I have no conflicts of interest to report
Objectives

• Briefly review the AAOS evidenced-based Clinical Practice Guideline on diaphyseal femur fractures in children
  http://www.aaos.org/research/guidelines/PDFFguideline.asp

• Introduce the SIGN Pediatric Nail

• Examine the results of treatment of diaphyseal pediatric femur fractures at Seattle Children's Hospital
AAOS Guidelines for Treatment of Diaphyseal Femur Fractures in Children

- Desirable Treatments *minimize* the *emotional* and *physical impact* of injury.

  *Minimize*
  - duration of immobilization
  - time out of school

- Children *younger* than 3 years of age should be *evaluated* for child abuse.
AAOS Guidelines for Treatment of Diaphyseal Femur Fractures in Children

- Treatment with a Pavlik harness or a spica cast are options for infants six months and younger with a femoral shaft fracture.

- For children age six months to five years with less than 2 cm of shortening:
  - early spica casting or traction with delayed spica casting are recommended
  - Use caution when spica casting for children age 6m – 5yrs with greater than 2 cm of shortening.
AAOS Guidelines for Treatment of Diaphyseal Femur Fractures in Children

- **Flexible intramedullary nailing** can be effective in children 5-11yrs.

  - Patients over age 11 or with weight > 49 kg are at increased risk of a poor outcome with flexible intramedullary nailing.

- Options include:
  - pediatric rigid intramedullary nails
  - bridge plating for inclusion in the current guideline.
Pediatric diaphyseal femur fracture

- flexible intramedullary nailing

These are titanium nails, also known as a TENs – Titanium Elastic Nails
 Typically placed retrograde
Stainless steel nails *preferable* over titanium

**Wall, et al., JBJS Am, 2008**: Retrospective case-control study comparing outcomes of Ti vs. stainless steel flexible nail treatment

- Malunion rate 4 X higher with Ti vs stainless steel nails
- Complication rate 2X higher with Ti nails
- Cost of Ti nails 3-4X higher per nail than stainless steel nails

**Sink, et al., Journal of Pediatric Orthopedics, 2010**

Retrospective case-control study

- Decreased complications by limiting flexible Ti nail use to femur fractures with stable patterns

*unstable = comminution, long oblique (fx length > diameter of femur at fx)*
Potential Complications

Flexible Nails

- Knee pain at nail insertion site
- Fracture shortening
- Nail back-out and migration
- Nail prominence
- Malunion
- Delayed union
- Refracture after nail removal
Should Hardware be removed?

- No recommendation for or against removal of surgical implants from asymptomatic patients
Diaphyseal femur fracture retained flexible nail

- 4-5 years after implantation:
  - painful prominent hardware
  - difficult to remove with resultant stress riser in femur

- Long term maintenance of hardware may lead to growth irregularities of unclear significance
• **Rigid trochanteric entry nailing, submuscular plating, and flexible intramedullary nails** are treatment options for children **age 11 yrs to skeletal maturity**

• **Avoid** piriformis or near piriformis entry

• Use lateral entry/trochanteric entry femoral nails when rigidly nailing a child 11 yrs of age or older.
Rigid trochanteric entry nailing

- Avoid the piriformis fossa (history of prior fem nailing)
Avoid external fixation in adolescents if possible

- External fixation associated with the highest rate of complications

BUT

- Important option for damage control orthopaedics
Treatment Principles for Periarticular fractures

1. If the fracture enters the joint, make an open reduction if possible – *do a good job!*
2. If stable fixation *requires* crossing the physis, *then cross the physis.*
3. Remove hardware that crosses the physis.
4. Follow growth in patients who have sustained peri-physeal fractures if possible, to identify growth anomalies early.
Pediatric nail
Mid-Proximal 1/3 Fracture
Healed fracture
Pediatric Femur
Distal 1/3 fracture
Good healing and function
Standard Fin Nail
Healed fracture
Standard Fin Nail
Nonunion
Healing after revision

- Adult Fin nail
- Wide canal in some ethnic groups
SIGN pediatric nail

- Trochanteric entry
- Allows early weight bearing
- Results in good function
What are the results of treatment of diaphyseal femur fractures in children treated with nails at Seattle Children's Hospital?
Hypotheses

1. Use of stainless steel nails results in fewer complications than Titanium nails in the 5+ year-old age group.

2. All types of flexible nails result in more complications than rigid nails.

3. There is a learning curve for this surgery - more complications by less experienced surgeons.
Research Methods

• Examine all femur fractures treated at Seattle Children's Hospital between 2009 and 2014

• Compare complications in patients by nail
  – Flexible titanium (*Synthes, Orthopediatrics*)
  – Stainless Steel (Enders, Yancey)
  – Rigid (Biomet, Zimmer, Synthes)

• Examine complication rates as a function of years of surgeon experience
Seattle Children's Femur Fracture Review

Patients Identified through Search (n=488)

Duplicates Removed (n=218)

Unique Patients Identified (n=270)

Excluded from the cohort:
- 65 had surgery within last year
- 63 medically complex patients or treated elsewhere
- 79 were treated with a cast or splint
- 2 had proximal or distal fractures

Eligible Patients Identified (n=61)
Seattle Children's Hospital Experience
for patients with fractures undergoing intramedullary fixation

Total number patients 61

Mean age at surgery 9.7 y (4.5-17 y)
Average F/U 9.8 months (1 wk – 32m)
Sex 17 Female 44 Male
Number of surgeons 11 (1-20 yrs exp)
Flexible nailing

SCH surgical technique

• Use a fracture table, but not required
• Use fluoroscopy, but not required
  – feel for the distal metaphyseal flair, small incision, drill obliquely just above the flair
• Pre-bend nails (premeasure if stainless steel or no fluoro)
• Tap nails to fracture site – one medial, one lateral
• Reduce (open if necessary)
• Advance one nail, then second
• Cut nails (if Ti) and close
• Splint or brace
10 yo patient
10 yo, 7 m p-op
Results

- No delayed or non-unions requiring reoperation
- No persistent angular deformities
- 13/61 required open reductions
- Many patients with symptomatic hardware (9+/61)
- *No routine assessment of function at latest follow-up*
Complications

- Shortening/overgrowth > 1 cm: 3*
- Nail prominence: 9*#
- Infection: 2#
- Fat embolism: 1
- Rotational Deformity: 1

Total: 16 in 14 pts/61 (23%)

* One patient with shortening also had nail prominence
# One patient with nail prominence had wound dehiscence and infection
Complications by type of nail

Titanium nails
3/13 = 23%

Enders/Stainless Steel Nails
7/27 = 26%

Rigid nails
4/18 = 22%
5 yr 8 m old

healed at 4 months, 2 cm short
## Complications

### Symptomatic Hardware

<table>
<thead>
<tr>
<th>Material</th>
<th>Date</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium Nails</td>
<td>3/13</td>
<td>2 with unplanned removal</td>
</tr>
<tr>
<td>Stainless Steels Nails</td>
<td>2/27</td>
<td>1 with unplanned removal</td>
</tr>
<tr>
<td>Rigid Nails</td>
<td>3/18</td>
<td>2 with unplanned removal</td>
</tr>
</tbody>
</table>
Removal by Type of Nails

- **Titanium**
  - Planned: 10
  - Non-planned: 2
  - Non-removed: 1

- **Enders**
  - Planned: 23
  - Non-planned: 2
  - Non-removed: 2

- **Rigid**
  - Planned: 2
  - Non-planned: 3
  - Non-removed: 13
# Complications by surgeon years of experience

<table>
<thead>
<tr>
<th>Surgeon years of experience</th>
<th># Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2 years</td>
<td>3 /11 (27%)</td>
</tr>
<tr>
<td>2-5 years</td>
<td>1 /3 (33%)</td>
</tr>
<tr>
<td>&gt; 5 years</td>
<td>10 /47 (21%)</td>
</tr>
<tr>
<td>Overall</td>
<td>14 /61 = 23%</td>
</tr>
</tbody>
</table>

Median years of experience: 14 yrs
Summary of the Seattle Children's experience with intramedullary nailing

- Union is reliable
- Complication rates are high
  - "Avoid flexible nails in length-unstable fractures"
    - consider temporary splinting or casting until callous
  - flexible nails are often symptomatic
    - planned removal resolves symptoms and encourages normal growth
  - Rigid nails are often symptomatic
    - Required trochanteric entry may lead to bursitis
Study Limitations

• Retrospective review, small number of patients
• Many patients with limited follow-up
• No routine assessment of function
  – "Back to sports"
  – "No limp, no pain, no limitations in activities"
• No routine objective assessment of leg lengths and alignments
  – "Pelvis is level on standing" not routinely assessed
  – femur films without alignment films
  – no routine measurement of standing intermalleolar distance with knees nearly touching
Next Steps/future questions

• Compare complication rates between treatments:
  
  Flexible nails vs. SIGN pediatric nails

  – Review the data base and compare retrospectively
  – *Do a prospective study*
Summary
Diaphyseal Femur Fractures

• Consider patient and family related factors:
  – living situation
  – available resources
    • for the treating physician
    • for the family with home care
  – size and co-morbidities of the patient
Thanks