Pediatric Diaphyseal Femur Fractures

Wendy Ramalingam MD

Assistant Professor of Orthopaedic Surgery

Cincinnati Children's Hospital Medical Center

University of Cincinnati College of Medicine

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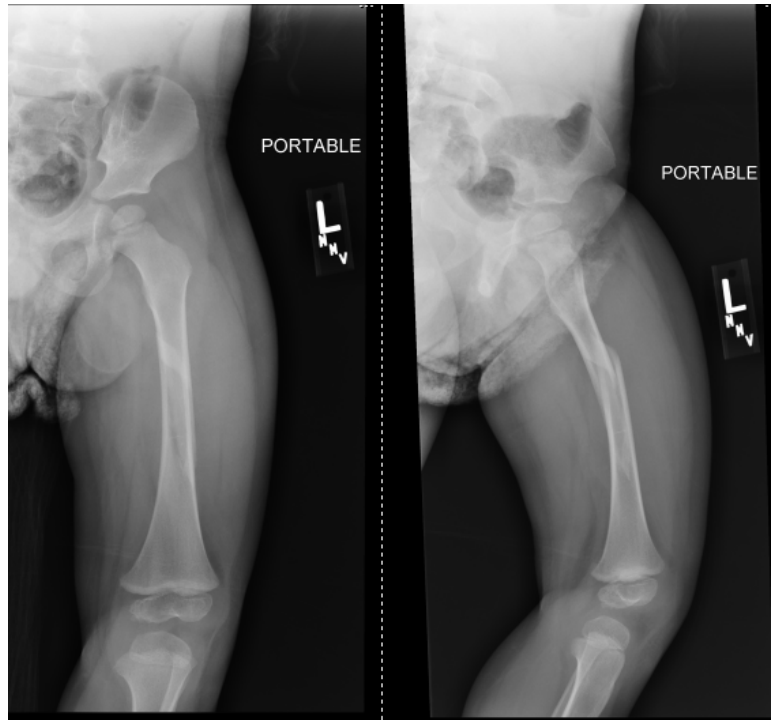
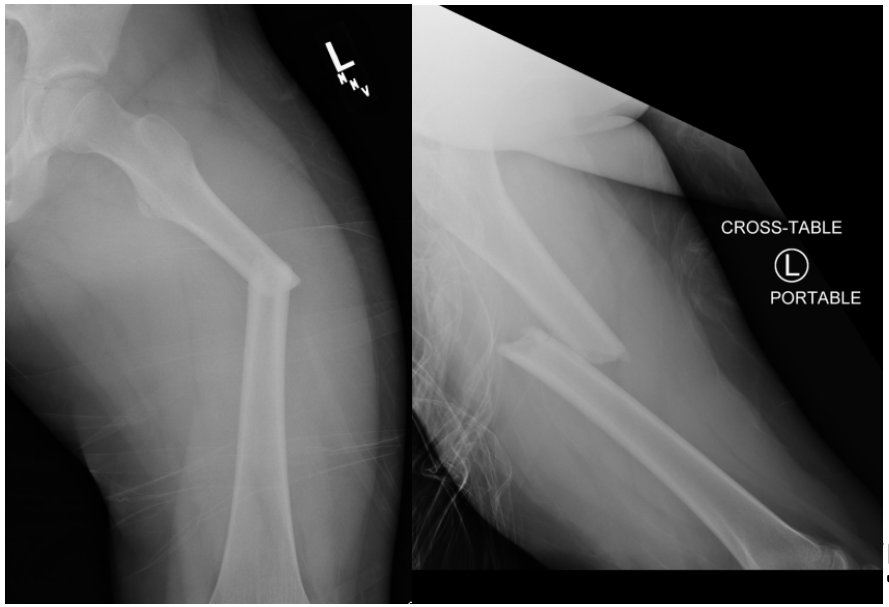
Outline

- Background
- Clinical Practice Guidelines
- Treatment Options
  - Pavlik harness
  - Spica Casting
  - Flexible Nailing
  - Submuscular Plating
  - Rigid Nail
  - External Fixation
- Complications
- References

Epidemiology

- 1.4-1.7% of all pediatric fractures
- Bimodal distribution
  - Toddlers
    - Low energy
      - Simple falls
  - Adolescents
    - Higher energy
      - ATVs, MVCs, sporting activities
- Boys > Girls





Background

- Treatment decisions based on
  - Patient age
  - Patient weight/size
  - Fracture characteristics
  - Family social situation

- Recent trend towards surgical intervention over closed treatment

AAOS Clinical Practice Guidelines 2015

- **Grade A recommendation** ★★★★
  - Children aged <36 months with a diaphyseal femur fracture should be evaluated for non-accidental trauma.
    - Level of Evidence: II
    - 12-14% of femur fractures in this age group are secondary to NAT
- **Grade B Recommendation** ★★★
  - Treatment with early spica casting or traction with delayed spica casting for children aged 6 months to 5 years with a diaphyseal femur fracture with <2 cm of shortening.
    - Level of Evidence: II

Kocher MS, Sink EL, Blasier RD, Luhmann SJ, Mehlman CT, Scher DM, Matheney T, Sanders JO, Watters WC 3rd, Goldberg MJ, Keith MW, Haralson RH 3rd, Turkelson CM, Wies JL, Sluka P, Hitchcock K. Treatment of pediatric diaphyseal femur fractures. J Am Acad Orthop Surg. 2009 Nov;17(11):718-25.

AAOS Clinical Practice Guidelines 2015

- **Grade C Recommendations** ★★
  - Treatment with a Pavlik harness or spica cast are both options for infants aged ≤6 months with a diaphyseal femur fracture.
  - When the spica cast is used in children aged 6 months to 5 years, you may consider altering the treatment plan when the fracture shortens >2 cm.
  - Waterproof cast liners for spica casts are an option for use in children diagnosed with pediatric diaphyseal femur fractures.

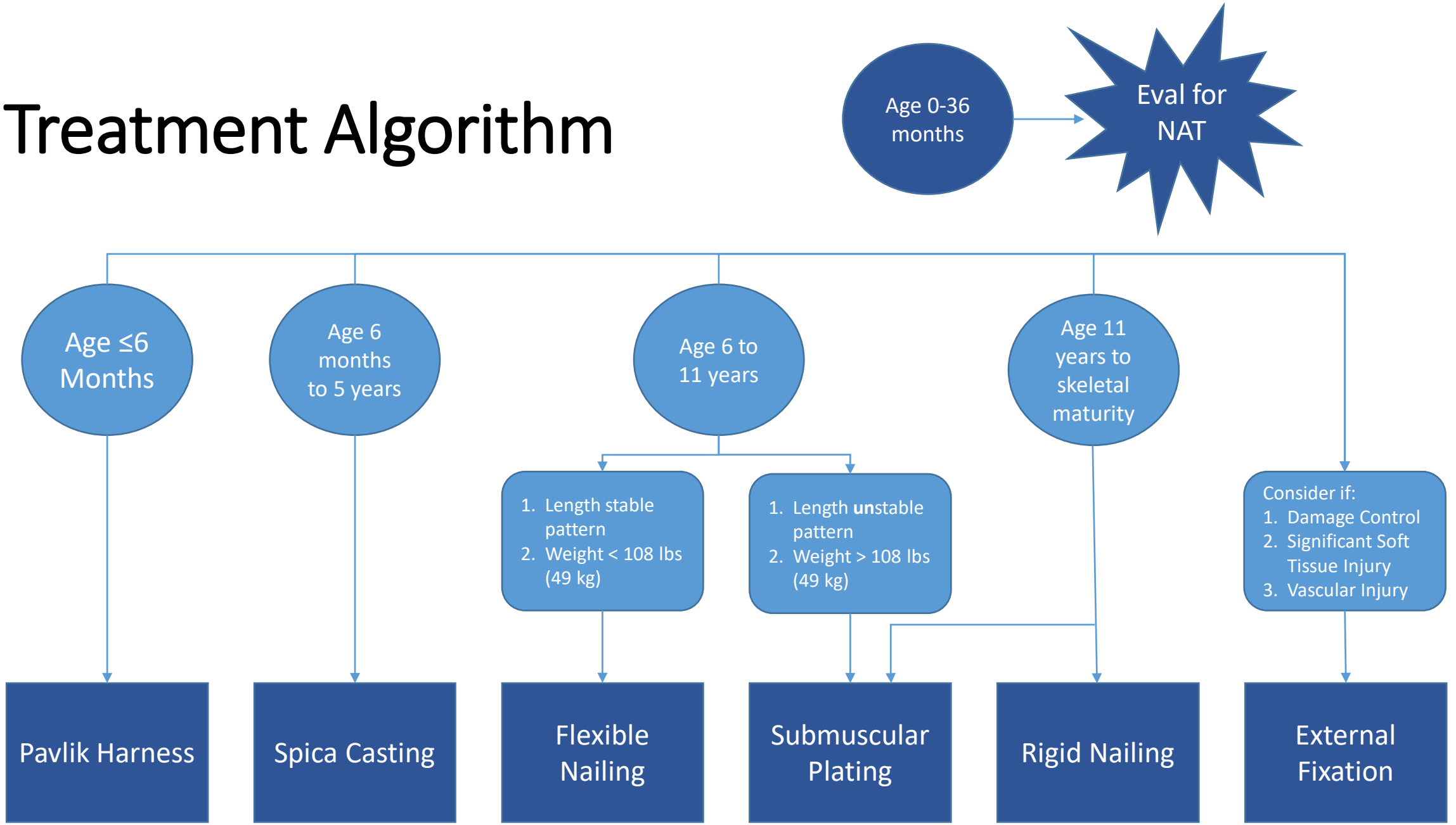
Kocher MS, Sink EL, Blasier RD, Luhmann SJ, Mehlman CT, Scher DM, Matheney T, Sanders JO, Watters WC 3rd, Goldberg MJ, Keith MW, Haralson RH 3rd, Turkelson CM, Wies JL, Sluka P, Hitchcock K. Treatment of pediatric diaphyseal femur fractures. J Am Acad Orthop Surg. 2009 Nov;17(11):718-25.

AAOS Clinical Practice Guidelines 2015

- **Grade C Recommendations** ★★
  - Flexible intramedullary nailing may be used to treat children aged 5 to 11 years with diaphyseal femur fractures.
  - Rigid trochanteric entry nailing, submuscular plating, and flexible intramedullary nails are treatment options for children aged 11 years to skeletal maturity with diaphyseal femur fractures but AVOID PIRIFORMIS ENTRY for rigid nailing.
  - Consider regional pain management for patient comfort perioperatively.

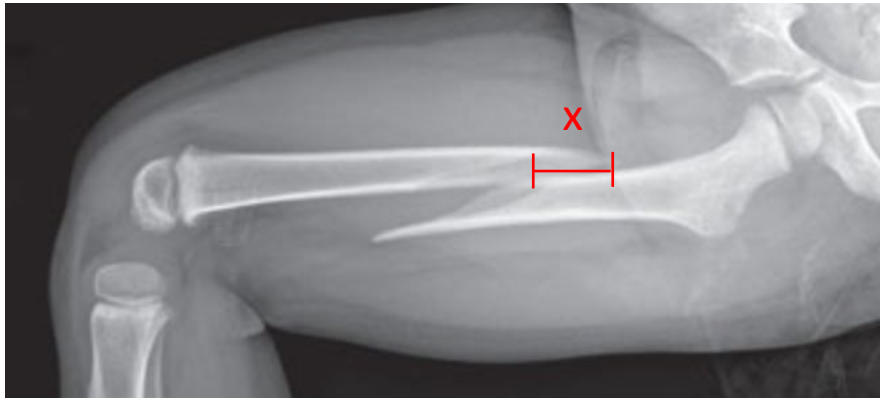
Kocher MS, Sink EL, Blasier RD, Luhmann SJ, Mehlman CT, Scher DM, Matheney T, Sanders JO, Watters WC 3rd, Goldberg MJ, Keith MW, Haralson RH 3rd, Turkelson CM, Wies JL, Sluka P, Hitchcock K. Treatment of pediatric diaphyseal femur fractures. J Am Acad Orthop Surg. 2009 Nov;17(11):718-25.

Treatment Algorithm



Treatment

- Acceptable limits based on age
  - ≤10 year olds
    - 15 deg of varus or valgus
    - 20 deg of procurvatum or recurvatum
    - 2-2.5cm shortening
      - Overgrowth is common in 2-10 y/o
      - *Telescope test* in higher energy trauma
        - (+) test→ shortening of >30mm with gentle compression
          - 20x higher likelihood of ending with >25mm of shortening
    - Malrotation of 30°



Pavlik Harness

- **Patients age 0-6 months**
  - ***MUST Evaluate for NAT***
    - Social services consult
    - Skeletal survey
- Abduction ≤50° with pillow under leg to maintain abduction
- 80-90 degrees of flexion
  - Reduces the distal fragment to the flexed proximal fragment
- Follow up at regular intervals to adjust harness
  - 1-2 weeks to ensure harness is fitting appropriately
- ~4 weeks of treatment

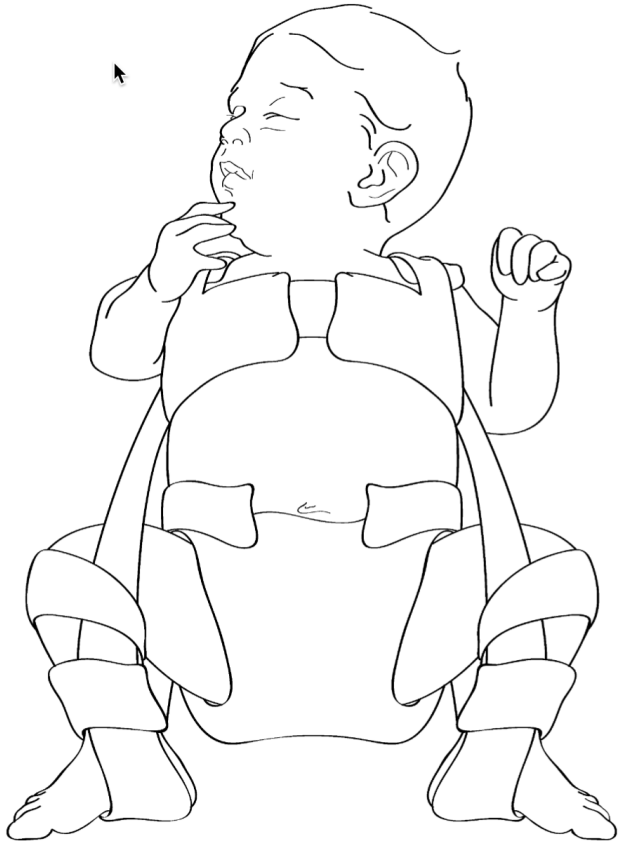
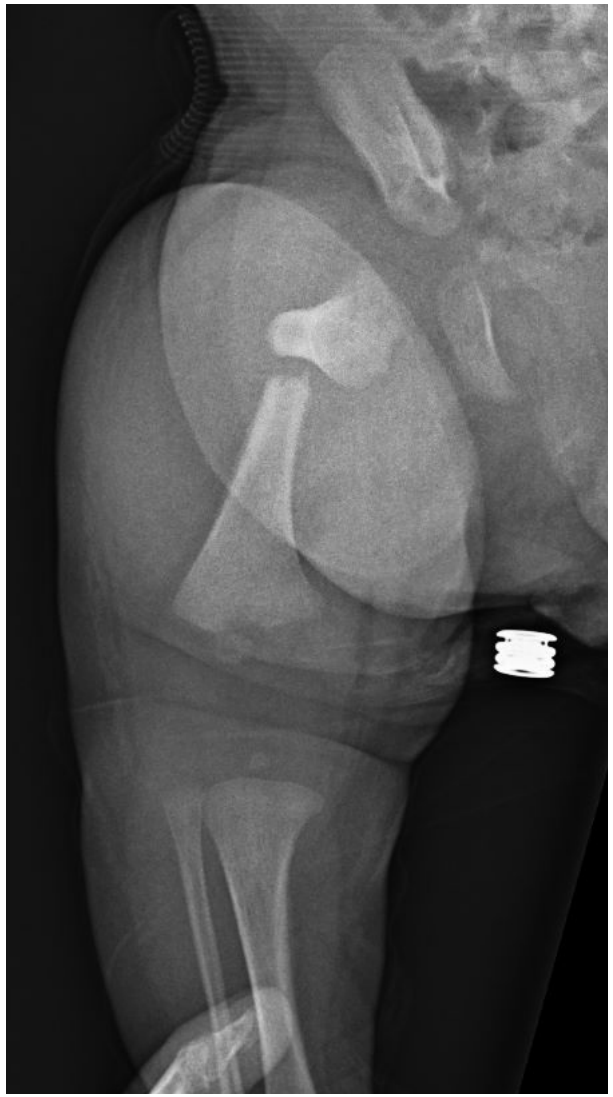
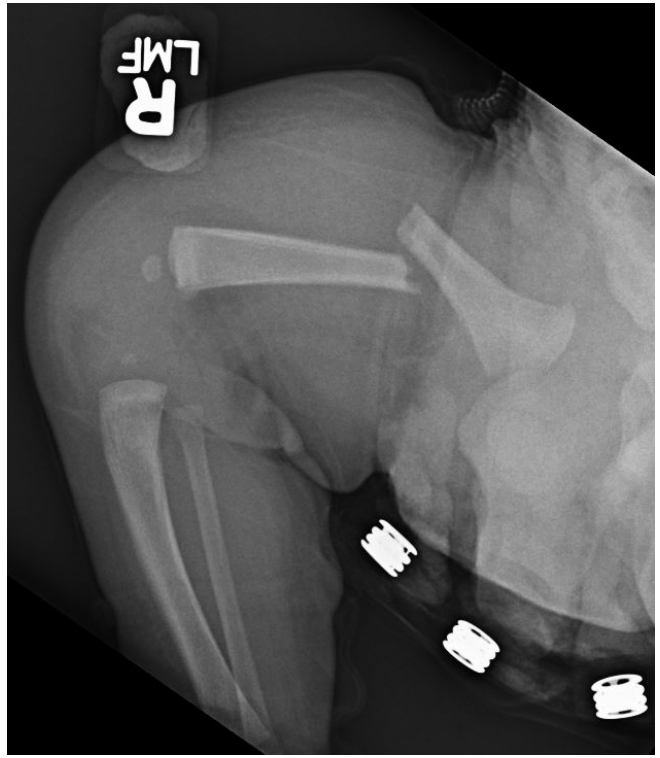


Figure: Anglen JO, Choi L. Treatment options in pediatric femoral shaft fractures. J Orthop Trauma. 2005 Nov-Dec;19(10):724-33

Pavlik Harness

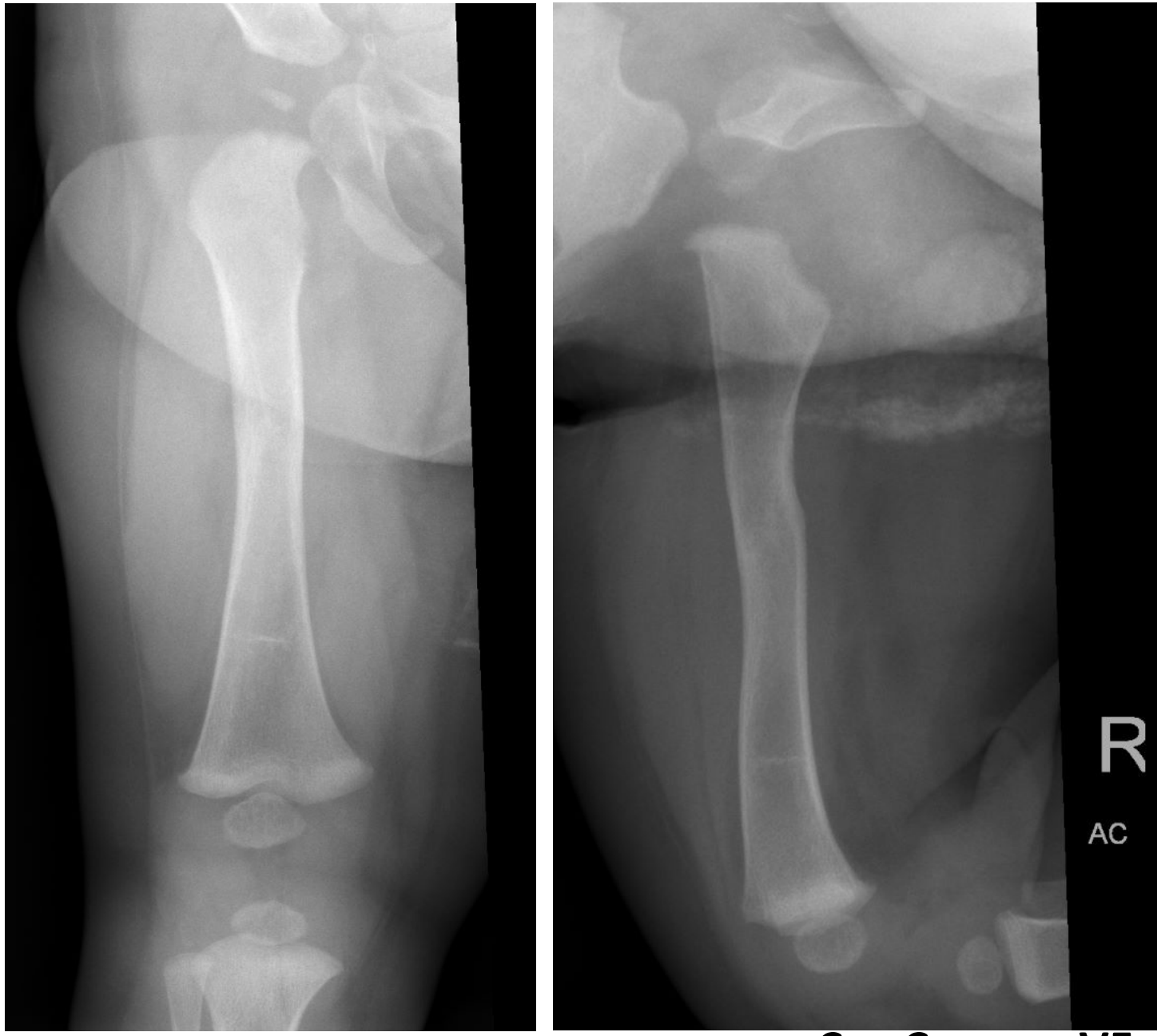
- 5-week-old male
- Presented to OSH with right leg swelling
  - Unknown mechanism
- NAT workup initiated
  - L parietal bone fracture on skeletal survey
- Treated in Pavlik harness x 4 weeks
- Removed from care of mother





Pavlik Harness

- 6 months post-treatment
- Completely healed and remodeled
- Remains in foster care and doing well



Spica Casting

- **Age 6 months to 5 years**
- Early vs delayed application acceptable
- Applied in Emergency Room or Operating Room on spica table
- Waterproof liners/padding available
- Flex knee and hip equal amount to obtain alignment with more flexion for a more proximal fracture
- Remove in 4-6 weeks when adequate callus is present

Figure: Cassinelli EH, Young B, Vogt M, Pierce MC, Deeney VF. Spica cast application in the emergency room for select pediatric femur fractures. J Orthop Trauma. 2005 Nov-Dec;19(10):709-16.

Spica Casting

- Single vs Double leg
  - Equivalent radiographic results
  - Single leg spica
    - Parents had fewer days off work
    - Improved sitting in chairs
    - Improved sitting in car seats
- Reduction typically requires a **valgus mold**
- Acceptable angulation
  - 15 degrees varus/valgus
  - 20 degrees anterior/posterior
  - 2 cm shortening

Figure: Cassinelli EH, Young B, Vogt M, Pierce MC, Deeney VF. Spica cast application in the emergency room for select pediatric femur fractures. J Orthop Trauma. 2005 Nov-Dec;19(10):709-16.

Spica Casting

- Complications:
  - Cast complication
  - Shortening or malalignment of fracture
  - Skin breakdown or ulcerations

- Tips to avoid cast complications
  - Keep cast well padded, especially around edges
  - Use waterproof liners if available
  - Double diaper to keep patient from soiling cast
  - Frequent turning to avoid pressure sores

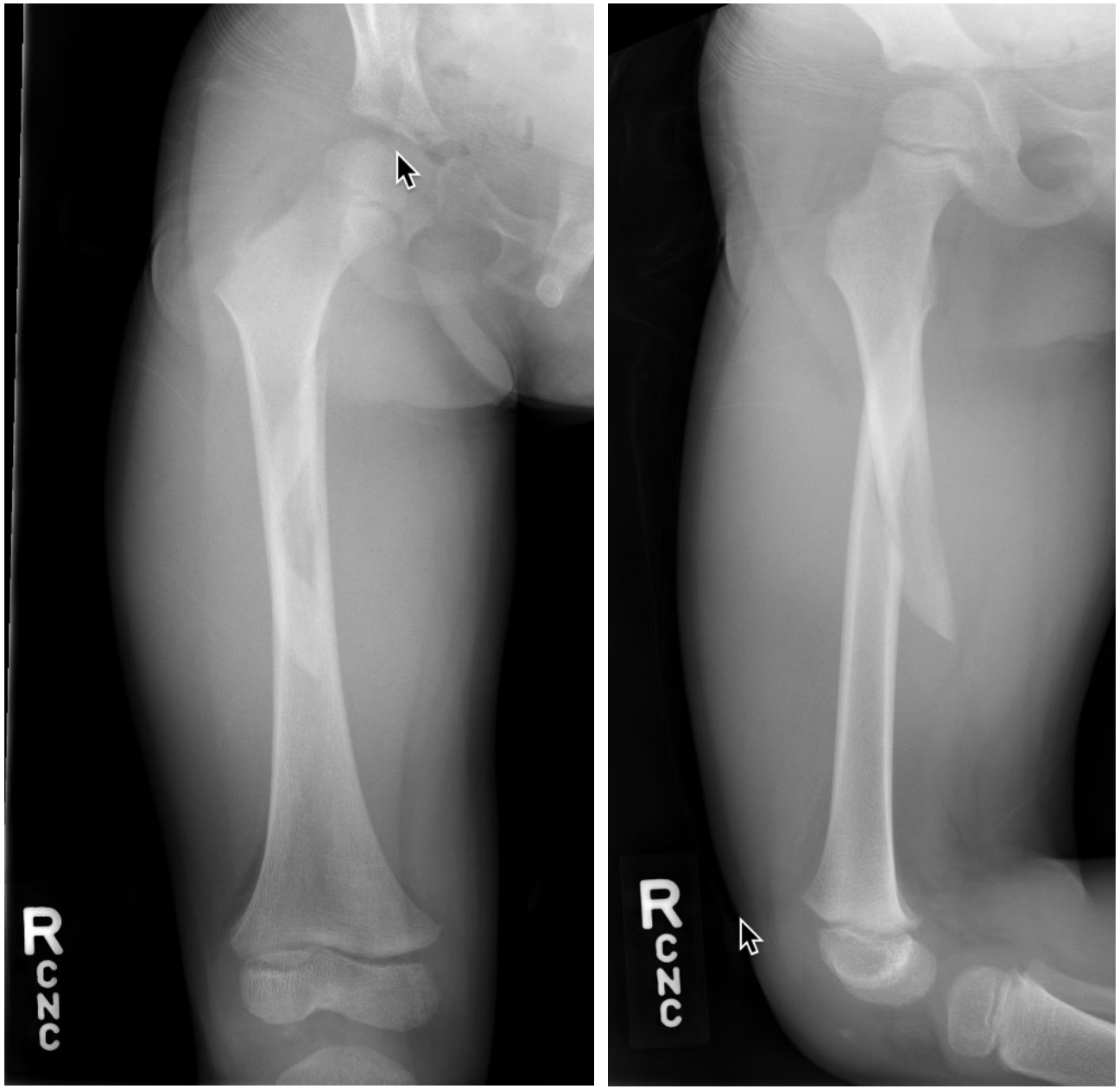
Photos courtesy of Patrick Whitlock, MD

Spica Casting in ED – Keys to Success

- Coordinate with ER doctors for appropriate sedation
- Have two sets of “knowledgable” hands for cast application
  - Two residents, resident plus ortho tech/fellow/attending
- Use single leg spica when possible
- Make sure you have all necessary equipment available before starting procedure
  - C-arm
  - Spica table
  - Cast padding/liner and fiberglass laid out
  - Cast saw and tape for adjustments
- If appropriate spica teaching and car seat not available in ER, then admit patient to floor

Spica Casting

- 3 yo M
- R femoral shaft fracture
- Mechanical fall while running

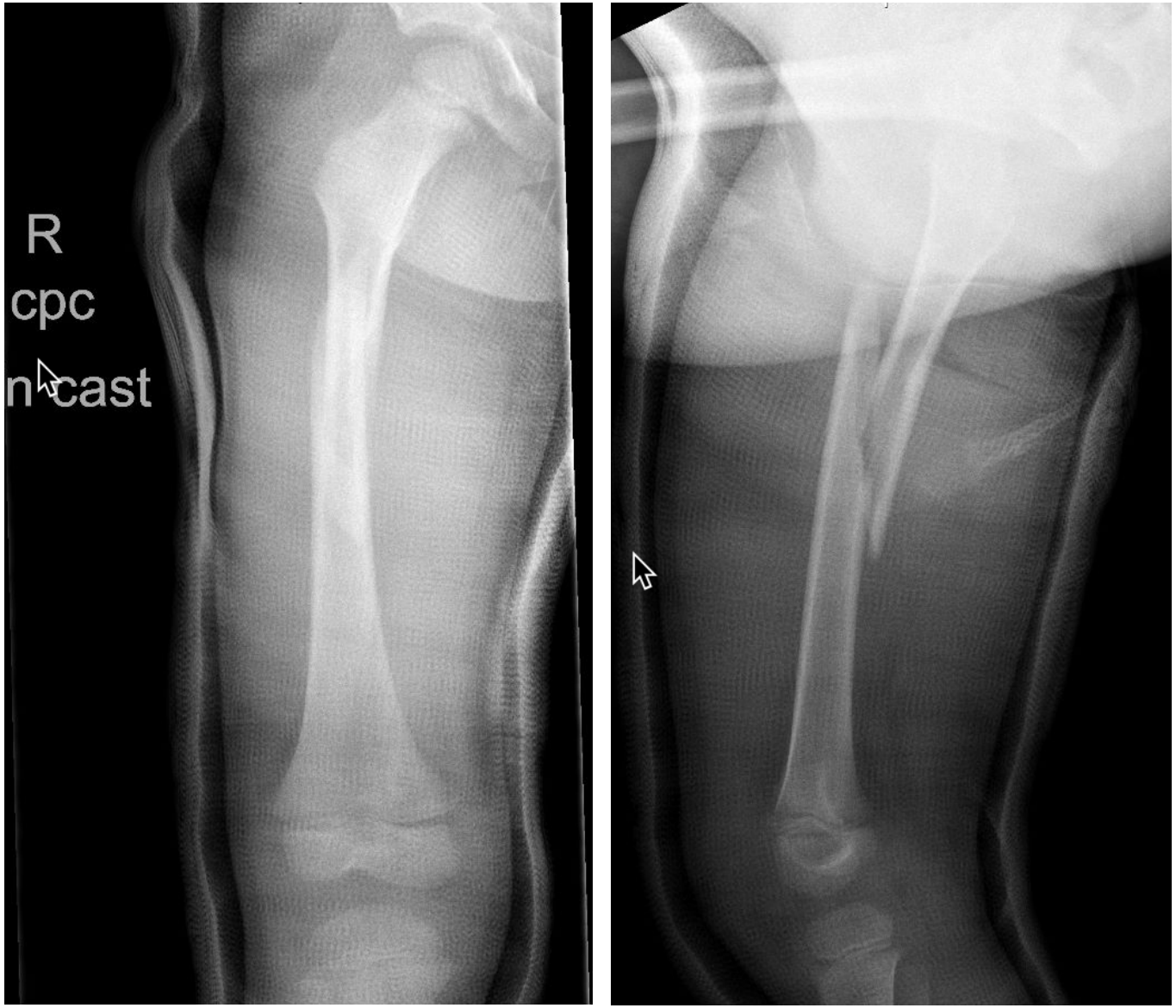


Spica Casting

- Single leg hip spica applied in ER

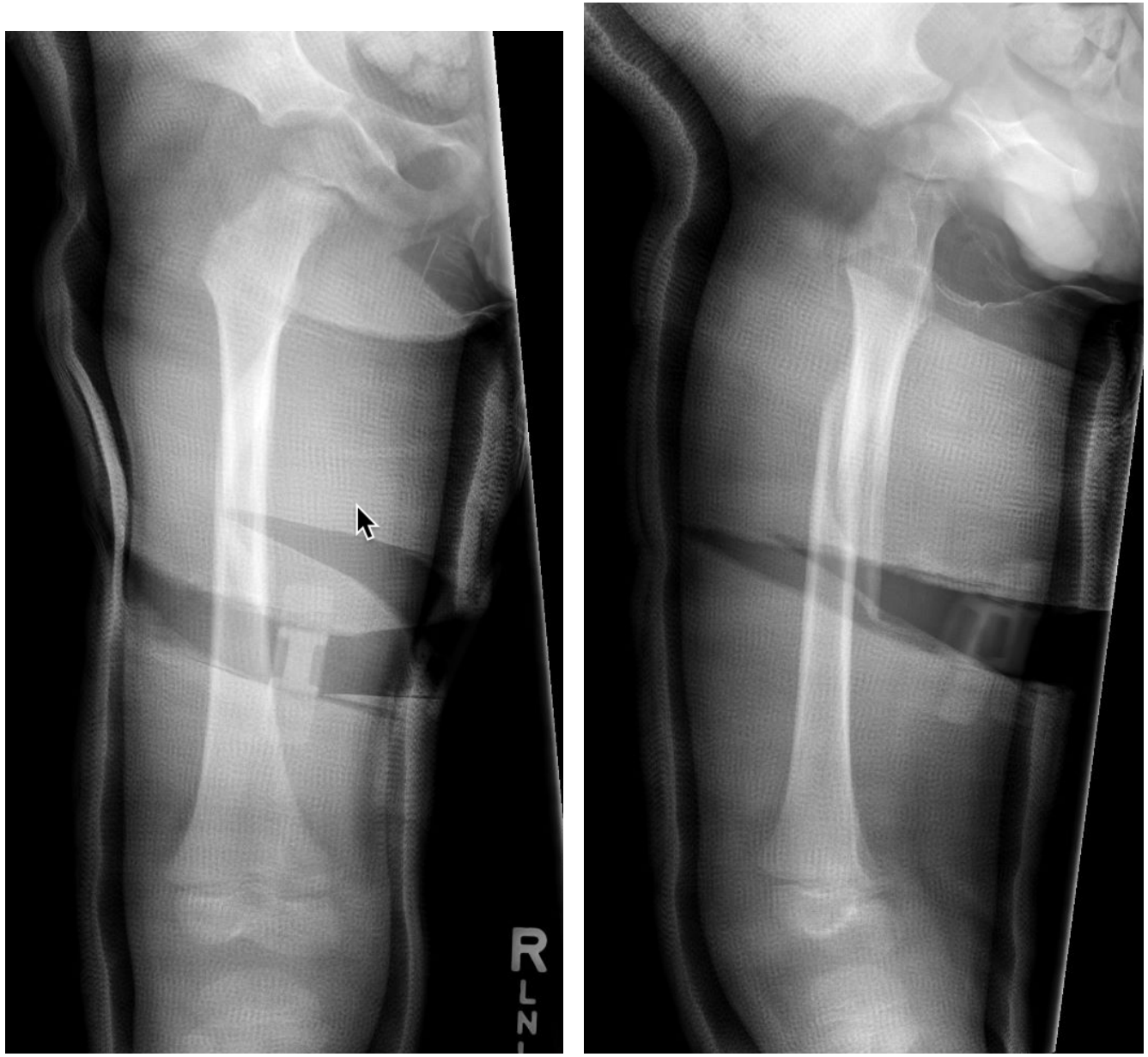
Spica Casting

- 1 week alignment check
- Increased varus and apex anterior angulation



Spica Casting

- Cast wedging performed in clinic
- Improved alignment

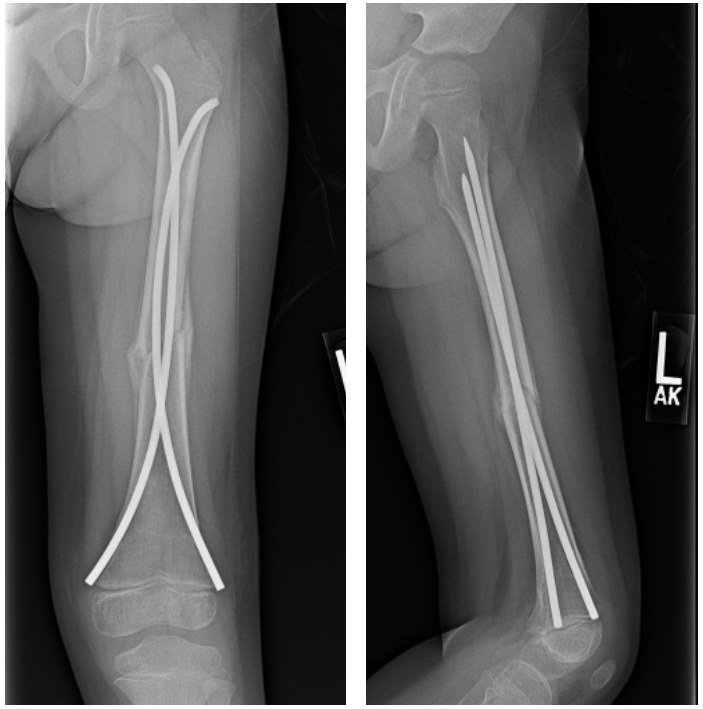


Spica Casting

- Healed at 8 weeks

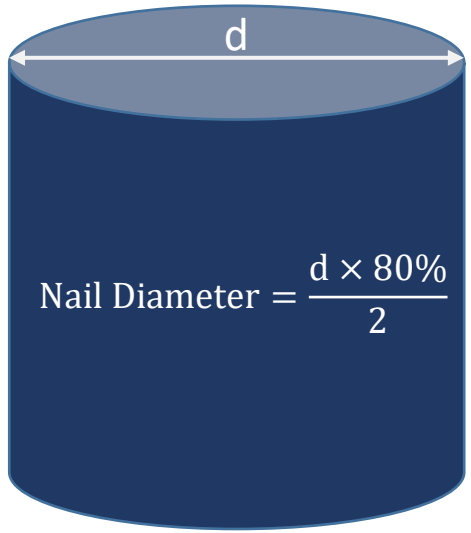
Flexible Nailing

- **Age 5-11 years**
- Length stable fractures
- Complication rate increases with weight over 108 lbs (49 kg) and age >11 years
  - Adjunct bracing, casting or prolonged immobilization in heavier, older patients
- Can consider in length unstable fractures, proximal and distal fractures depending on surgeon preference and expertise



Flexible Nailing

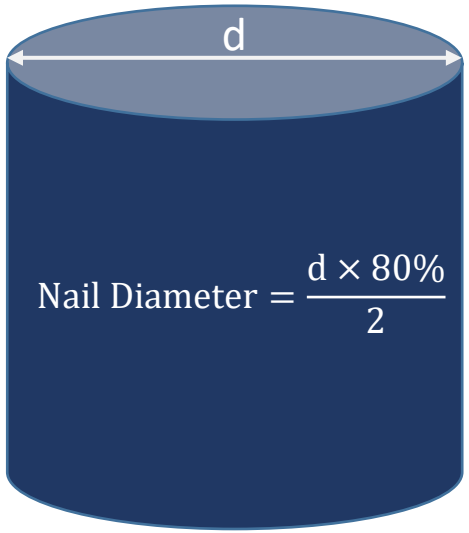
- Radiolucent table or fracture table
- Starting point for retrograde nails is the metaphyseal diaphyseal junction
- **Aim for combined nail diameter 80% canal fill**



Wall, Eric J., et al. "Complications of titanium and stainless steel elastic nail fixation of pediatric femoral fractures." *JBJS*90.6 (2008): 1305-1313.

Flexible Nailing

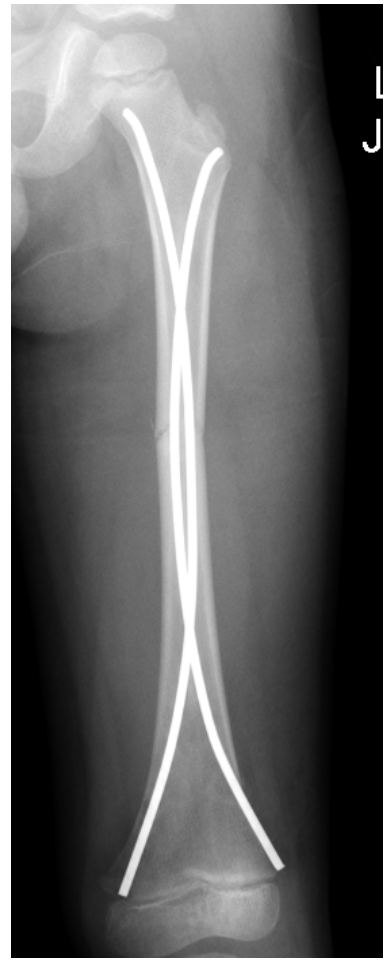
- Stainless steel vs. titanium nails
  - Stainless steel has higher stiffness/modulus of elasticity
  - Titanium better biomechanical stability in axial compression and torsion
  - Stainless steel less expensive
  - Clinical outcomes improved with stainless steel
    - Decreased rate of malunion
    - Decreased rate of major complications



Wall, Eric J., et al. "Complications of titanium and stainless steel elastic nail fixation of pediatric femoral fractures." *JBJS*90.6 (2008): 1305-1313.

Flexible Nailing

- Techniques
  - Retrograde medial and lateral
    - Most common technique
    - 2 ‘C-shaped’ nails



Flexible Nailing

- Techniques
  - Retrograde all lateral
    - Possibly quicker procedure
    - 1 ‘C-shaped’ & 1 ‘S-shaped’ nail

Flexible Nailing

- Techniques
  - Antegrade
    - Consider for distal fractures or distal soft tissue wounds
    - 1 ‘C-shaped’ & 1 ‘S-shaped’ nail

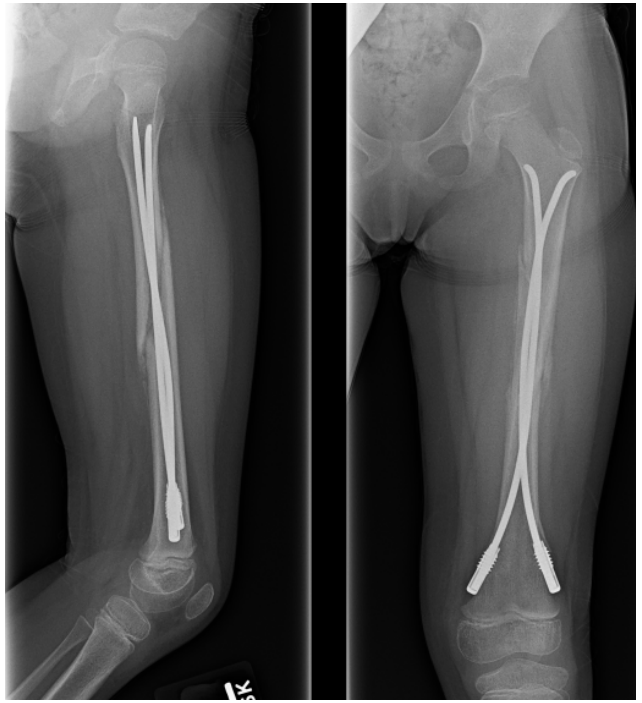
Flexible Nailing

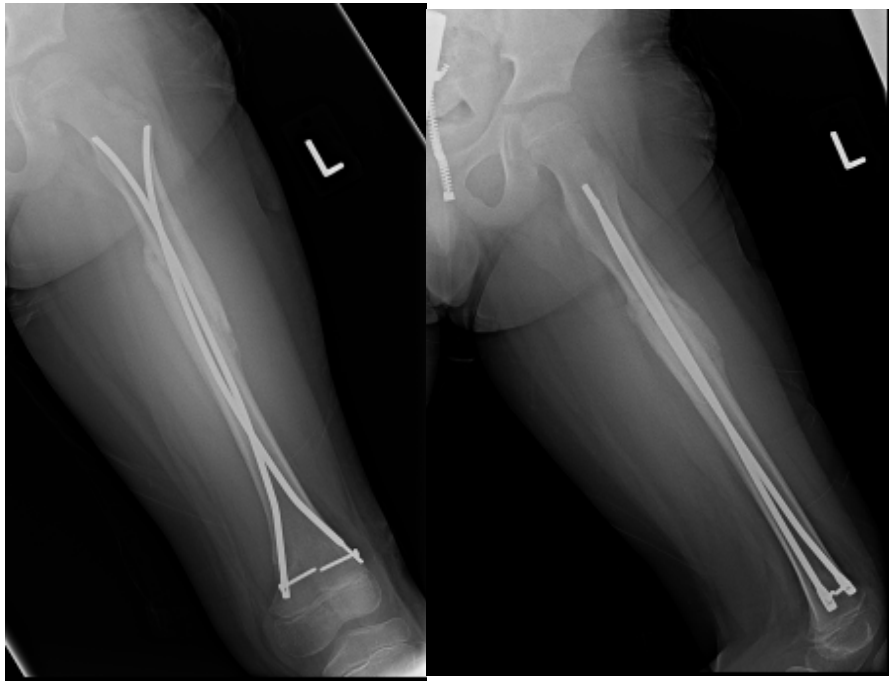
- Complications
  - Shortening
  - Nail irritation requiring revision surgery
  - Infection
  - Delayed union
  - Hardware failure

- Tips to prevent complications:
  - Add supplemental immobilization
    - Casting or bracing
  - Weight bearing restrictions until healing on x-rays (4-6 weeks)

Flexible nailing

- Length unstable fractures
  - Comminuted
  - Long oblique fractures
  - Shortening can result with standard ESIN techniques
  - Alternatives
    - Supplemental single leg spica cast x 4 weeks
    - Locked Enders nail
    - End caps on titanium flex nails



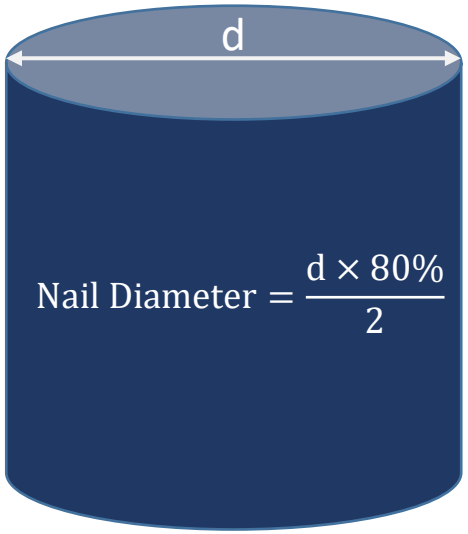


Flexible Nailing

- 6 yo Female
- 44 lbs (20 kg)
- Pedestrian struck by motor vehicle
- Injuries:
  - Bilateral pulmonary contusions and pneumothoraces
  - Bilateral rib fractures
  - L diaphyseal femur fracture

Flexible Nailing

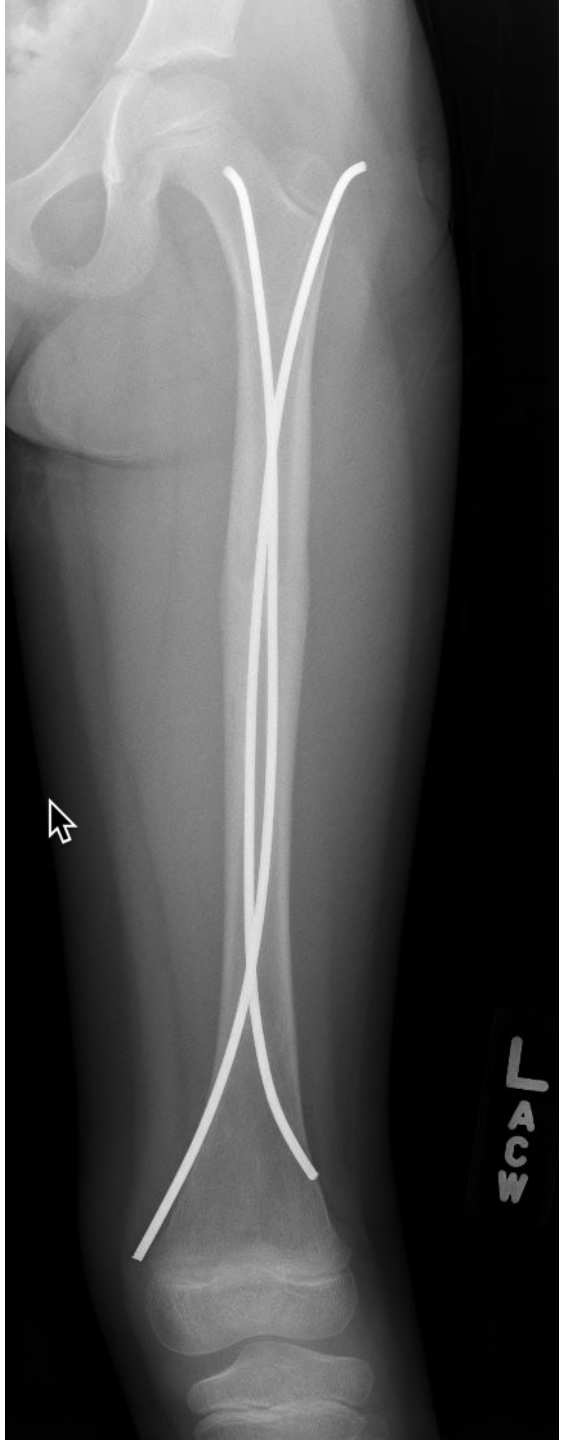
- Flat Jackson table
- Nail size chosen based on 80% canal fill



- NWB until 4 weeks post-op

Flexible Nailing

- 5 months post-op



Flexible Nailing

- Removal of hardware at 7 months post-op
  - Timing of removal varies
    - 4-6 months
    - Complete healing of fracture
      - 4 cortices
  - Limit impact activities for at least 4 weeks post-op

Submuscular Plating

- **Age 5 through skeletal maturity**
- Length unstable fractures
  - Comminuted
  - Spiral
  - Shortened > 2 cm
- Internal splint

- Preserves endosteal and periosteal blood supply around fracture site

Figure: Hedequist DJ, Sink E. Technical aspects of bridge plating for pediatric femur fractures. J Orthop Trauma. 2005 Apr;19(4):276-9.

Submuscular Plating

- Supine
- Radiolucent table vs fracture table
- 3.5 mm or 4.5 mm plates available
  - Bicortical non-locking screws
- Minimally invasive
  - Insert through incisions – proximal and distal
- Slide plate retrograde along femur between the incisions
- Typically non-weight bearing post-operatively

- Hardware removal between 6-12 months

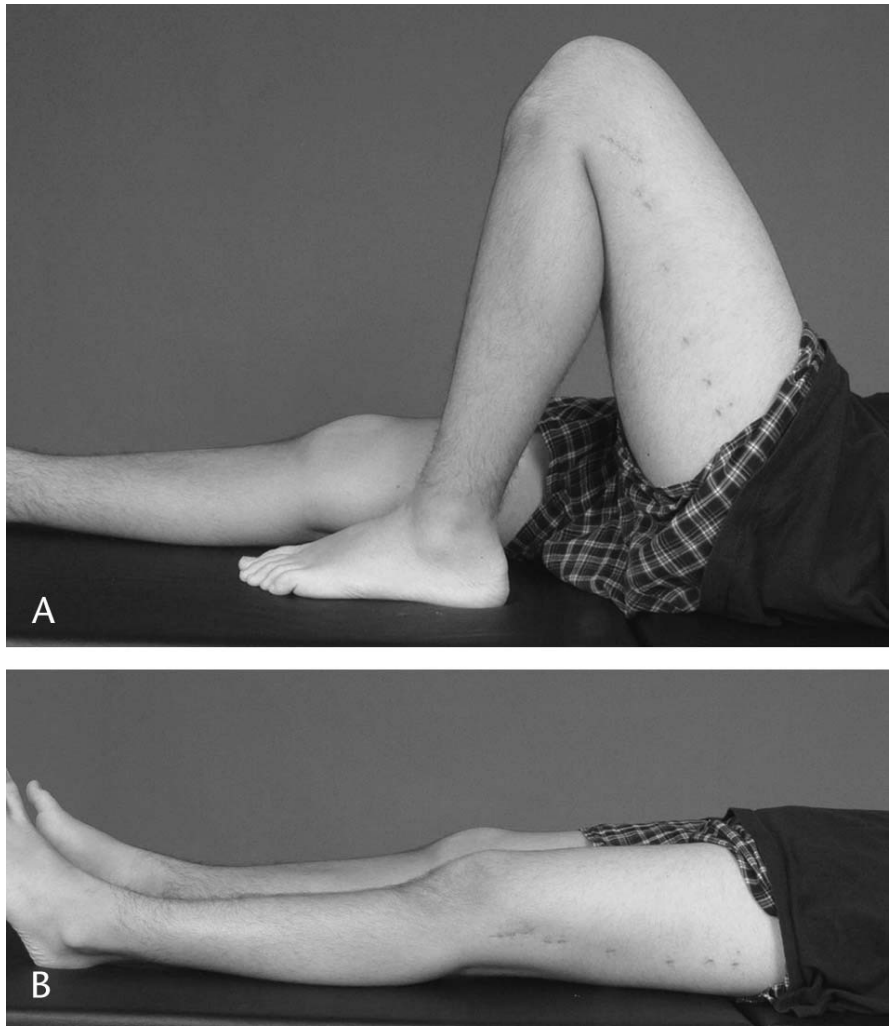


Figure: Hedequist DJ, Sink E. Technical aspects of bridge plating for pediatric femur fractures. J Orthop Trauma. 2005 Apr;19(4):276-9.

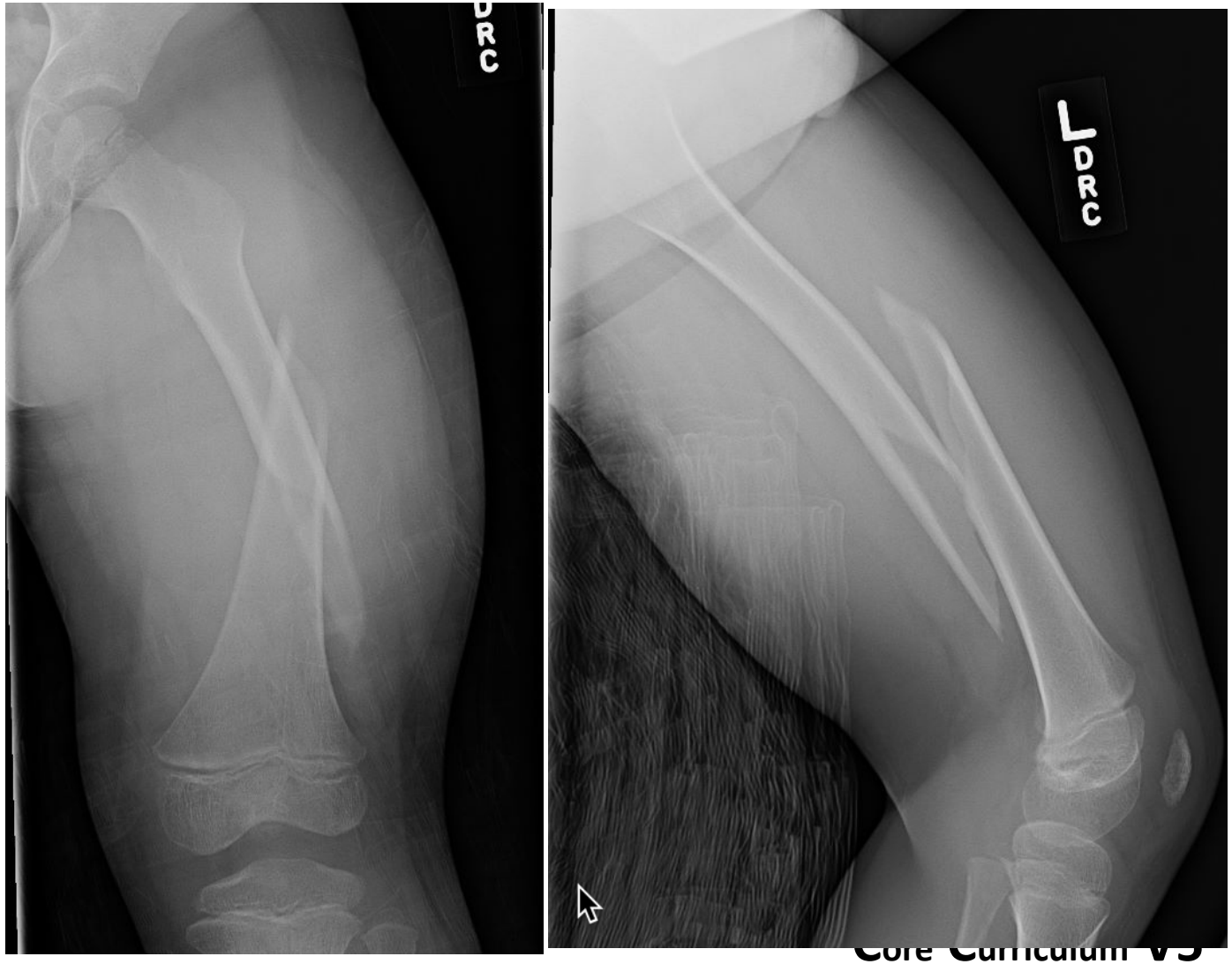
Submuscular Plating

- Complications
  - Infection
  - Bony overgrowth
  - Distal femoral valgus
  - Hardware failure
  - Symptomatic hardware
  - Malunion

Figure: Hedequist DJ, Sink E. Technical aspects of bridge plating for pediatric femur fractures. J Orthop Trauma. 2005 Apr;19(4):276-9.

Submuscular Plating

- 6-year-old male
- 28 kg
- L femur fracture sustained during rough housing/wrestling

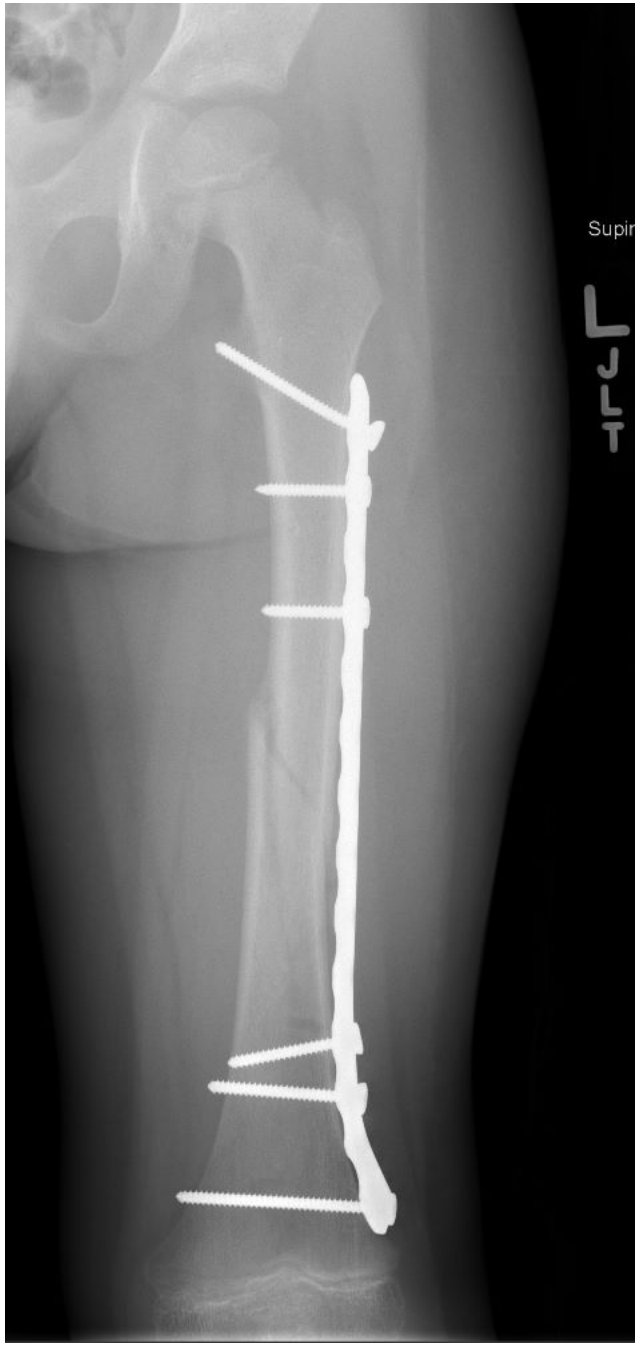


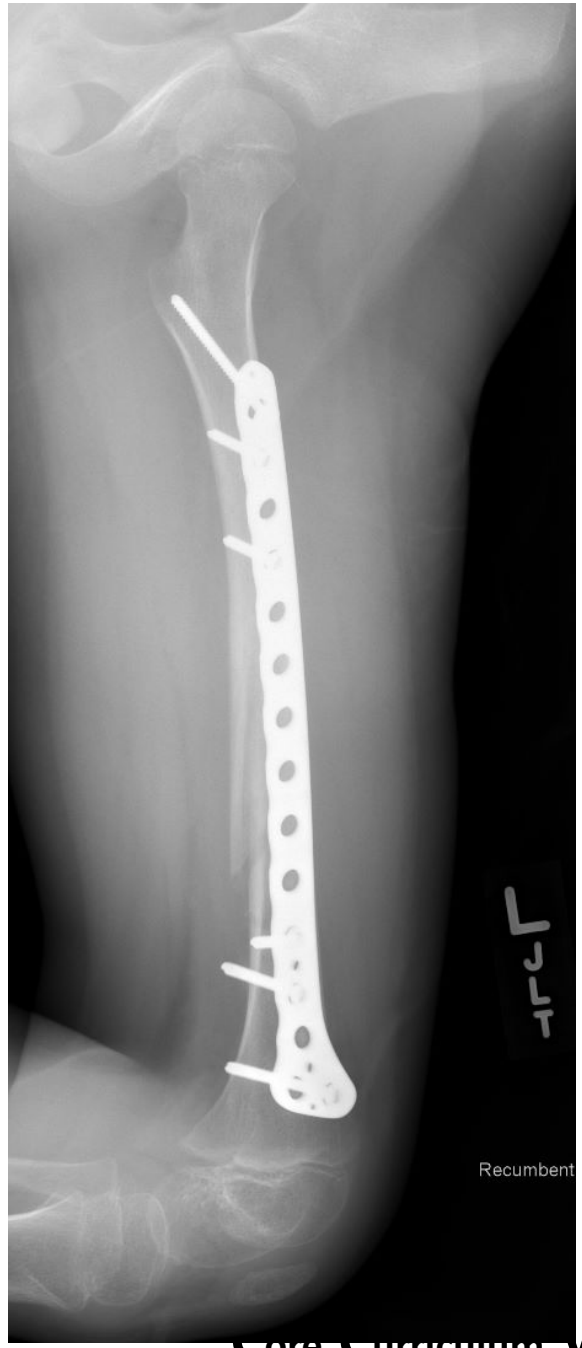
Submuscular Plating

- Flat Jackson radiolucent table
- Distal and proximal incisions
- Slide plate under the vastus lateralis along the bone with indirect reduction of femur
- Tip: Keep plate at least 1 cm proximal to the distal femoral physis
  - prevent damage to growth plate and distal femoral valgus

Submuscular Plating

- 6 weeks post-op
- NWB until now
  - Advance to progressive weight bearing
    - X-rays show some healing/callus formation and patient without pain at fracture site



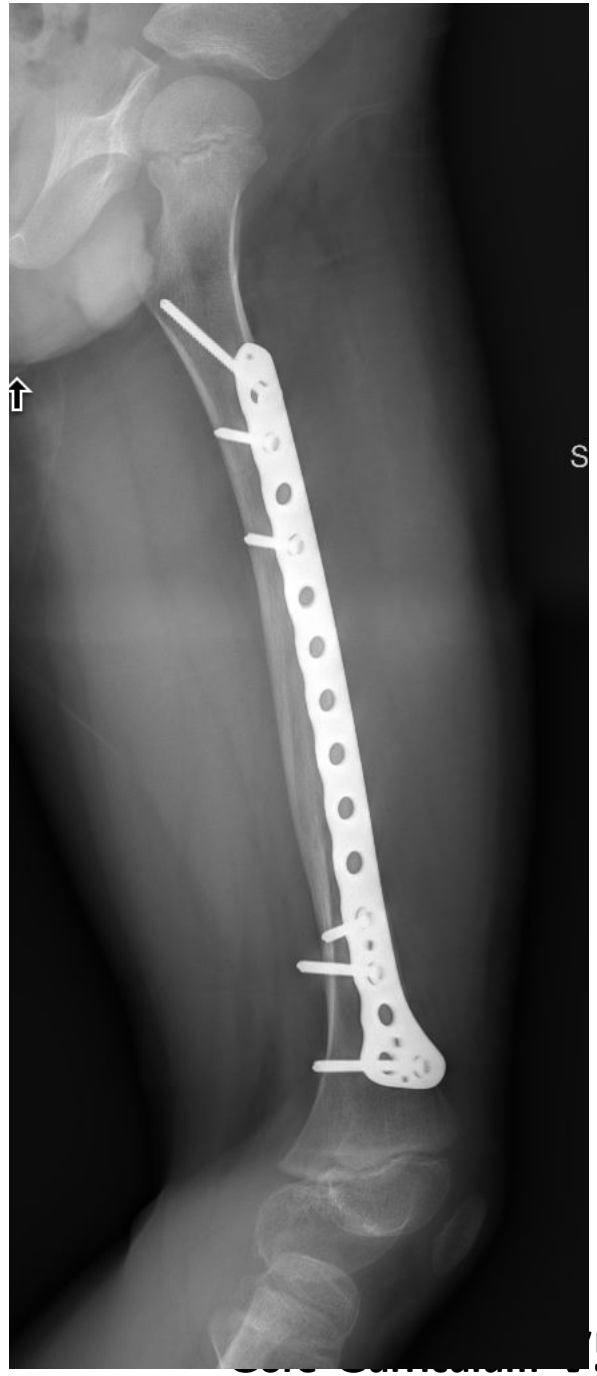


Submuscular Plating

- 3 months post-op
- Participating in PT
- Ambulating without a limp
- Resumed normal activities

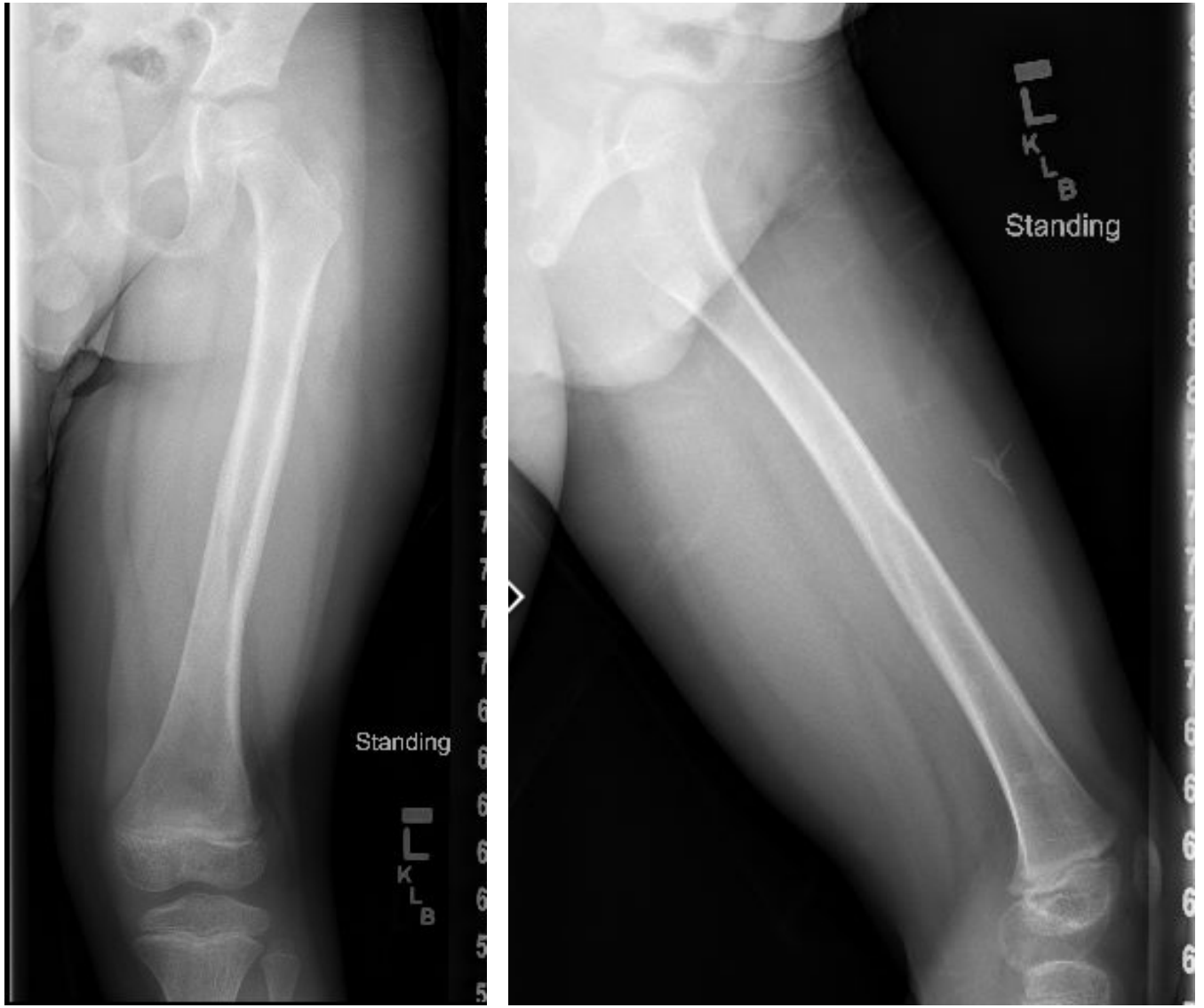
Submuscular Plating

- 5 months post-op
- Completed PT
- Ambulating without a limp and back to normal activities



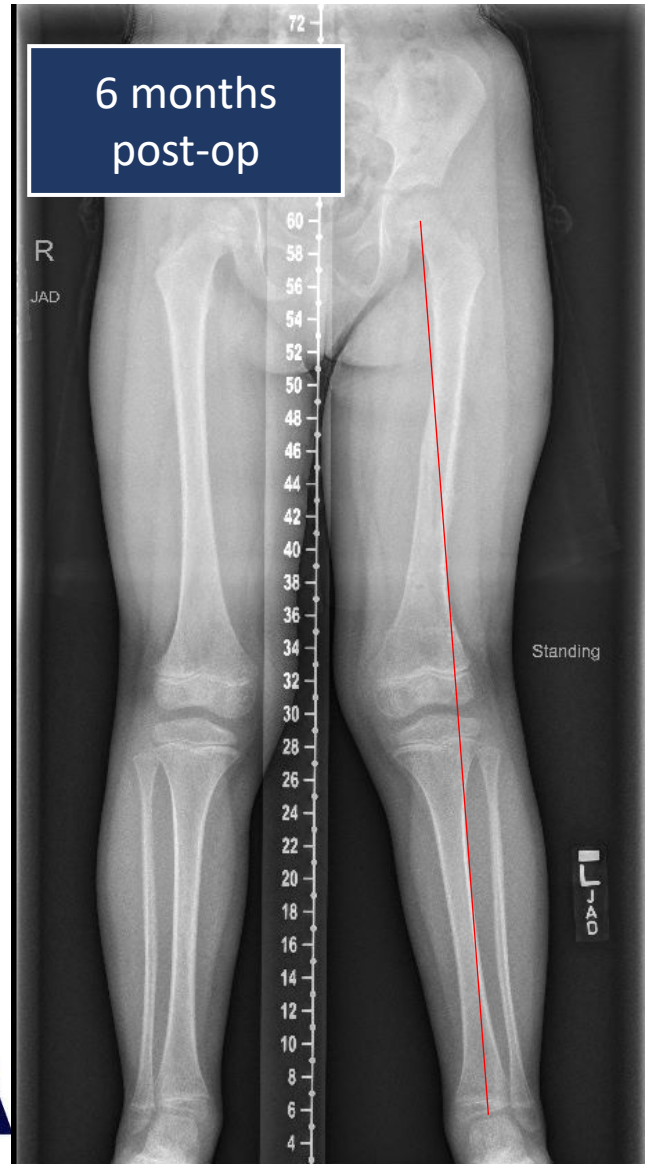
Submuscular Plating

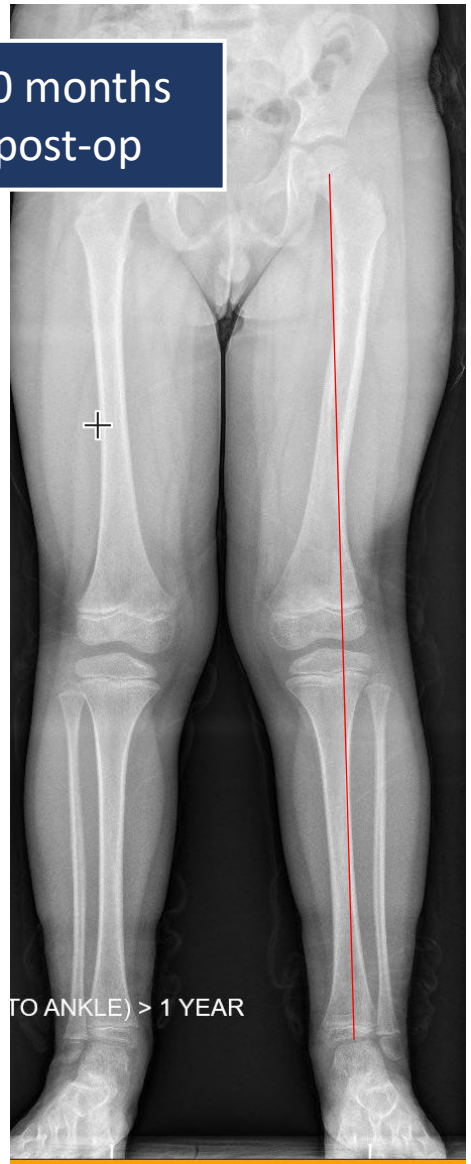
- Removal of hardware at 6 months post-op
- Mild valgus alignment at distal femur
- No impact activities for 4 weeks post-operatively



Submuscular Plating

Distal femoral valgus can occur following submuscular plating



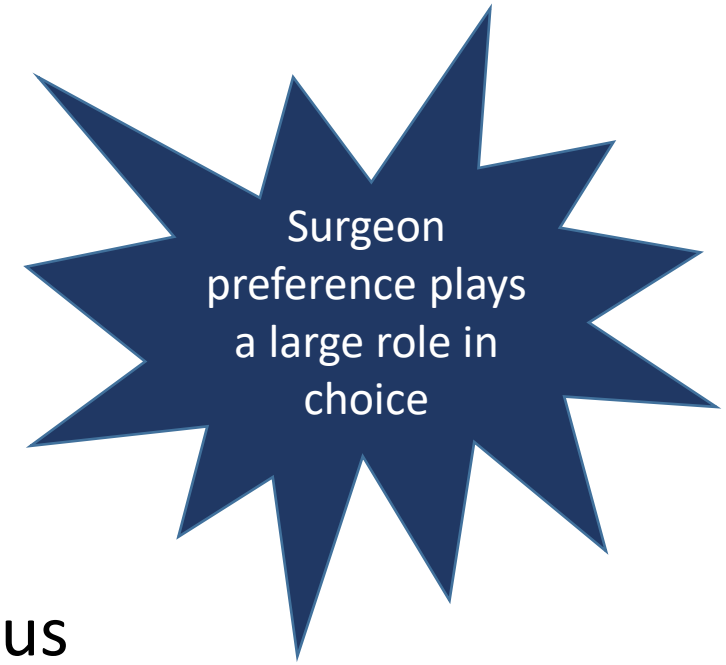


Resolved without treatment

Rigid Nailing

- **Age 11 through skeletal maturity**
- Weight > 108 lbs (49 kg)
- Appropriate for length unstable, comminuted, oblique, proximal or distal fractures
- ***Avoid Piriformis entry nails***
  - Increased risk of AVN
- Lateral entry antegrade nails preferred

Rigid Nailing – Patient Positioning



- Supine
  - Easy to position
  - Easy to administer anesthesia
  - Able to identify rotational malalignment
- Fracture table
  - Allows for fewer assistants
  - May increase risk of compartment syndrome in well leg
  - Difficult to identify rotational malalignment
- Lateral decubitus
  - Improved access to lateral starting point, particularly in obese patient
  - Access limb from both sides
  - Easier lateral imaging of proximal femur

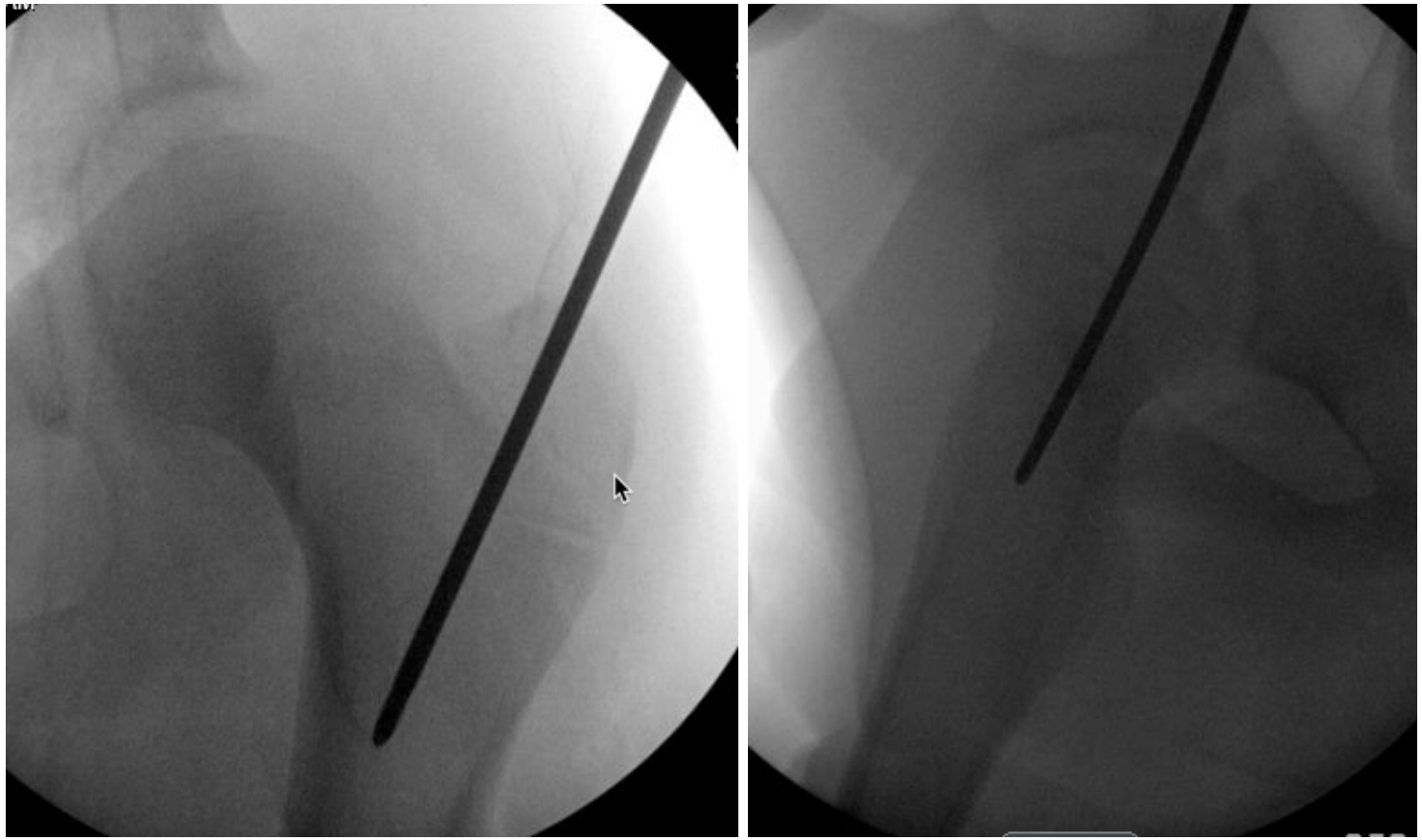
Rigid Nailing

- 10-year-old male
- 80 kg (176 lbs)
- ATV rollover
- Isolated L diaphyseal femur fracture

- Flex nails?
  - Too heavy
- Plating vs rigid (IMN) nailing
  - Immediate weight bearing with IMN
  - Possible growth arrest of greater trochanter and AVN with IMN

Rigid Nailing

- Fracture table
- Adolescent lateral entry nail
- AVOID piriformis starting point



Rigid Nailing

- 4 weeks post-op
- Ambulating without crutches
  - Still using wheelchair for long distances/school
- No pain medications
- Weight bearing immediately post-op

Rigid Nailing

- 8 weeks post-op
- Ambulating without a limp

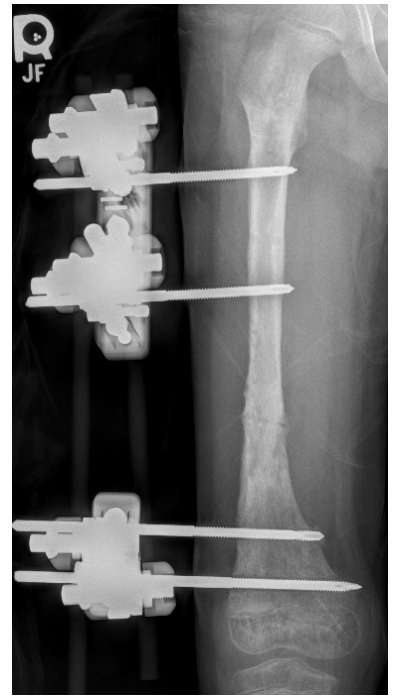
Rigid Nailing

- 16 weeks post-op
  - Has returned to regular activities
  - No pain
  - Will plan for hardware removal given age and remaining growth

External Fixation

- Temporary stabilization if patient too unstable for definitive fixation
- Useful in cases of pathologic fractures and infection
- Allows access to large soft tissue injury for wound care

Fracture through chronic osteomyelitis

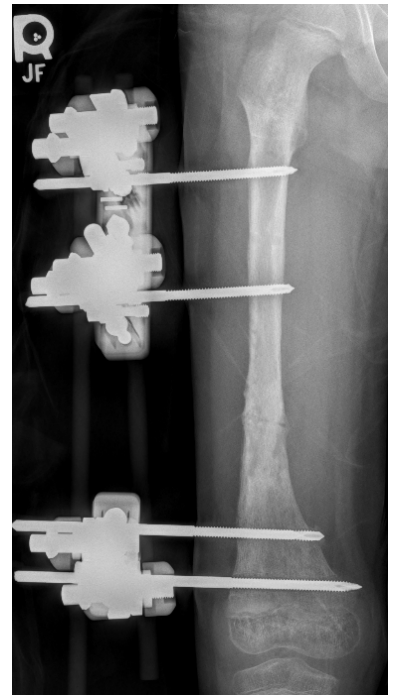


Length unstable fracture

External Fixation

- Convert to internal fixation within 2 weeks
  - Reduced risk of infection
- May use as definitive treatment if necessary
  - Risk of pin tract infections
  - Risk of refracture after removal
    - At fracture site or pin sites

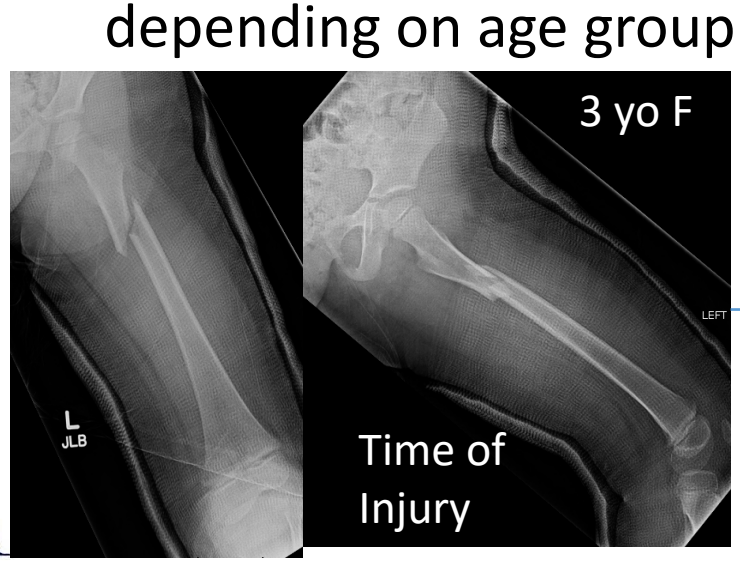
Fracture through chronic osteomyelitis



Length unstable fracture

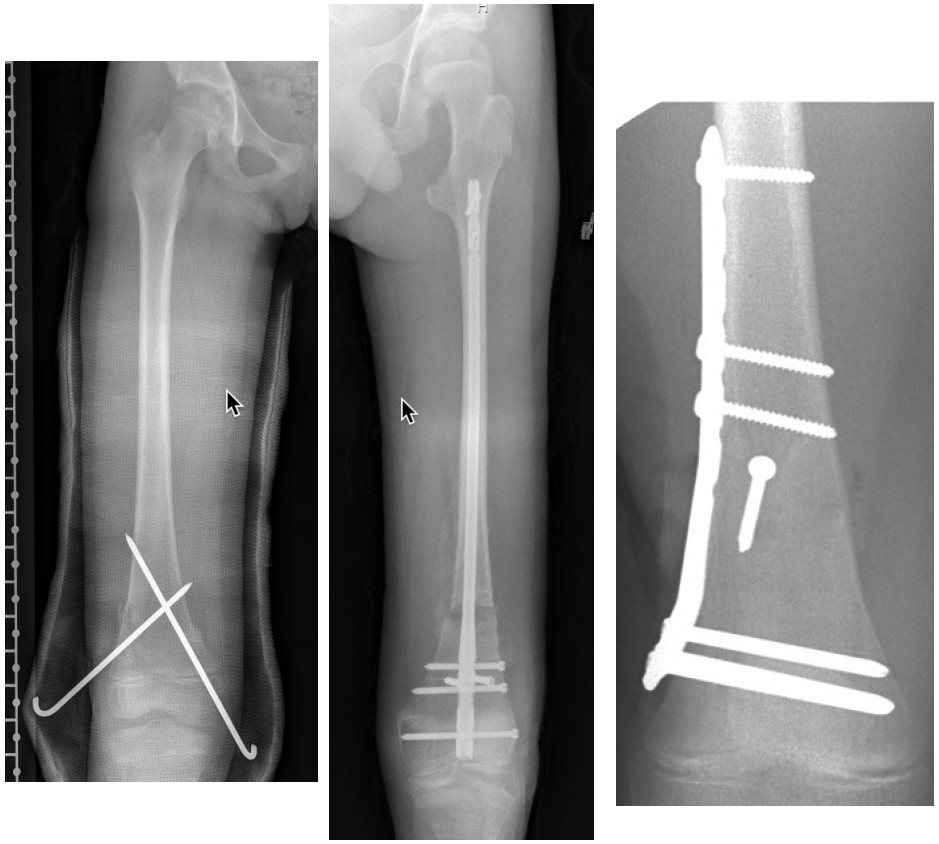
Special Circumstances

- Subtrochanteric fractures
  - 12% of all femur fractures
  - Large deforming forces
    - Short proximal segment in flexion (psoas), abduction (gluteal muscles) and external rotation (short external rotators)
  - Can use spica, flex nails, plate or locked IMN to treat depending on age group



Special Circumstances

- Distal femoral shaft fractures
  - Close proximity to distal femoral physis
  - Short distal segment
    - May need to temporarily span the physis
    - Monitor for growth arrest over time
  - Treatment options
    - CRPP
    - ORIF – try to stay 1 cm proximal to physis
      - 3.5/4.5 plates
      - Distal femoral metaphyseal plates
    - Retrograde nail if physis is closed/closing



Complications

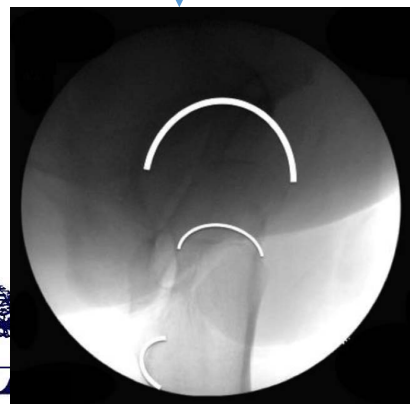
- Can occur with all treatment modalities
  - Leg length discrepancy
    - Shortening
    - Overgrowth
      - Unknown mechanism – activation of growth plate, fracture site instability, disrupted periosteum
      - Average 10.5 +/- 7.3 mm for 87 femur fractures treated with elastic nails or plating*
        - No fractures with > 2 cm overgrowth
  - Infection
  - Nonunion
    - Exchange nail
    - Revision ORIF ± bone graft

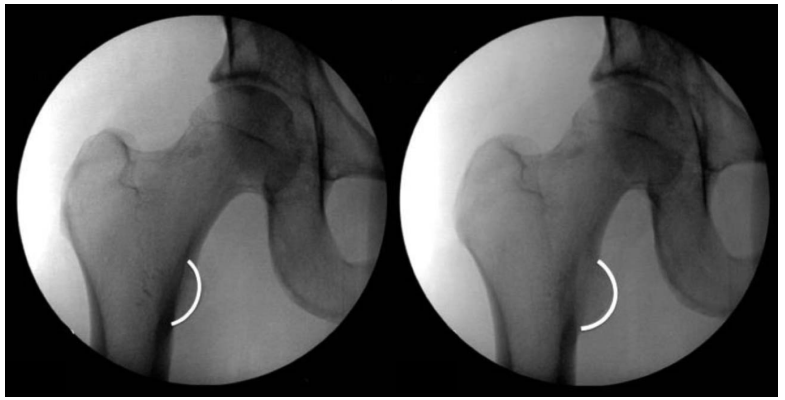
6w after exchange IMN

*Park KH, Park BK, Oh CW, Kim DW, Park H, Park KB. Overgrowth of the Femur After Internal Fixation in Children With Femoral Shaft Fracture-A Multicenter Study. J Orthop Trauma. 2020 Mar;34(3):e90-e95.

Complications

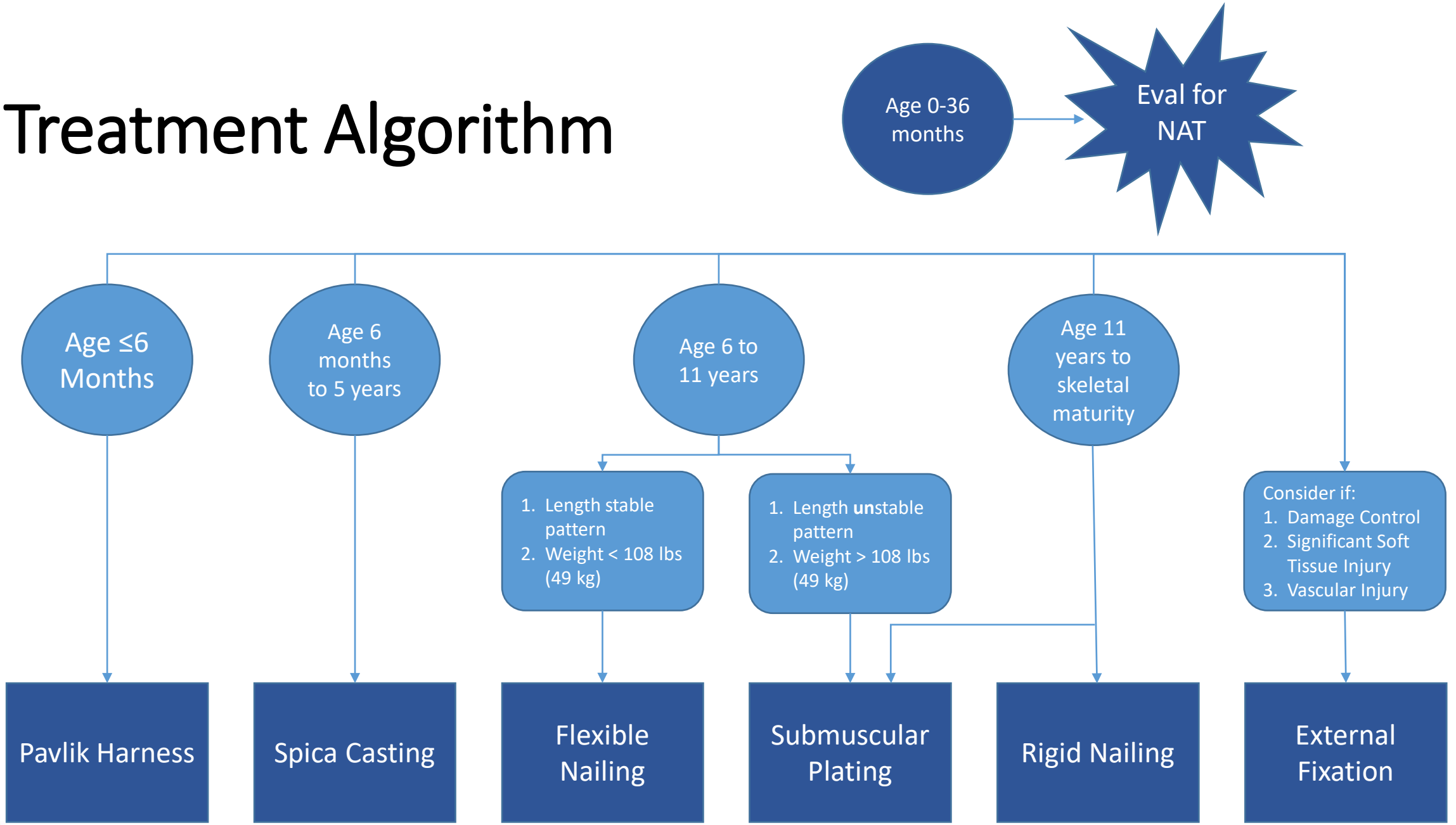
- Malunion
  - Varus and flexion most common
    - Remodeling is greatest in sagittal plane
  - Malrotation
    - Rotational deformity does not remodel
    - Multiple techniques exist to determine rotational deformity intraoperatively for comminuted fractures
      - True Lateral Technique (Tornetta 1995)
      - Lesser Trochanter Profile





Gordon JE, Mehlman CT. The Community Orthopaedic Surgeon Taking Trauma Call: Pediatric Femoral Shaft Fracture Pearls and Pitfalls. J Orthop Trauma. 2017 Nov;31 Suppl 6:S16-S21.

Treatment Algorithm



Summary

- Treatment of pediatric diaphyseal femur fractures is based on patient age, weight/size, fracture characteristics and family social situation.
- NAT should always be considered in patients under 36 months of age.
- Options include Pavlik harness, spica casting, flexible nailing, submuscular plating, rigid nailing and external fixation.
- Each treatment option has its own set of technical challenges and possible complications to consider.

References

- Anglen JO, Choi L. Treatment options in pediatric femoral shaft fractures. J Orthop Trauma. 2005 Nov-Dec;19(10):724-33. doi: 10.1097/01.bot.0000192294.47047.99. PMID: 16314721.
- Cassinelli EH, Young B, Vogt M, Pierce MC, Deeney VF. Spica cast application in the emergency room for select pediatric femur fractures. J Orthop Trauma. 2005 Nov-Dec;19(10):709-16. doi: 10.1097/01.bot.0000184146.82824.35. PMID: 16314719.
- Gordon JE, Mehlman CT. The Community Orthopaedic Surgeon Taking Trauma Call: Pediatric Femoral Shaft Fracture Pearls and Pitfalls. J Orthop Trauma. 2017 Nov;31 Suppl 6:S16-S21.
- Hedequist DJ, Sink E. Technical aspects of bridge plating for pediatric femur fractures. J Orthop Trauma. 2005 Apr;19(4):276-9. doi: 10.1097/01.bot.0000142324.59313.50. PMID: 15795577.
- Herrera-Soto JA, Meuret R, Phillips JH, Vogel DJ. The management of pediatric subtrochanteric femur fractures with a statically locked intramedullary nail. J Orthop Trauma. 2015 Jan;29(1):e7-e11.
- Hosalkar HS, Pandya NK, Cho RH, Glaser DA, Moor MA, Herman MJ. Intramedullary nailing of pediatric femoral shaft fracture. J Am Acad Orthop Surg. 2011 Aug;19(8):472-81. doi: 10.5435/00124635-201108000-00003. PMID: 21807915.
- Kocher MS, Sink EL, Blasier RD, Luhmann SJ, Mehlman CT, Scher DM, Matheney T, Sanders JO, Watters WC 3rd, Goldberg MJ, Keith MW, Haralson RH 3rd, Turkelson CM, Wies JL, Sluka P, Hitchcock K. Treatment of pediatric diaphyseal femur fractures. J Am Acad Orthop Surg. 2009 Nov;17(11):718-25. doi: 10.5435/00124635-200911000-00006. PMID: 19880682.
- Leu D, Sargent MC, Ain MC, Leet AI, Tis JE, Sponseller PD. Spica casting for pediatric femoral fractures: a prospective, randomized controlled study of single-leg versus double-leg spica casts. J Bone Joint Surg Am. 2012 Jul 18;94(14):1259-64. doi: 10.2106/JBJS.K.00966. PMID: 22695973.
- Marchand LS, Jacobson LG, Stuart AR, Haller JM, Higgins TF, Rothberg DL. Assessing Femoral Rotation: A Survey Comparison of Techniques. J Orthop Trauma. 2020 Mar;34(3):e96-e101.
- Park KH, Park BK, Oh CW, Kim DW, Park H, Park KB. Overgrowth of the Femur After Internal Fixation in Children With Femoral Shaft Fracture-A Multicenter Study. J Orthop Trauma. 2020 Mar;34(3):e90-e95.
- Rush JK, Kelly DM, Sawyer JR, Beaty JH, Warner WC Jr. Treatment of pediatric femur fractures with the Pavlik harness: multiyear clinical and radiographic outcomes. J Pediatr Orthop. 2013 Sep;33(6):614-7. doi: 10.1097/BPO.0b013e318292464a. PMID: 23774204.
- Sargent MC. Single-Leg Spica Cast Application for Treatment of Pediatric Femoral Fracture. JBJS Essent Surg Tech. 2017 Sep 13;7(3):e26.
- Sutphen SA, Beebe AC, Klingele KE. Bridge Plating Length-Unstable Pediatric Femoral Shaft Fractures. J Pediatr Orthop. 2016 Jun;36 Suppl 1:S29-34. doi: 10.1097/BPO.0000000000000761. PMID: 27078229.