Osteomyelitis

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Definitions

- Osteomyelitis – Infection involving bone
- Acute osteomyelitis
  - Infection of short duration
  - Characterized by suppuration (i.e. abscess) but <u>not biofilm</u>
  - Systemic symptoms common

Definitions

- Chronic osteomyelitis
  - Long standing infection (weeks to years)
  - Characterized by necrotic bone and bacterial colonies in protein/polysaccharide matrix (biofilm)
  - Often no systemic symptoms
- Occurs along spectrum with no clear time cutoff to separate acute vs. chronic infection

Etiologies

- Hematogenous
  - Metaphysis of long bones
    - Most common in children
  - Vertebral osteomyelitis
- **Contiguous spread**
  - **Post-traumatic**
    - **Open fractures**
    - **Infections associated with deep implants**
  - Prosthetic Joint Infections
- Vascular Insufficiency and/or Diabetes
  - Secondary to ulceration
  - Commonly affects the forefoot bones

Epidemiology

- Estimates vary widely, but overall increasing incidence in US
  - Increasing
    - Osteomyelitis from a contiguous focus of infection (e.g. post-trauma, post-surgery)
    - Osteomyelitis of the foot and ankle related to diabetes
  - Stable/Decreasing
    - Hematogenous osteomyelitis in children

Kremers, et al. JBJS 2015

Pathogens

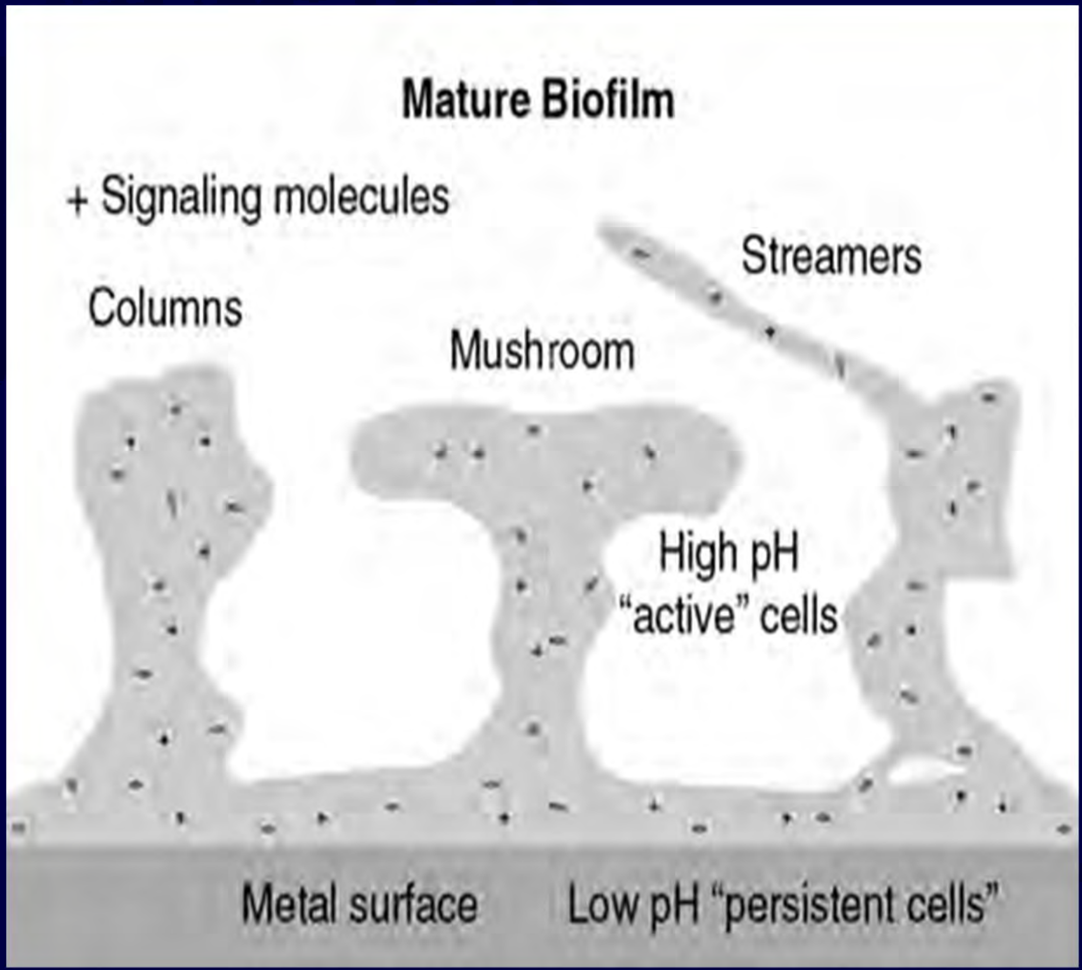
- Staph aureus most common (45% in series by Kremers et al., JBJS, 2015)
- Staph epidermidis and steptococcal species next most common
- Diabetes more commonly polymicrobial

Pathophysiology: Implant-associated osteomyelitis

- Planktonic cells attach to metal substrate
- Initial cells undergo apoptosis
- “Sacrificial cells” become matrix for biofilm

Establishment of Infection

- *Biofilm* occurs due to the organized cell death of the first waves of bacterial invasion on a host site ("death of the privates, corporals, and sergeants.")



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Presumed Timeline

(Definitive time for biofilm unknown)

Importance of Bacterial "Phase" in the Host

Planktonic

- This represents the initial innoculum phase.
- The bacteria have a high metabolic rate.
- They are "free floating"
- Cause systemic symptoms

Biofilm (Sessile)

- This represents the semi-dormant bacterial phase where the microbe is "trying" to live in a symbiotic state.
- Low metabolic rate.
- Adherent to the biofilm.
- 10^3 times less sensitive to most antibiotics.
- Represents 98% of biofilm population

Why does bacterial adaptation occur so rapidly?

ORGANISM	GENERATIONAL CYCLE
Bacteria (planktonic)	20 – 30 minutes
Bacteria (sessile, in biofilm)	hours to a day
Man	20 – 30 years

Biofilm antibiotic resistance

1. Cells hidden within hydrophobic matrix
2. Low metabolic rate (sessile cells)
   – Impossible to achieve effective dose safely with systemic antibiotics
3. Ability to mutate due to short generational cycle

Clinical evaluation: Pertinent history

- Characterize infection
  - Clinical history (e.g. onset, timeline)
  - Prior treatment
  - Prior surgeries
- Characterize host
  - Age
  - Comorbidities
  - Habits (tobacco, alcohol, drugs)
  - Social support, housing
  - Baseline function (ambulatory status, assistive devices)

Vs.

Physical exam

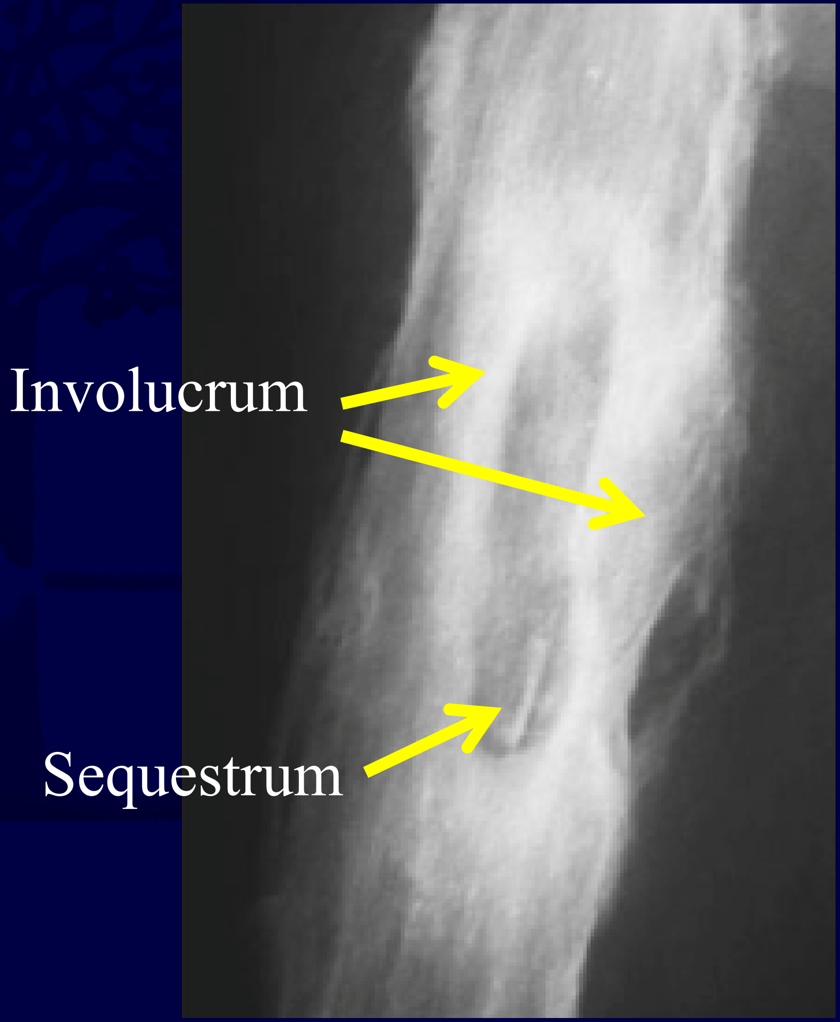
- Rule out sepsis (fever, tachycardia, hypotension)
- Signs of active infection
  - Warmth
  - Redness
  - Drainage
- Soft-tissues
  - Open wounds
  - Sinus tracts
  - Scars
- Evaluate for limb deformity (limb length, alignment)
- Evaluate joints above and below affected area
- Neurovascular status of limb

Imaging studies

- Plain x-rays
  - First line exam
- CT
  - Less sensitive than MRI, but more specific for bony changes that may require debridement
  - Useful for assessing for union in cases of infection associated with fracture implant

Plain x-rays

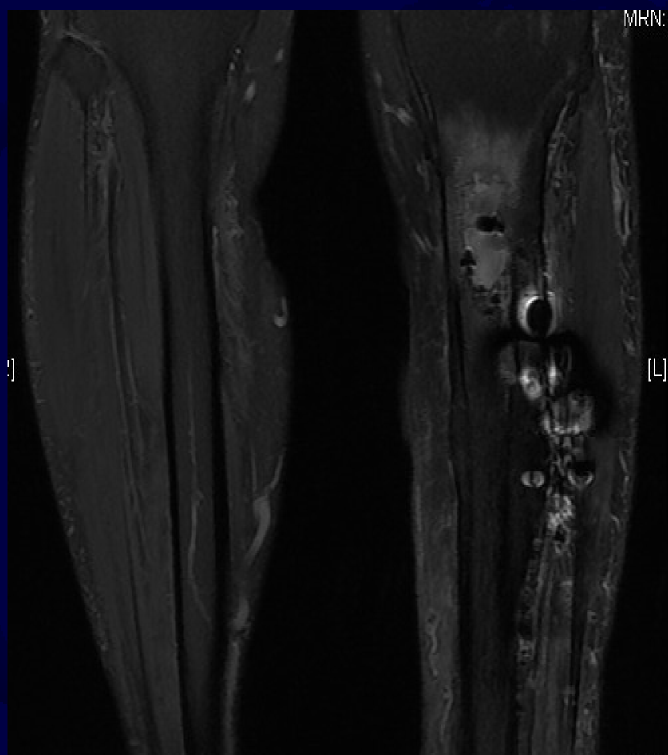
- Virtually always the first line exam
- Can be normal for 2-3 weeks after onset
- Sensitivity can be variable, specificity is higher
- Findings
  - Periosteal thickening
  - Lytic lesions with surrounding sclerosis
  - Osteopenia
  - Loss of trabecular architecture
- Sequestrum: Dead bone walled off in granulation tissue
- Involucrum: Reactive bone that surrounds the sequestrum

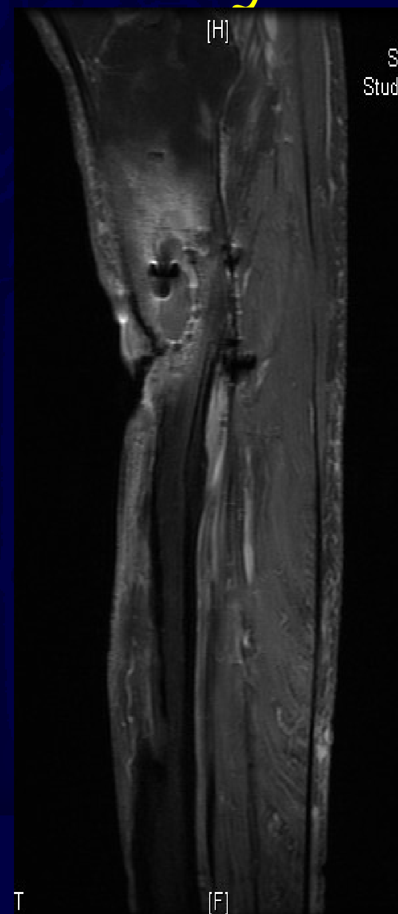


MRI

- Characterizes both bone and soft-tissue infection
- Quite sensitive but often not specific, and tends to overcall the extent of the lesion due to edema
- Best read on the T2 sequence.
- May be obstructed by hardware
- Not necessary in every case

63 y/o M with chronic recurrent Stage 3 tibial osteomyelitis





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Nuclear medicine

- Technetium 99 Bone scan
  - Detects new bone formation
  - High sensitivity (90-100%), but poor specificity (~30%)
- Tagged WBC scan
  - Good sensitivity (~90%), moderate specificity (~60%)
  - Particularly useful in chronic osteomyelitis when hardware or other factors preclude MRI
- In general nuclear medicine rarely adds to diagnosis and treatment plan

Laboratory evaluation

- WBC
  - Low sensitivity (normal in many cases of chronic osteomyelitis)
- Platelets
  - 500-1000K can be indicative of acute phase infection
- ESR/CRP
  - Improved sensitivity
  - Lack specificity
  - CRP more responsive to change
  - Negative ESR and CRP cannot definitively rule out osteomyelitis
- Only ~50% of chronic musculoskeletal infections will have elevated inflammatory markers

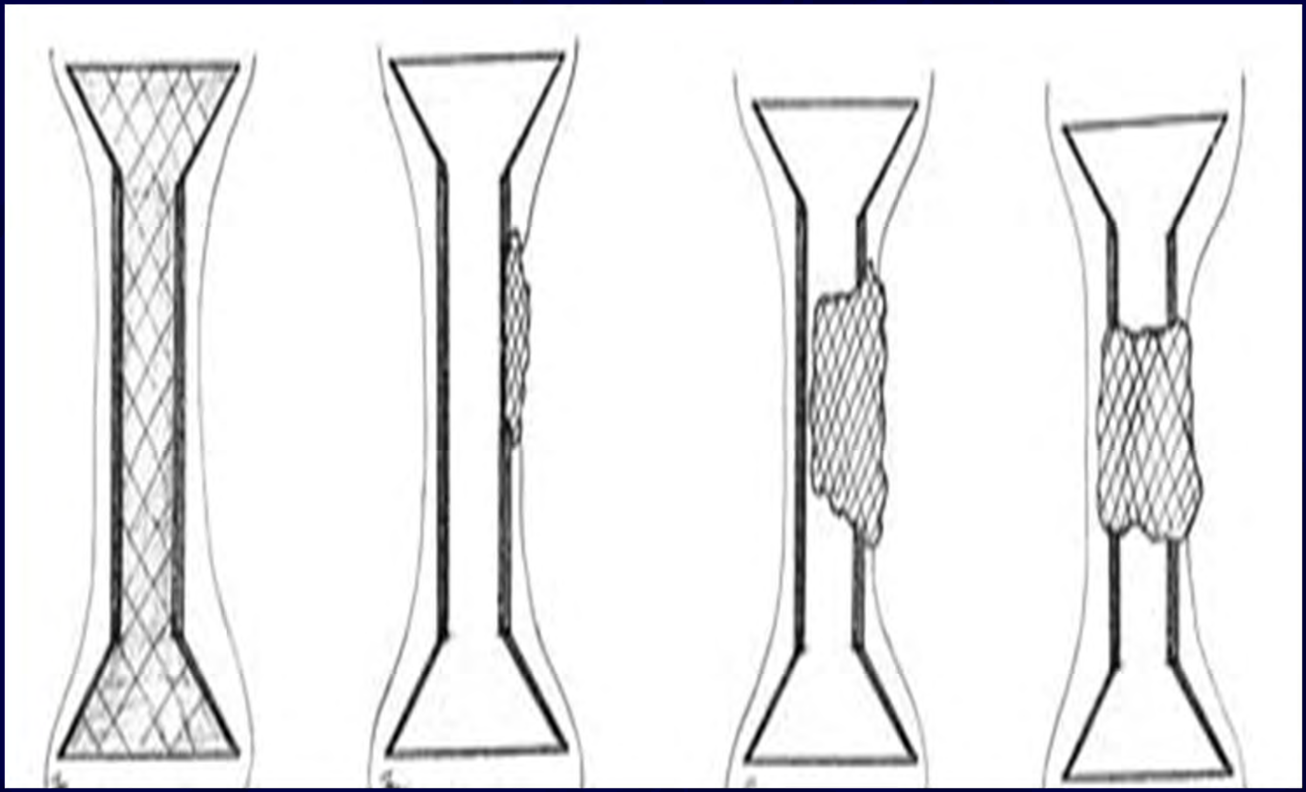
- Labs for drug toxicity (e.g. creatinine, liver enzymes)
- Labs to evaluate comorbidities (e.g. blood glucose, Hba1c for diabetes)

Classification: Cierny-Mader

Anatomic type + Host =
Clinical Stage

George Cierny

Cierny-Mader Classification



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Cierny-Mader Staging System

STAGE	ANATOMIC TYPE	TYPICAL ETIOLOGY	TREATMENT
1	Medullary	Infected intramedullary nail	Removal of the infected implant and isolated intramedullary débridement
2	Superficial; no full-thickness involvement of cortex	Chronic wound, leading to colonization and focal involvement of a superficial area of bone under the wound	Remove layers of infected bone until viable bone is identified

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Cierny-Mader Staging System

STAGE	ANATOMIC TYPE	TYPICAL ETIOLOGY	TREATMENT
3	Full-thickness involvement of a cortical segment of bone; endosteum is involved, implying intramedullary spread	Direct trauma with resultant devascularization and seeding of the bone	Noninvolved bone is present at same axial level, so the osteomyelitic portion can be excised without compromising skeletal stability.
4	Infection is permeative, involving a segmental portion of the bone.	Major devascularization with colonization of the bone	Resection leads to a segmental or near-segmental defect, resulting in loss of limb stability.

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Cierny-Mader Physiologic Host

Type	Infection Status	Perpetuating Factors	Treatment
A	Normal physiologic response	Little or no systemic or local compromise	No contraindications to surgical treatment
B (local)	Locally active Impairment of response	Prior trauma, or surgery to area; chronic sinus; free flap; impaired local vascular supply	Consider healing potential of soft tissues and bone, consider adjunctive measures
B (systemic)	Systemically active Impairment of response	Diabetes, immunosuppressio n, vascular, or metabolic disease	Treat correctable metabolic/nutrition al abnormalities first
C	Severe infection	Severe systemic compromise and stressors	Suppressive treatment or amputation

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Treatment approach

1. Determine clinical stage
2. Develop treatment plan
   - A or B host
     - Limb salvage
   - C host
     - Palliation (Limited I&D, antibiotic suppression)
     - Amputation
       - When limb salvage or palliation not safe or feasible
3. Medical optimization

→Treat correctable systemic medical comorbidities

Example: Improved glycemic control for diabetic

Antibiotic suppression

- Reserved for type C host (treatment worse than disease)
- Affects planktonic cell state only

→prevent systemic symptoms

- Cells may remain in sessile state unaffected by systemic antibiotics

Limb salvage: Surgical Principles

1. Excise ALL devitalized/infected bone and soft-tissue
2. Manage the dead space
3. Address soft-tissue envelope
4. Reconstruct the bone defect
   - Reconstruction always the last stage

Debridement

- Removal of non-viable soft-tissue
  - Excise sinus tracts
- Systematic removal of all necrotic and/or infected bone
- Debride to bleeding bone ("Paprika sign")

Step 1: Debridement

Dead space management

- Antibiotic beads
  - PMMA + antibiotic
  - Antibiotic should be heat stable and hydrophilic
- Beads plus occlusive dressing = bead pouch
- Wound vac?
  - Can temporize a wound but not ideal when trying to achieve high antibiotic concentrations

Example: Dead space management →antibiotic beads

Open Antibiotic Bead Pouch

- Highly useful for short periods to sterilize a wound as well as preserve bone and soft tissue health following diaphysectomy for osteomyelitis.

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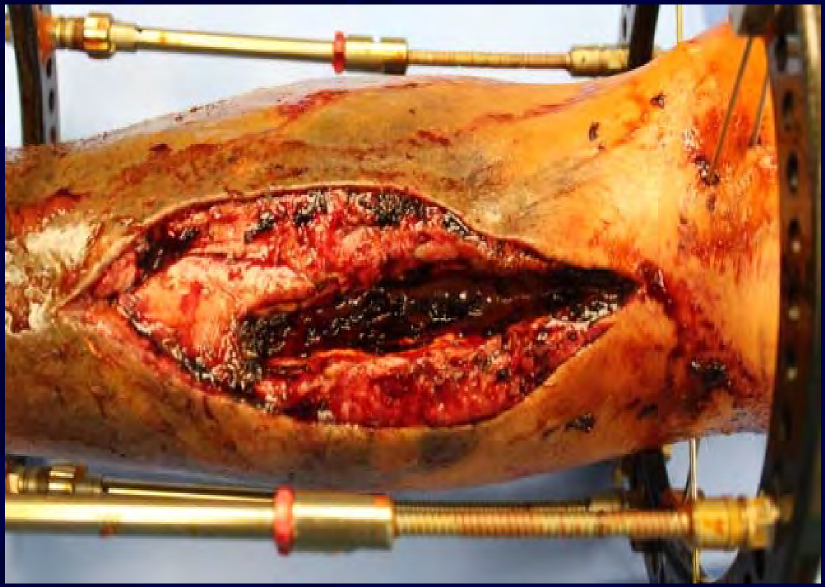
Open Antibiotic Bead Pouch

- 5 days following diaphysectomy at time of soft tissue reconstruction.



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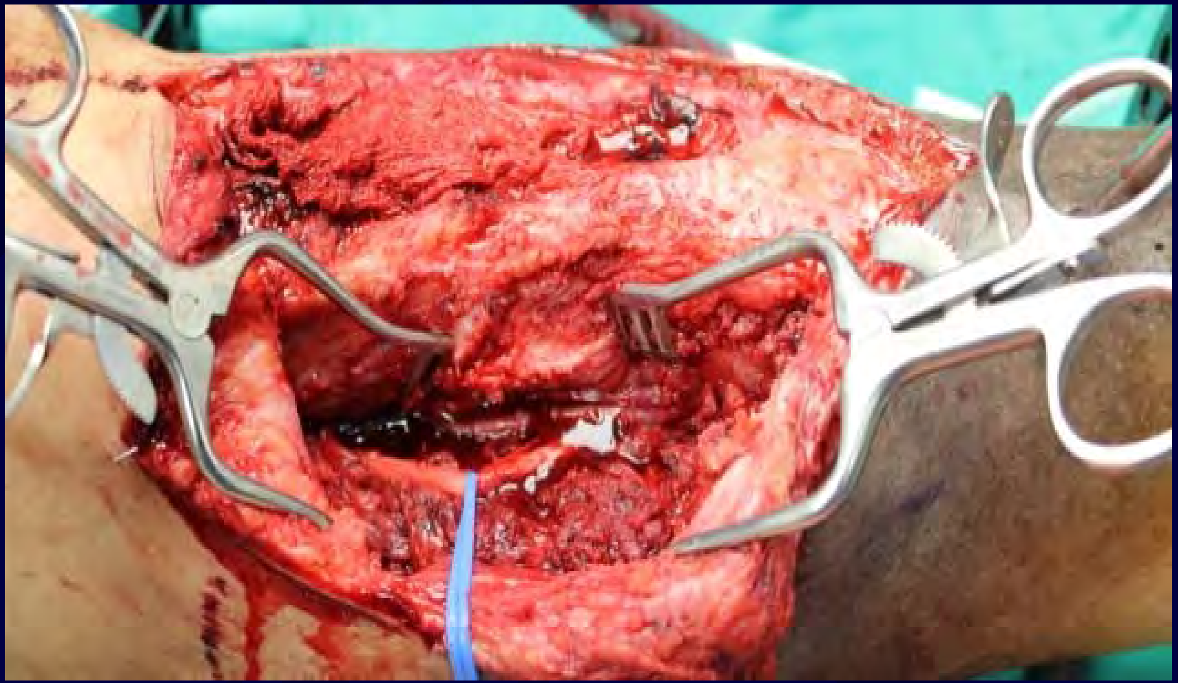
Open Antibiotic Bead Pouch

- Following removal of beads, with clean bone bed.



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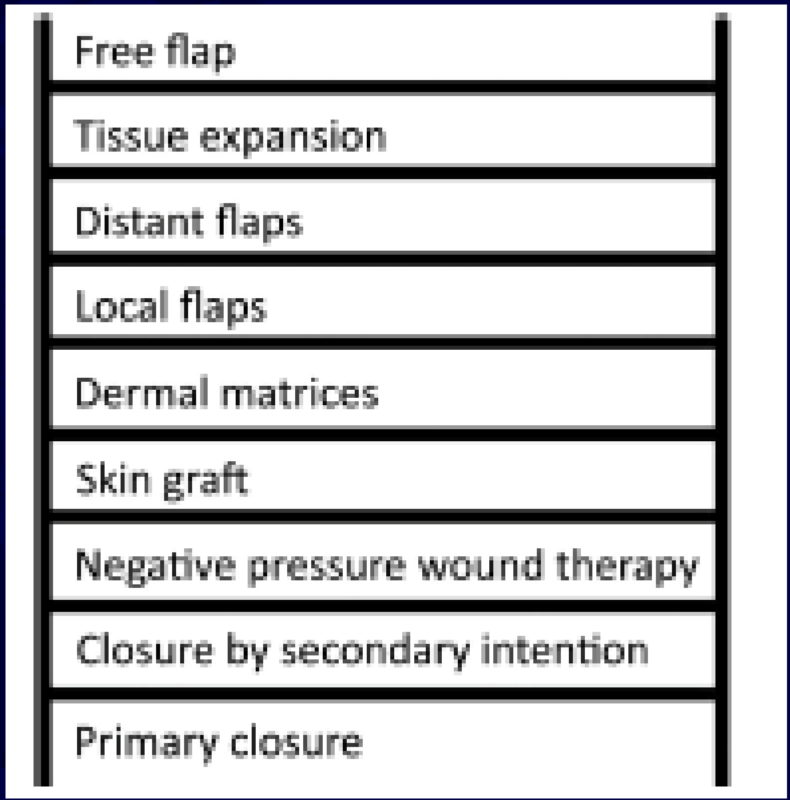
Soft-tissue reconstruction

- Based on reconstructive ladder
- Often requires local or free-tissue transfer
  - Must have skilled microsurgeon available



Example: Soft-tissue coverage →Medial gastroc flap

Example: Anterolateral thigh free flap

Bone reconstruction

- Non-segmental defects
  - Additional stability may not be needed
  - Plan for bone grafting 6-8 weeks after infection eradicated
- Segmental defects
  - Need provisional stability (most commonly external fixator)
  - Plan for bone defect
    - Masquelet technique
    - Bone transport

Masquelet technique (Induced membrane)

- Antibiotic spacer placement + soft-tissue coverage
- Staged Bone grafting (6-8 weeks later)
- Reported success ~80% for implant dependent union
- 10-12 months for union, weight bearing

Induced membrane properties

- Membrane secrets BMP-2, VEGF and other growth factors
- Peak at 4 weeks after membrane induction then decreases rapidly (Aho et al. JBJS 2013)

Bone transport

- Corticotomy opposite the defect
- Segment transported gradually, new bone formed by distraction osteogenesis
- Multiple techniques
  - External fixation
    - Uniplanar
    - Ring fixator
  - Transport over nail

From Giannikas et al. JBJS 2005

Circular fixation

- Advantages
  - Many options for pin placement
  - Excellent stability
  - Allows multiplanar deformity correction in addition to lengthening/transport
- Disadvantage
  - Pin site issues common
  - Technically demanding
  - Psychologically long process for patients

Shortening

- Acute shortening >3cm may cause arterial flow impairment
- Results in limb length discrepancy and muscle shortening/dysfunction
- Reasonable option for small bone defects and/or resources limited

Infections associated with trauma implants

- Three scenarios:
  1. Stable hardware, fracture healed
  2. Stable hardware, fracture not healed
  3. Unstable hardware, fracture not healed

Stable hardware, fracture healed

- Treatment→I&D, remove hardware
- Follows Stage 3 treatment principles
- Typically no need for additional bony stabilization assuming non-segmental defect

Stable hardware, fracture not healed

- If infection acute, can attempt I&D, retain hardware, suppress until fracture healing
- Goal to convert from Stage 4 to Stage 3 osteomyelitis
- 71% success in achieving fracture healing with antibiotic suppression (Berkes et al. JBJS 2010)
  - Requires eventual hardware removal in ~30% cases
  - Hardware removal less likely in proximal (e.g. pelvis) vs. distal locations (e.g. tibia)
- If fracture healing achieved, principles follow Stage 3 treatment

Unstable Hardware, Fracture Not Healed

- I&D, removal of hardware
- Equivalent to Stage 4 Osteomyelitis (i.e. Segmental Defect)
- Requires strategy for bone stability (e.g. ring fixator, antibiotic nail, etc.) and management of segmental bone defect

Results (of Comprehensive, Multidisciplinary Treatment Protocol)

- 2207 cases from 1981 through 2007
  - 1898 limb-salvage protocols
  - 230 amputations (as primary treatment)
- 85% overall success (infection-free, functional reconstruction at 2 years)
  - A-hosts 96%
  - B-hosts 74%
  - Limb-salvage 84%
  - Amputation 91%

Cierny G. Surgical Treatment of Osteomyelitis: Plastic and Reconstructive Surgery. 2011 Jan;127:190S–204S.

Results (cont)

- Treatment failures (n=319)
  - 43% aseptic nonunions
  - 28% wound sloughs
  - 15% unanticipated impairment
  - 12% recurrent sepsis
  - 2% deaths
- 82% success with retreatment
- Overall 2 year success rate of 95%
  - 99% A hosts
  - 90% B hosts

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Case Examples

Cierny-Mader Stage 1 ….
A confined intramedullary process

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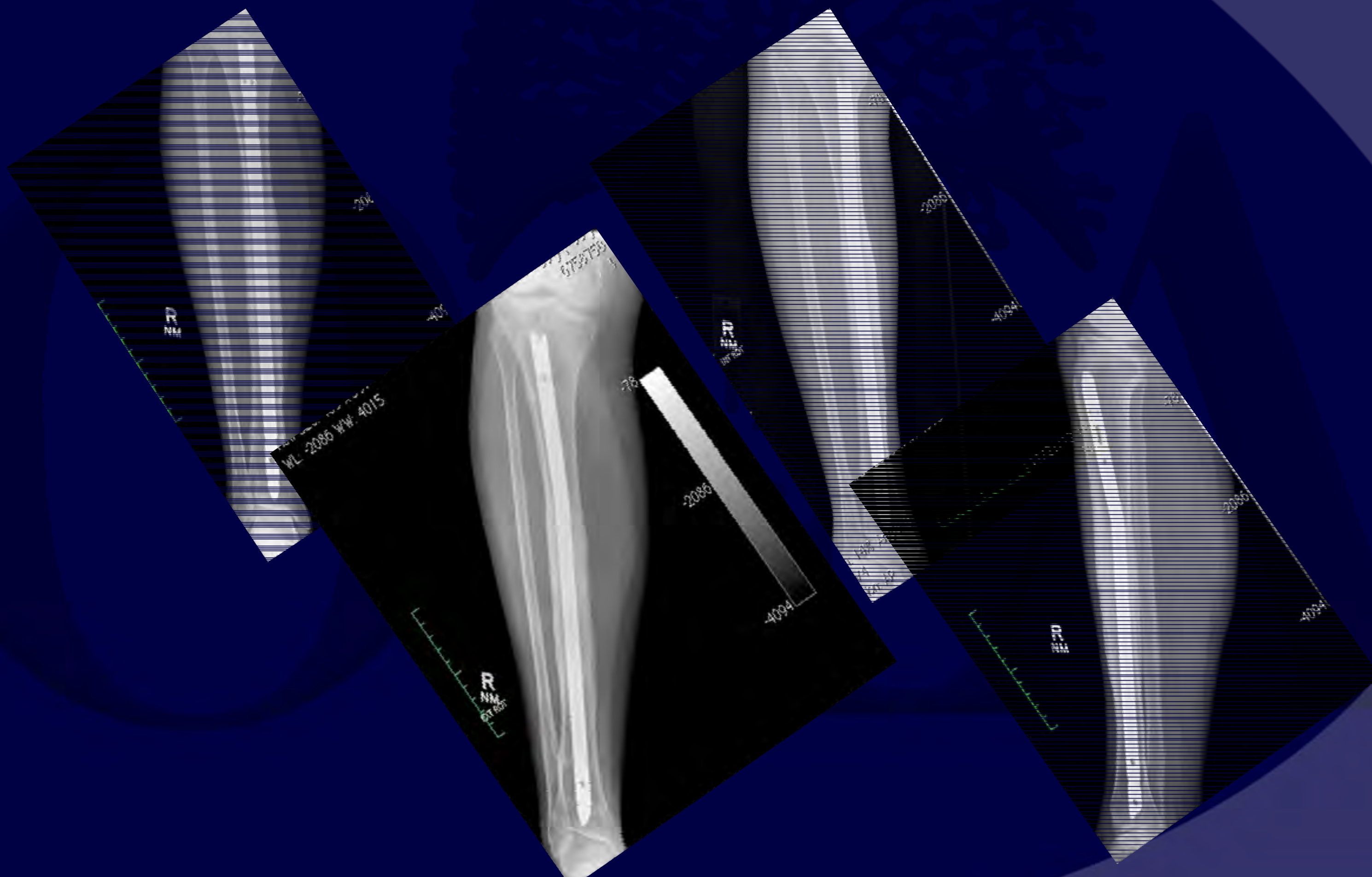
Cierny Mader Stage 1

- Currently the most common cause is secondary to infected intramedullary implants.

66 y/o F now 8 years s/p tibial rodding. With chronic leg pain and limited ability to ambulate.



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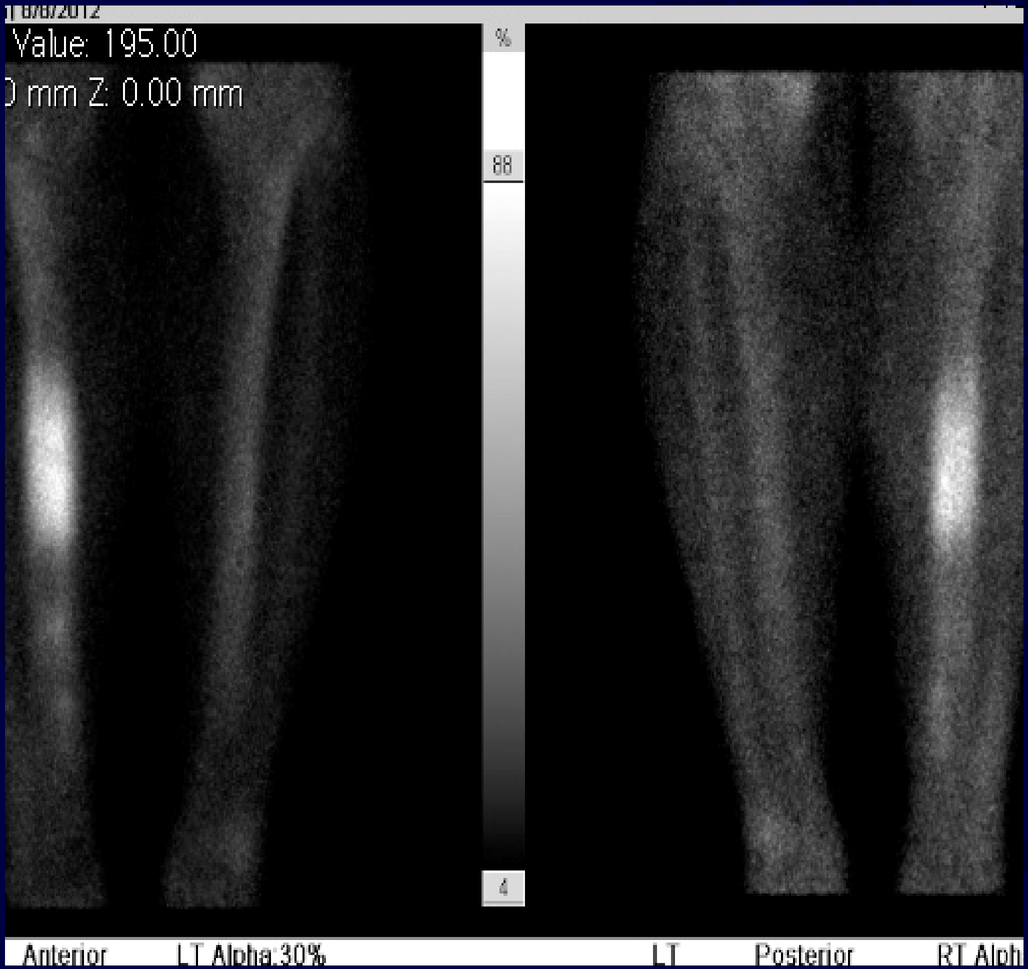
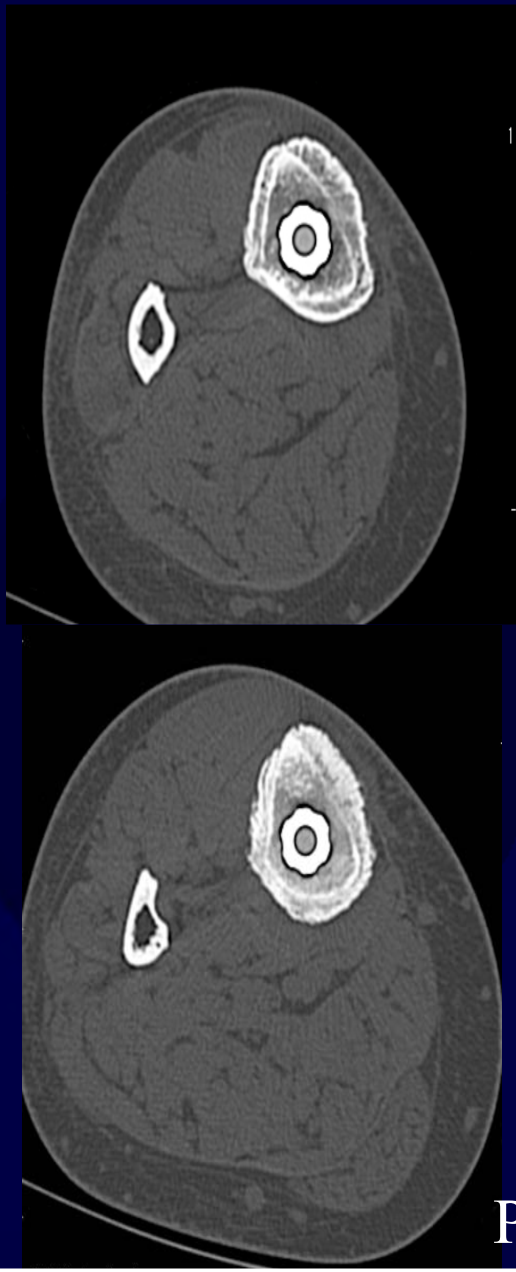
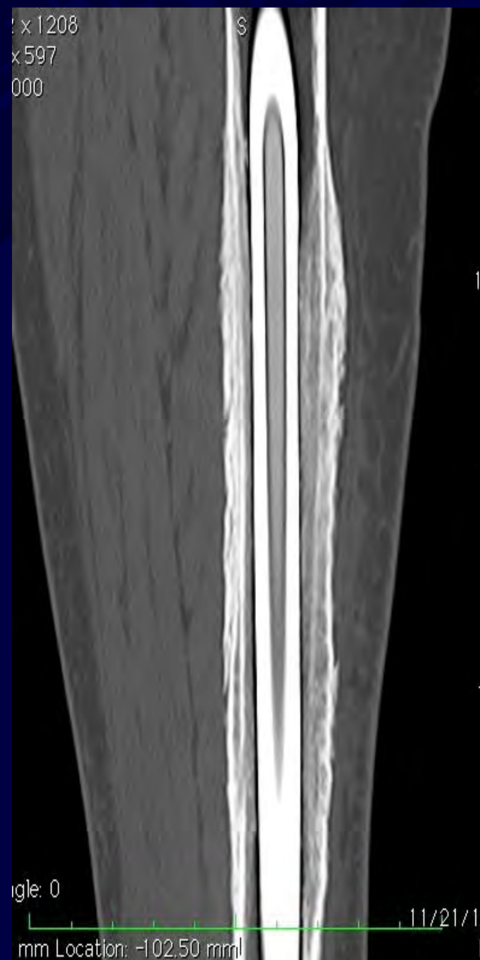
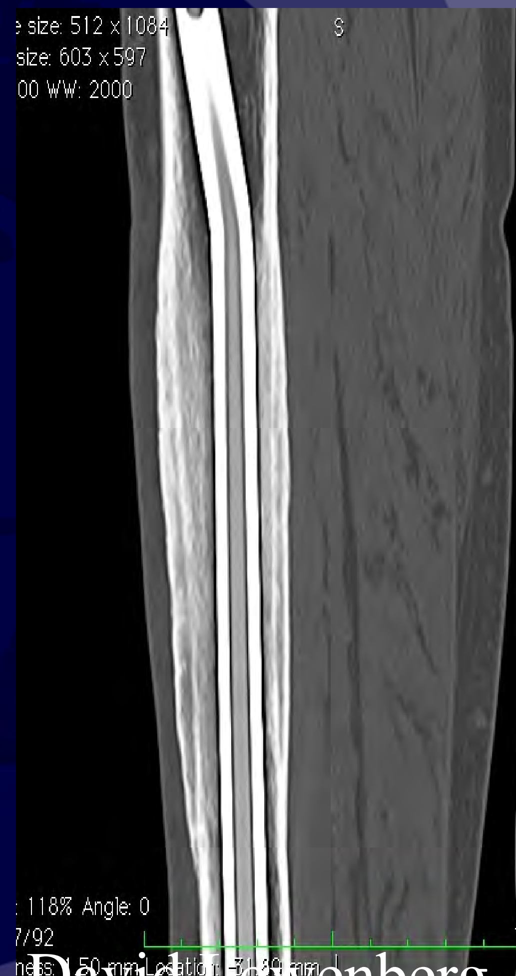
Tc^{99} performed



CT of right leg







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What do you do???

A. Tell her that you can't cure chronic pain.
B. Take punch biopsies of bone.
C. Start her on empiric Doxycycline.
D. Stage her for neoplasm then perform open biopsy with later plan for wide en bloc resection.
E. Call it for what it is, Type 1 C-M osteomyelitis, and treat appropriately.

Cierny-Mader Stage 2 Osteomyelitis

- In clinical practice, the rarest form of osteomyelitis seen.
- With the wider use of Negative Pressure Therapy, there has been a resurgence in cases.

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Cierny Mader Stage 3 Osteomyelitis

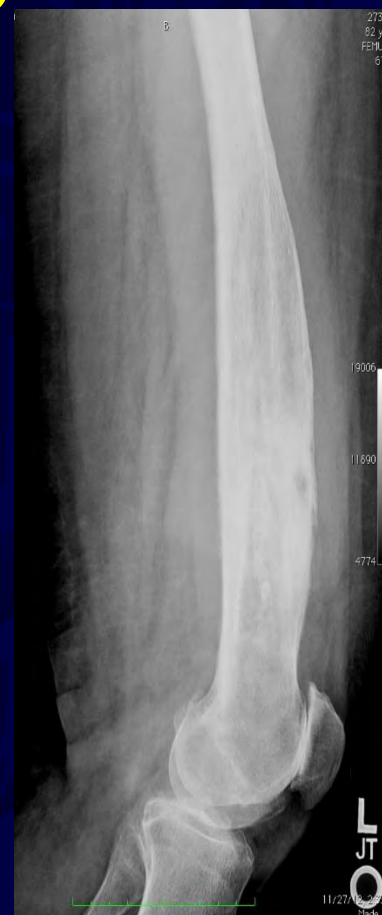
- The most common form of osteomyelitis seen in clinical practice.
- Requires the basic tenants of osteomyelitis surgery to be followed:

1. Surgical resection
2. Dead space management
3. Soft tissue reconstruction
4. Bone reconstruction

80 y/o F s/p hematogenous distal femoral osteomyelitis at age 15

- Initially treated with surgical debridement.
- This remained completely quiescent for 65 years until she developed a mild case of the flu and presented draining with a distal lateral femoral sinus tract.
- Had remained completely active and asymptomatic until this event.

80 y/o F s/p hematogenous distal femoral osteomyelitis at age 15



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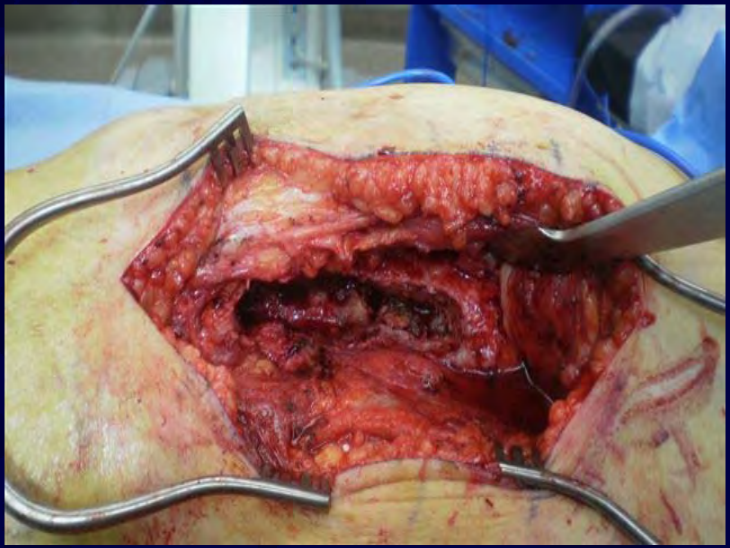
Saucerization of the femur, removal of all infected necrotic bone, dead space management



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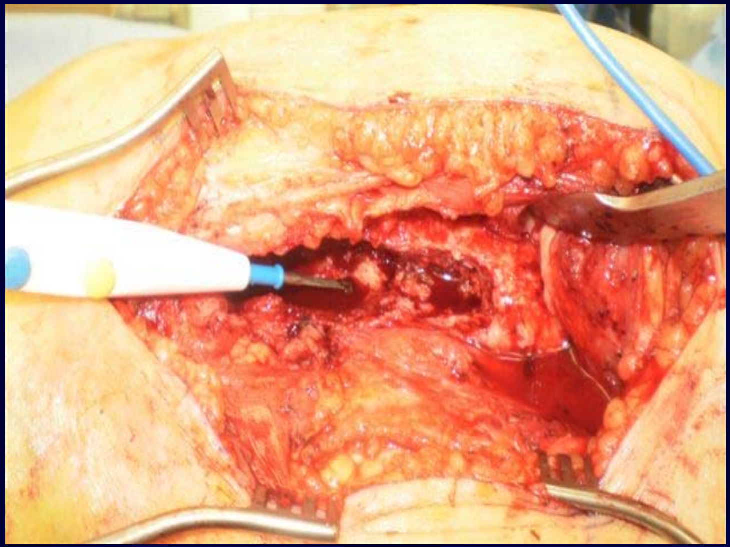

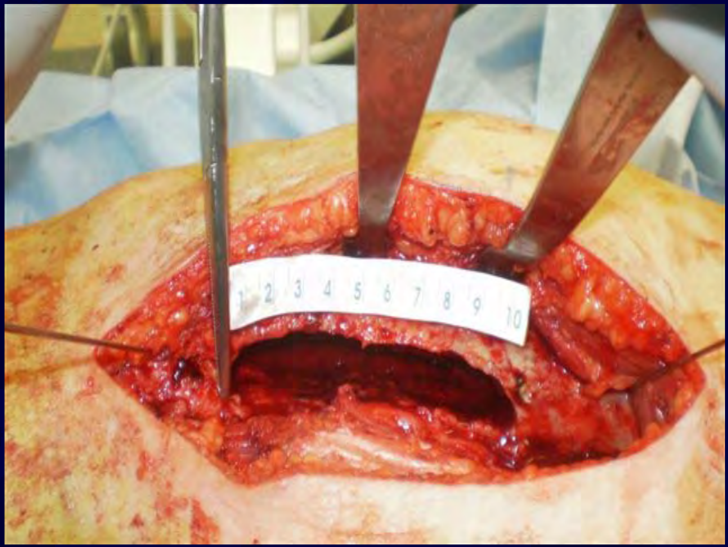

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Saucerization of the femur, removal of all infected necrotic bone, dead space management

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70 y/o M now 40 years following blast injury

- Suffered an open tibia fracture which healed with deformity.
- Has had a chronic sinus tract with atrophic soft tissue envelope since then.
- Now with knee pain.

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70 y/o M with 40 year sinus tract

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Classify the Cierny-Mader Stage?

- Stage 3
- Look at the posterior cortex.

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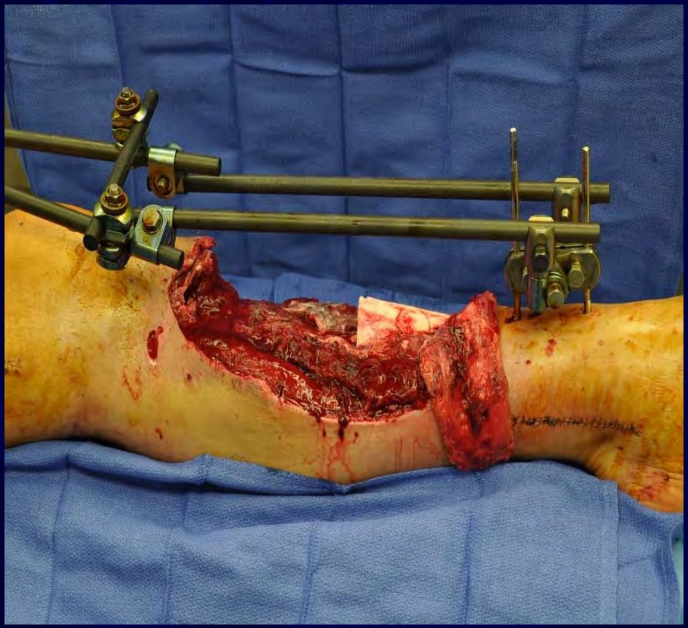
Cierny-Mader Stage 4 Osteomyelitis

- Also quite common.
- Implies diffuse and complete or near complete circumferential involvement of a long bone which following resection leads to a segmental defect in the limb.



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What is an Infected Nonunion???

- By definition it is a nonunion of a fracture ***with Cierny-Mader stage 4 osteomyelitis.***

Hence, infected nonunions are a surgical disease

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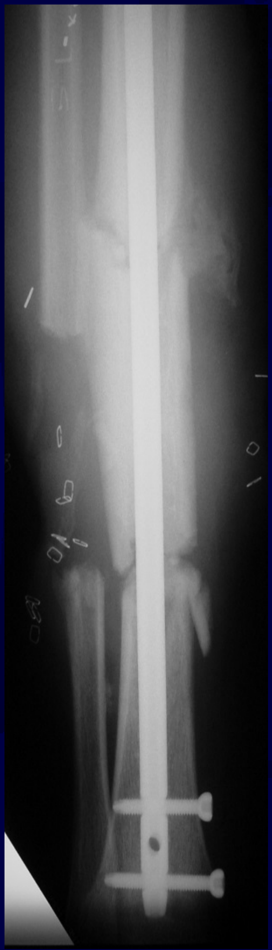
28 y/o M s/p Peds. Vs. MVA

- 28 y/o M (6’4” tall, 275 pounds) status post crush injury to leg when pinned by bumper of a car traveling at 35 MPH to rear of his tow truck.
- Initially rodded, then 3 week delay in flap coverage.

28 y/o M s/p Peds. Vs. MVA

- Persisitent drainage under free flap for 3 months.
- Treated with 3 months of IV antibiotics.
- Referred 4 months after injury with persistent drainage under flap.

28 y/o M with drainage at this site under the flap



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28 y/o M

- Note the cortical density that has developed at the intercalary segment.

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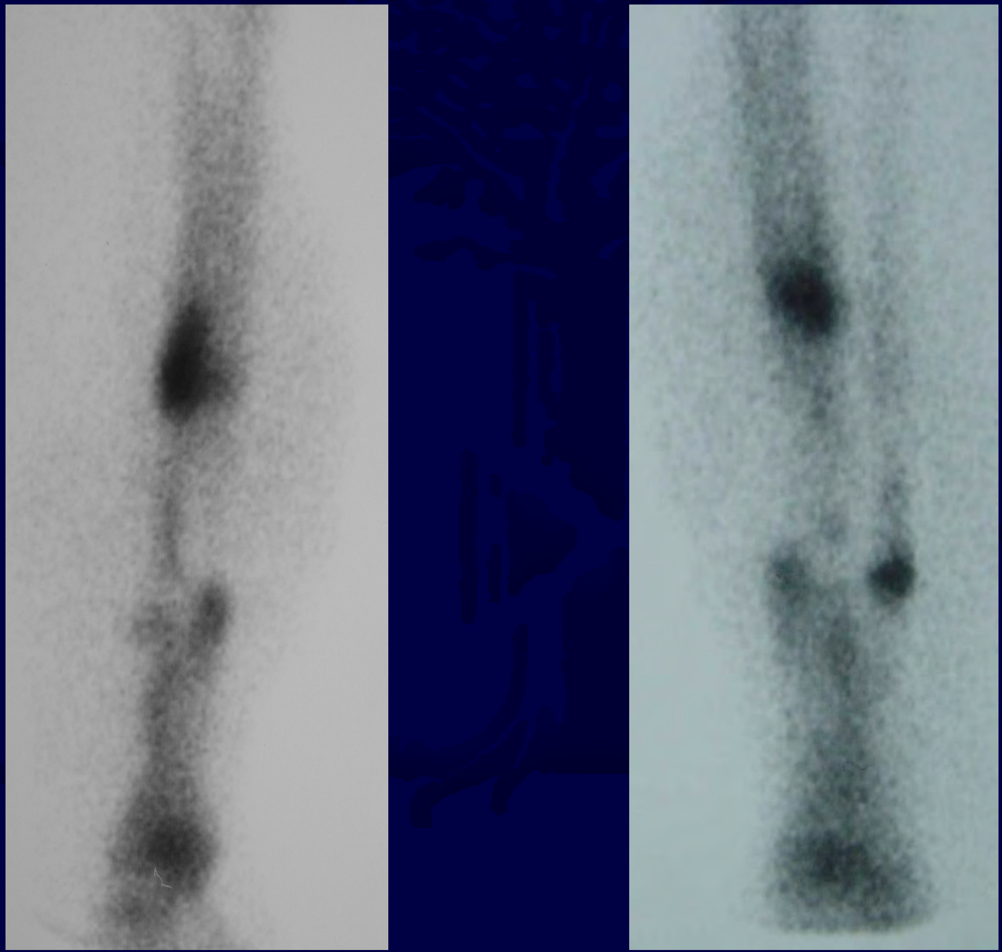
28 y/o M: Tc^{99} flow phase study cofirming lack of perfusion to intercalary segment



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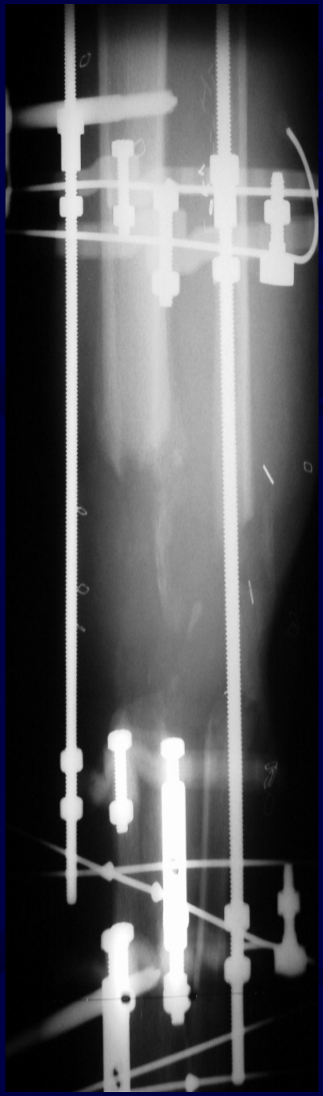
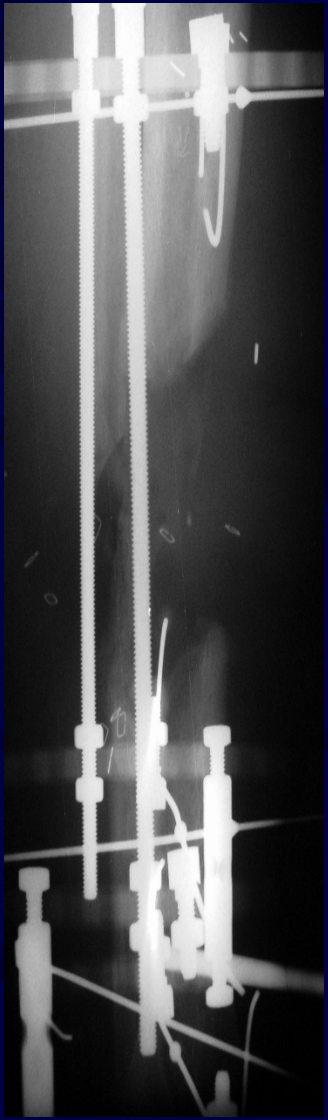
28 y/o M: C-M Stage 4 osteomyelitis

- Complete devascularization of intercalary segment.
- Treated with en bloc resection and antibiotic nail, followed by bone transport.

28 y/o M: C-M Stage 4 osteomyelitis





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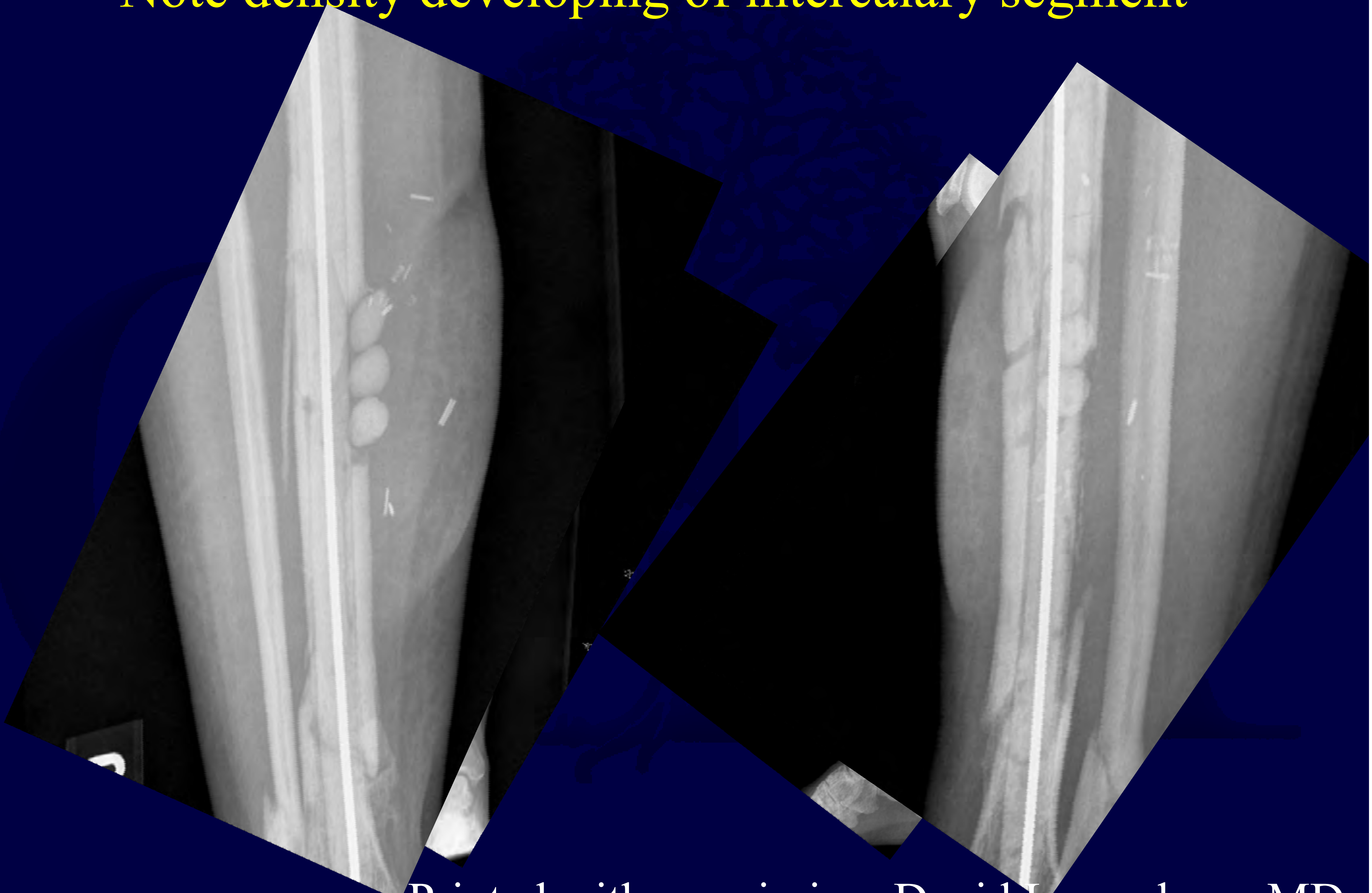
47 y/o F s/p low energy distal tibia shaft fracture treated with IM rodding

- At the time of rodding a tourniquet was utilized.
- The tibia was reamed up in size due to her small intramedullary diameter.
- Developed swelling and a new fracture at the isthmus proximally which was not present previously.
- Then developed drainage and soft tissue breakdown necessitating free flap placement.
- Underwent debridement and antibiotic nail and beads but still concern for infection.
- Referred then for care.

47 y/o female with infected nonunion of tibia: Note density developing of intercalary segment



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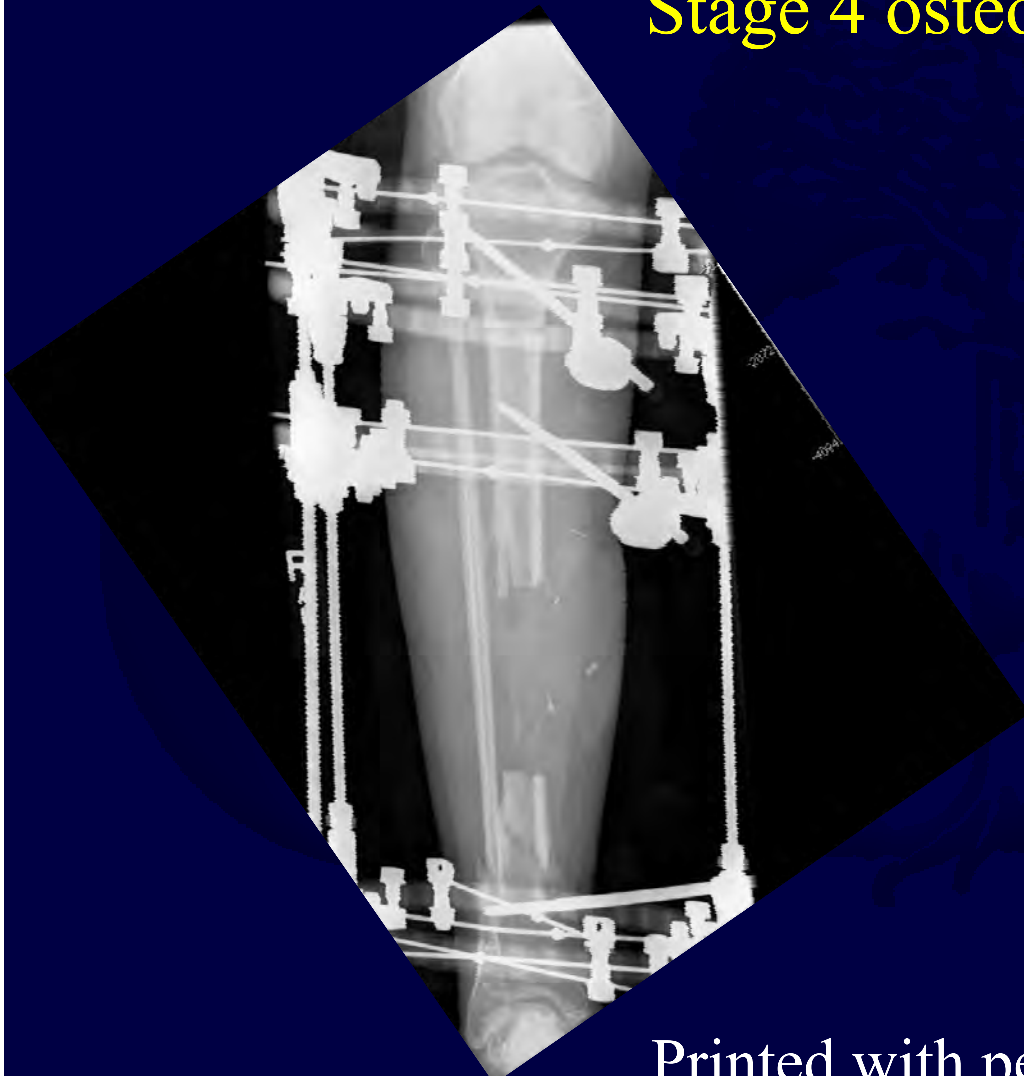
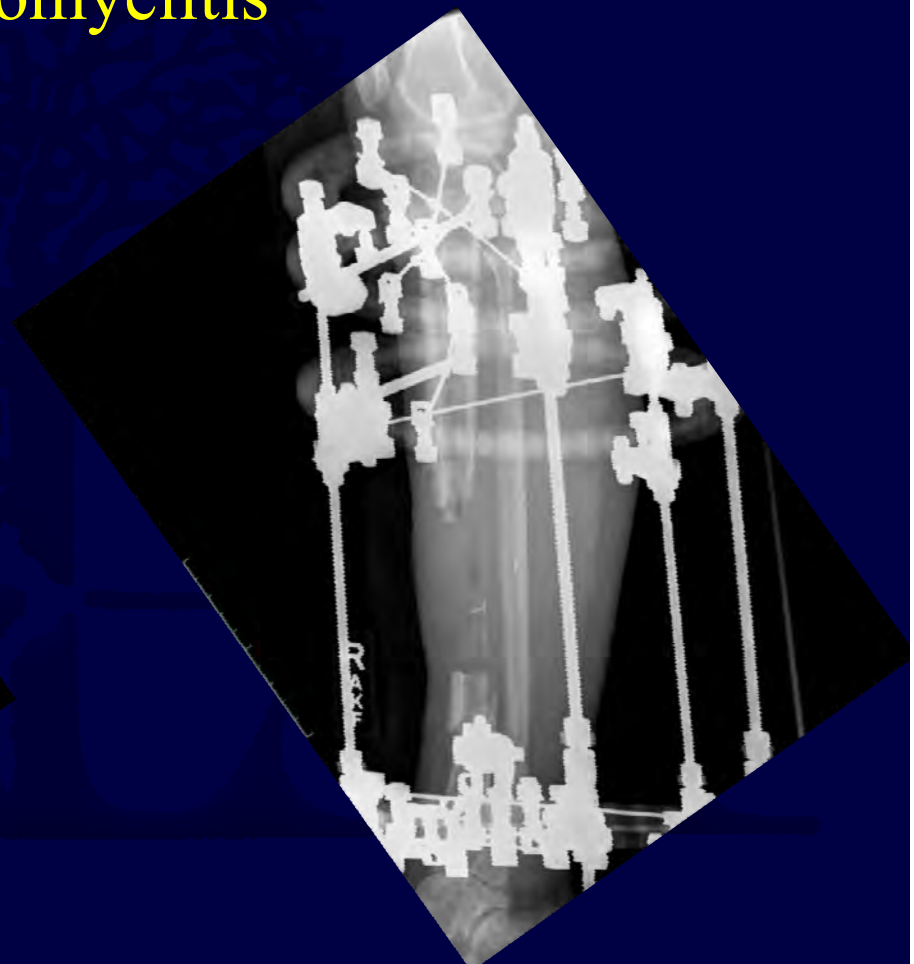
Underwent flap elevation and exploration, intercalary segment avascular and infected, C-M Stage 4 osteomyelitis





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Conclusions

- Osteomyelitis after trauma is increasing
- Biofilm is the hallmark of chronic infection that makes osteomyelitis a surgical disease
- Thorough workup and staging of the bone and the host using the Cierny-Mader Classification is crucial to developing an effective treatment plan
- Systematic approach can lead to successful outcomes (1. Debridement, 2. Dead space management, 3. Soft-tissue coverage, 4. Address bone defect)

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