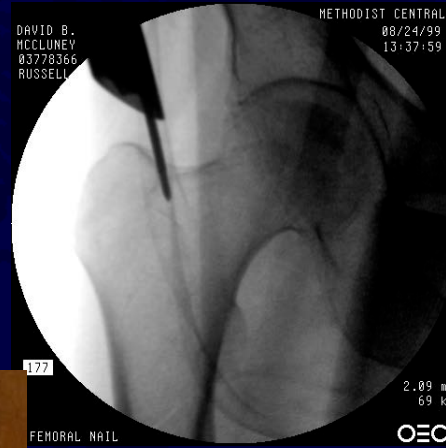
- Antegrade nailing is still the gold standard
 - Highest union rates with reamed nails
 - Extraarticular starting point
 - Refined technique
- Antegrade nailing problems:
 - Varus alignment of proximal fractures
 - Trendelenburg gait
 - Can be difficult with obese or multiply injured patients

Antegrade Femoral Nailing: piriformis fossa starting point

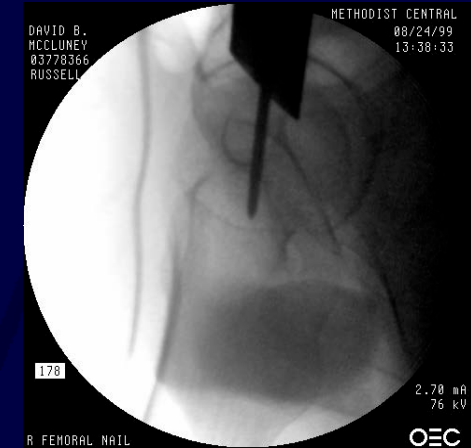
Caution !! Anterior starting point leads to increased proximal femur stresses



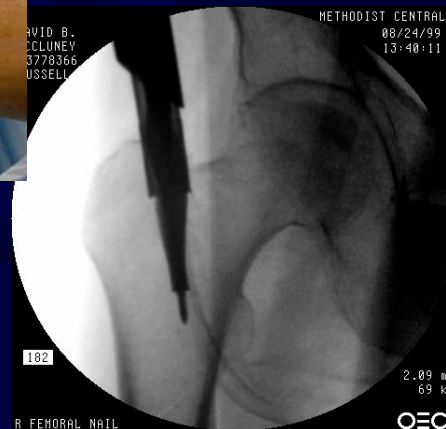
Minimally Invasive Nail Insertion Technique (MINIT)



1



2



3

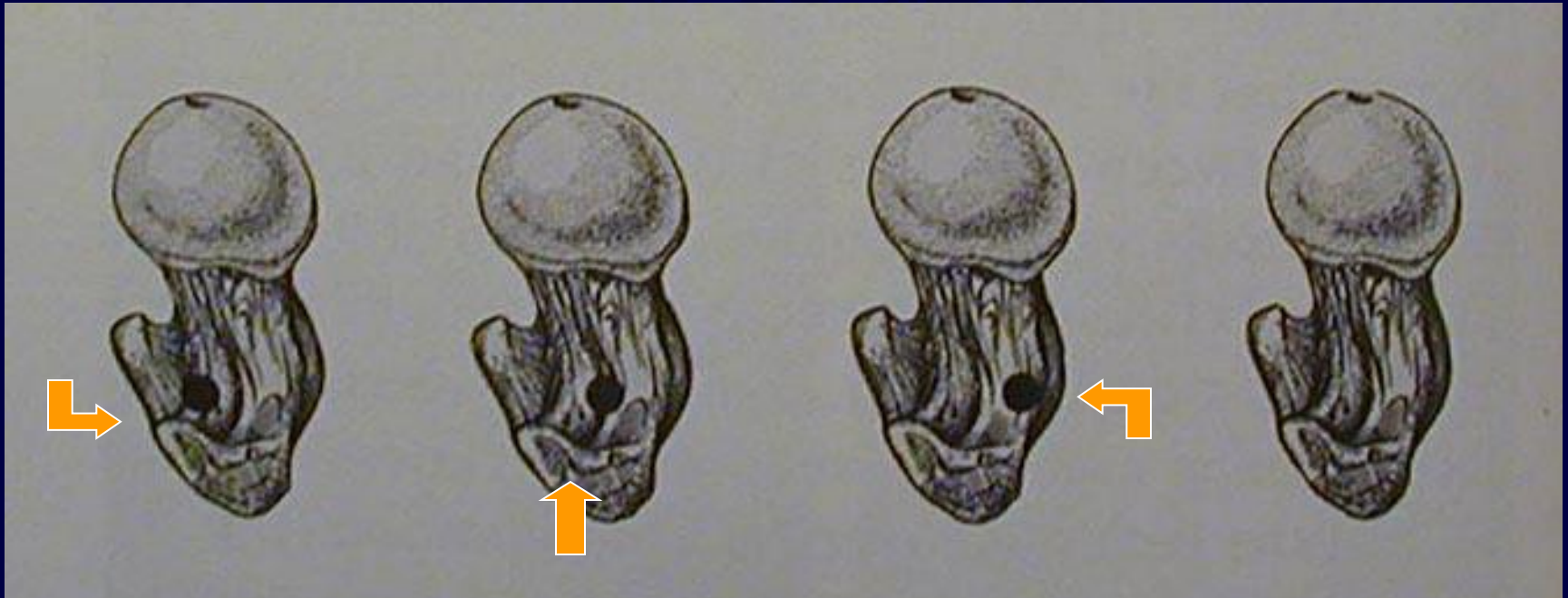


4

Courtesy T.A. Russell, M.D.

Antegrade Femoral Nailing

starting point

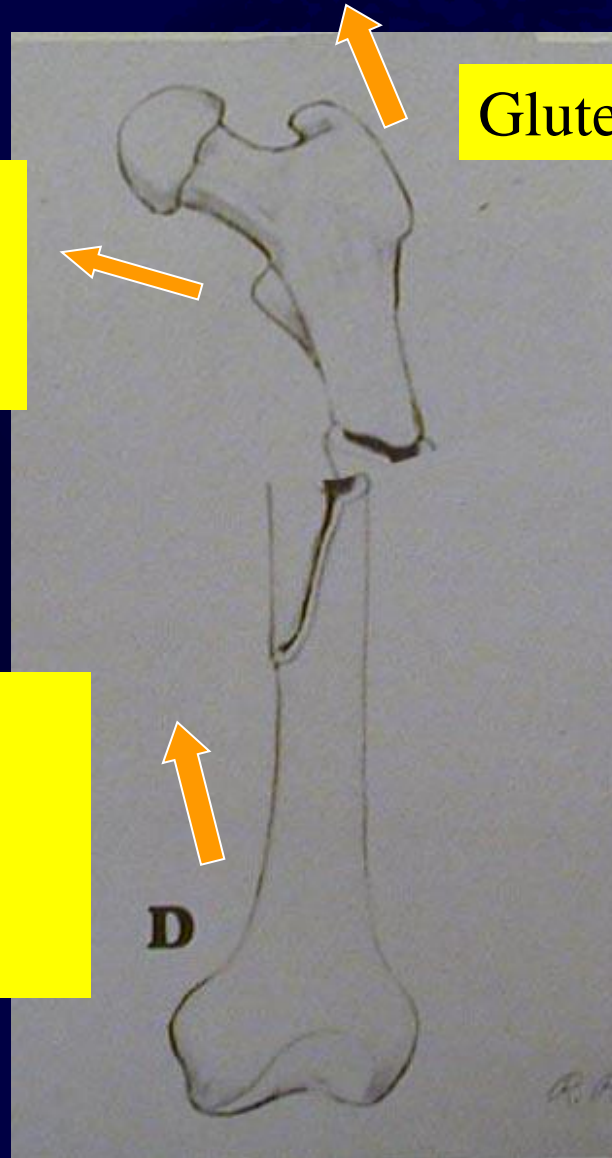


Posterior -
loss of
proximal
fixation

Piriformis
fossa- proper
starting point

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

Femur Fractures



Gluteal muscles

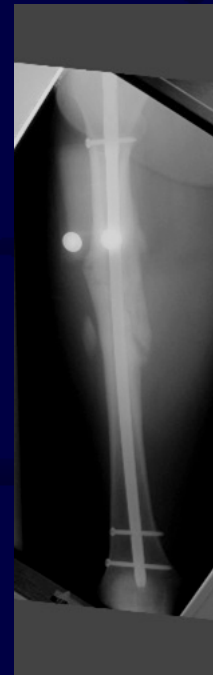
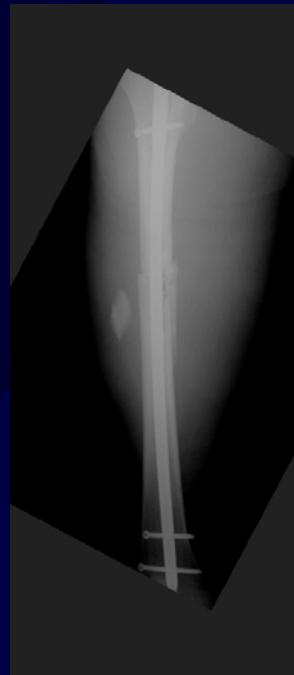
Iliopsoas leads to flexion of the proximal fragment

Adductor muscles shorten the femur

These muscle forces must be overcome to reduce and intramedullary nail the femur

Static Locking of All Femoral IM Nails !!!

- Brumbach- 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 ?

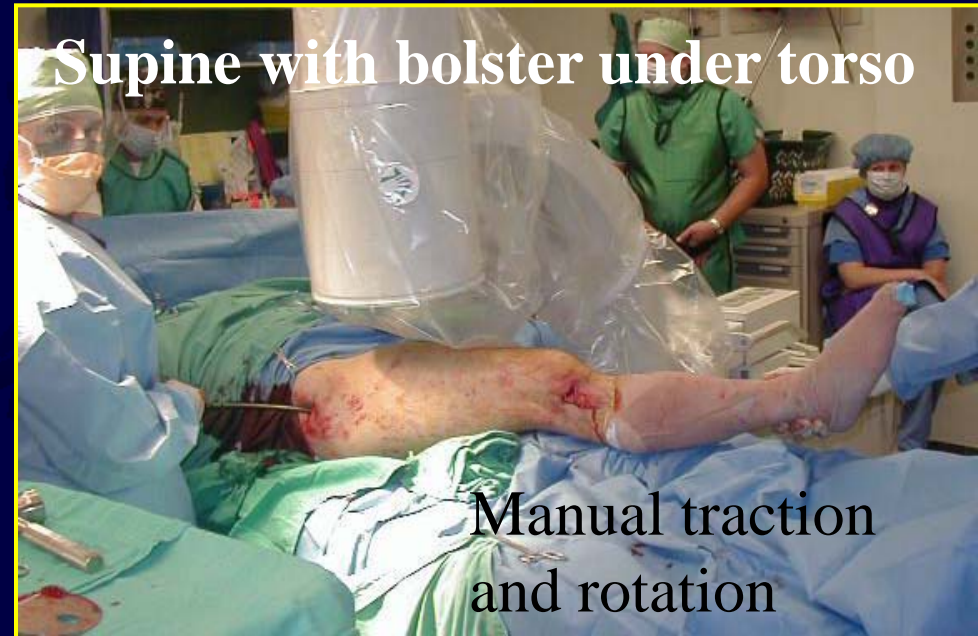
Supine - better for multiply injured patients, tough starting point

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

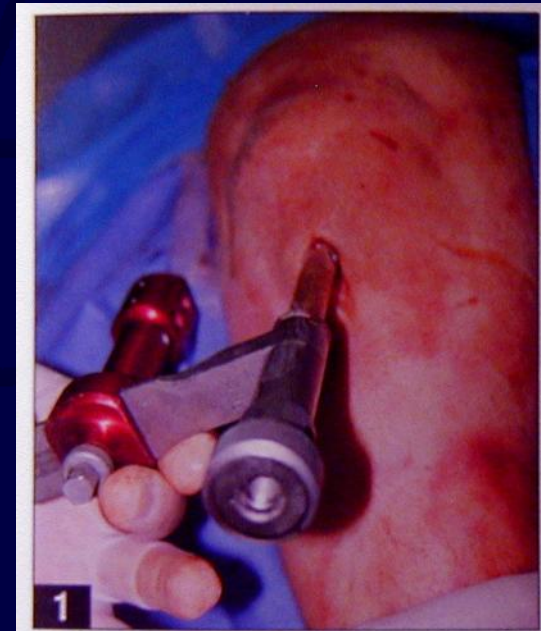
Femur Fracture Technique

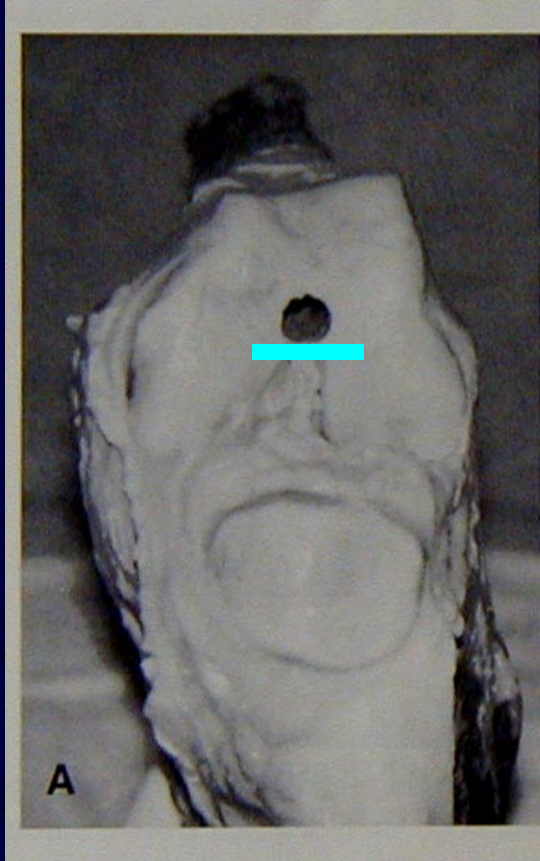
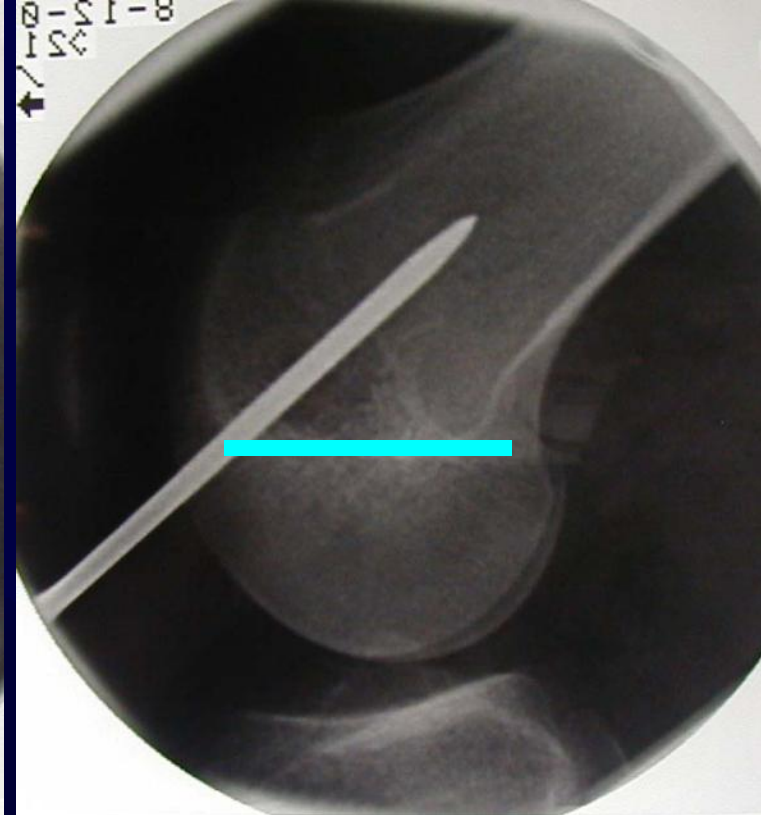
- Retrograde Intramedullary Nailing
 - Supine - flex the knee 50° to allow access to Blumensaat's line



Percutaneous with
fluoro OR

Limited open
technique





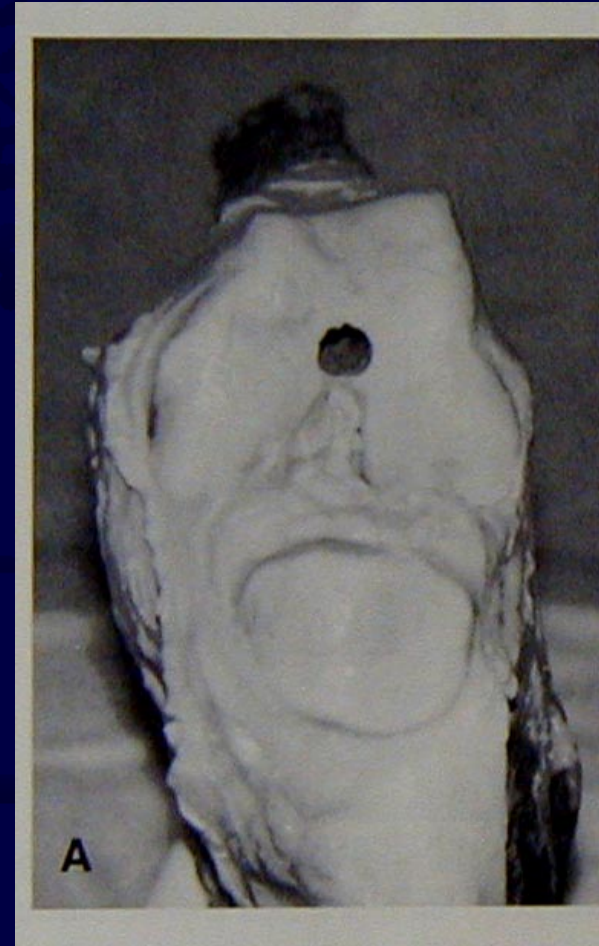
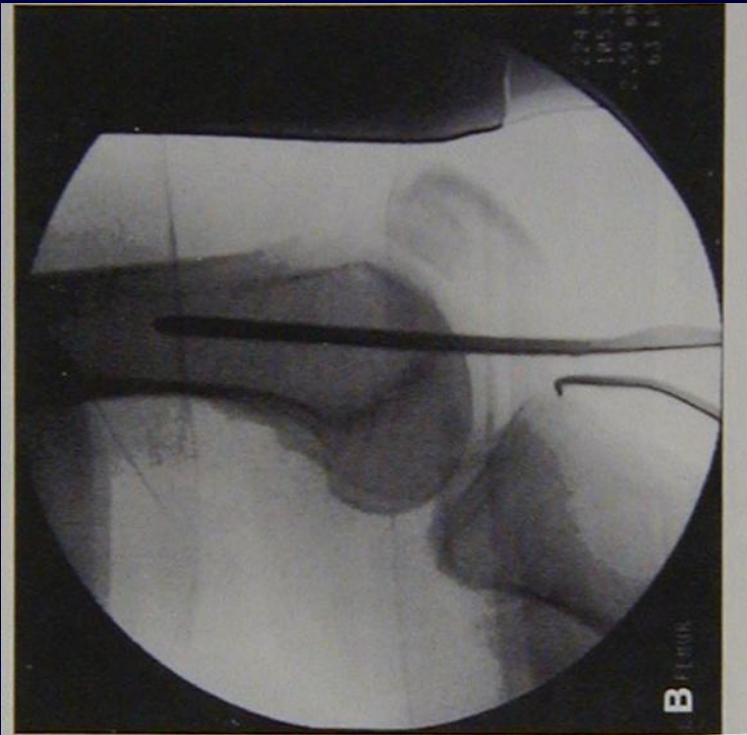
Center guide pin on AP and Lateral

Especially important for distal 1/3 fractures

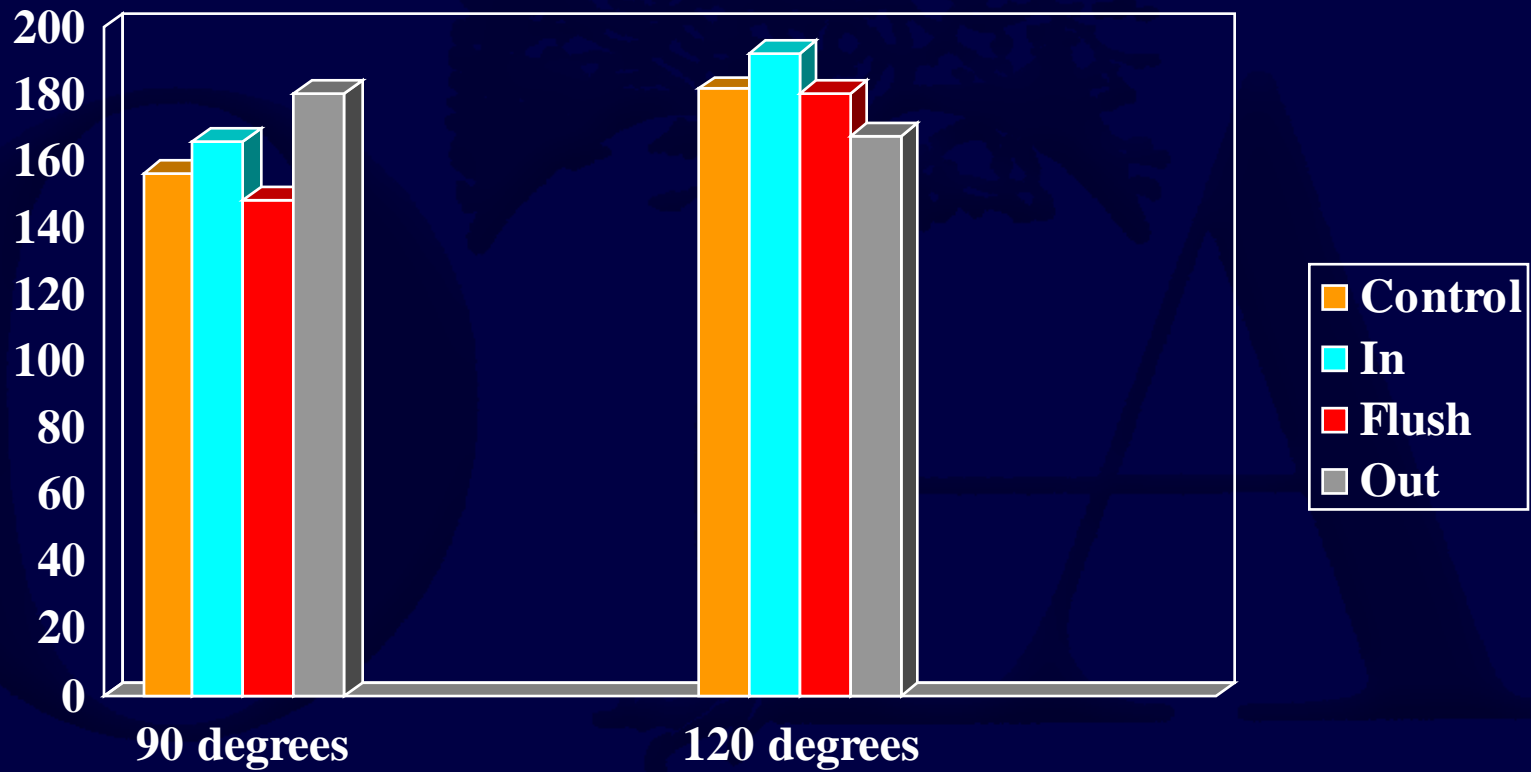
Above Blumensaat's Line

Retrograde Femoral Nailing

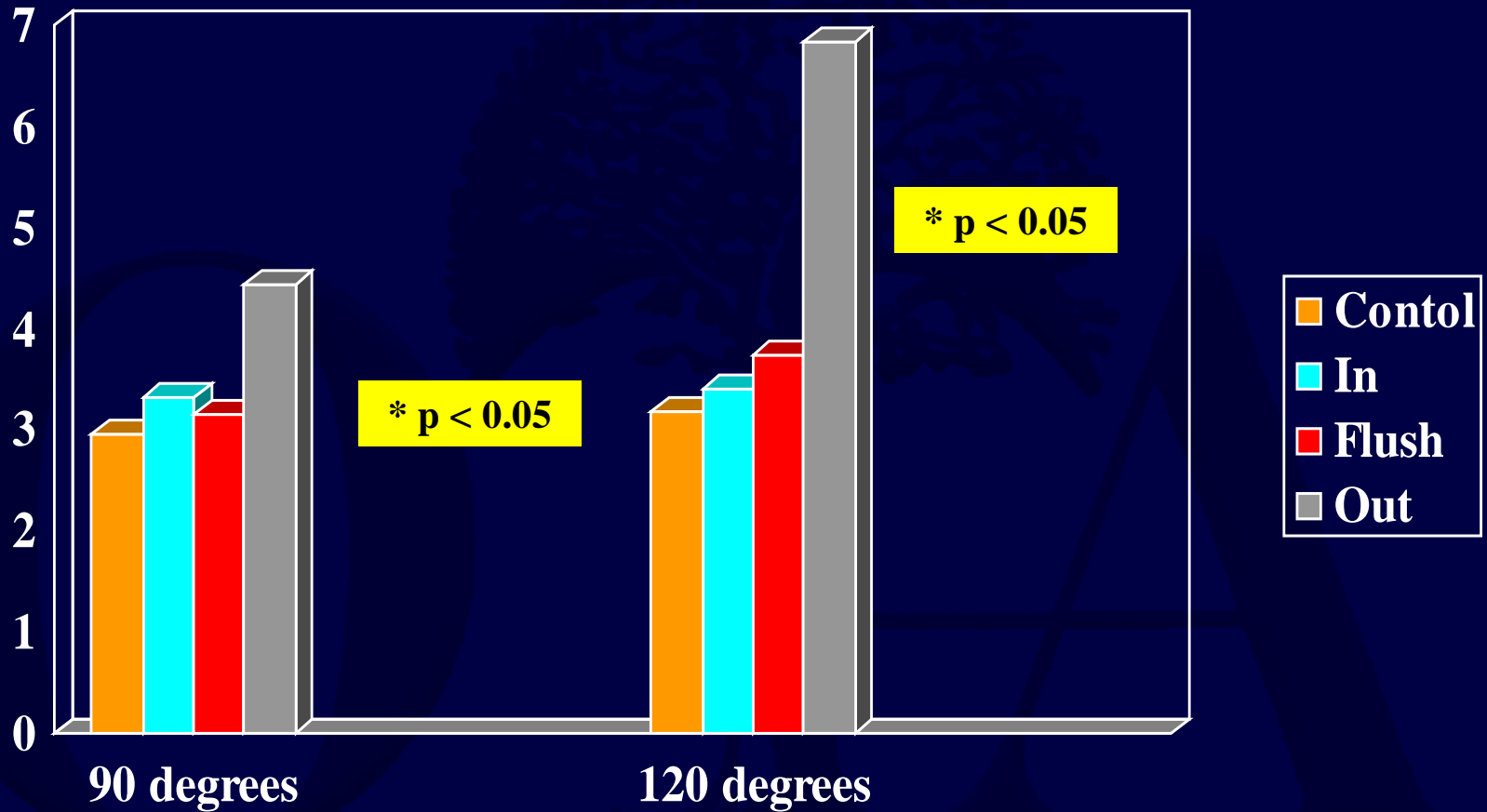
Starting Point



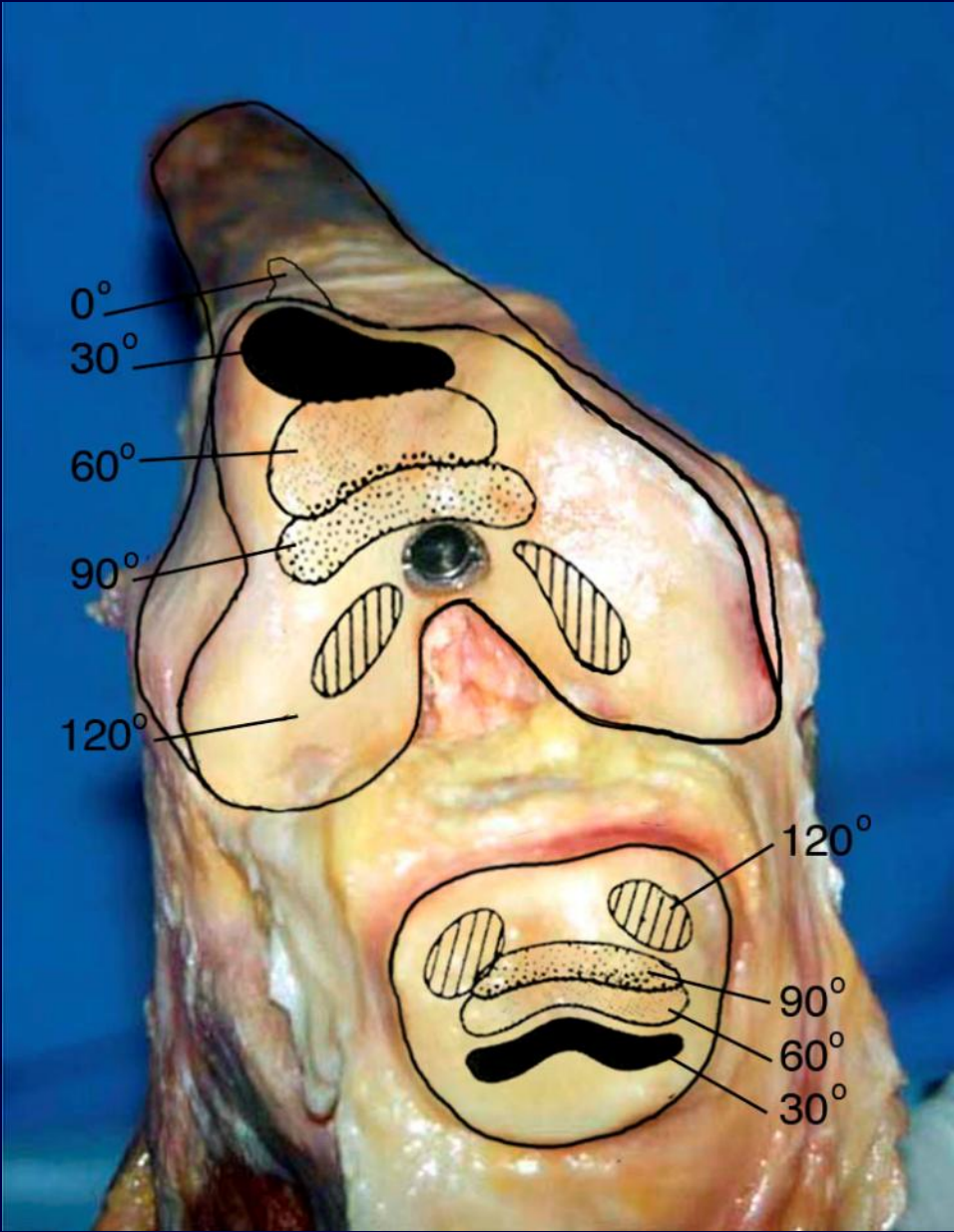
Mean Contact Area



Maximum Pressure



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

1



2



**Bilateral femur fractures
nailed retrograde**

**Less comminuted fracture
nailed first to assess length
for segmental fracture**

Retrograde IM Nail
Femur Fractures

- 42 yo male C2 femur, Gr 2 open ipsilateral tibia fx



- Immediate post-op with treatment through a limited 4cm knee incision



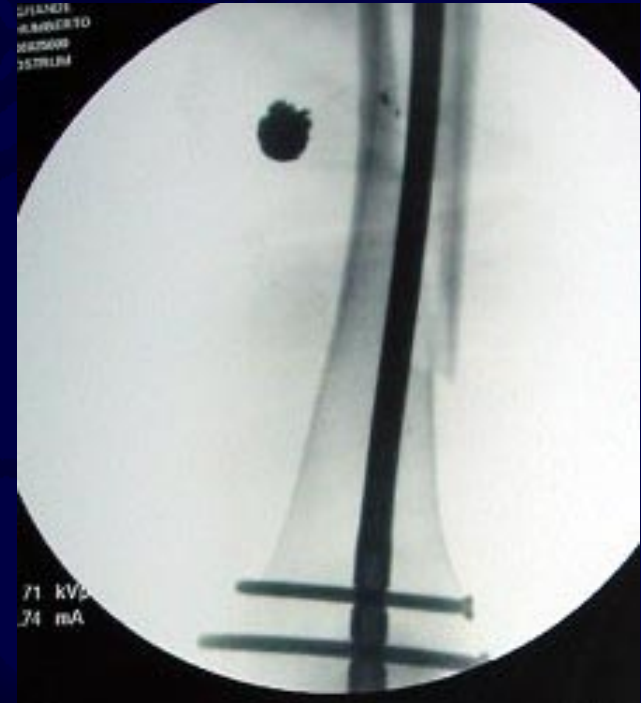
Femur Fracture Management

- 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 ?

	<u>20cm</u>	<u>36cm</u>
2 prox,sagittal	7.2*	1.8*
2 prox,coronal	6.3	4.3
1 prox,sagittal	7.6*	2.2*
1 prox,coronal	13.6*	4.4*

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

	Obese BMI >30	Non-Obese BMI <30	
Ante OR Time	94	Retrograde nailing is easier in obese patients !!	
Retro OR Time	67		
Ante Fluoro	247	135	P<.03
Retro Fluoro	76	63	nss

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 Nail: Poor T

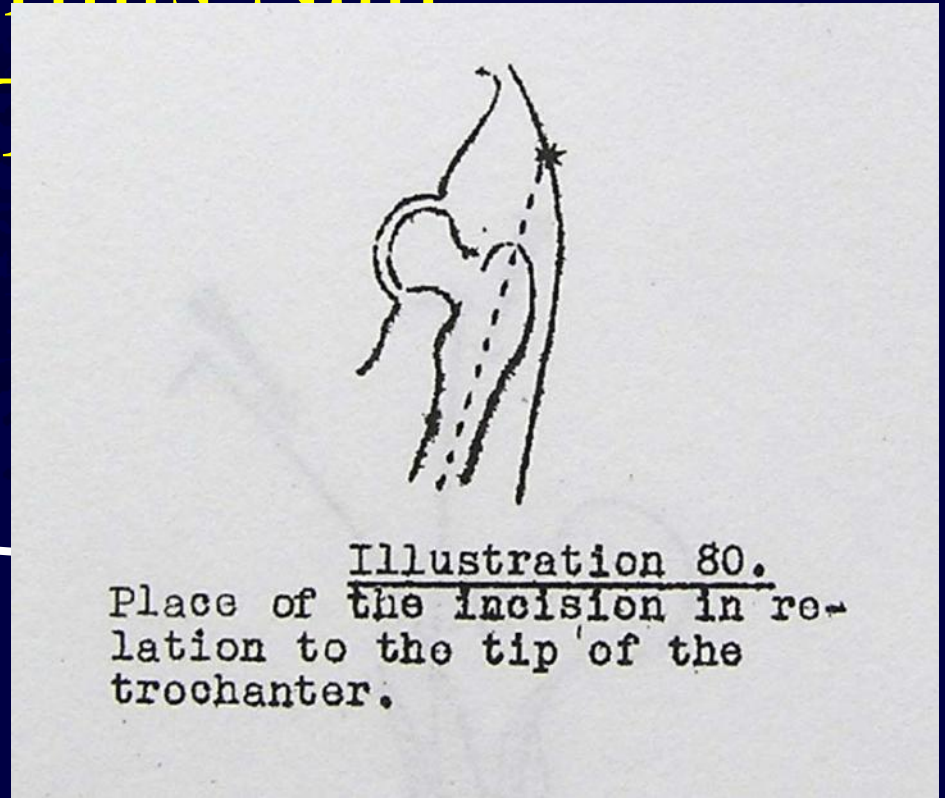
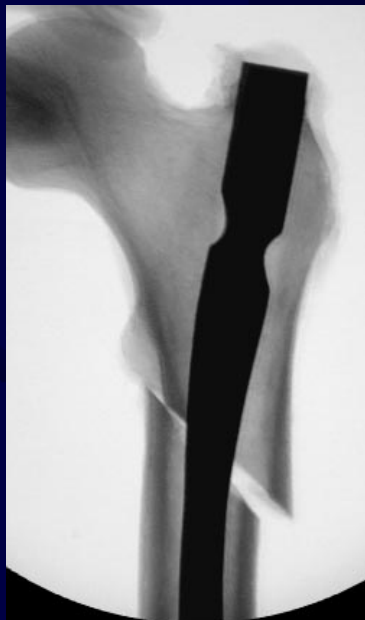


Illustration 80.
Place of the incision in re-
lation to the tip of the
trochanter.



three different
starting points
were used



**Tip of
Trochanter**

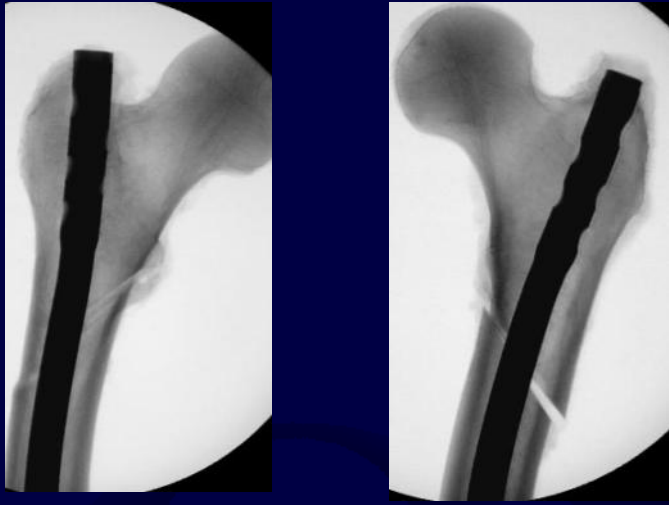


**2-3 mm
medial to tip**



**2-3 mm
lateral to tip**

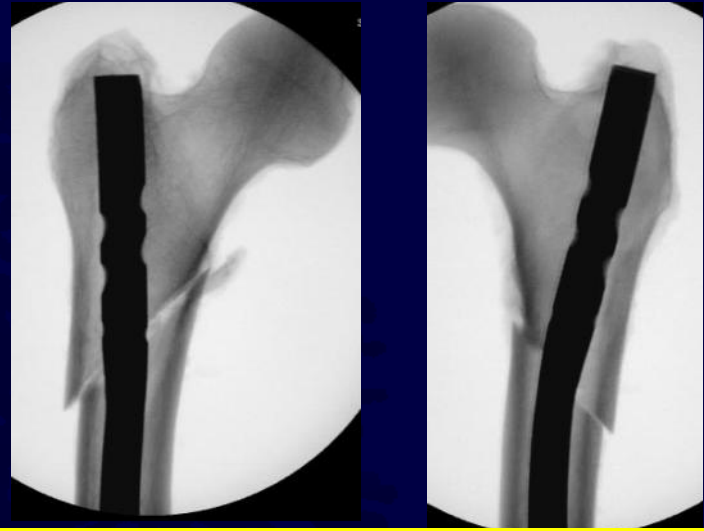
TAN



Medial

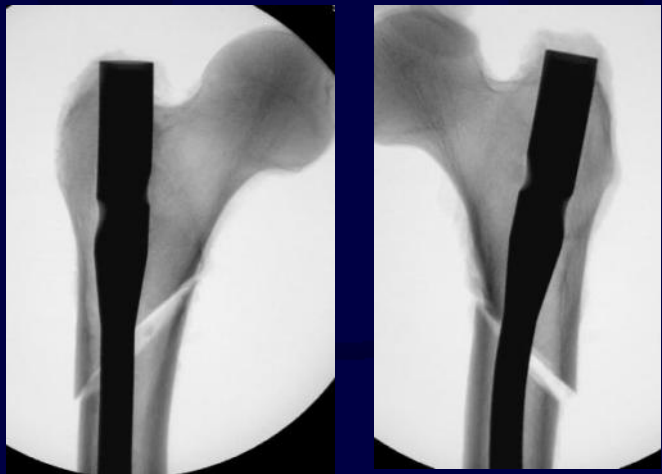
Lateral

Holland



Femur # 9

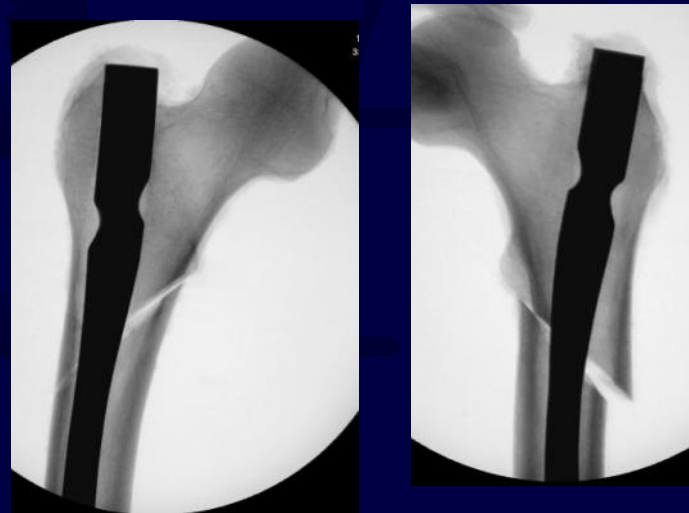
TFN



Medial

Lateral

Gamma



Medial

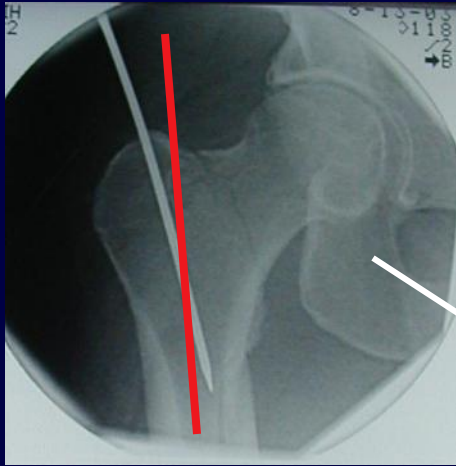
Lateral

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

Lateral starting point with varus !

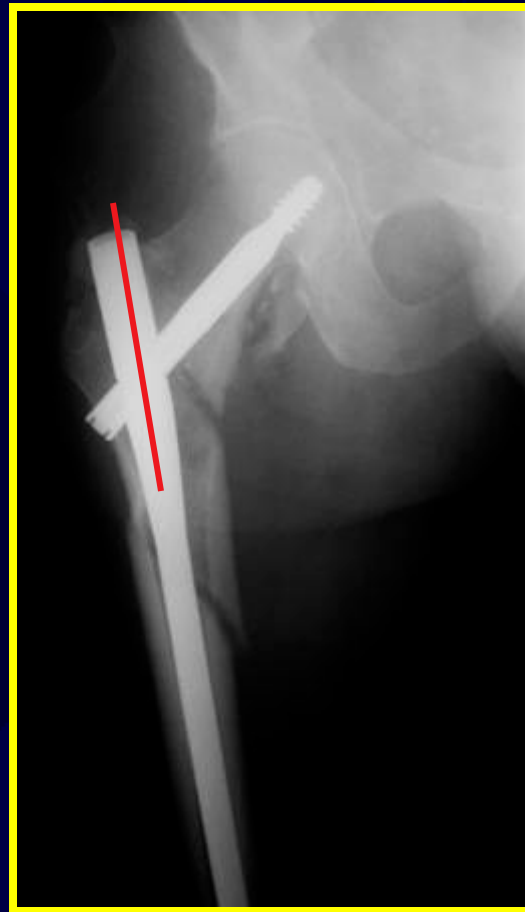


Lateral to tip of GT is OK for shaft fractures

Medial to the tip of the GT for subtrochanteric fractures



Reduction with **medial** tip starting point

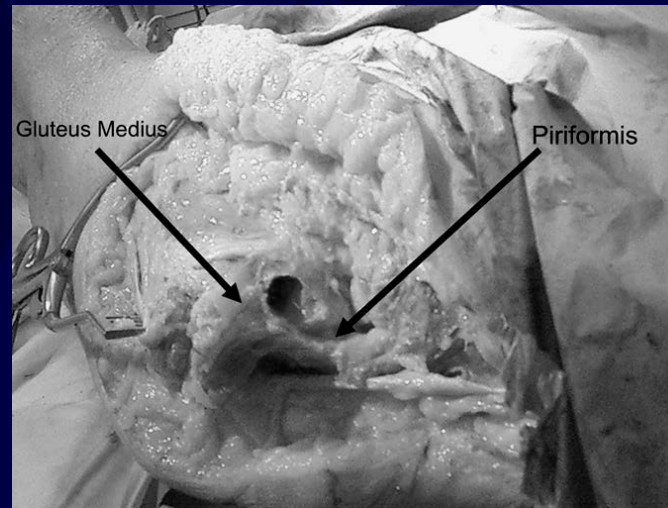




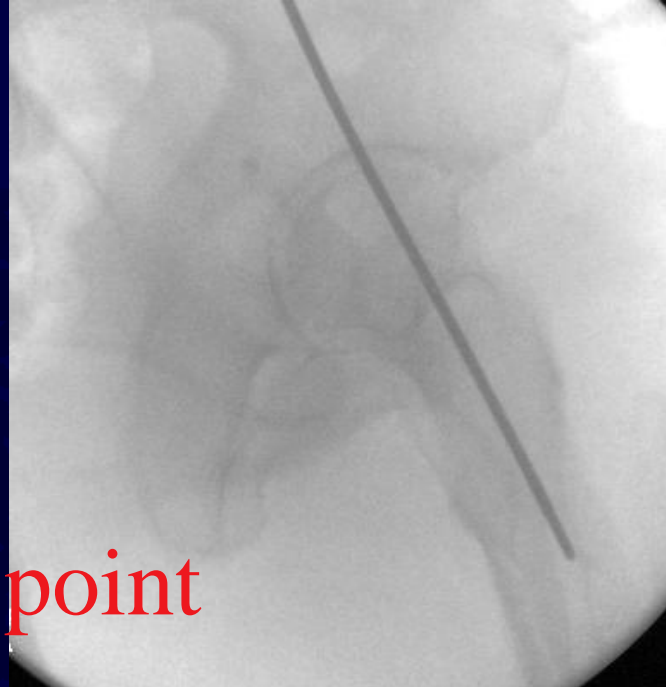
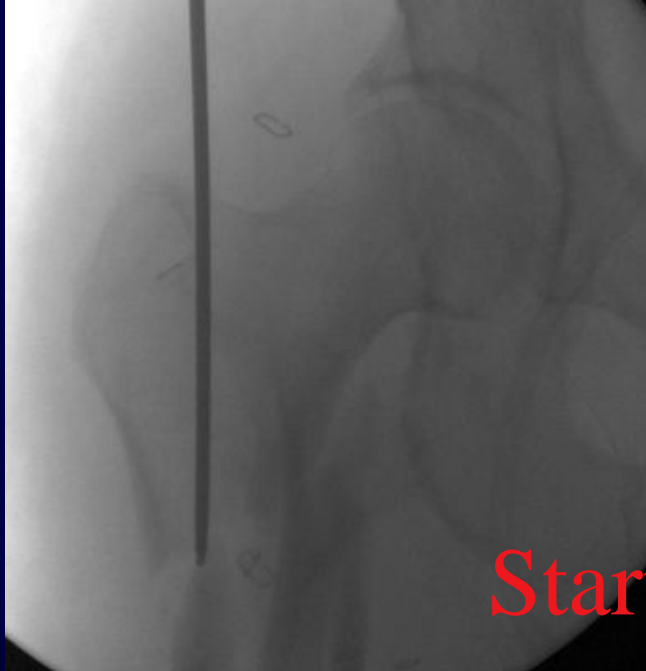
AP

Lateral

Medial Trochanteric Portal



Perez E, Russell TA. JOT 2007



Starting point



Reduction

0 kVp
6 mA



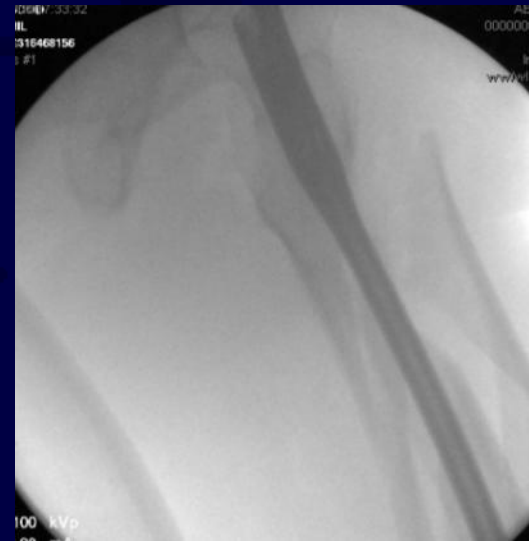
- Assessing rotation in the lateral position



- 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

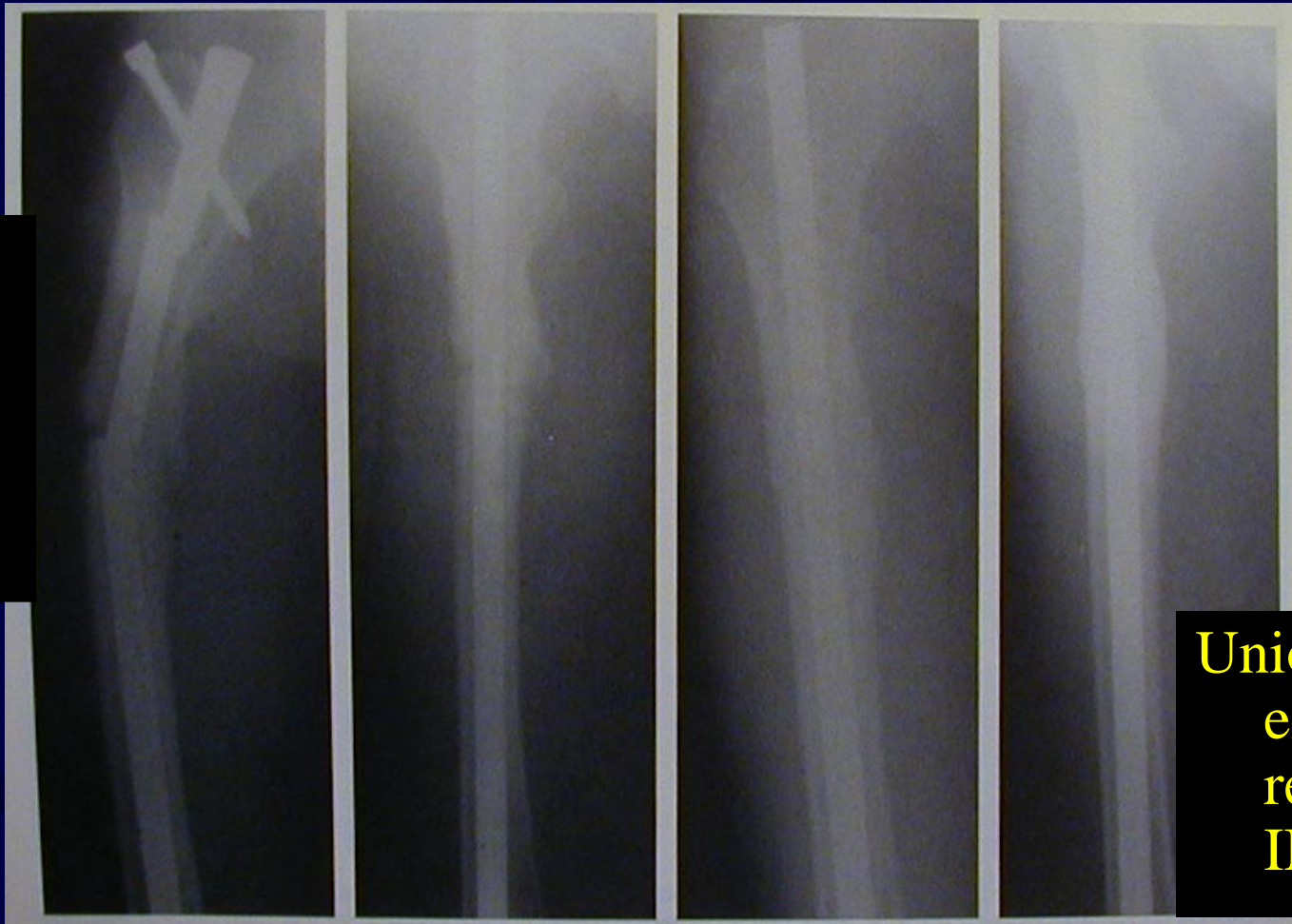
A prospective, randomized comparison of trochanteric vs piriformis fossa entry portal for high energy proximal femur fractures

- NO difference in : Hip Scores, RTW, Ambulation, Hip/Knee ROM
- Varus ≥ 5 degrees
 - Recon = 2
 - Gamma = 4
- BMI significantly linked to duration of OR and length of incision, NOT EBL

Femur Fracture Complications

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

Femur Fracture Nonunion

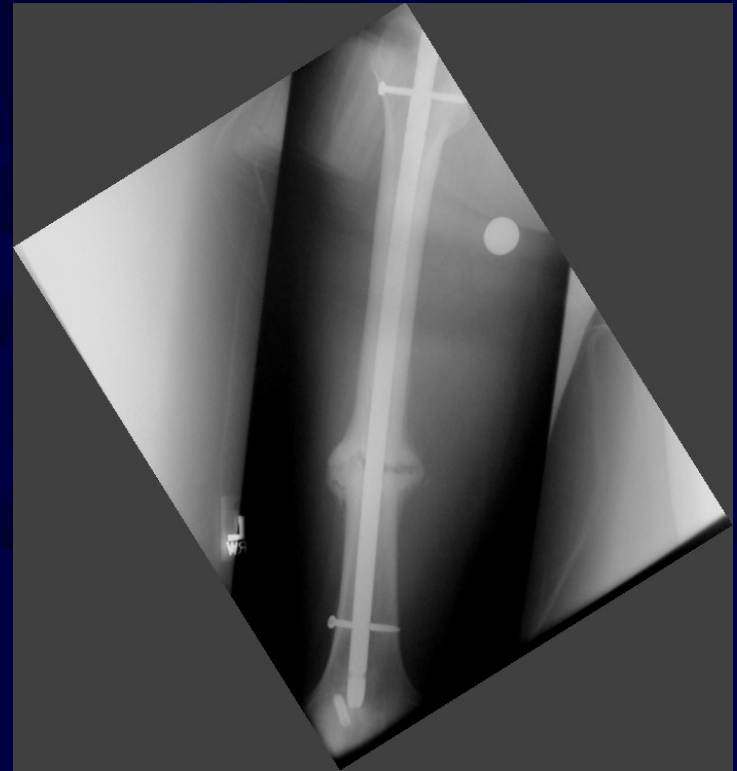
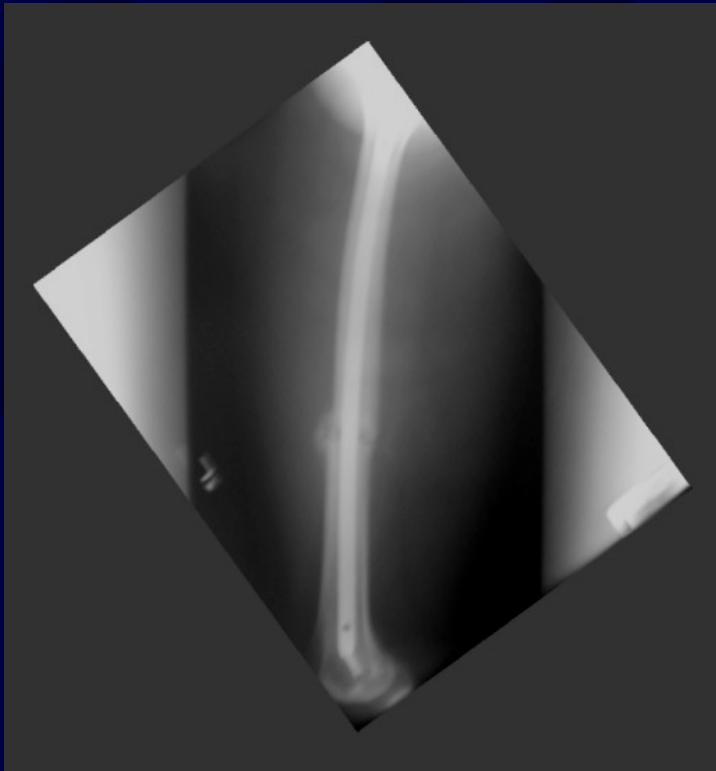


Femoral
nonunion
with
broken IM
Nail

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)

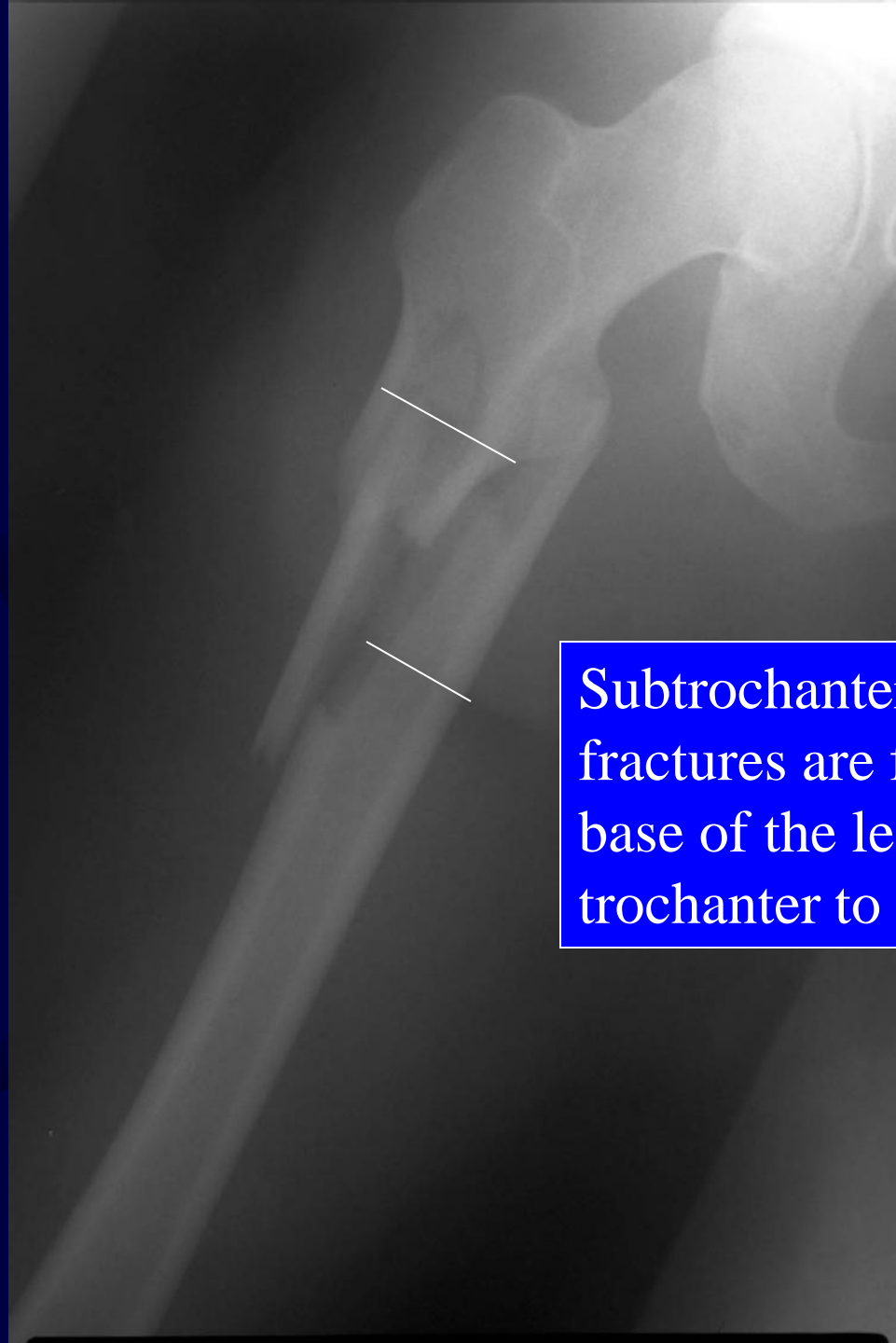
Exchange Nailing of femoral Nonunions

- 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

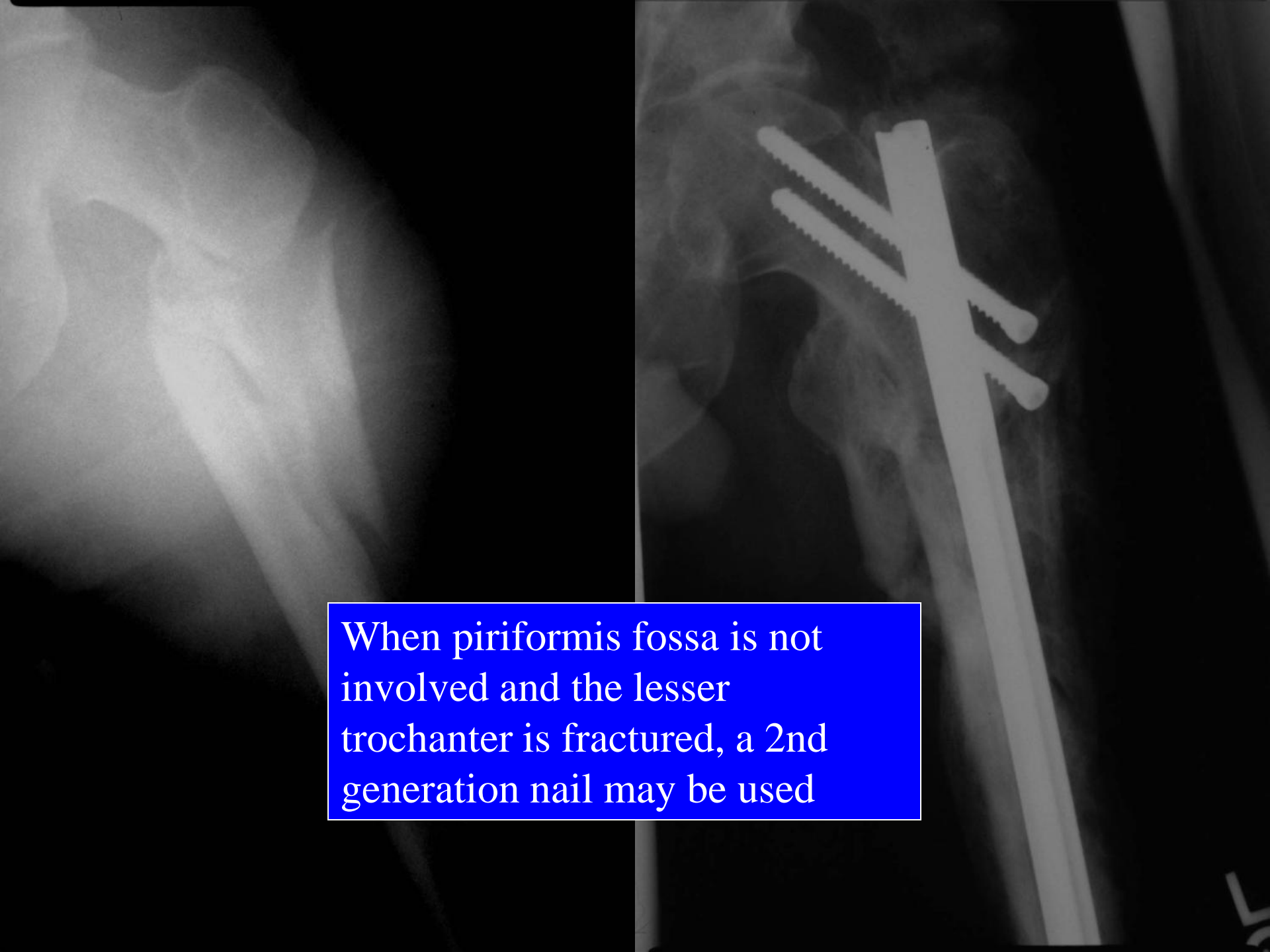


Subtrochanteric fractures are from the base of the lesser trochanter to 5 cm distal

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

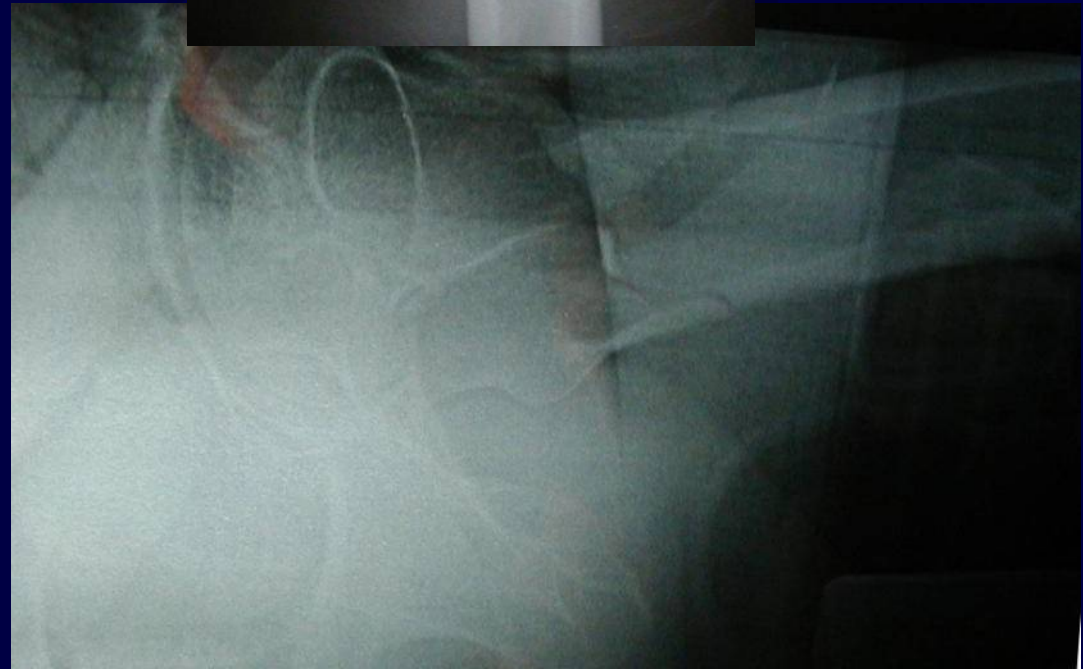
or...

Plate



R

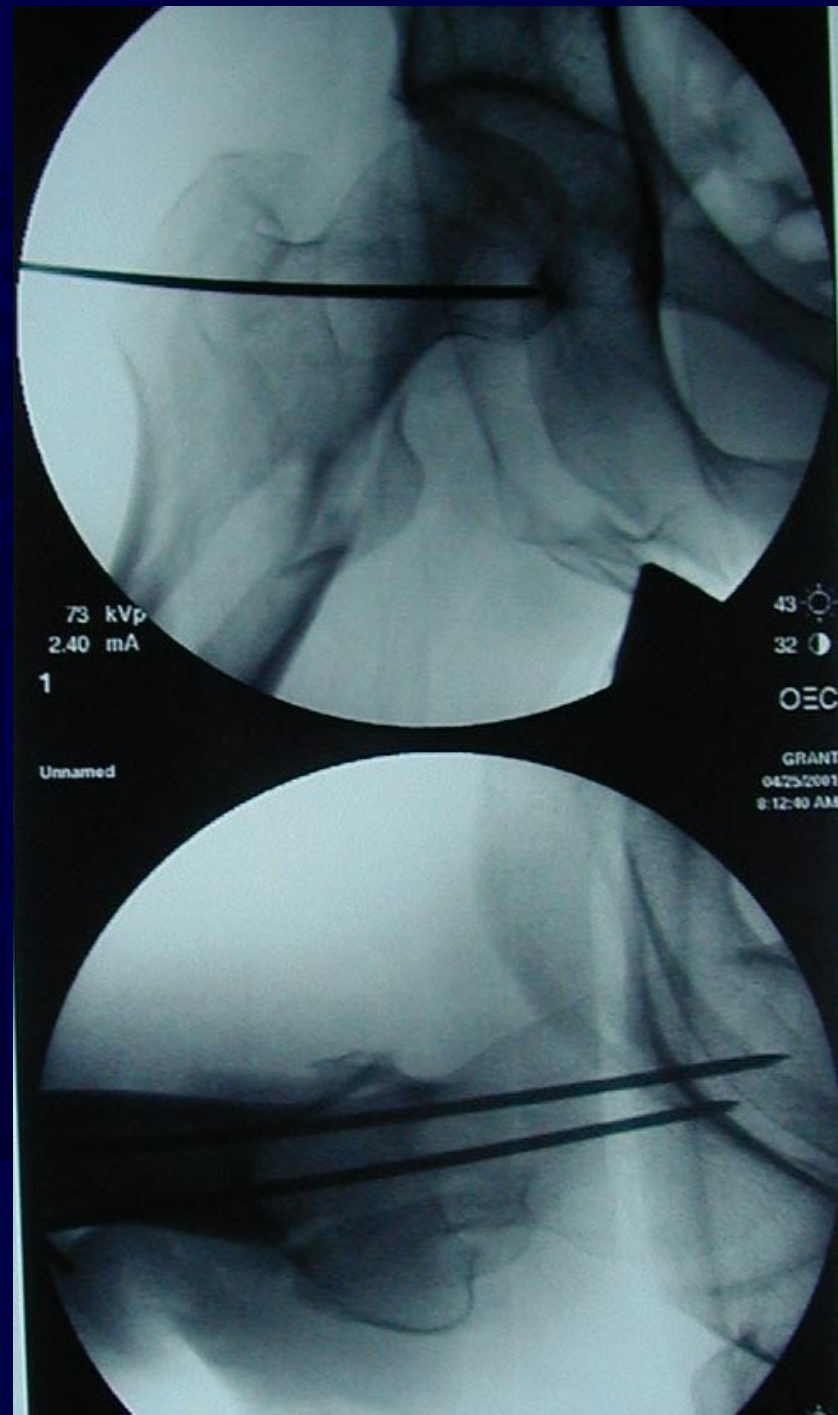
Indirect Reduction: Technique



Indirect Reduction

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

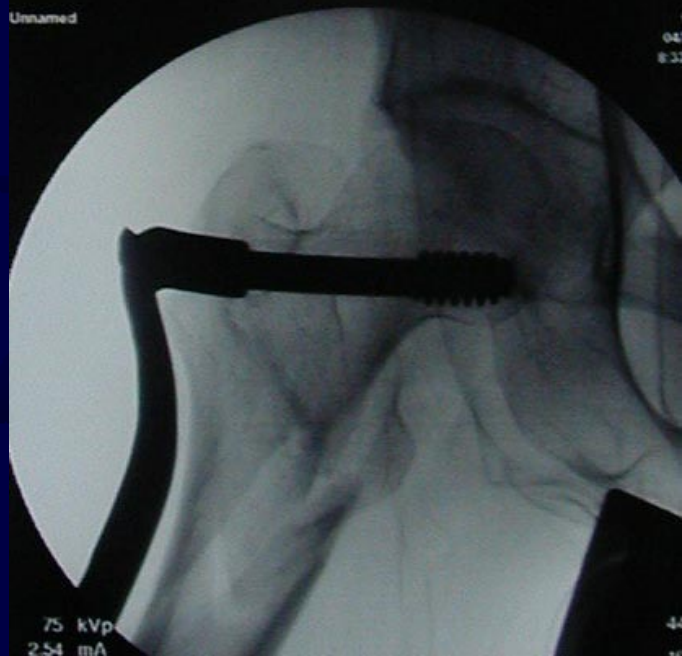
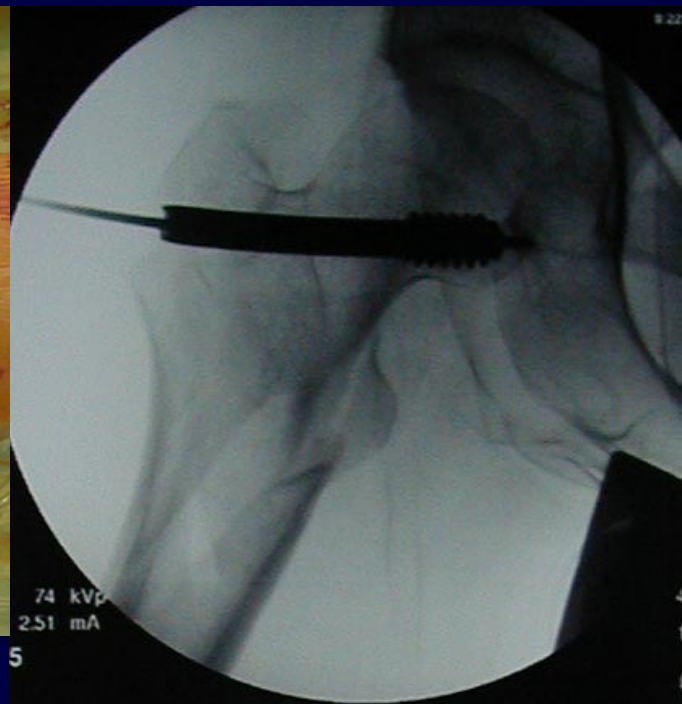
Step 2 - Percutaneous
insertion of guide pins



Knee



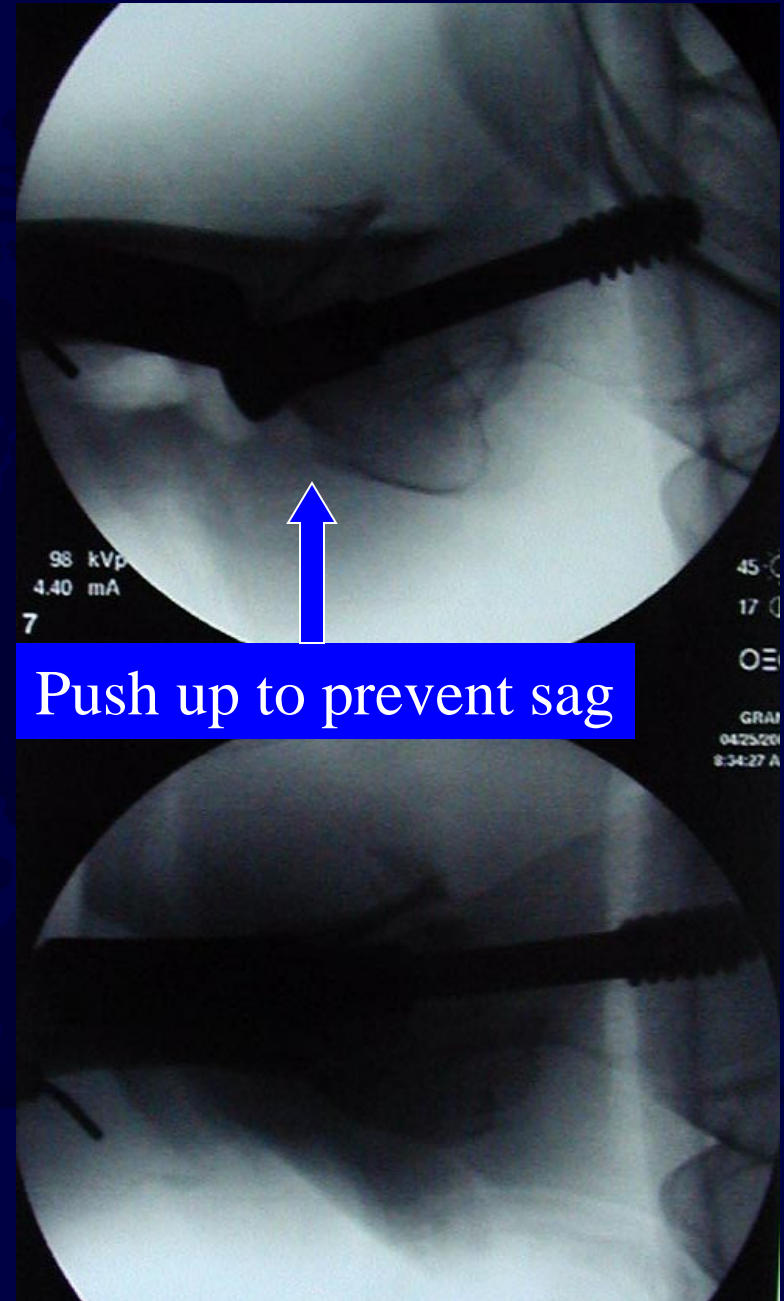
Head →

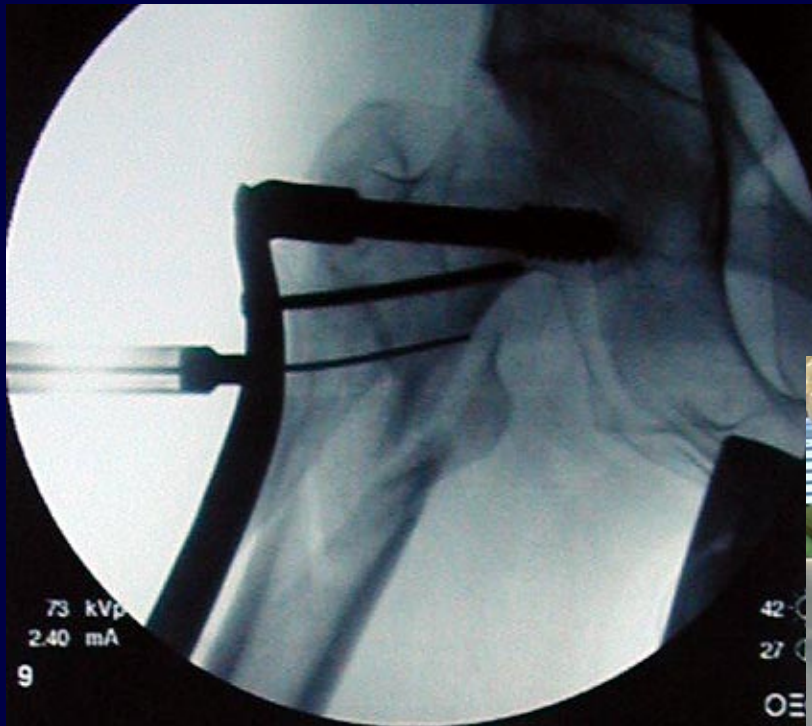


Step 3 -
Placement of
lag screw and
percutaneous
plate placement

Indirect Reduction

Step 4 - Final
reduction with
percutaneous screw
placement

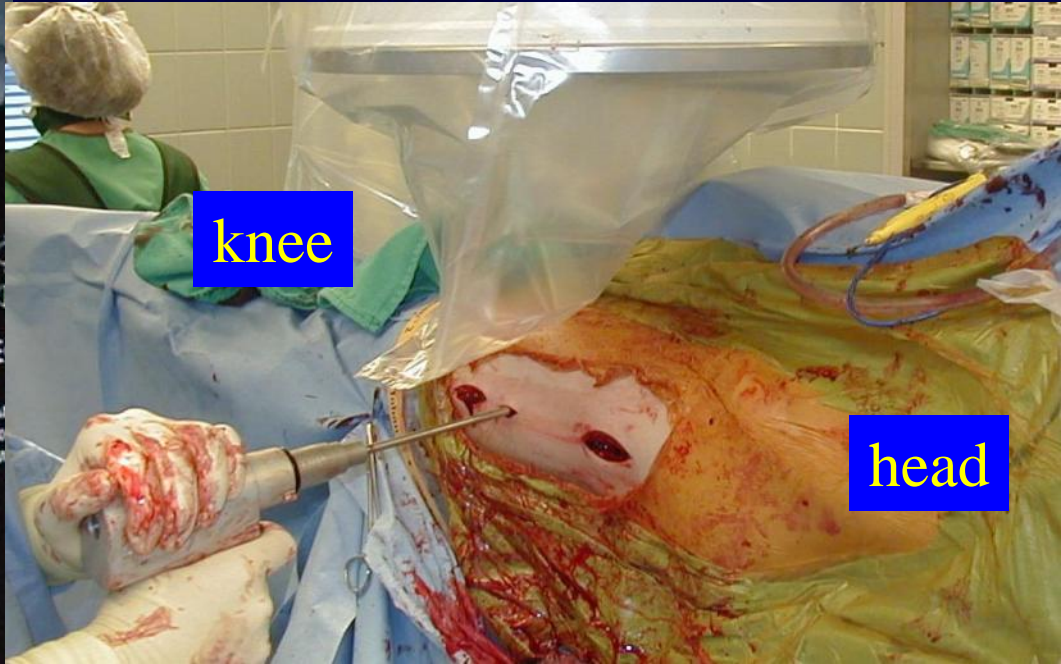




73 kVp
2.40 mA

9

Unnamed



knee

head

Screw Placement

Final films after percutaneous
Indirect Reduction of a
Subtrochanteric femur fracture

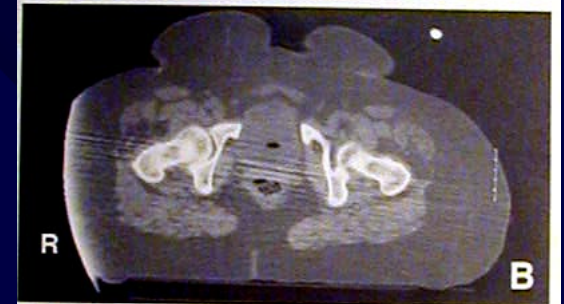


Ipsilateral Femoral Neck & Shaft Fractures

- 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 $> 70^\circ$)
- Rate of avascular necrosis is low, 3%, even when missed

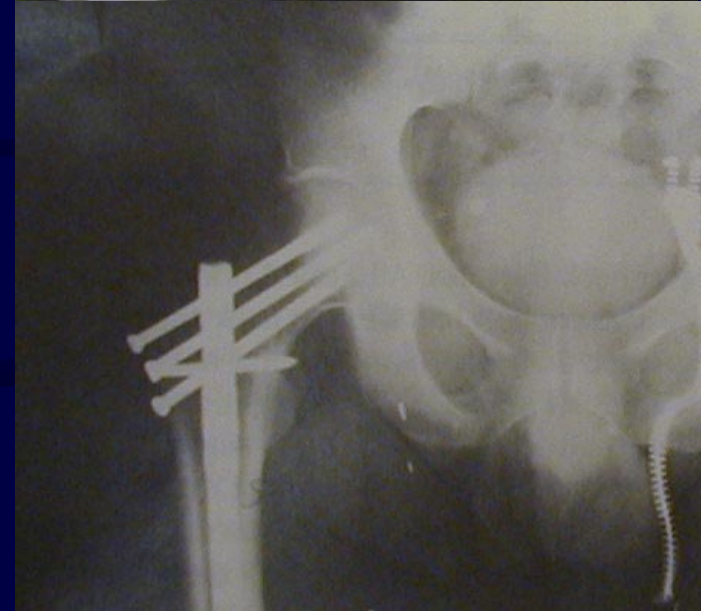
Ipsilateral Femoral Neck & Shaft Fractures

- 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



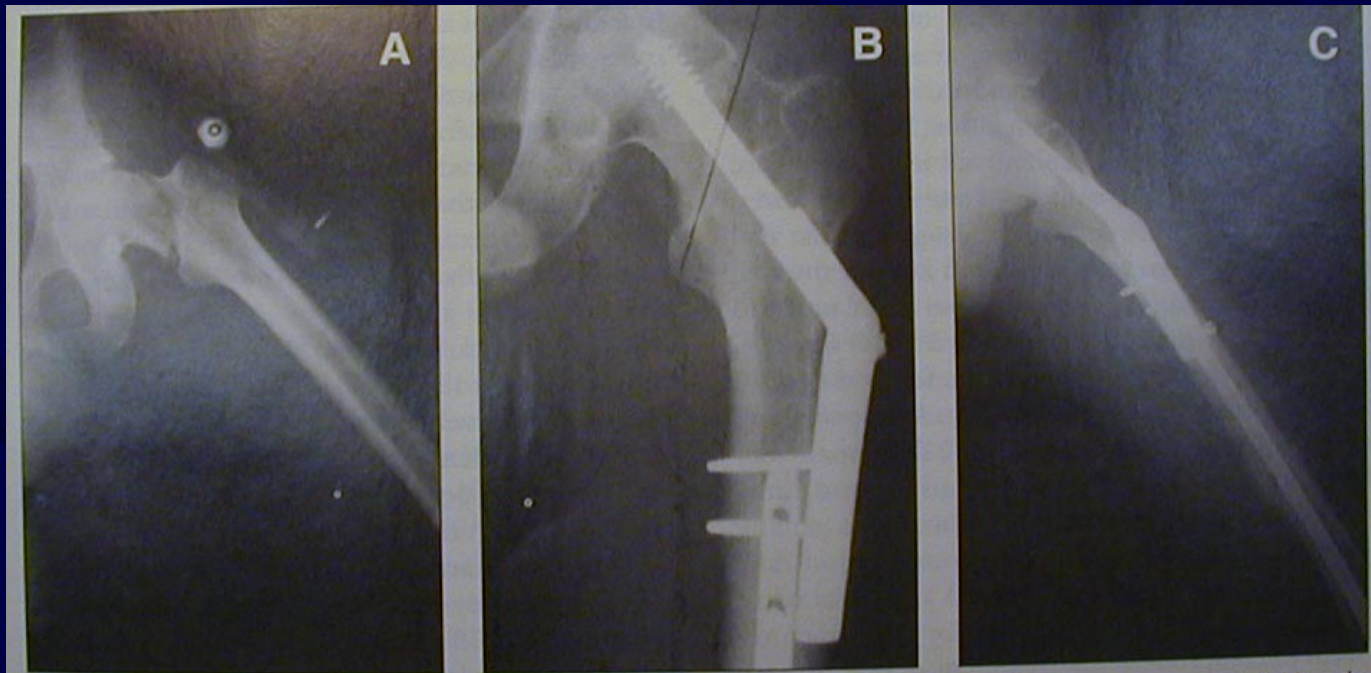
Ipsilateral Femoral Neck & Shaft Fractures

- 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

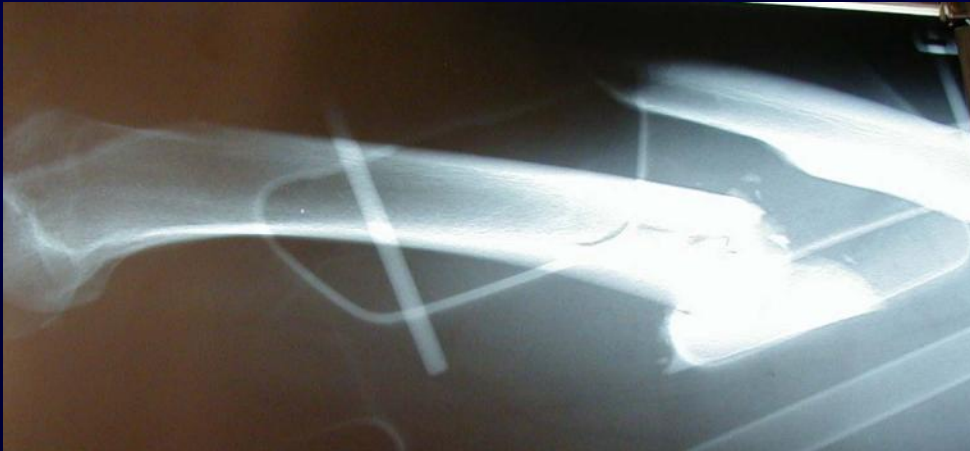
- Exchange femoral nail either in same setting or in a few days
- When found early plating or rodding of femur is rarely possible first
- Do **NOT** perform IM nailing after arterial repair without initial length restoration

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*

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Index


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