Nonunions

Boston Medical Center

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, JAAOS, JBJS; Reviewer

- Research:
  - NIH, OTA, FDT, OREF, AIOD

- Consultant / Designer
  - Smith and Nephew, Kinespring

Diagnosis

- Not that hard!
- Symptoms
- Oblique radiographs
- CT
- MRI
- Symptoms!!
The Accuracy of Computed Tomography for the Diagnosis of Tibial Nonunion

By Theodore Hjortenstuen, MD, Konerisa A. Boukaid, BA, Anjana Patnaik, BA, James R. Moe, MD, Alex Kassarjian, MD, and Habib Salamoun, MD

- 35 Patients x 9.7 months
- 25 OR, 10 observed
- ICC 0.89
- PPV: 81%, Sensitivity: 100%

False Positive

45 YO Male
CT

Revision

Bone Scans
- Limited data
- Helpful
  - Partially healed
  - Intramedullary fixation
  - Ends of implants
Bone Grafting

Infection

- Infection workup
- Skip early infection
- Culture (+) fractures

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

Cierny-Mader
1985
Preoperative Diagnosis of Infection in Patients with Nonunions

Charleen Stachon, MD; Dana C. Obenshank, MD; MPH; William R. Creery, MD; Akira M. Murakami, MD; and Paul Tornetta III, MD

- 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**

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<th>Closed</th>
</tr>
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<tbody>
<tr>
<td>Humerus</td>
<td>4</td>
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</tr>
<tr>
<td>Ulna</td>
<td>0</td>
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</tr>
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<td>12</td>
<td>15</td>
</tr>
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<td>30</td>
<td>18</td>
</tr>
<tr>
<td>Pilon</td>
<td>3</td>
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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

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<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>
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<td>WBC &gt; 11,000</td>
<td>22%</td>
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Predicted Probability of Infection

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

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

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<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>
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</tbody>
</table>

WBC, ESR and CRP

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Predicted Probability of Infection (%)</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>0.05</td>
</tr>
<tr>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Intra-operative Components Utility

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<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>
<tr>
<td>Test</td>
<td>Sensitivity</td>
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<td>PPV</td>
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<td>--------------------------</td>
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**Intra-operative Components Utility**

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

**NPV of WBC, ESR and CRP**
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

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

### 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>Propionibacterium</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>Pseudomalleococcus</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>Anaerobes</td>
<td>1</td>
</tr>
<tr>
<td>Clostridium</td>
<td>1</td>
</tr>
<tr>
<td>E. coli, Staph epidermidis, Beta hemolytic, strep, Borrelia, Candida and Aspergillus</td>
<td>1</td>
</tr>
</tbody>
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### 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>
<tr>
<td>E. Coli, Staph Epidemicis, Candida</td>
<td>5</td>
</tr>
<tr>
<td>Bacillus</td>
<td>4</td>
</tr>
<tr>
<td>Pseudomicrococcus, Corynebacillus, Bacillus, Beta</td>
<td>3</td>
</tr>
<tr>
<td>Hemolytic Strep, Christaplast, Kocoblast</td>
<td>2</td>
</tr>
<tr>
<td>Alpha Hemolytic Strep, Staph, Streptococcus, Proteus</td>
<td>2</td>
</tr>
<tr>
<td>Acinetobacter, Salmonella, Proteus, Eikenella, Acinetobacter, Escherichia, Morganella</td>
<td>1</td>
</tr>
</tbody>
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Defect Management

<table>
<thead>
<tr>
<th>Antibiotic Beads</th>
<th>34</th>
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</thead>
<tbody>
<tr>
<td>Antibiotic Nail</td>
<td>33*</td>
</tr>
<tr>
<td>Antibiotic Spacer</td>
<td>21</td>
</tr>
</tbody>
</table>

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

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<th>All 169</th>
<th>Cx(+) 60</th>
<th>Cx(-) 72</th>
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<tr>
<td>Union</td>
<td>121</td>
<td>33 (55%)</td>
<td>60 (87%)</td>
</tr>
<tr>
<td>Union p 2° procedure</td>
<td>139</td>
<td>45 (75%)</td>
<td>65 (94%)</td>
</tr>
<tr>
<td>Persistent nonunion</td>
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<td>15 (25%)</td>
<td>4 (6%)</td>
</tr>
<tr>
<td>Amputation</td>
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<td>1 (1%)</td>
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Example From Earlier

- WBC: 6
- CRP: 5.9

[Image: Positive for MRSA]

- Indium scan: Neg
- Gram stain: Neg

Intraoperative culture positive for MRSA

Defect Management

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

Flap Coverage
Comparing Muscle and Fasciocutaneous Free Flaps in Lower Extremity Reconstruction—Does It Matter?
John Potts, MD, Grace Cunno, MD, and Subhes K. Seo, 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**

- Antibiotic nails
  - 70% Union
- Many ways to make
  - Exchange nail
    - 34% 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

- 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!!