Principles of Nonunion Management

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• Nonunions present in a wide spectrum – we will seek to find the principles of treatment for these cases
• Incidence and impact of nonunions
• Factors predisposing to nonunion

  **Systemic:**

  *Endocrine*

  *Smoking*

  *medications (NSAIDS etc)*

  **Local:**

  *Infection/vascular*

• Mechanical factors – strain theory
• Deformity and bone loss
• Approaches to management
When is it a nonunion?

Radiographic and clinical diagnosis

• Non-progression towards radiographic union over multiple points of evaluation.

• Usually accompanied by non-improving clinical progression.

• Broken/failing hardware – common finding

![Radiographic images showing progression of a nonunion over 5 months.](image-url)
Incidence & cost of tibial nonunions

- Large series (853 patients) ~ 12% nonunion
- 87% likelihood of an open fracture
- All categories of care – more expensive in patients with nonunions vs healed fractures
  - Outpatient physical therapy (60% vs 42%) \( p < 0.001 \)
  - Median total cost ($25,556 vs 11,686) \( p < 0.001 \)
  - Opioid pain medication (90% vs 76%) \( p = 0.002 \)
  - Duration of opioids (5.4 vs 2.8 mo) \( p < 0.001 \)

Quality of Life Impact

- 237 tibial nonunions over a 10-year period
- Distal third 49%  Infection 18%
- SF-12 physical component score  24.7  
  extremely disabling
- AAOS Lower limb Core score  52.0  
  high level of physical disability
- SF-12 Mental Component Summary  42.3  
  substantial effect on mental health

Quality of Life Impact

Nonunion Workup

Radiographs +/- CT scan – can be very surprising!

Good history and exam:
Focus on **correctable co-morbidities** and ask the question “**could this be infected?**”
Nonunion Workup

Laboratory evaluation:
consider on all patients:

• CBC/ESR/CRP
• TSH/PTH
• Vitamin D
• Albumin/prealbumin
• HgB A1C
• Testosterone

Endocrine Evaluation

Unexplained nonunion

- 83% one or more new diagnosis
- New metabolic or endocrine abnormalities
- 67% Vitamin D deficiency
- 24% thyroid abnormality
- 13% central hypogonadism

- 25% healed with medical treatment only
- Workup every patient with a nonunion

Hyperparathyroidism

An unexplained nonunion can be the presenting feature of primary hyperparathyroidism.

Prevalence: Elevated PTH

- tibial nonunion: 33%
- normal union: 9%

Severe Vitamin D deficiency can present as secondary hyperparathyroidism

NSAIDS

• Use of NSAIDs in the early post-operative period may double the chance of fracture healing problems.

• Multiple studies suggest that use of NSAID’s for HO prophylaxis will increase the rate of nonunions in patients with long bone fractures.

• Controversial topic at present – NSAID’s now being used more often in early fracture care to avoid opiod issues. This may increase rate of nonunions.

• Avoid NSAID’s when treating a nonunion.

Smoking / Nicotine

- 2 to 3 x increased risk of nonunion
- May also be true for marijuana smoke (THC?)
- Ask about tobacco chewing

- **Smoking - treatment of a tibia fracture**
  - increased time to union: 17 vs 12 wks
  - time out of work: 21 vs 16 wks
  - 3-18 x risk of impaired bone healing

- Open fracture: Flap failure, infection

Tobacco Cessation

• Smoking and chewing (marijuana-ask)
• Consider Varenicline (Chantix) – FDA approved for smoking cessation

  overall very good efficacy
  neuropsychiatric side effects
  cardiovascular side effects

Discuss risk with smoking patients!

Overall Nonunion Strategy

Correct as many factors as possible prior to additional surgery

- correct Vit D levels
- smoking cessation
- glucose control
- plastic surgery eval for coverage issues
- optimize medications (NSAID cessation)

Work on the rest – during treatment
Create a plan with a high likelihood of success
Refer patients that exceed your skill set!
Nonunion - Checklist for Treatment

• Mal-alignment
• Hardware (+ broken) present
• Biology-systemic
• Biology-local
• Mechanical stability
• Infection
• Bone loss
• Soft tissue loss/Coverage needs
To understand these nonunions, You need to understand “strain”
What is Strain?

How a material responds to loading by deforming

Strain = \frac{L}{L}  \quad \text{AXIAL Strain}
What is Strain?

How a material responds to loading by deforming

Strain = \frac{\Delta L}{L} \quad \text{SHEAR Strain}
Shear Strain – Two Sources

Translational shear

Torsional shear
Shear Strain – Why is it a problem?
Shear Strain = \[ \frac{\triangle L}{L} = \frac{1}{100} = 1\% \]

Shear Strain = \[ \frac{\triangle L}{L} = \frac{1}{1} = 100\% \]
Shear Strain = \frac{\Delta L}{L} = \frac{1}{100} = 1\%

Imagine that the rope is a fragile capillary
Interfragmentary Strain Theory

*Stephan Perren Ph.D*

CORR 1979 138

“A tissue cannot survive in an environment that exceeds its strain tolerance”

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Strain tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granulation tissue</td>
<td>100%</td>
</tr>
<tr>
<td>Cartilage</td>
<td>10%</td>
</tr>
<tr>
<td>Bone</td>
<td>2%</td>
</tr>
</tbody>
</table>
Strain theory

Each tissue prepares the local environment biologically and mechanically for the next tissue
Callus Stiffens

Granulation

Initially:
Strain 10% – 50%
Optimal callus

Interfragmentary motion decreases
Callus Stiffens

Cartilage

Interfragmentary motion decreases
Healed Fracture

Bone

Interfragmentary motion decreases
What is the oxygen tension in an osteocyte in the middle of your tibia?

~ 100 mm Hg
same as arterial blood

Bone is a very aerobic tissue and requires an intact capillary network to survive
Strain theory

• Bone cannot exist in a region of high strain because the capillary network to support bone cannot survive

• Precursor tissues create an environment stable enough for a capillary network to form
Bone needs a capillary network
Capillaries need low strain

bridging capillary = fracture union
Compression – indirectly useful

Very efficient way to control shear strain through friction and interdigitation

No need for intermediate tissues
To Obtain Union

**Implant** and the **callus** together must control motion at the fracture gap such that capillaries can begin to cross.

Control of torsional and translational shear **strain** is most difficult.
How does distraction and re-alignment affect shear strain?

Alignment normalizes forces and reduces strain
Distraction actually widens the gap and can decrease strain in that way
Analyze your Nonunion

• What tissues are in the fracture gap?
• What is the strain in the fracture gap?
• Can the local tissue undergo **metaplasia** if strain is controlled?
• If not – biologic augmentation is needed to allow the creation of callus.
• Restore axial alignment
• Control translational and torsional strain
• Create stability and protect the capillary bed!
Case:
32 yo healthy male – closed fracture
Placed using an MIPPO technique with a 4 cm distal incision

8 days in ex-Fix
Is this a bridge plate??
What do you think will happen here?

Not exposed or compressed
What is the strain here?
Why did it fail?

Strain was very high because of small gap and no compression.

Callus attempted to control motion/strain

Fatigue life of plate was exceeded
Shear strain controlled with lag screw/compression
Case: 71 yo male – IDDM
severe venous stasis disease
6 mo in a cast

High angle nonunion:
difficult to plate – bad soft tissue – options?
Case: 71 yo male – IDDM
severe venous stasis disease
6 mo in a cast

High angle nonunion:
difficult to plate – soft tissue
Case: 71 yo male – IDDM severe venous stasis disease 6 mo in a cast

Frame controlled shear – very slow correction
21 days......then compressed
SL waking cast x 6 weeks
Time in frame 5 mo
Case: 35 yo male healthy MCA
Type IIIA open femur, proximal tibia with extensor mechanism injury, open pilon
ORIF femoral neck
Retrograde femoral nailing
Extension of ring fixator across the knee to protect extensor mechanism repair
18 mo later: pain with ambulation
0-110 ROM knee: no infection
femoral neck has healed

What to do now?
reamed exchange nailing
compression plating of nonunion
no bone grafting – DBX putty
4 mo later
55 yo nonunion after osteotomy
Deformity analysis
In the Sagittal Plane
Fracture not opened: Slow
distraction and deformity correction
Bone in fracture gap undergoes metaplasia into bone when alignment is corrected and strain is controlled by frame.
44 yo woman – 18 mo s/p a closed pilon fracture. Infection w/u negative

Goals:
Correct Deformity
Create Stability
Restore Biology
Pivot around CORA

Opening/closing wedge
2 years later – some pain
Fracture Gaps/Bone Loss

- Fractures with critical bone loss are the subject of another lecture
- Fracture gaps (including distraction) are an issue and effect on healing very dependent on the bone.
- Femur gaps may spontaneously heal without grafting.
- Tibia is much less forgiving
Fracture gaps / bone loss

- Tibia healing much more impaired by a gap compared to femur
- Tibia fractures with < 25% cortical contact highly predictive of nonunion (OR 4.72  p=0.02)
- Highlights the need for early bone grafting in situations with significant bone loss

Case: 45 yo male – non smoker
closed fracture – 9 mo

Reamed exchange nailing
Partial fibulectomy
Open bone grafting from prox. tibia
Healed 4 mo later
The Infection Problem

• Consider every nonunion that was open or has had surgery as potentially infected
• Preop w/u to include WBC, CRP, ESR
• If all are negative, high likelihood not infected
• However... could still be infected with a quiescent organism (p. acnes, staph epi.)
• Always culture and include fungus and AFB
• Have the lab hold for slow growing organisms
• Consider two stage if obviously infected
Exists on a time spectrum....

• Acute infection with hardware

• Late infection with hardware

• Chronic osteomyelitis
Infected Nonunion - spectrum

Bone involvement

Time
Osteomyelitis
Cierny – Mader classification

Medullary

Superficial

Localized

Diffuse

Infected nonunion
Infected nonunion

How does it happen?

• Inadequate debridement of an open fracture
• Bacterial contamination at the time of surgery
• Failure of primary wound healing
Inadequate Debridement

That intramedullary cortical fragment will become a sequestrum!
Poor surgical timing
Case: 57 yo nonsmoker – healthy male
6 months s/p grade II open fracture
2 incision technique

What is happening on the surface of the plate and bone?
The race for the surface!

• surfaces colonized by healthy tissue are rarely colonized by bacteria
• surface bacterial colonies are rarely replaced by healthy tissue
Bacterial adherence

Gristina AG Science 1987

Reversible - early

6 - 8 hours

Irreversible - late
Antibiotic Resistance

• Biofilm layer dramatically reduces the metabolic rate of the bacteria.
• MIC 50-100 times higher in biofilm colonies than swarmer cells

• “You can’t kill me, I’m sleeping”

• surface specific:
  
titanium < stainless steel < PMMA < BONE
After the biofilm is well established, the surface has to be debrided or removed to resolve the infection.
Debridement - bone

Get it done in 2 visits to OR
Consider a CT scan after hardware out
Based on the location of dead bone

- External: *burr / curette*
- Medullary diaphysis: *ream / RIA*
- Metaphyseal: *slot the cortex to gain access*
Debridement

*create a LIVE contaminated wound*

- 2 debridements to clean (maybe more)
- plan approach to remove all necrotic tissue (bone/muscle/skin)
- Send everything for culture (+fungus)
- Consider fastidious organisms
- excise sinus tracts present >1 year - *send to path (squamous cell carcinoma)*
- do not elevate flaps (make a canyon)
- use a burr with constant cooling
Imaging – infected nonunion

- Plane radiographs
- CT scan – very useful after hardware out
- MRI – medullary extent of infection
- Indium WBC scans – beware false negative
Debridement - hardware

Hardware / Tracts are contaminated

- **Plates:** curette/burr under surface
- **Screws:** overdrill – remove broken
- **IM nail:** ream and flush canal
  antegrade and retrograde
Dead space management

**Temporary:**
- antibiotic beads (pouch)
- +/-VAC sponges

**Permanent:**
- muscle grafts
- resorbable antibiotic delivery
- bone graft or transport / shorten
Systemic Antibiotics

• Generally 4-6 weeks IV
• Consider short IV (2 weeks) then PO (A host)
• Oral Rifampin in Gm+ if hardware retained – penetrates biofilm
• Don’t use: bacteriostatic antibiotic *with* bacteriocidal antibiotic

• ID consult
  - manage antibiotic levels
  - monitor toxicity
  - good medicolegal sense
Definitive Reconstruction

All methods viable if the debridement was done well.

- Plate
- IM nail
- Ring Fixator

Consider adding specific antibiotic to bone graft.

1 gm Vanco powder well tolerated
Case: 32 yo male 1 ppd smoker
IIIA open fracture
ESR 85 – CRP 4.3 – previous plating

Staged resection (6 cm) – MRSA & serratia
Quit smoking – vitamin D level very low -

Bone transport
Bone grafting at distal site:
12 mo in frame
Case: 54 yo local attorney
10 weeks after IM nailing grade 1 open fracture - MVA

- WBC 15.5
- ESR 95
- CRP 6.3
Same day
After 7 days – Redebride
Antibiotic coated IM nail + IV Vanco
Infection cleared

re-nailed
standard IM nail
iliac crest BG
vanco added
cultures negative
What to do?

dehisence of lateral wound – corner of plate exposed – growing MRSA
Staged Treatment

Part one:
- Hardware removal
- Debridement
- Antibiotic Bead placement
- Gastroc Flap – IV antibiotics
- CT scan
Part two: six weeks later
revision ORIF
iliac autograft (+ vanco)
Joint surface elevated and supported with autograft
3 mo s/p ORIF
10 – 85 ROM
No infection
Infected Nonunion

• Image as needed to stage it
• Plan thoroughly – refer if necessary
• Optimize host factors
• Debride aggressively
• Shorten judiciously
• Create stability and axial alignment
• Immuno-competent coverage
• Bone graft / substitute / transport
Thank You!

"Well, I'll be damned...I'm OK!"
Topic