NONUNION
OTA Advanced
Dallas 2017
Horwitz, Jones, Anders

Definition
**Nonunion Definition(s)**

1. Historically: Fracture that has not united within 6 months s/p treatment
2. Historically: Fracture that has not demonstrated healing progress over 3 months
3. FDA: Fracture that has not united within 9 months s/p treatment
4. Fracture that lacks potential to heal without further intervention

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**Diagnosis**
**Diagnosis: Imaging**

1. Radiographs
   - Residual Fracture Line
   - Exuberant Callus
   - No Remodeling of Callus
   - Resorption at Fracture Ends
   - Implant Failure

2. CT
   - Incomplete or No Osseous Bridging

3. SPECT CT
   1. Uptake at fracture site

**Diagnosis: Clinically**

1. Pain
   - At fracture site
   - When weight bearing

2. Limp
   - With or without pain
   - Dyskinesia

3. Mechanical Irritation
   - Mobility at fracture site
   - Crepitus

4. Swelling
   - At fracture site
   - At hardware site
Classification

Classifying

- Location in bone:
  - diaphyseal, metaphyseal, intra
- Infection: septic or aseptic
- Alignment: with or without deformity
- Manual testing: stiff or mobile
- Radiographic appearance:
  - Hypertrophic, Atrophic, Bone loss, Oligotrophic
Types of Non-unions

VASCULAR
Hypertrophic

AVASCULAR
Atrophic

Mechanical Problem

Biologic Problem

Hypertrophic Nonunion

- Inadequate Mechanical Stabilization
- Biology (vascularity) intact
- Too much motion exceeds strain tolerance for bone formation
- Abundant Callus (watch for infection!!)
- Fibrous Tissue Interposed
- “Elephant’s Foot”
Atrophic Nonunion

- Inadequate vascularity
- There may also be a lack of stability
- Little or no callus
- Smooth bone ends/resorb
- Sclerotic medullary canal

Synovial Pseudarthrosis

- Cavity
- Synovium-like lining
- Joint Fluid
- Sclerotic Bone Ends
Types of Non-unions

Dror Paley Classification

1. Bone Loss (< 1cm >)
2. Mobility
3. Deformity

Risk Factors
What causes healing problems?

- Defects
- Dysvascular segments
- Infection
- Poor mechanical stabilization, fibrous union

Infection - Lab Studies

- WBC - unreliable
- Differential - ↑ neutrophils
- Sedimentation rate
  - ↑ ESR - nonspecific for infection
  - Peak 3 - 5 days after onset
- C-reactive protein
  - Peak elevation within 6 hours
  - Useful to follow treatment
Workup

• Intermittently draining sinus

Osteomyelitis Imaging

• Plain radiographic signs
  – Bone destruction - 2-3 week delay
  – Sequestrum - avascular sclerotic cortical bone
  – Implant/bone resorption - endosteal halo around IM nail and locking screws
  – Implant loosening
Osteomyelitis Imaging

- CT scan - identify sequestrum, abscess, intramedullary extension
  - Disadvantage - metallic artifact

Osteomyelitis Imaging

- MRI
  - $T_1 \downarrow$ marrow signal
  - $T_2 \uparrow$ marrow signal
  - 90% sensitive/specific
  - Disadvantage - metallic artifact, false positives due to healing fracture
    - More difficult than in atraumatic osteo workup, soft tissue changes...
Osteomyelitis Imaging

- 3 phase Tc99 bone scan
  - Flow phase - drug injection
  - Blood pool phase - 5 minute intervals
  - Delayed bone imaging phase - 3 hours later
- Osteomyelitis image
  - ↑ activity all 3 phases
- Disadvantages
  - nonspecific with healing fracture/post-op changes (↑ osteoblastic activity)

Osteomyelitis Imaging

- Indium-111 labeled WBC scan
  - Radiolabelled patients WBC go to osteomyelitis focus
  - Fair specificity alone
**Osteomyelitis Imaging**

- Sequential Tc99/Indium-111 or Ceretec Labeled WBC scan
  - Best mode for detecting infection in unhealed fracture
  - Infection ruled out with cold WBC scan
  - 90% sensitive/specific

\[ \text{Tc-99 ~ Indium-111} \]

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**Infection - Intraop Diagnosis**

- STAT gram stains - poor sensitivity
- Surgeon’s opinion - poor sensitivity
- Frozen section
  - <5 PMN/HPF - negative
  - >10 PMN/HPF - positive
  - 5-10 PMN/HPF - equivocal
- Positive culture - Gold Standard?
**Infection - Intraop Diagnosis**

- As high as 15 – 20% positive cultures from asymptomatic hardware removal
- Multiple sites
- Clinical dilemma?

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**Nonunion: Risk Factors**

- Patient
- Injury
- Surgeon
Injury Factors

1. Traumatic Vascular Injury
2. Periosteal Stripping
3. Muscle Loss & Necrosis

Blood Supply
Rhinelander, CORR, 1974
Blood Supply
Rhinelander, CORR, 1974

• **Normal** - endosteal/medullary 2/3-3/4
  • internal → external

• **Fracture** - periosteal/external majority
  • internal → external

Centripetal Flow
Rhinelander, CORR, 1974
Soft Tissue Injury > Osseous Injury


<table>
<thead>
<tr>
<th>Type</th>
<th>Description: Gustilo Anderson Classification for Open Tibial Fractures</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open clean wound &lt; 1 cm length</td>
<td>2%</td>
</tr>
<tr>
<td>2</td>
<td>Open wound &gt; 1 cm &amp; &lt; 10 cm without extensive soft tissue damage</td>
<td>7%</td>
</tr>
<tr>
<td>3A</td>
<td>Open wound &gt; 10 cm that is able to be reapproximated with extensive soft tissue damage, special circumstance for gun shot wounds &amp; farm/contaminated wounds</td>
<td>7%</td>
</tr>
<tr>
<td>3B</td>
<td>Open wound that requires rotational or free tissue transfer for osseous coverage</td>
<td>10-50%</td>
</tr>
<tr>
<td>3C</td>
<td>Associated vascular injury that requires repair for viability of limb</td>
<td>25-50%</td>
</tr>
</tbody>
</table>
### Factor Subgroup Description: OTA Open Fracture Classification for All Fractures

<table>
<thead>
<tr>
<th>Factor</th>
<th>Subgroup</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>1</td>
<td>Mild, &lt; 5 cm and approximates</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Moderate, &gt; 5 cm and approximates</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Severe, does not approximate</td>
</tr>
<tr>
<td>Muscle</td>
<td>1</td>
<td>Mild, no muscle injured or necrotic</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Moderate, localized damage requiring debridement but muscle unit functional</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Severe, extensive damage requiring debridement, muscle unit excised and no longer functional</td>
</tr>
<tr>
<td>Arterial</td>
<td>1</td>
<td>Mild, no major vessel disruption</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Moderate, vessel injury but does not require repair</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Severe, vessel injury requires repair for limb viability</td>
</tr>
<tr>
<td>Contamination</td>
<td>1</td>
<td>Mild, none or minimal contamination</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Moderate, surface contamination easily removed &amp; not imbedded</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>a. Severe, imbedded in bone or soft tissues</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Severe, high risk environmental conditions such as farm, fecal, dirty water, etc</td>
</tr>
<tr>
<td>Bone Loss</td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Moderate, bone missing but still some contact between proximal &amp; distal segments</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Severe, segmental bone loss without any osseous contact</td>
</tr>
</tbody>
</table>

Overall severity: Any 2 above makes it a Type 2, Any 3 above makes it a Type 3
Type 1 – Mild, Type 2 – Moderate, Type 3 - Severe

### Patient Factors

1. Injury
2. Nutrition
3. Age
4. Disease
5. Social/Behavioral
Patient Systemic Biology: Age

- **Periosteal fracture healing potential decreases with age**
  - ↓ periosteal thickness
  - ↓ total cell #
  - ↓ cellular activity

O’Driscoll SWM, JOR 2001

Patient Systemic Biology: Nutrition

- **Malnutrition correlates with delayed fracture healing**
  - Serum albumin
  - Serum transferrin
  - Total lymphocyte count

- Do not assume obese patients are well nourished

Dwyer AJ et al, Orthopedics 2007
Patient Systemic Biology: Disease

• **Diabetes**
  – Diminished osteoblastic activity
  – Reduced bone mineral density
  – Low PDGF levels inhibits cell proliferation
  – Delayed fracture healing

  Lu H, Endocrinology 2003

Patient Systemic Biology: Disease

• **Chronic anemia**
  – ↓ oxygen tissue tension:
  – ↓ bone cellular metabolism
  – Anemic rat model
  – 33% vs 0% nonunion

  Rothman RH, CORR 1971
Patient Systemic Biology: Disease

- Many other diseases
  - Peripheral vascular
  - Chronic renal/hepatic
  - Cancer
  - HIV/AIDS
  - CTD/rheumatoid
- Chronic immunosuppression

Patient Systemic Biology: Age

- Fracture healing gene expression decreases with age
  - BMP-2
    (bone morphogenetic protein)
  - Ihh
    (indian hedge hog)

Meyer RA et al, JBJS 2003
Systemic Biology: Medications

- Many, MANY medications
  - NSAIDS
  - Corticosteroids
    - BMP effective in animal studies
  - RA DMARDs
  - Anti-epileptics
  - Psychotropics
  - Antacids
  - Bisphosphonates
    - Stop meds, add PTH?
- Scrutinize med list

Systemic Biology: Smoking

- Nicotine
  - Small vessel vasoconstriction
  - Delayed neoangiogenesis
  - Demineralization
- Carbon monoxide
  - Hypoxemia
Systemic Biology: Smoking

<table>
<thead>
<tr>
<th>Smoking status at baseline</th>
<th>N</th>
<th>% Unhealed Fracture at 24 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never smoked</td>
<td>81</td>
<td>9.9</td>
</tr>
<tr>
<td>Quit smoking</td>
<td>82</td>
<td>11.0</td>
</tr>
<tr>
<td>Current smoker</td>
<td>105</td>
<td>24.1</td>
</tr>
</tbody>
</table>

Castillo RC & LEAP. JOT 2005

- Even if patient currently smokes: beneficial to quit right now

Surgeon Factors

1. Approach
2. Implant
3. Timing
4. Infection
Approach: Soft Tissue Sparring

Older, Anatomic, Stripping  Modern, Soft tissue sparring

Stabilization
Summary – Non Unions

- Definition: variable & arbitrary
- Diagnosis: pain, limp, fixation failure
- Classification: location, biology, infected, mobility
- Risk Factors: injury, patient, surgeon