The Infected Nonunion

Disclosures!

• Publications:
  • Rockwood and Green, Tornetta and Ricci TIFS, Tornetta and Einhorn; Subspecialty series, Court-Brown, Tornetta; Trauma, AAOS, OKU Trauma, ICL Trauma, Tornetta; Op Techn in Ortho Surg, OTA Slide project.
  • Journals: JOT; Deputy editor, CORR, JAAGS, JBJS; Reviewer

• Research:
  • NIH, OTA, FOT, OREF, AIOD

• Consultant / Designer
  • Smith and Nephew, Kinespring

Infection & Nonunions

• Infection workup

• Skip early infection

• Culture (+) fractures

• Gross Infection
**Diagnosis**
- Patient factors
  - Immunosuppression
    - HIV, IDDM, smoking, ETOH, steroids, chemo, etc
  - Malnutrition
    - Total lymphocyte, albumin, prealbumin, vit D, etc

**Classification**
- Physiologic class
  - Normal host
  - Compromised
    - Local
    - Systemic
    - Treatment worse than disease

**History**
- Open fracture
- External fixation pins
- Prior surgery
- Compartment syndrome
- Any redness, drainage
Preoperative Diagnosis of Infection in Patients with Nonunions

- At risk nonunions
- Blood tests
- Radiology
- Intra-op tests

Nonunions
- Prior to operative treatment
- Must rule out infection
  - Require different treatment
  - Staged procedures
- No consistent workup
  - Blood tests (CBC, ESR, CRP)
  - Nuclear tests (Bone, Indium)
  - Intraoperative tests
**Protocol**

- **Preop**
  - CBC, ESR, CRP
  - Bone Scan
  - White cell scan
- **Intraop**
  - Gram Stain
  - Pathology….WBC/HPF

**Positive tests**

- WBC: > 11,000
- ESR: > 30 mm/hr
- CRP: > 1.0 mg/dl
- Bone/Indium: radiologist confirmed
- Gram stain: Any bacteria
- WBC/HPF: > 3 WBC/HPF

**At Risk Population**

- Prior surgery: 92 pts
- Open fracture: 50 pts
- History of Infection: 1pt
### Patient Demographics

<table>
<thead>
<tr>
<th></th>
<th>Open</th>
<th>Closed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humerus</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Ulna</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Femur</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Tibia</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>Pilon</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Ankle</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

### Infection

- Defined as:
  - (+)culture at time of revision surgery
  - Finding of gross infection
  - Development of infection in the immediate postoperative period
- 30 of 95 (32%) infected
### Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Cell Scan</td>
<td>19%</td>
<td>92%</td>
<td>50%</td>
<td>72%</td>
</tr>
<tr>
<td>ESR &gt;30</td>
<td>58%</td>
<td>80%</td>
<td>58%</td>
<td>80%</td>
</tr>
<tr>
<td>CRP &gt; 1.0</td>
<td>61%</td>
<td>75%</td>
<td>54%</td>
<td>75%</td>
</tr>
<tr>
<td>WBC &gt; 11,000</td>
<td>22%</td>
<td>89%</td>
<td>50%</td>
<td>70%</td>
</tr>
</tbody>
</table>

### Predicted Probability of Infection

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Predicted Probability of Infection (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>83</td>
</tr>
</tbody>
</table>

**Risk Factors include WBC, ESR, CRP and nuclear scans.**
**Risk Factors include only WBC, ESR and CRP.**

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Predicted Probability of Infection (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>58</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
</tr>
</tbody>
</table>
### Intra-operative Components Utility

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path WBC &gt; 3/HPF</td>
<td>40%</td>
<td>81%</td>
<td>40%</td>
<td>81%</td>
</tr>
<tr>
<td>Gram Stain</td>
<td>25%</td>
<td>100%</td>
<td>100%</td>
<td>68%</td>
</tr>
</tbody>
</table>

### NPV of WBC, ESR, CRP & nuclear scans

![NPV graph](image_url)
Example:
- 21 y/o male
- Bilateral tibia fractures
- IM Nails

Example:
- WBC: 6
- CRP: 5.9
- (+) MRSA
- Indium scan: Neg
- Gram stain: Neg
Conclusions

• One test alone is not sufficient to diagnose an infected nonunion
• Nuclear scan is not a cost effective diagnostic tool for infected nonunions
• Simple blood tests recommended

What if the Culture is Positive?

• What are the implications?
  • Antibiotics??
  • Duration?
  • Success rate??

Fate of Patients With a “Surprise” Positive Culture After Nonunion Surgery

Dana Olczewski, MD.,* Philipp K. Strombol, MD.,† Charles Stockton, MD.,* William M. Ricci, MD.,* Martin F. Hoffman, MD.,* Clifford B. Jones, MD.,* Debra L. Stetson, PhD.,* and Paul Tomatis III, MD.*

• At risk population
  • History of prior surgery or infection and/or open fracture
  • No clinical signs of infection
  • Cultures sent at time of definitive reconstruction
Results

- 460 patients
- Two cohort groups
  - 98 cultures (21%) “surprise” positive
  - 362 cultures (79%) negative

Fractures

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Tibia</th>
<th>61%</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Femur</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td>Humerus</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>6%</td>
</tr>
<tr>
<td>Open</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>Closed</td>
<td>40%</td>
<td></td>
</tr>
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Bacteria

<table>
<thead>
<tr>
<th>Type of Bacteria</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulase-negative Staphylococcus</td>
<td>45</td>
</tr>
<tr>
<td>Methicillin-resistant S. Aureus</td>
<td>12</td>
</tr>
<tr>
<td>Pseudomonas</td>
<td>8</td>
</tr>
<tr>
<td>Proteus</td>
<td>8</td>
</tr>
<tr>
<td>Methicillin-sensitive S. Aureus</td>
<td>7</td>
</tr>
<tr>
<td>Bacillus</td>
<td>4</td>
</tr>
<tr>
<td>Peptostreptococcus</td>
<td>3</td>
</tr>
<tr>
<td>Staph species unspecified</td>
<td>3</td>
</tr>
<tr>
<td>Enterococcus</td>
<td>2</td>
</tr>
<tr>
<td>Streptococci</td>
<td>2</td>
</tr>
<tr>
<td>Clostridium</td>
<td>2</td>
</tr>
<tr>
<td>E. coli, Staph epidermidis, Beta hemolytic strep, Serratia, Candida and Aspergillus</td>
<td>1</td>
</tr>
</tbody>
</table>
Union After Index
- Culture (+) = 66 / 90 (73%)
- Culture (-) = 347 / 362 (96%)
- P < 0.0001

Infection After Index
- Culture (+) = 11 / 90 (12%)
- Culture (-) = 15 / 362 (4%)
- P < 0.0001

Final Outcome
- Culture (+) = 86 / 90 (95.5%)
  - 24 Additional procedures
  - 9 / 13 Debridement only
  - 4 / 13 with 1 additional procedure
  - 4 / 90 (4.5%) infected nonunion
  - 2 BKA
- Culture (-) = 362 / 362 (100%)
  - 15 Additional procedures
- P < 0.0001
Summary
• Culture positive
  • 73% Index
  • 93% Final
• Culture negative
  • 95.5% Index
  • 100% Final

Recommendations
• Counsel patients
• Treat all positive cultures
• Potentially offer two-stage procedures
  • Unknown efficacy
  • 79% would be unnecessary

What if Really Infected?
• Can we do as well as if contaminated?
• Staged procedure
• How do they do?
The Fate of Patients After a Staged Procedure for Infected Nonunion

Participating Centers
- Boston University
- Michigan State
- Indiana University
- New York University
- Carolinas Medical Center
- University of Minnesota
- Inova Fairfax Hospital
- University of Mississippi

Infected Nonunions
- Biology vs Stability
- No consistent Treatment
  - Staged Procedure
  - Success of eradication?
  - Any way to predict?
Patient Demographics

- 169 Patients
  - 118 Men, 51 Women
- Avg age
  - 43.8 y/o (14 to 81)
- Primarily tibia fractures

Infection

- Defined as finding of gross infection
- Initial Procedure
  - 110/169 (65%) avg 27 wks
- Subsequent Procedure
  - 59/169 (35%) avg 45 wks

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<tr>
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<td>5</td>
</tr>
<tr>
<td>Serratia</td>
<td>4</td>
</tr>
<tr>
<td>Peptostreptococcus, Corynebacterium, Bacillus, Beta</td>
<td>3</td>
</tr>
<tr>
<td>Hemolytic Strept, Citrobacter, Klebsella</td>
<td>3</td>
</tr>
<tr>
<td>Alpha Hemolytic Strept, Straphlococcus, Proteus</td>
<td>2</td>
</tr>
<tr>
<td>Aspergillus, Salmonella, Proteus, Eikenella,</td>
<td>1</td>
</tr>
<tr>
<td>Acinetobacter, Escherichia, Morganella</td>
<td>1</td>
</tr>
</tbody>
</table>
Antibiotic Beads 34
Antibiotic Nail 33*
Antibiotic Spacer 21

*Antibiotic nails were not counted as exchange implants, but as adjuvant treatment.

Defect Management

Treatment

• Debridements
  • Avg 2.8
• Antibiotics
  • Avg 6.1 wks (2 wks – 16 months)

Definitive Treatment

• 75% Nail or ORIF
• 60% 1° closure
• 60% Grafted
  • 55% Included autograft
Laboratory tests

• Cultures at reconstruction:
  • Positive 45% (60/132)
  • Negative 55% (72/132)
• ESR: > 30 mm/hr
• CRP: > 1.0 mg/dl

Inflammatory Values

• Elevated ESR and CRP
  • 59% (+) cultures
• Normal ESR and CRP
  • 63% (-) cultures

Culture Based Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>All 169</th>
<th>Cx(+) 60</th>
<th>Cx(-) 72</th>
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<tr>
<td>Union</td>
<td>121 (74%)</td>
<td>33 (55%)</td>
<td>60 (87%)</td>
</tr>
<tr>
<td>Union p 2nd procedure</td>
<td>139 (85%)</td>
<td>45 (75%)</td>
<td>65 (94%)</td>
</tr>
<tr>
<td>Persistent nonunion</td>
<td>25 (15%)</td>
<td>15 (25%)</td>
<td>4 (6%)</td>
</tr>
<tr>
<td>Amputation</td>
<td>10 (6%)</td>
<td>5 (8%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Lost to F/U</td>
<td>5</td>
<td>0</td>
<td>3</td>
</tr>
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<td>Lost to F/U</td>
<td>5</td>
<td>0</td>
<td>3</td>
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### Example From Earlier

- WBC: 6
- CRP: 5.9
- (+) MRSA
- Indium scan: Neg
- Gram stain: Neg

### Intraoperative culture positive for MRSA
Defect Management
Two stage reconstruction versus bone transport in management of resistant infected tibial diaphyseal nonunion with a gap
Ahmed Fathy Saad1 • Mohamed A. Lakhd2 • Ezzel H. Fathy1 • Mohamed Elshafei1

• 16 Staged: 14 Frames
• All salvaged
• Only difference
  • Ankle and ST motion

Treatment

Now
Example

Debridement

Flap Coverage

Comparing Muscle and Fasciocutaneous Free Flaps in Lower Extremity Reconstruction—Does It Matter?

John Parks, MD, Grace Chua, MD, and Subran k. Sen, MD

- 86 Muscle; 35 FC
- Primarily ALT
- Smokers worse
- Days to union, WB same
- Both work well
At Procedure

• Culture: negative
• CRP: 0.5
• ESR: 21

Outcome: Union

Intramedullary

• Antibiotic nails
• Many ways to make
• Exchange nail

Antibiotic Cement-Coated Interlocking Nail for the Treatment of Infected Nonunions and Segmental Bone Defects

70% Union

34% Union
Recommendation

- Staged procedures
- Wide resection!
- CRP/ESR after Ab
  - If high, redebridement?
- Fixation
  - Stable
  - Defect grafting vs transport

Summary

- Preop
  - ESR, CRP, WBC
  - Not nuclear studies
- Intraop
  - Gram stain
  - Not WBC/HPF
  - Cultures are predictive!!

Thank You

Boston Medical Center