Atrium Health
Musculoskeletal Institute

Carolina NeuroSurgery & Spine Associates

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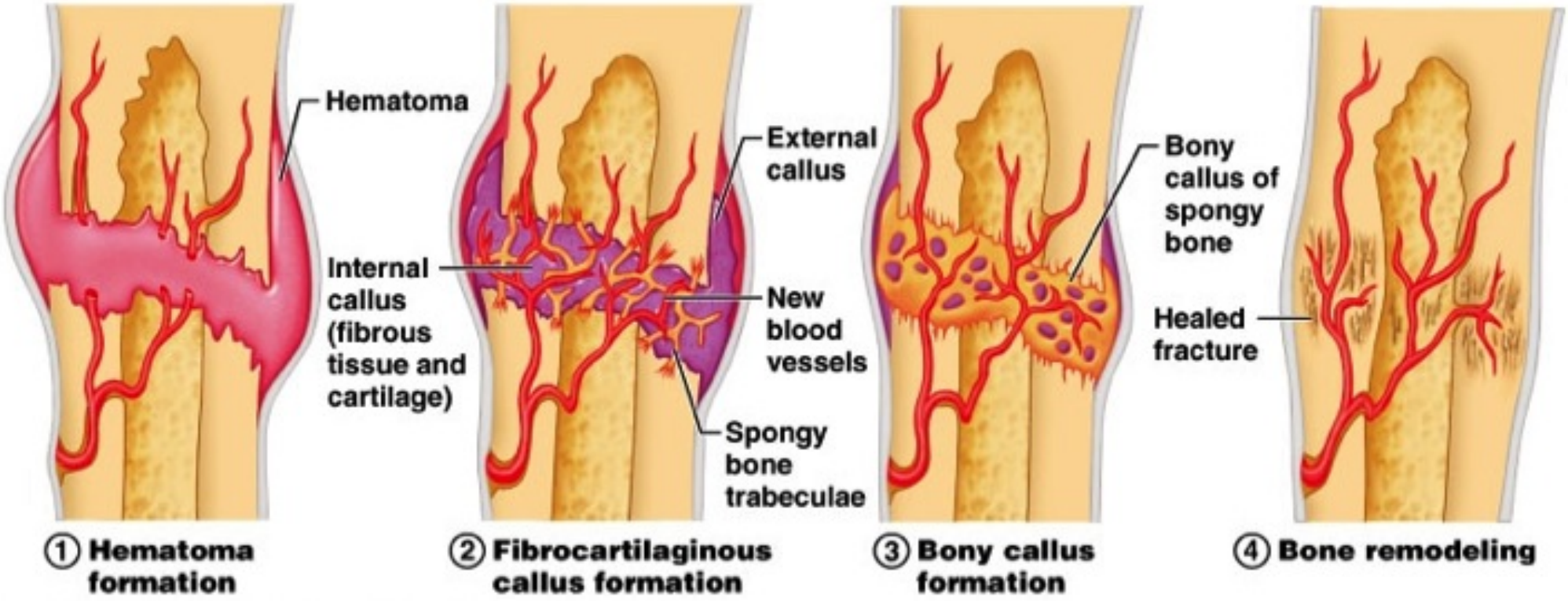
Nonunion

Kevin Hickey PA-C

What is a nonunion?

- Arrest in Fracture repair process
- Length of time can vary
- FDA definition: Fracture that persists >9 months without signs of healing for 3 months
- Delayed healing: > 6 months before fracture healed

Pathophysiology of bony healing



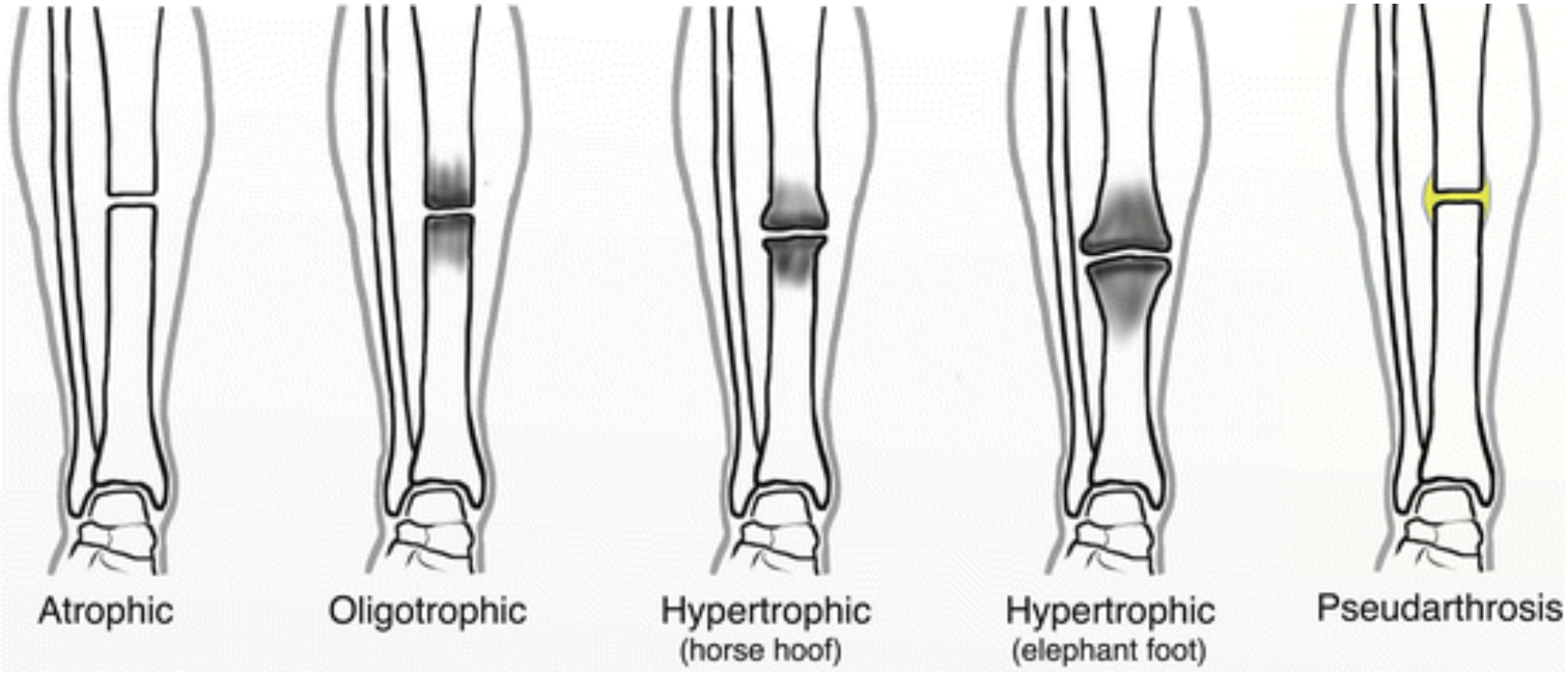
[1]

Causes: Multifactorial

- Inadequate blood supply: Decreased osteogenic cells due to inadequate blood supply
- Inadequate stability: Increased distance or micromotion can damage the osteoconductive scaffold
- Infection: Increased risk in high velocity, Open fractures, post-operative fractures
- Pattern: Segmental, butterfly fragments, bone loss/gaps (>3mm), open fractures, significant soft tissue (high velocity injuries). Commonly these types disrupt blood supply as well as stability

Types of Nonunions

- Atrophic
- Oligotrophic
- Hypertrophic
- Pseudoarthrosis
- Septic



[2]

Types: Atrophic

- Absent callus formation with absent radiographic union
- Indicates poor blood supply, biology, fixation

[3]

Types: Hypertrophic

- Indicates adequate blood supply
- Has abundant callus formation

[4]

Types: Oligotrophic

- Not hypertrophic and callus is absent
- Some indication of vascularity and healing but minimal
- Likely due to inadequate reduction/stability

Types: Pseudoarthrosis

- Sufficient biology with inadequate stability
- Constant micromotion forms a type of false joint with intra-op capsule formation seen
- Sometimes excluded in nonunion types

Types: Septic

- Reduces blood flow from organisms consuming the nutrition to healthy bone
- Decreases the new bone formation

Epidemiology

- Rate: 1.9-10%. This varies depending on varying factors
  - Location: femoral neck, scaphoid wait, 5th metatarsal base (zone 2), distal tibia/fibula, tarsal navicular body
  - Risk factors
  - Reduction/stability
  - Soft tissue injury
- Some open fractures with significant soft tissue damage can be as high as 16%

Risk Factors

- Smoking
- Hormone disorders: DM, Thyroid abnormalities, testosterone/estrogen deficiency, Vit D deficiency, Ca or Ph abnormality
- Malnutrition
- Alcoholism
- Medications: Steroids, chemotherapy, immunomodulators
- Osteoporosis (multifactorial)
- BMI
- Multiple fractures

HPI

- Injury date
- Injury mechanism
- Previous treatments
- Current symptoms
- Medical history and Medications
- Risks factors
- Functional status

Physical exam

- Inspection: **deformity**, swelling, wounds
- Palpation: Tenderness, crepitus
- Vascular status
- Motor function
- ROM at adjacent joints
- Functional status

TABLE I Criteria Used to Define Clinical Fracture Union*

Clinical Criteria Used to Define Fracture Union	Number of Articles (N = 77)
1. No pain/tenderness when bearing weight	38 (49%)
2. No pain/tenderness on palpation/ examination	30 (39%)
3. Ability to bear weight	14 (18%)
4. Ability to walk/perform activities of daily living with no pain	11 (14%)
5. Ability to walk/perform activities of daily living	9 (12%)
6. No residual pain at fracture site	8 (10%)
7. No motion at fracture site on examination	4 (5%)
8. Full range of motion at adjacent joint	4 (5%)
9. "Clinically stable/asymptomatic"	2 (3%)
10. No residual warmth at fracture site	1 (1%)
11. Full range of motion at adjacent joint without pain	1 (1%)
12. Fracture stiffness measured mechanically†	1 (1%)

*The clinical criteria were grouped into twelve similar categories and were arranged in order of most to least common use. †A fracture stiffness of >15 Nm/deg in two orthogonal planes was reported to indicate sufficient healing for external fixator removal in the case of a tibial fracture[9].

Variability in the Assessment of Fracture-Healing in Orthopaedic Trauma Studies

By Luis A. Corrales, MD, Saam Morshed, MD, MPH, Mohit Bhandari, MD, MSc, FRCSC, and Theodore Miclau III, MD

J Bone Joint Surg Am. 2008;90:1862-8

Imaging

- X-rays:
  - AP/lateral. Obliques if poor visualization with views.
  - AP Mechanical axis for LE injuries to assess alignment. Can also obtain lateral mechanical axis
  - Typically looking for 3 out of 4 cortices (see next slide)

- CT:
  - Controversial when to obtain
  - Good diagnostic tool for additional information
  - Angular deformity (axial cut)
  - If current hardware, can has artifact limiting visualization (metal suppression available)

- Bone scan:
  - Assess for vascularity
  - Less commonly used

- US:
  - Look for hyperechoic fracture callus
  - Less commonly used: user dependent

RUST: Radiographic Union Score for Tibia

- Score of 10 or greater associated with radiographic union
- Dependent on intra-observer and inter-observer reliability

	Radiographic Criteria	
Score per Cortex	Callus	Fracture Line
1	Absent	Visible
2	Present	Visible
3	Bridging	Visible
4	Remodeled	Invisible

A score is given to each cortex (anterior, posterior, medial and lateral) and the RUST score is the sum of all cortex scores.

[8]

Imaging

Labs

- All nonunions should have labs to r/o septic nonunion
- CBC, CRP, ESR: Standard in all nonunions
- Other labs to consider:
- Metabolic workup: CMP, testosterone, PTH, Thyroid panel, Vitamin D, Ca, alk phos, albumin
- Serum cotinine: To ensure smoking cessation (levels >10ng/ml associated with active smoking)

Labs

- Probabilities with labs excluding infection with zero, one, two, and three negative tests: 0%, 48.0%, 76.4%, and 81.6%, respectively.

TABLE III Predicted Probability of Infection with Use of All Tests*

Number of Positive Tests Under Consideration	Predicted Probability of Infection *(%)*
0	18.3
1	23.5
2	50.0
3	85.7

*The predictors include WBC count, ESR, CRP level, and nuclear scans.

TABLE IV Predicted Probability of Infection with Use of All Tests Except Nuclear Scan*

Number of Positive Tests Under Consideration	Predicted Probability of Infection *(%)*
0	19.6
1	18.8
2	56.0
3	100.0

*The predictors include only WBC count, ESR, and CRP level.

Preoperative Diagnosis of Infection in Patients with Nonunions

Charlton Stucken, MD, Dana C. Olszewski, MD, MPH, William R. Creevy, MD, Akira M. Murakami, MD, and Paul Tornetta III, MD

The Journal of Bone & Joint Surgery · jbjs.org
Volume 95-A · Number 15 · August 7, 2013

Metabolic and Endocrine Abnormalities in Patients With Nonunions

Mark R. Brinker, MD, Daniel P. O'Connor, PhD,† Yomna T. Monla, MD,‡ and Thomas P. Earthman, MD§*

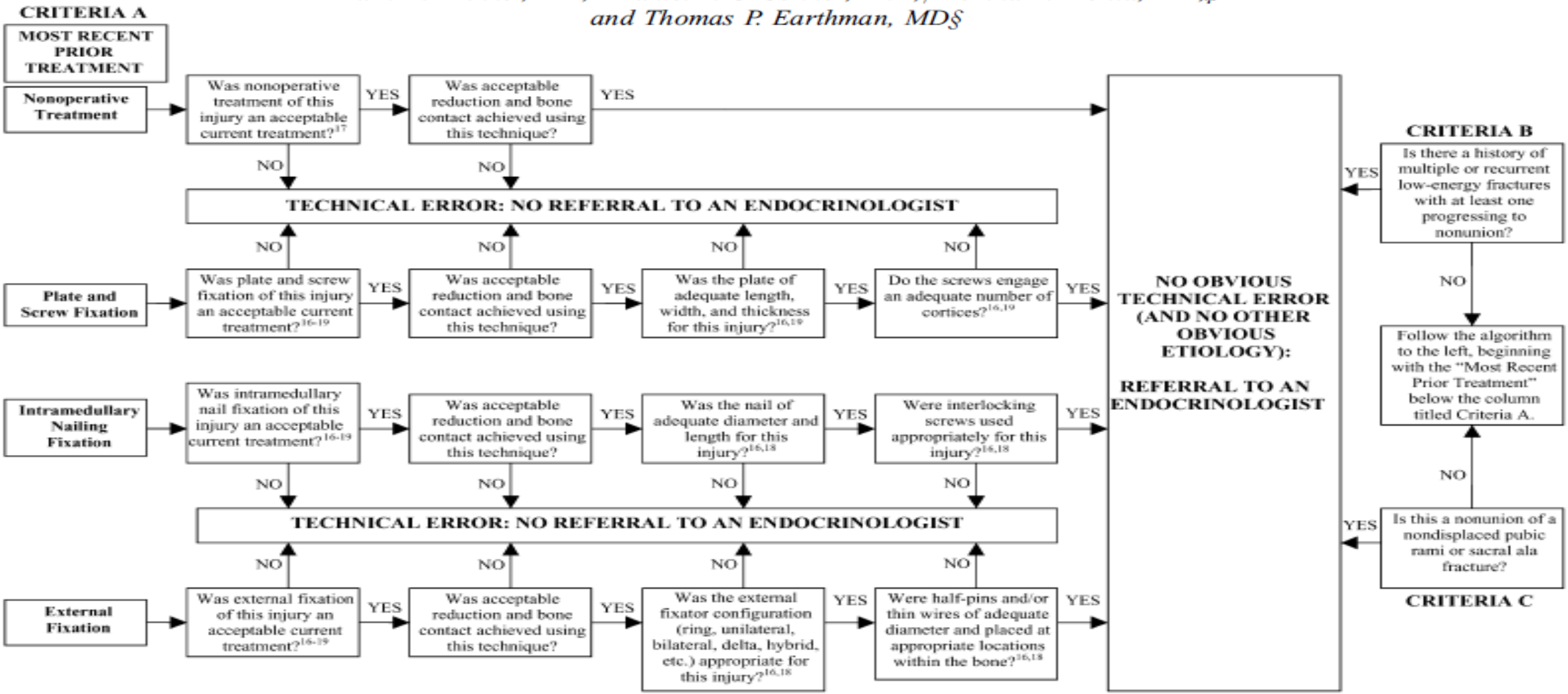


FIGURE 1. Algorithm illustrating the application of our screening criteria.

Risk of Obtaining Routine Cultures During Presumed Aseptic Orthopaedic Procedures

MAJ Matthew A. Napierala, MD[1]; MAJ Jaime L. Bellamy, DO[2]; COL Clinton K. Murray, MD[2]; CPT Richard K. Hurley, Jr., MD[2]; Joseph C. Wenke, PhD[3]; and Joseph R. Hsu, MD[4]

- 29% rate of antibiotic complication
  - Renal Failure
  - Neutropenia
  - Anemia

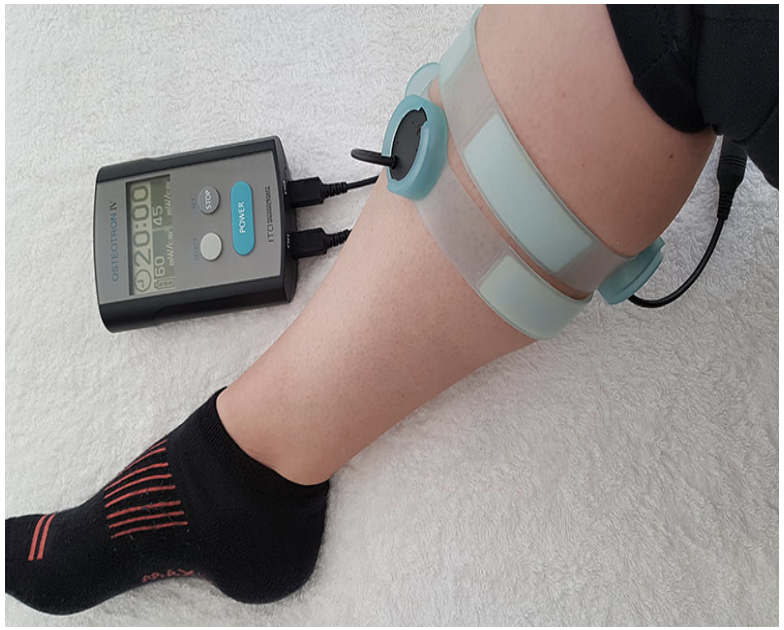
Treatment: Non-operative

- Monitoring: If asymptomatic, functional, with delayed/nonunion on x-rays and functional, can monitor closely with repeat radiographs
- Fracture bracing
  - Poor surgical candidates
  - More appropriate in delayed union
  - Atypical for symptomatic nonunion

[10]

Treatment: Non-operative

- Bone stimulator:
  - Basic science research suggests that electrical stimulation enhances the process of bone healing by stimulating the calcium-calmodulin pathway secondary to the upregulation of bone morphogenetic proteins, transforming growth factor-β and other cytokines
  - DC current: decrease osteoclast activity and increase osteoblast activity by reducing oxygen concentration and increasing local tissue pH
  - AC current: affect synthesis of cAMP, collagen and calcification of carilage
  - Pulsed electromagnetic field therapy (PEMF): cause calcification of fibrocartilage [11]



[12]

Treatment: Operative

- Typical treatment of nonunion is surgical
- Often tailored by nonunion type
- Multiple surgical techniques exist and may require varying approaches depending on type, patient, situational factors

- Commonly used concepts:
  - Exposure of the fracture site
  - Freshening of sclerotic edges to get a bleeding surface.
  - The opening of intramedullary cavities of fragments to facilitate the flow of blood circulation
  - Rigid fixation
  - Bone grafting to augment bone healing
  - External splintage if required.

Treatment: Hypertrophic nonunion

- The goal is to improve mechanical stability with internal fixation
- Compression plates
- Exchange nailing
- Augmented plating with ORIF
- Dynamization of nail (should not be used in the humerus because dynamization cannot work in a non-weight bearing limb

Nonunion with rotational deformity

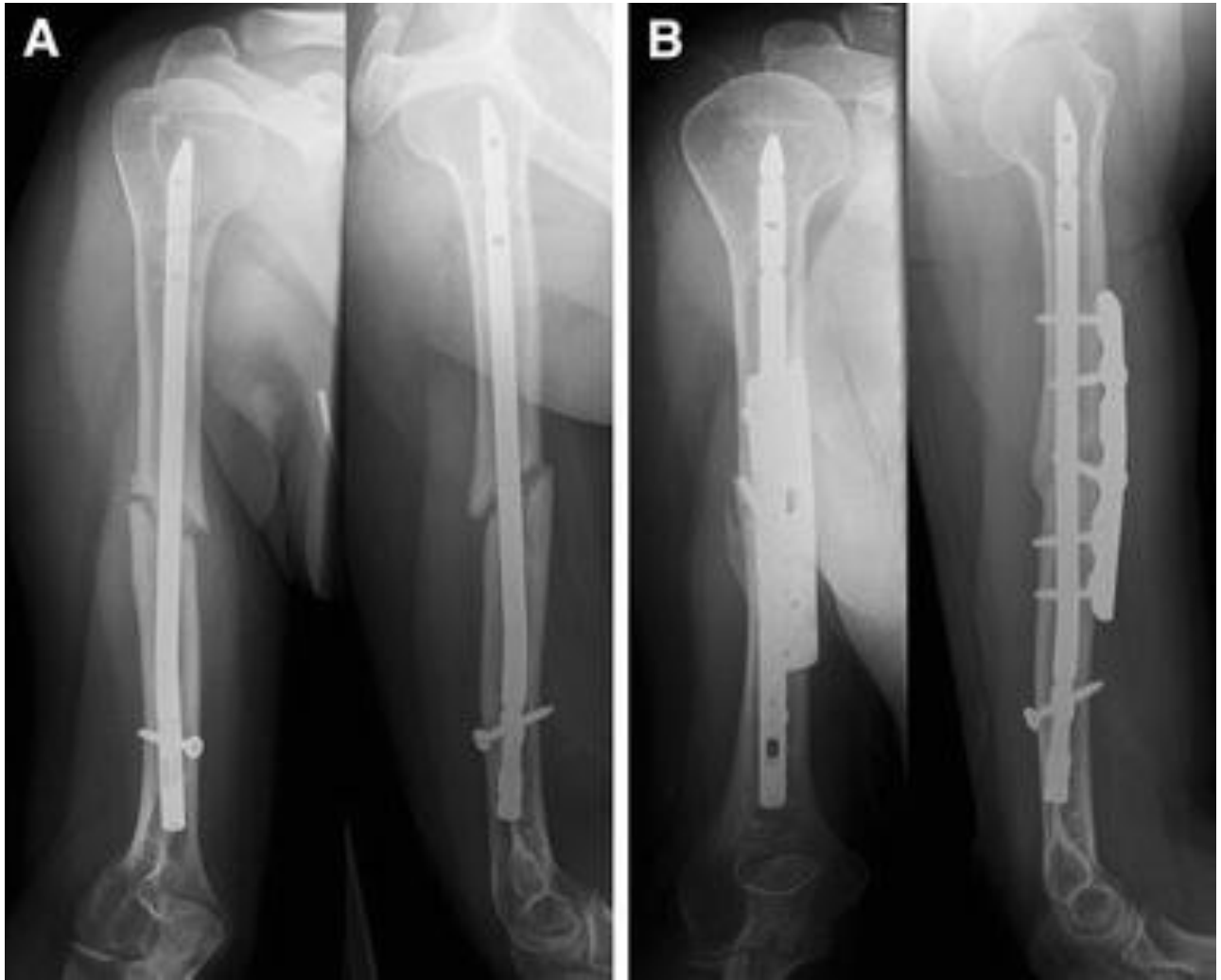
Percutaneous osteotomy above nonunion

Post-operative union

Treatment: Atrophic nonunion

- The goal is to fix the biology and mechanical stability
- Internal fixation with biologic stimulation
- Biologic stimulation with bone graft
  - Bone morphogenetic protein (BMP)
  - Autologous iliac crest bone graft
- Intramedullary reaming, irrigation, and debris aspiration (RIA)
- Demineralized bone matrix (DBM)

Treatment: Atrophic nonunion



[15]

Treatment: Oligotrophic nonunion

- Use a combination of both internal fixation and biologic stimulation depending on the clinical situation

Treatment: Septic Nonunion

- A 2-staged surgical treatment protocol is the gold standard but not always required

- 1st stage - removal of loose or chronic infected hardware, debridement, and revision fixation of nonunion, and treatment of infection with culture-specific local and systemic antibiotics
- Modalities used for initial fixation in case of infection
  - Antibiotic beads
  - Antibiotic nails
  - Antibiotic cement spacers
  - Masquelet technique:temporary cement spacer followed by staged bone grafting
  - External fixation
  - Soft tissue coverage with a flap

- 2nd stage
- Begins after a period of antibiotic therapy when both serologic and clinical signs of infection are absent
- Definitive fixation proceeds with internal fixation and bone grafting, other biological treatment, bone transport, depending on specific fracture characteristics.

Improve the odds

- Fracture stabilization (reduction, splint/cast, fixation)
- Wound management
- Modify risk factors
- Vit D, Ca post-injury/surgery
- Early loading

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Thank You

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