

Nonunions



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, FOT, OREF,, AIOD

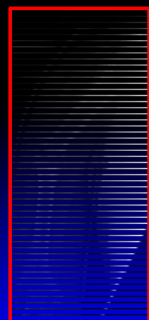
• Consultant / Designer

- Smith and Nephew, Kinespring



Diagnosis

- Not that hard!
- Symptoms
- Oblique radiographs
- CT
- MRI
- Symptoms!!

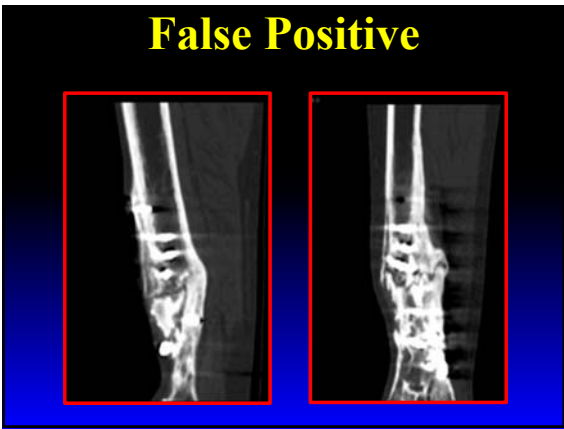


**THE ACCURACY OF COMPUTED
TOMOGRAPHY FOR THE
DIAGNOSIS OF TIBIAL NONUNION**

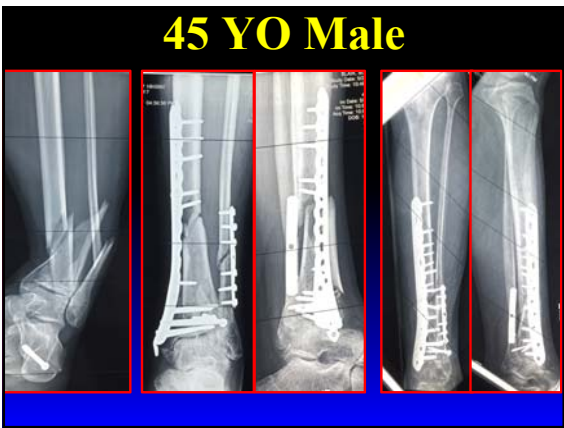
BY TIMOTHY BHATTACHARYA, MD, KIMBERLY A. BOUCHARD, BA, ANURADA PHADKE, BA,
JAMES B. MEIGS, MD, ARA KASSARIAN, MD, AND HAMID SALAMPOUR, MD

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

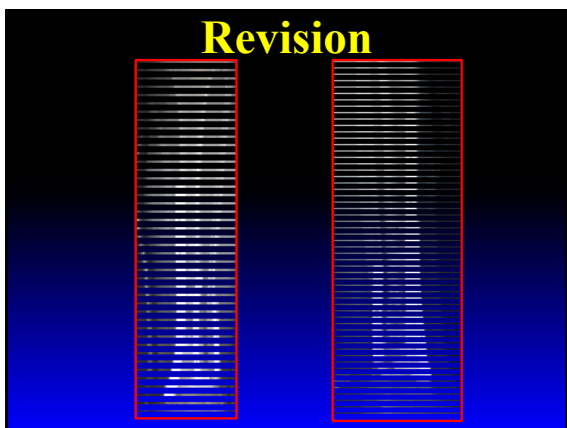
False Positive



45 YO Male

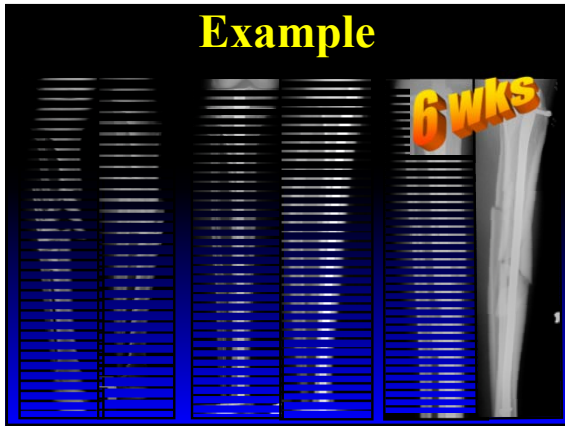




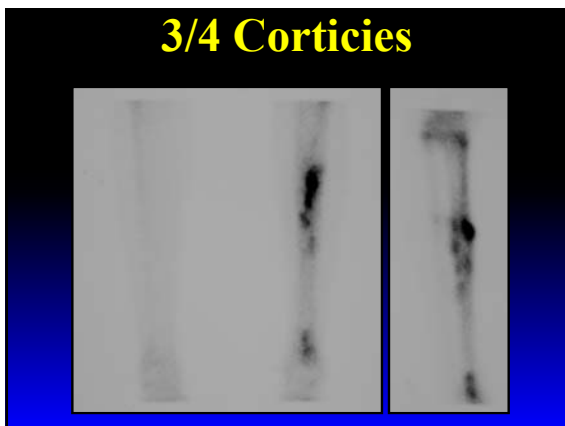


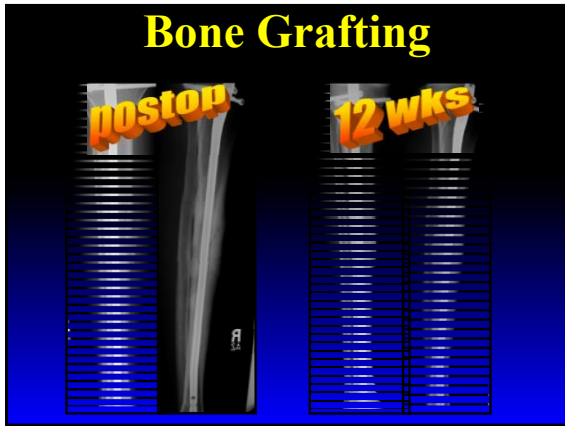
Bone Scans

- Limited data
- Helpful
 - Partially healed
 - Intramedullary fixation
 - Ends of implants



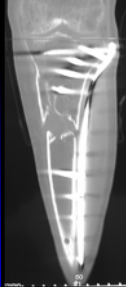







Infection

- 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

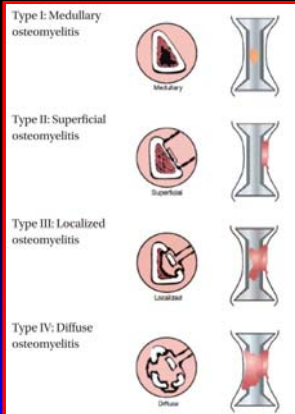
- Prior surgery

- Compartment syndrome

- Any redness, drainage



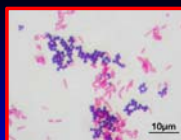
Cierny-Mader 1985



Preoperative Diagnosis of Infection in Patients with Nonunions

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

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



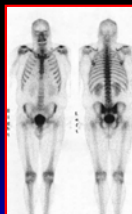
Nonunions

- 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



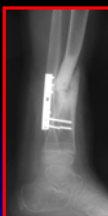
Positive tests

- 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

	Open	Closed
Humerus	4	4
Ulna	0	4
Femur	12	15
Tibia	30	18
Pilon	3	3
Ankle	1	3

Patient Demographics

	Open	Closed
Humerus	4	4
Ulna	0	4
Femur	12	15
Tibia	30	18
Pilon	3	3
Ankle	1	3

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

Test	Sensitivity	Specificity	PPV	NPV
White Cell Scan	19%	92%	50%	72%
ESR >30	58%	80%	58%	80%
CRP > 1.0	61%	75%	54%	75%
WBC > 11,000	22%	89%	50%	70%

Results

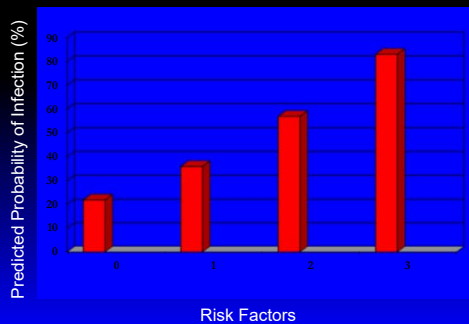
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CRP > 1.0	61%	75%	54%	75%
WBC > 11,000	22%	89%	50%	70%

Predicted Probability of Infection

Risk Factors	Predicted Probability of Infection (percent)
0	22
1	36
2	57
3	83

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

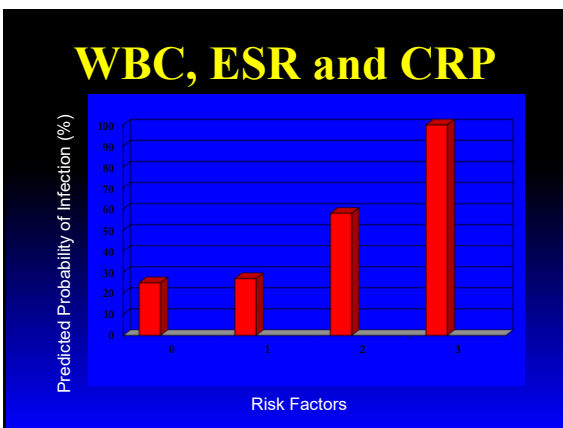
WBC, ESR, CRP & Nuclear scans



Predicted Probability of Infection

Risk Factors	Predicted Probability of Infection (percent)
0	25
1	27
2	58
3	100

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

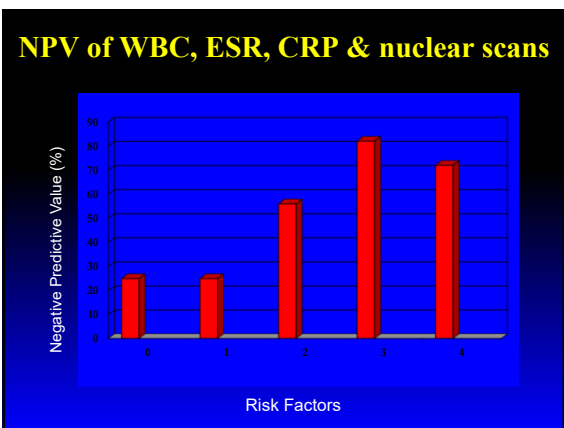


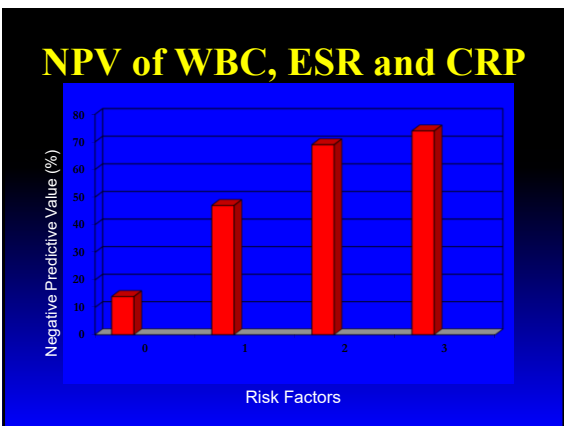
Intra-operative Components Utility

Test	Sensitivity	Specificity	PPV	NPV
Path WBC > 3/HPF	40%	81%	40%	81%
Gram Stain	25%	100%	100%	68%

Intra-operative Components Utility

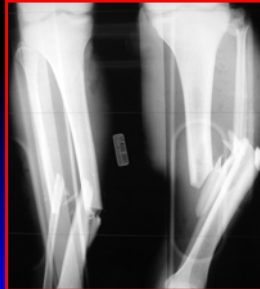
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Path WBC > 3/HPF	40%	81%	40%	81%
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Example

- 21 y/o male
- Bilateral tibia fractures
- IM Nails

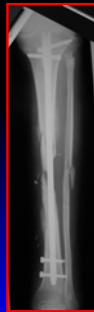


Example

- WBC: 6
- CRP: 5.9

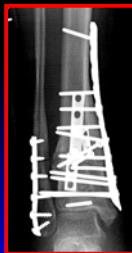
(+) MRSA

- Indium scan: Neg
- Gram stain: Neg



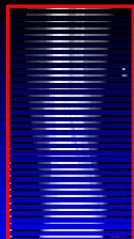
Conclusions

- 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 Olszewski, MD,* Philipp N. Streubel, MD,† Charlton Stucken, MD,* William M. Ricci, MD,‡ Martin F. Hoffmann, MD,§ Clifford B. Jones, MD,|| Debra L. Sietsema, PhD,|| and Paul Tornetta 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

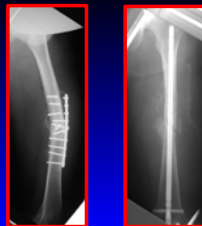
	Percentage
Tibia	61%
Femur	28%
Humerus	5%
Other	6%
Open	60%
Closed	40%

Bacteria

Type of Bacteria	Number
Coagulase-negative Staphylococcus	45
Methicillin-resistant S. Aureus	12
Pseudomonas	8
Propionibacterium	8
Methicillin-sensitive S. Aureus	7
Bacillus	4
Peptostreptococcus	3
Staph species unspecified	3
Enterococcus	2
Strep viridans	2
Clostridium	2
E. coli, Staph epidermidis, Beta hemolytic strep, Serratia, Candida and Aspergillus	1

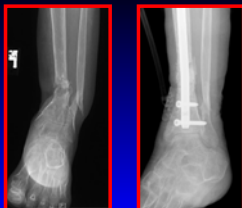
Union After Index

- 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



Boston Medical Center

Tornetta III P, Dale K, Jones C, Mullis B, Egol M, Robinson E, Bosse M, Schmidt A, Hymes R, Waespe D

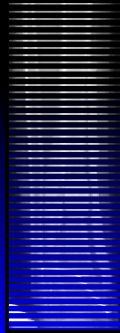
Participating Centers

- 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



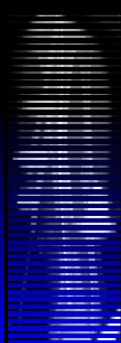
Bacteria

Type of Bacteria	Number
Methicillin-resistant S. Aureus	28
Methicillin-sensitive S. Aureus	27
Coagulase-negative Staphylococcus	17
Enterococcus	15
Enterobacter	12
Pseudomonas	10
E. Coli, Staph Epidermis, Candidia	5
Serratia	4
Peptostreptococcus, Corynebacterium, Bacillus, Beta	
Hemolytic Strep, Citrobacter, Klebsiella	3
Alpha Hemolytic Strep, Streptococcus, Proteus	2
Aspergillus, Salmonella, Proventella, Eikenella,	
Acinetobacter, Escherichia, Morganella	1

Defect Management

Antibiotic Beads	34
Antibiotic Nail	33*
Antibiotic Spacer	21

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



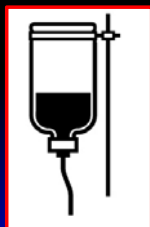
Treatment

- 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

Outcome	All 169	Cx(+) 60	Cx(-) 72
Union	121 (74%)	33 (55%)	60 (87%)
Union p 2° procedure	139 (85%)	45 (75%)	65 (94%)
Persistent nonunion	25 (15%)	15 (25%)	4 (6%)
Amputation	10 (6%)	5 (8%)	1 (1%)
Lost to F/U	5	0	3

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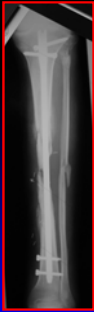
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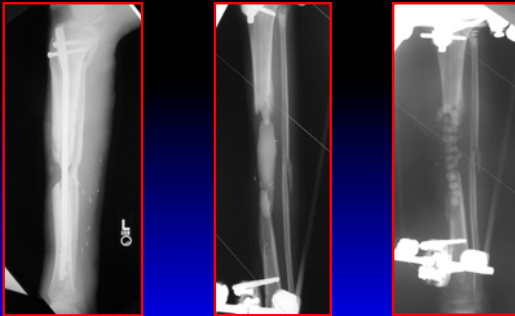
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Example From Earlier

- 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 Sadek¹ · Mohammed A. Laklok¹ · Ezzat H. Fouly⁴ · Mohamed Elshafie⁵

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



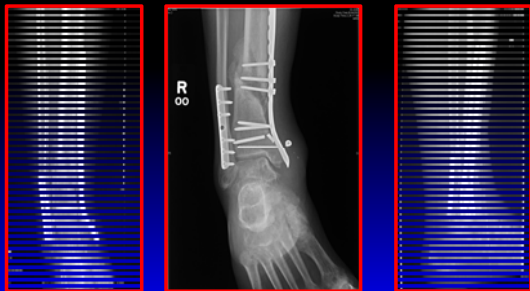
Treatment



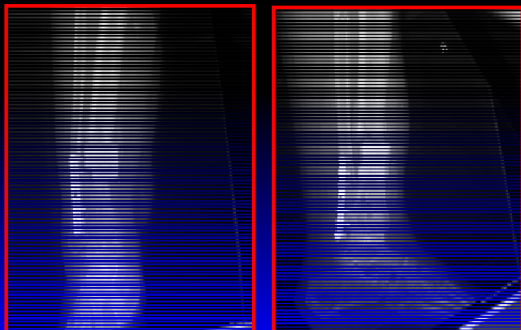
Now



Example



Debridement

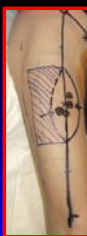


Flap Coverage

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

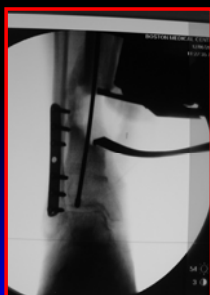
John Puro, MD, Grace Chiou, MD, and Subbro K. Sen, MD

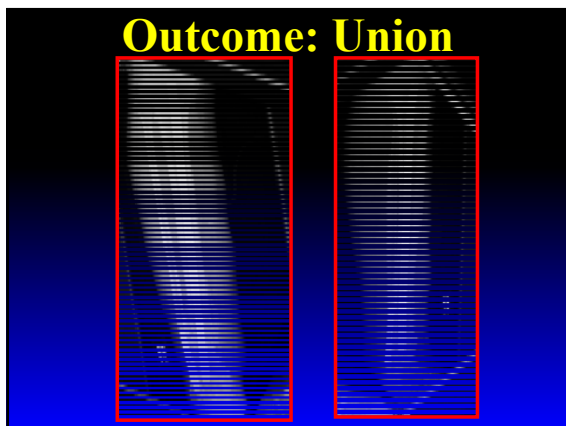
- 86 Muscle; 35 FC
 - Primarily ALT
 - Smokers worse
 - Days to union, WB same
 - Both work well



At Procedure

- Culture: negative
- CRP: 0.5
- ESR: 21





Intramedullary

- Antibiotic nails
- Union
- Many ways to achieve
- Exchange nail


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

Raghuvaran Thomsen, MS Orth, DNB Orth, FRCS Ed, FRCS, Glasg and Janet Conway, MD†*

• 54% UNION

Recommendation

- Staged procedures
- Wide resection!
- CRP/ESR after Ab
 - If high, debridement?
- 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
