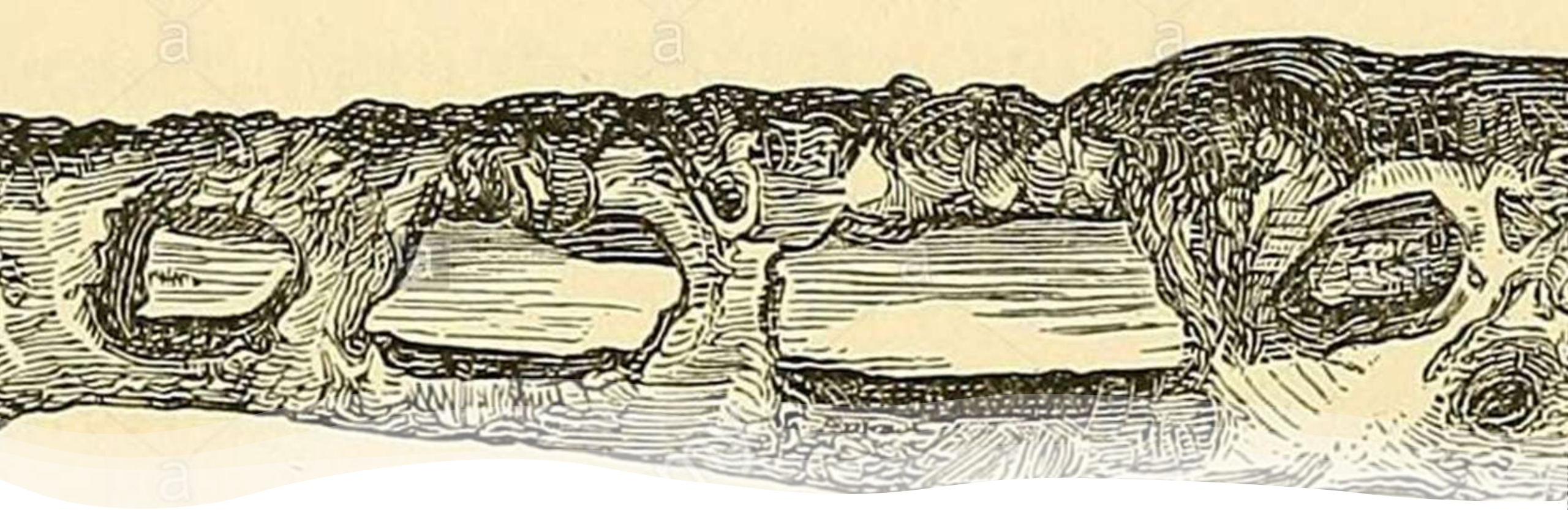


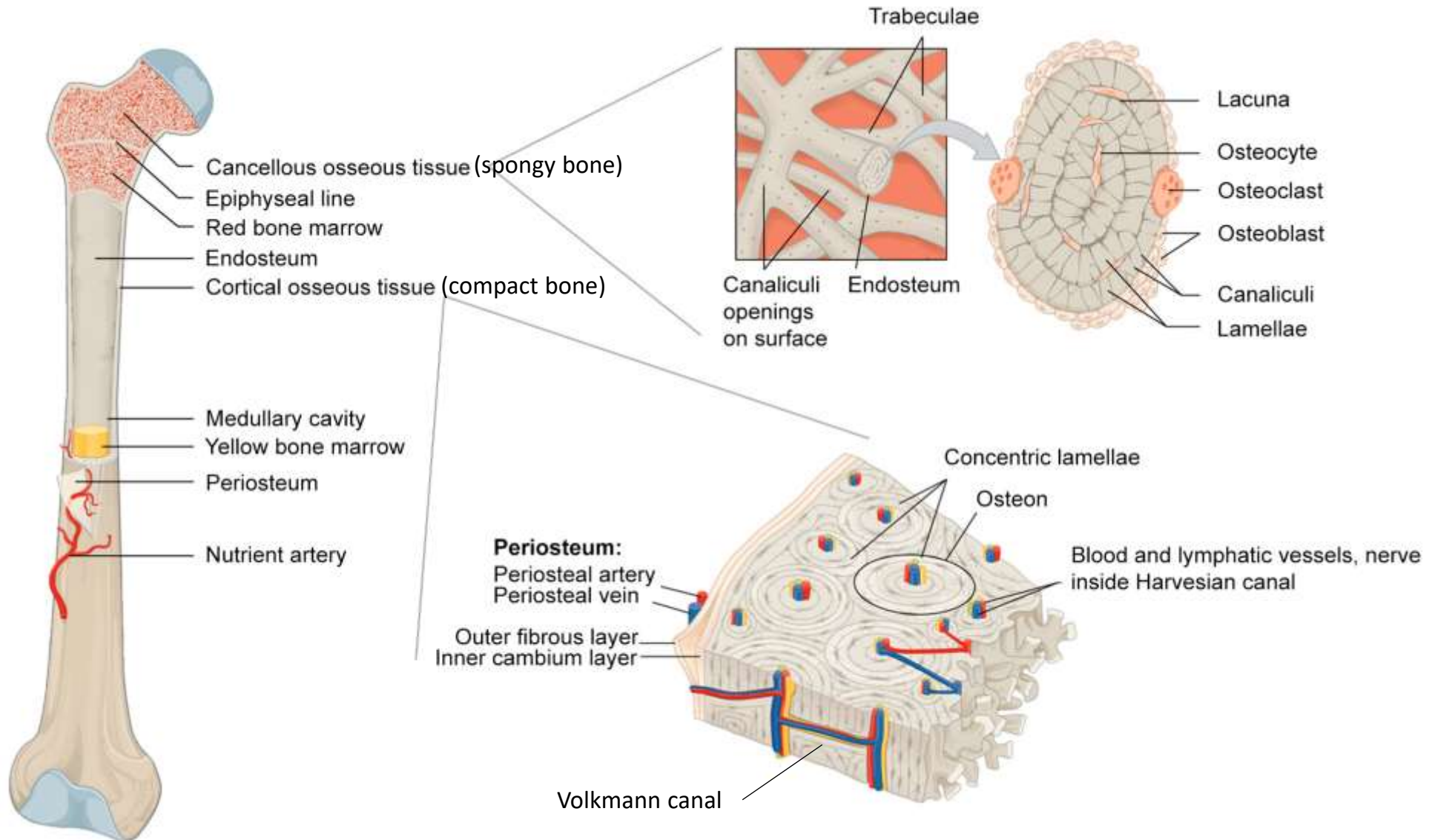


Osteomyelitis & Septic Arthritis

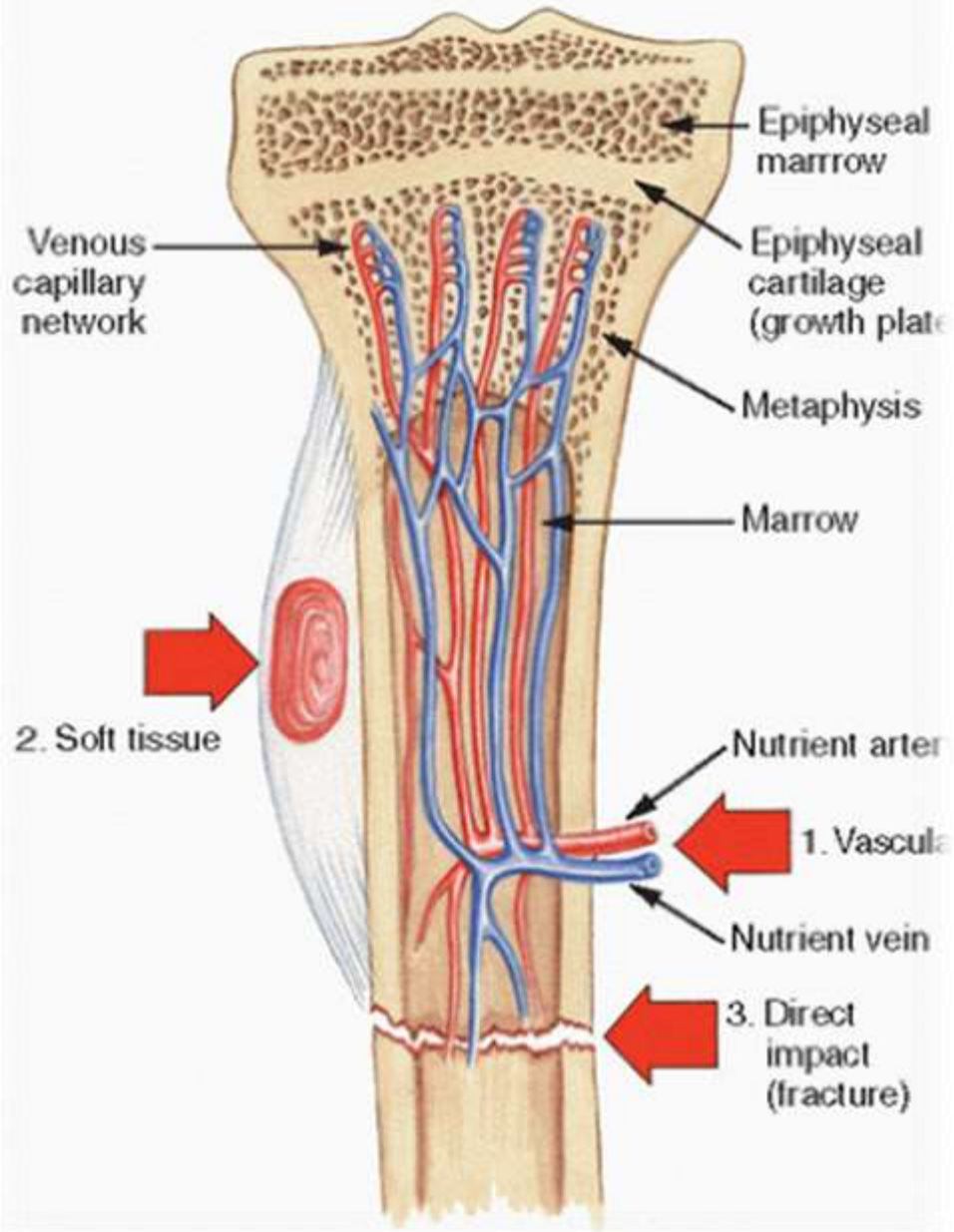
Osteomyelitis

- Osteomyelitis is an infection localized to bone.
- It is usually caused by microorganisms (predominantly bacteria) that enter the bone hematogenously.
- Other pathogenic mechanisms include direct inoculation (usually traumatic, but also surgical) or local invasion from a contiguous infection (eg, sinusitis, decubitus ulcers, deep wound infections, periodontal disease)

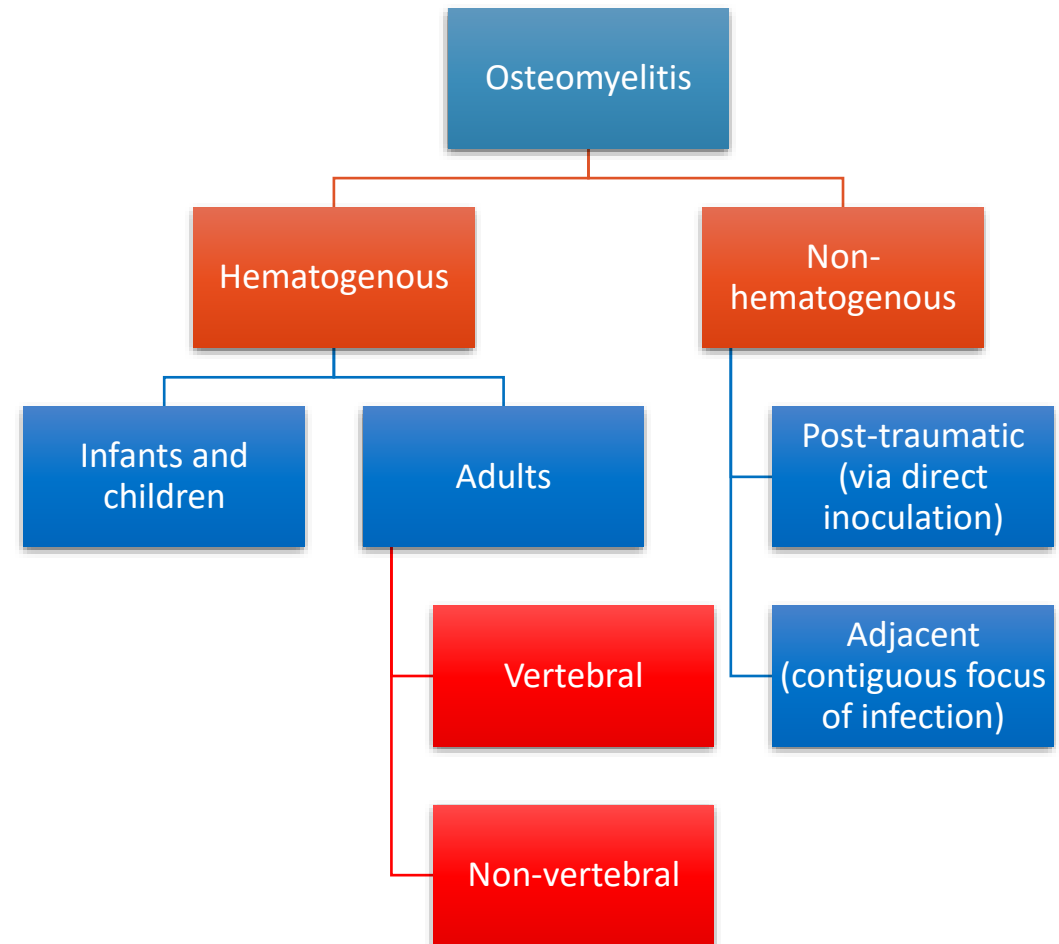
Bone anatomy



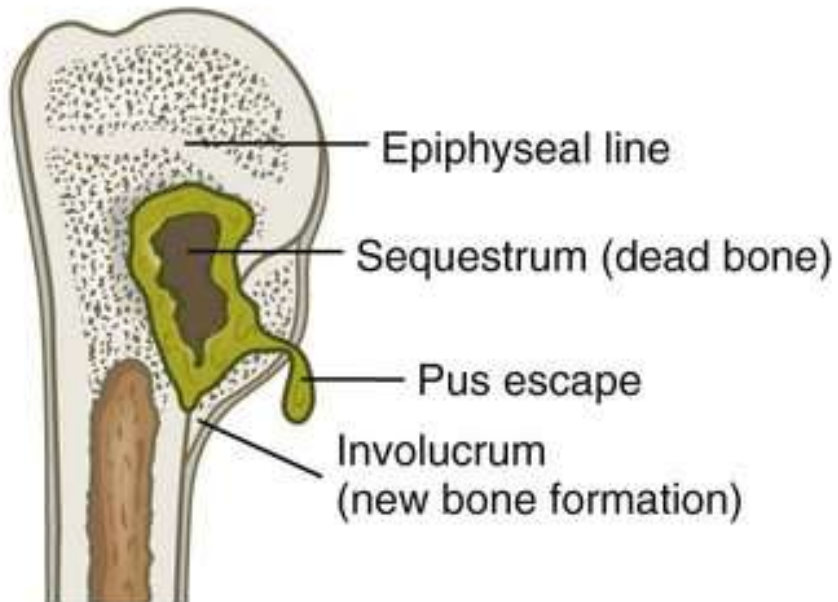
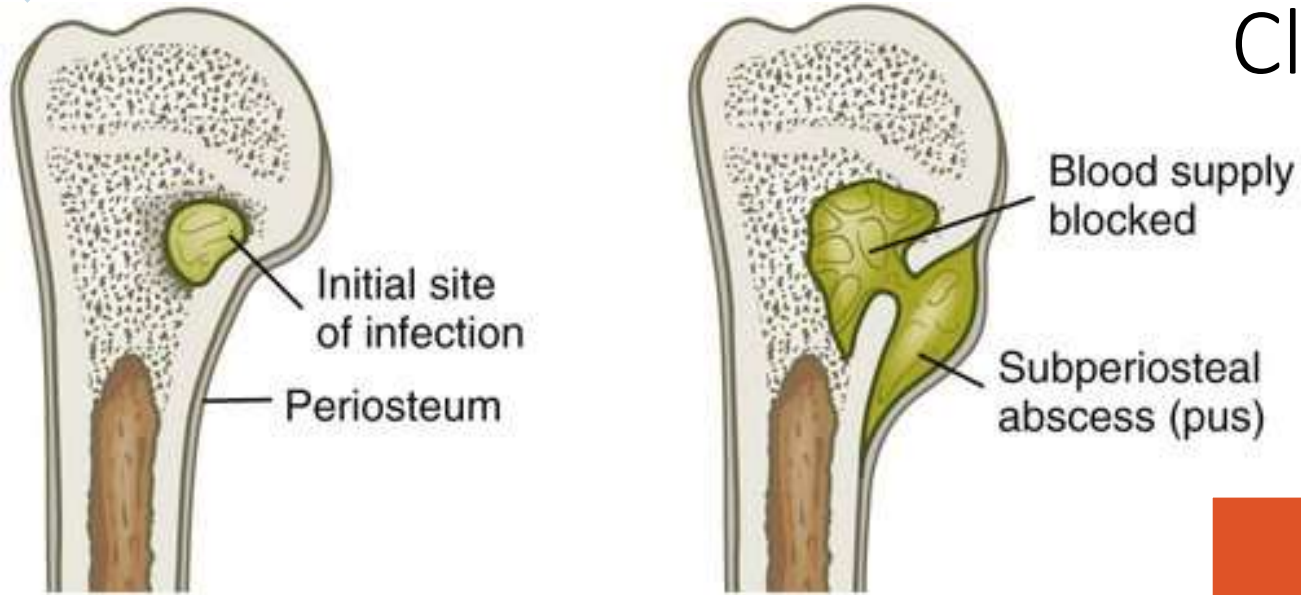
Sources of Long Bone Infection



Classification



Classification



Osteomyelitis

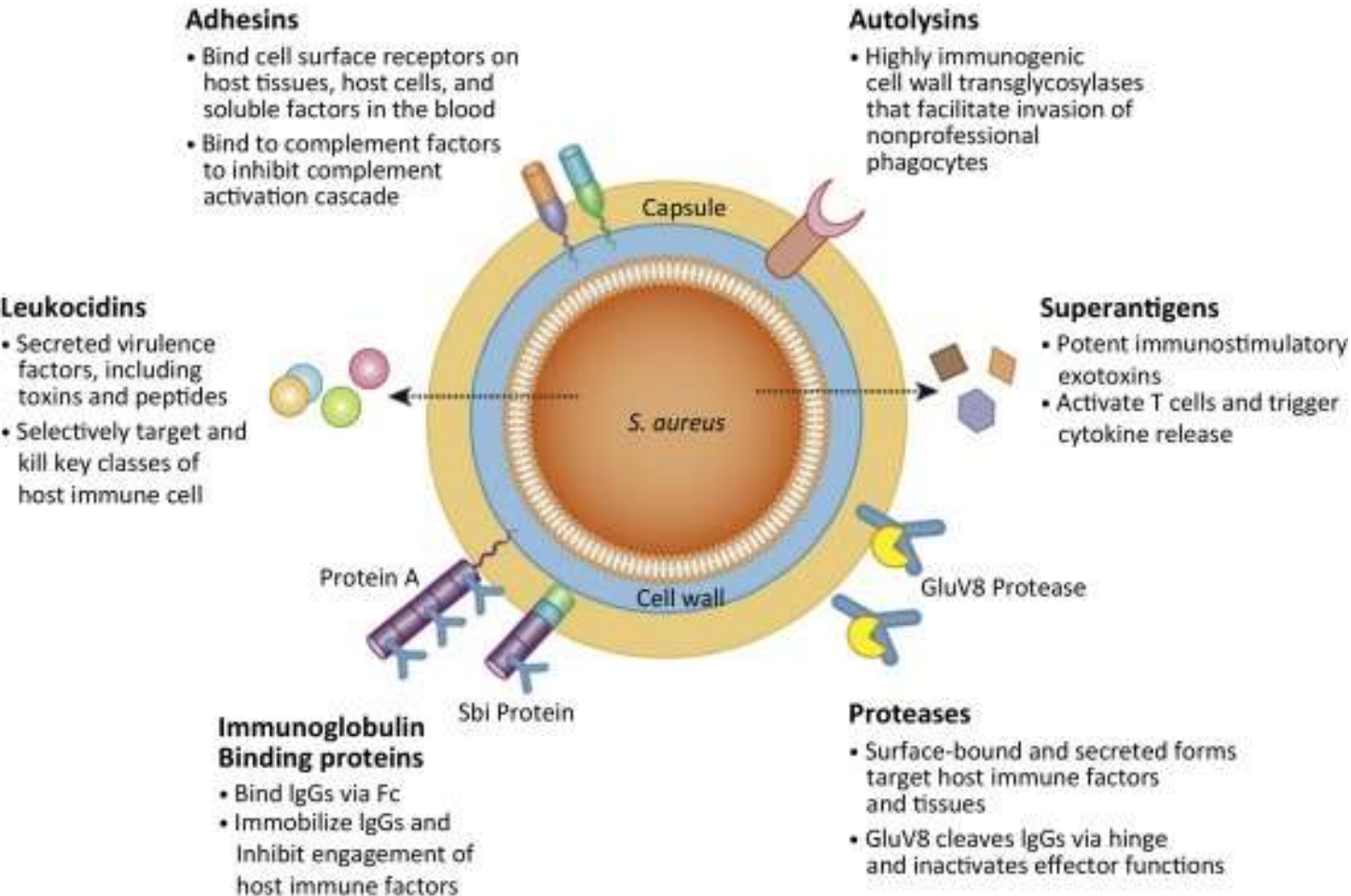
Acute

Chronic

- Sequestrum (dead bone)
- Involucrum (new bone growth)
- Sinus tract

Primary chronic

Etiology

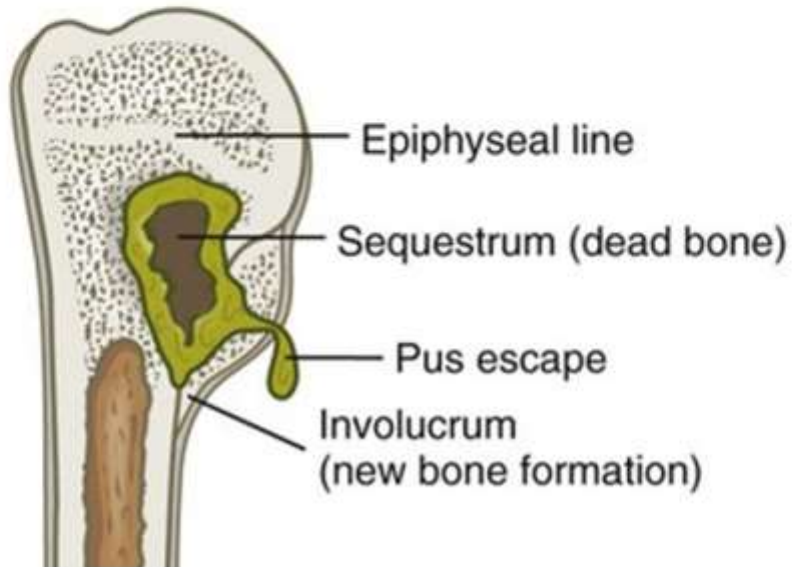
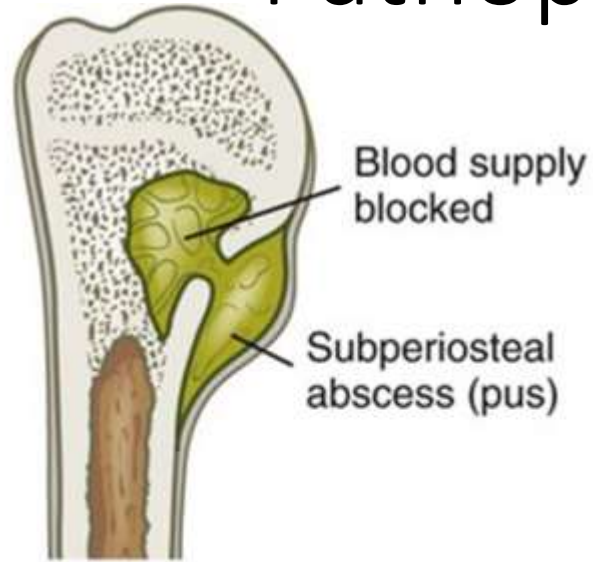
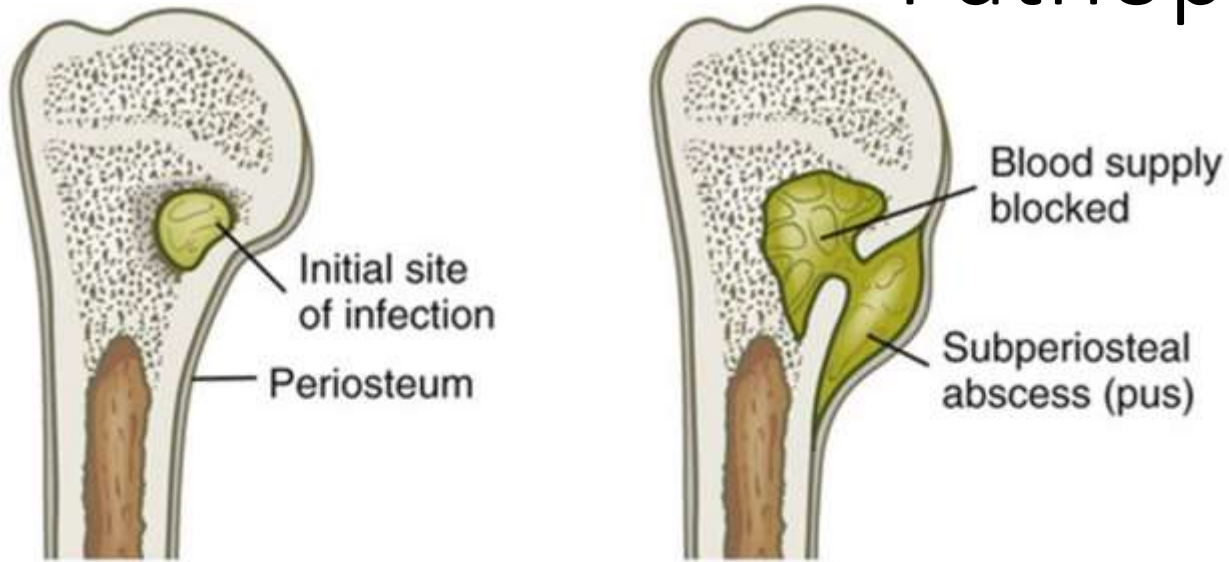


- In 1880, Scottish surgeon Sir Alexander Ogston first described staphylococci in pus from a **surgical abscess in a knee joint**: “the masses looked like bunches of grapes.”
- In 1884, German physician Friedrich Julius Rosenbach differentiated the bacteria by the color of their colonies: *S. aureus* (from the Latin aurum, gold) and *S. albus* (Latin for white). *S. albus* was later renamed *S. epidermidis* because of its ubiquity on human skin.
- *S. aureus* – the most common causative microorganism:
 - High adherence to the components of bone matrix (fibrinogen, fibronectin, laminin, collagen, bone sialoglycoprotein, clumping factor A) via specific adhesins
 - High resistance to host defense (can survive intracellularly in osteoblasts, can interfere with opsonization and phagocytosis, exotoxins)

Hematogenous osteomyelitis in children

	Clinical features
Gram-positive bacteria	
Staphylococcus aureus	All ages; possible associated skin or soft tissue infection; MRSA may be associated with venous thromboembolism and pulmonary disease
Coagulase-negative staphylococci	Neonates in intensive care unit; children with indwelling vascular catheters (eg, for chronic hemodialysis)
Group A Streptococcus	More common in children younger than 4 years; may occur as a complication of concurrent varicella-zoster virus infection
Group B Streptococcus	Infants younger than 3 months (usually 2 to 4 weeks)
Streptococcus pneumoniae	Children younger than 2 years who are incompletely immunized; children older than 2 years with underlying medical conditions (eg, sickle cell disease, asplenia, splenic dysfunction, immunodeficiency, chronic heart disease, chronic lung disease, diabetes mellitus)
Actinomyces	May affect the facial bones, the pelvis, or vertebral bodies
Gram-negative bacteria	
Kingella kingae	Children 6 to 36 months; indolent onset; oral ulcers preceding musculoskeletal findings; may affect nontubular bones
Nonsalmonella gram-negative bacilli (eg, Escherichia coli, Serratia)	Birth to 3 months; children with sickle cell disease; instrumentation of the gastrointestinal or urinary tract; immunocompromised host (eg, CGD)
Haemophilus influenzae type b	Incompletely immunized children in areas with low Hib immunization rates
Bartonella henselae	Children with cat exposure; may affect the vertebral column and pelvic girdle; may cause multifocal infection
Pseudomonas aeruginosa	Injectable drug use
Brucella	Travel to or living in an endemic area; ingestion of unpasteurized dairy products
Mycobacterium tuberculosis	Birth in, travel to, or contact with a visitor from, a region endemic for M. tuberculosis
Nontuberculous mycobacteria	Surgery or penetrating injury; CGD; other underlying immunodeficiency; HIV infection
Salmonella species	Children with sickle cell disease or related hemoglobinopathies; exposure to reptiles or amphibians; children with gastrointestinal symptoms; children in developing countries
Polymicrobial infection	More likely with direct inoculation (eg, penetrating trauma) or contiguous spread (eg, from skull, face, hands, feet)

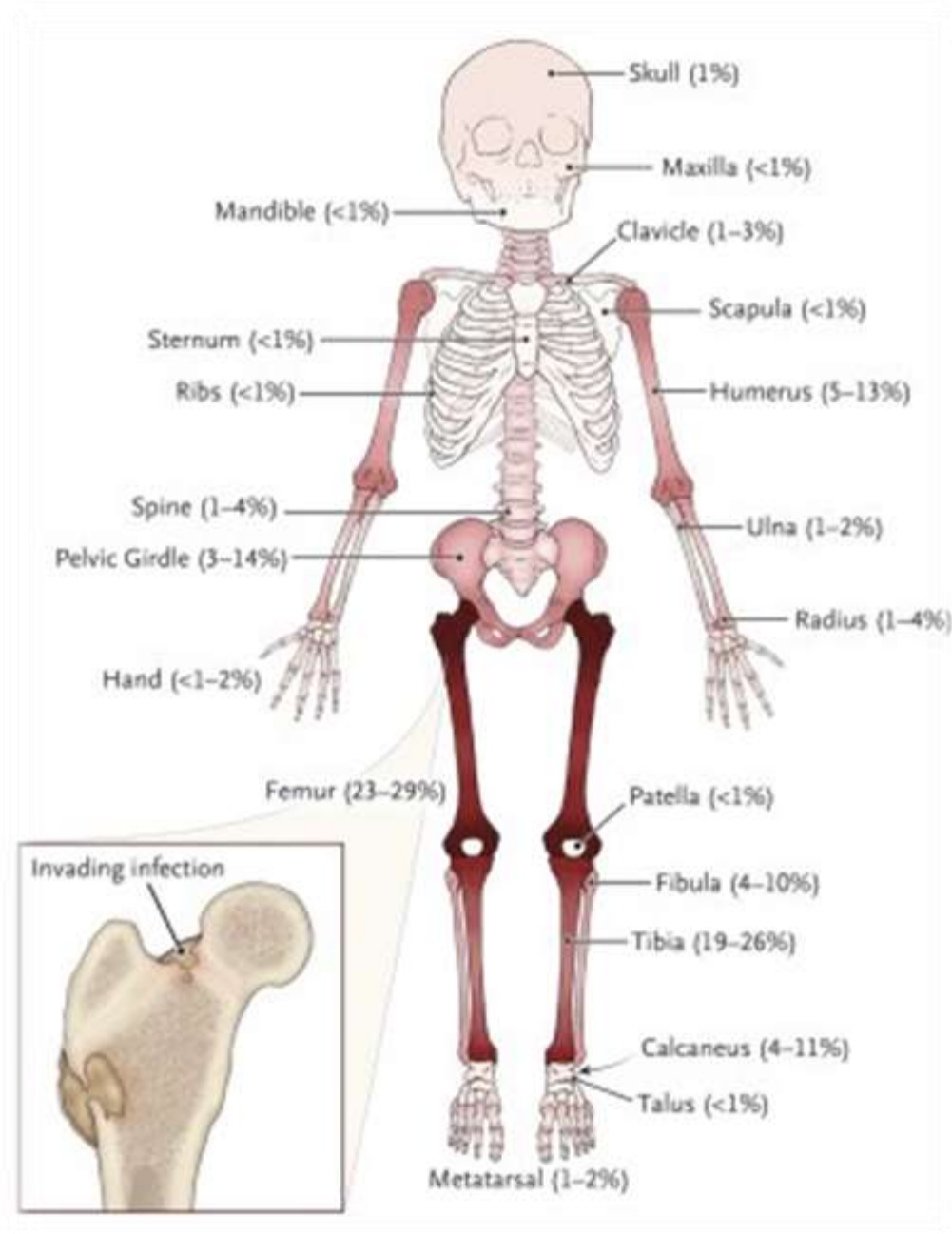
Pathophysiology



- Initial purulent infection in the bone
- Block of medullary and periosteal blood supply (oedema, thrombosis)
- Appearance of necrotic bone (sequestrum):
 - Absorption by granulating tissue
 - Trabecular bone: 2-3 weeks
 - Cortical bone: 2 weeks – 6 months
- Formation of the new bone by periosteum, endosteum and cortex (involucrum)
 - Irregular, perforated, connecting sequester cavity and sort tissues or environment (sinus tracts)
- Atrophy of the survived bone (osteoporosis)

Hematogenous osteomyelitis in children

- The incidence:
 - 1 in 5000 to 7700 children in developed countries
 - 1 in 500 to 2300 children in developing countries
- Boys are affected >2 times more often as girls.
- Age
 - <5 years: >50% of all pediatric cases
 - <2 years: 25% of all pediatric cases
 - Uncommon in young infants (<4 months) without underlying risk factors



Risk factors

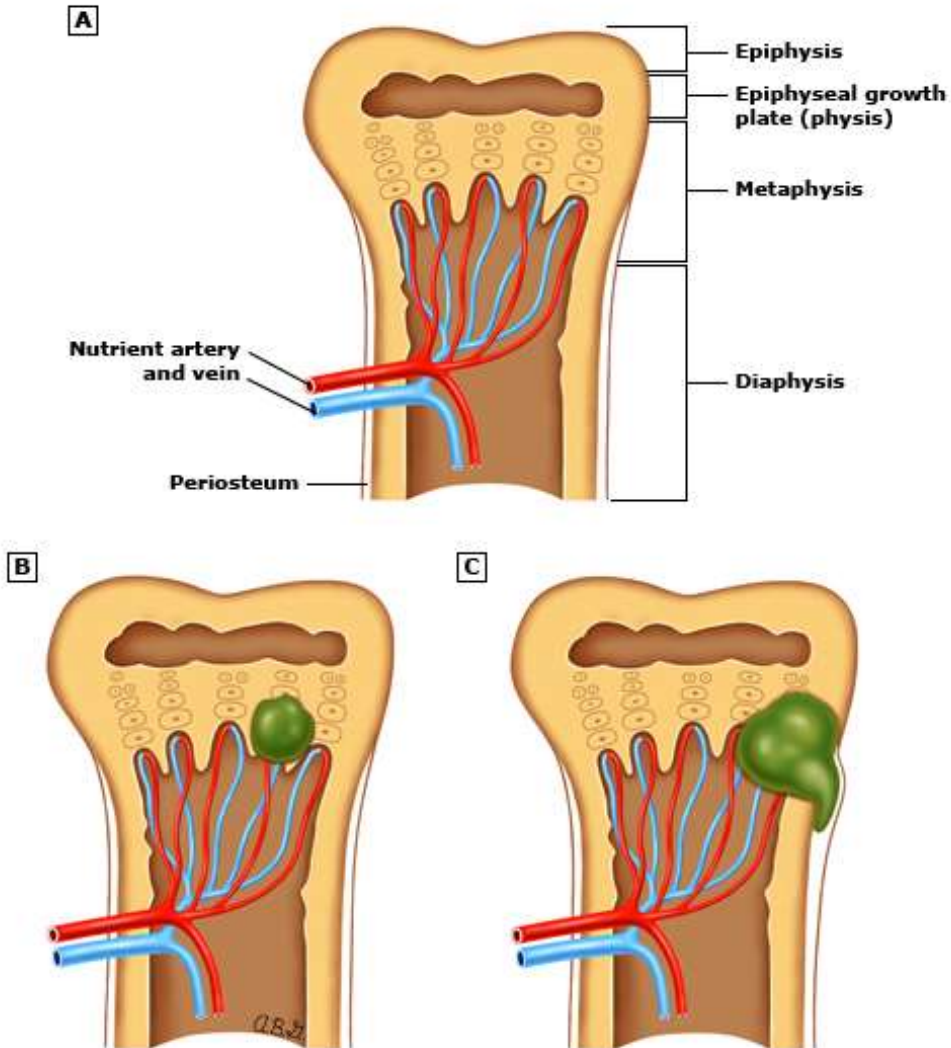
Neonates (<30 days of age)

- Complicated delivery
- Prematurity
- Skin infection
- Central venous catheter
- Urinary tract anomalies
- Active maternal infection at the time of delivery

Infants and children

- Sickle cell disease
- Immunodeficiency disorders, such as chronic granulomatous disease
- Sepsis
- Minor trauma coincident with bacteremia
- Indwelling vascular catheters, including hemodialysis catheters

Pathophysiological issues



- Specific loops of nutrient vessels in the epiphyseal growth plate
- In younger age vessels may penetrate to epiphysis
- Endothelial cells may permit microbial passage
- Trauma or emboli may cause occlusion of the slow-flowing sinusoidal vessel

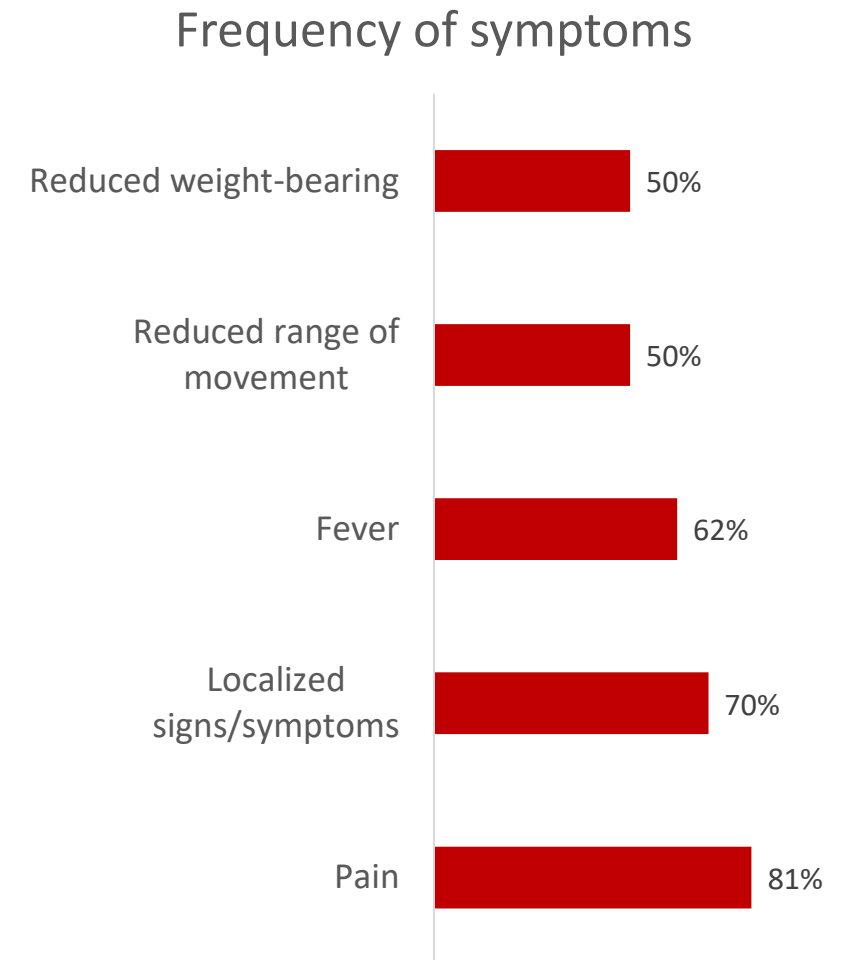
(A) During an episode of bacteremia, bacteria are deposited in the metaphysis from the metaphyseal vessels.

(B) A focus of infection develops in the metaphysis, which leads to cellulitis in the bone marrow.

(C) Exudate under pressure is forced laterally through the Haversian systems and Volkmann canals and into the cortex of the bone, where it can lift or rupture through the periosteum.

Clinical presentation

- The initial symptoms of hematogenous osteomyelitis can be nonspecific in children of all ages (eg, malaise, low-grade fever).
- Once the infection becomes established in bone, symptoms are more localized.
- Children with hematogenous osteomyelitis usually present acutely with:
 - Fever
 - Constitutional symptoms (eg, irritability, decreased appetite or activity)
 - Focal findings of bone inflammation (warmth, swelling, point tenderness)
 - Limitation of function (eg, limp, limited use of extremity)



Laboratory findings

- **White blood cell count:**

- Variable and nonspecific,
- Elevates in 36% of children at the time of presentation and normalizing rapidly,
- Mean count of 12,600 at presentation,
- Higher rate and longer persistence may be associated with MRSA, group A Streptococcus, or Streptococcus pneumoniae and concomitant septic arthritis

- **Erythrocyte sedimentation rate:**

- Elevation ≥ 20 mm/h occurs in most children with osteomyelitis
- Mean value of 51 mm/h at presentation
- Peak on day 3 to 5
- Normalization within 3-4 weeks

- **C-reactive protein:**

- Elevation of the C-reactive protein occurs in most children with osteomyelitis
- Mean value of 87 mg/L (8.7 mg/dL) at the presentation
- Peaked on day 2
- Normalization >1 week

Instrumental findings

Imaging modality	Abnormal findings
Plain radiograph	Deep soft tissue swelling (3 days after onset)
	Periosteal reaction or elevation (10 to 21 days after onset)
	Lytic sclerosis (≥ 1 month after onset)
Magnetic resonance imaging	Bone marrow inflammation (decreased signal in T1-weighted images; increased signal in T2-weighted images)
	Edema in marrow and soft tissues
	Penumbra sign (high-intensity-signal transition zone between abscess and sclerotic bone marrow in T1-weighted images)
	With gadolinium enhancement: absent blood flow, suggestive of necrosis or abscess
Scintigraphy	Focal uptake of tracer in the third phase (delayed phase). Bone radionuclide images are rapidly positive within the first 24–48 hours after the onset of symptoms.
Computed tomography	Increased density of bone marrow
	Cortex destruction
	Periosteal reaction (new bone formation) formation
	Periosteal purulence
	Sequestra (devitalized, sclerotic bone)
Ultrasonography	Fluid collection adjacent to bone without intervening soft tissue
	Thickening of periosteum
	Periosteal elevation

Comparison of imaging modalities in children with osteomyelitis

Modality	Indications	Advantages	Disadvantages	Comments
Plain radiographs	- Baseline - Excluding other conditions in differential diagnosis - Monitoring disease progression	- Inexpensive - Easy to obtain	Abnormal findings usually not present at onset of symptoms, except in newborns	- Sensitivity: 16-20% - Specificity: 80-100% - Normal radiograph at onset does not exclude osteomyelitis
MRI	- Identify location and extent of disease - Evaluation of adjacent structures for extension of infection (soft tissues, growth plate, epiphysis, joint) - Evaluation of difficult sites (eg, pelvis, vertebral bodies, intervertebral discs) - Planning surgical intervention	- No radiation risk - Demonstrates early changes in the marrow cavity - Improved demonstration of subperiosteal abscess - Demonstration of concomitant septic arthritis, venous thrombosis, or pyomyositis	- Costly Less useful in multifocal or poorly localized disease - Requires more time than CT - Young children may require sedation or anesthesia - Not always available	- Sensitivity: 80-100% - Specificity: 70-100% Osteomyelitis unlikely if MRI is normal - Repeat MRI seldom leads to management changes in patients with clinical improvement
Scintigraphy	- Poorly localized symptoms (eg, young children who cannot verbalize) Multifocal disease	More useful than MRI in multifocal or poorly localized disease - Demonstrates early changes - Readily available - May require less sedation than MRI	- Radiation exposure - Does not provide information about extent of purulent collections that may require drainage	- Sensitivity: 53-100% - Specificity: 50-100% Osteomyelitis unlikely if scintigraphy is normal May be falsely negative if blood supply to periosteum is interrupted (eg, subperiosteal abscess)
CT	- Evaluation of cortical destruction, bone gas, and sequestrum Delineating extent of bone injury in subacute/chronic osteomyelitis - Planning surgical interventions - Evaluation of complications if MRI not available or contraindicated	- Less time-consuming than MRI - Does not require sedation	- Expensive - Increased radiation exposure Poor soft tissue contrast	- Sensitivity: 67% - Specificity: 50% - Generally used only if other studies are not possible or inconclusive
Ultrasound	- Evaluate fluid collections in adjacent structures (eg, joint, periosteum) - Monitor abscess resolution or progression	- Inexpensive - No radiation burden - Noninvasive - Portable	Does not penetrate bone cortex	- Sensitivity: 55% - Specificity: 47%

Radiographs

Soft tissue swelling



Radiographs of the ankle demonstrate deep soft tissue swelling (arrow) inferior to the medial malleolus.

Periosteal reaction



Onionskin periosteal reaction. Frontal radiograph shows localized laminated periosteal reaction (arrow) along lateral cortex of distal femur. Suggestive of new bone formation or reactive edema

Periosteal elevation



Radiograph of the femur demonstrates periosteal elevation due to a subperiosteal abscess as the result of osteomyelitis. Suggestive of subperiosteal abscess

Lytic sclerosis

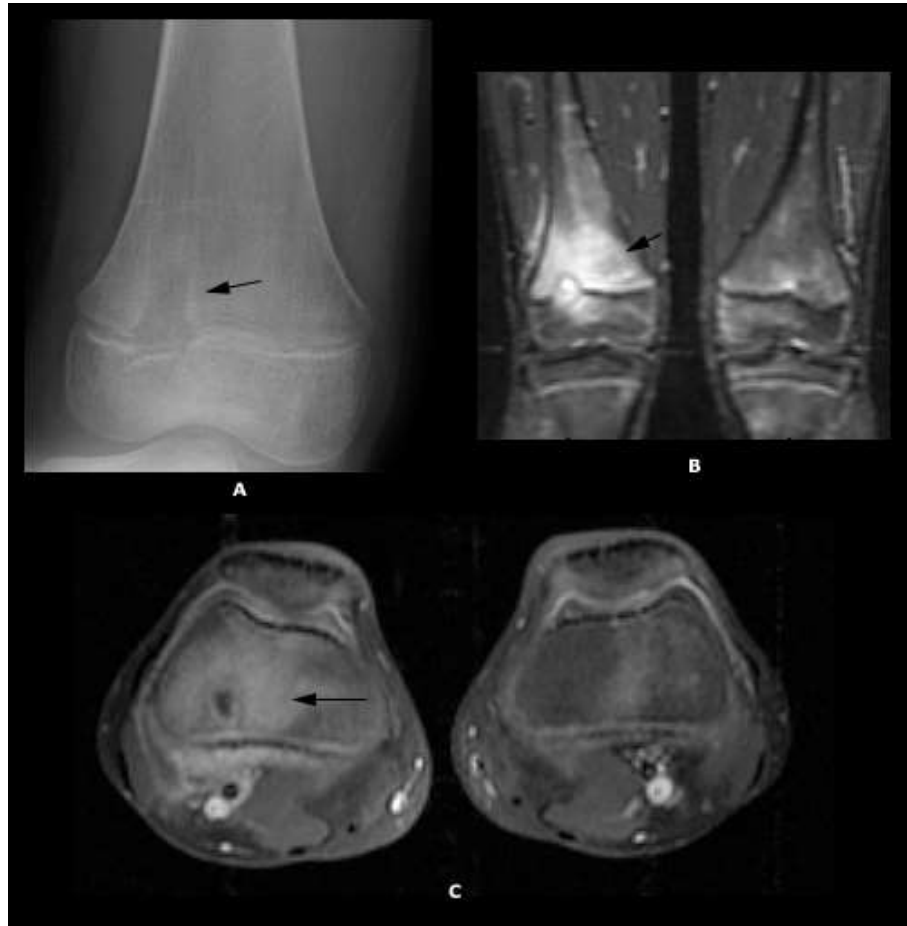


Radiograph at the initial evaluation of a nine-year-old with fever and limp demonstrates a lytic lucency in the distal femoral metaphysis. Suggestive of subacute/chronic infection

Magnetic resonance imaging



(A) The proximal shaft and metaphysis of the left tibia show an abnormal mottled appearance. (B) The marrow signal from the left tibia is abnormal. In addition, there is soft tissue inflammation surrounding the left tibia.



(A) Radiograph at the initial evaluation of a nine-year-old with fever and limp demonstrates a lytic lucency in the distal femoral metaphysis. (B, C) Axial and coronal magnetic resonance (MR) images delineate the area of osteomyelitis and adjacent marrow edema.

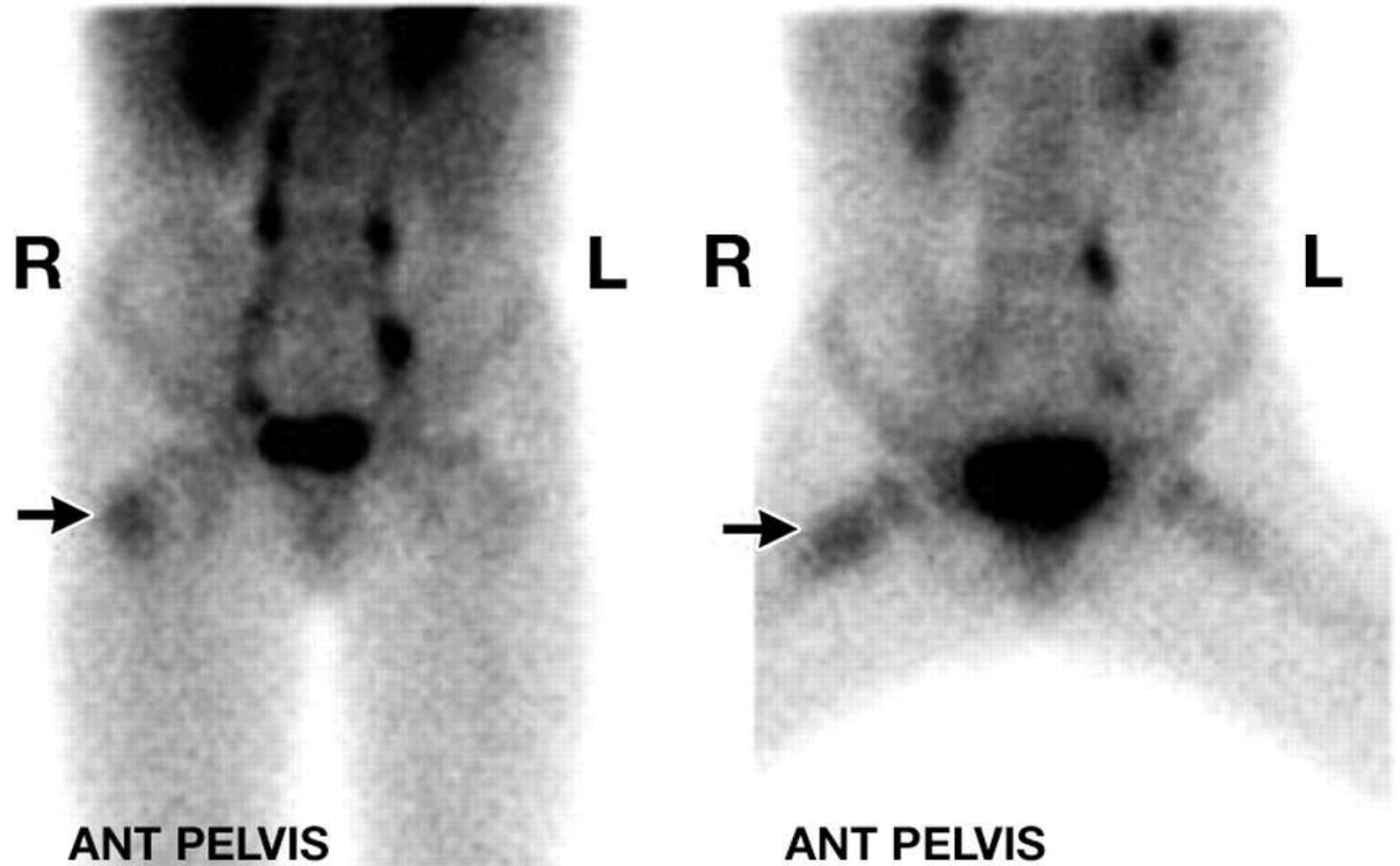


Magnetic resonance imaging (MRI) scan shows the penumbra sign (a transitional zone with relatively high signal intensity between abscess and sclerotic bone marrow on T1-weighted MRI).

Scintigraphy



Radiographs of the ankle (A) demonstrate deep soft tissue swelling (arrow) inferior to the medial malleolus. A technetium 99m bone scan shows increased uptake in the distal tibia in the blood flow (B) and bone uptake (C; four hour) phases.



Osteomyelitis in a 6-year-old boy with a painless right-sided limp for 3 days, fever, an elevated erythrocyte sedimentation rate, and a normal WBC count. Sequential anterior blood flow images of the pelvis acquired at 2-second intervals show increased flow to the proximal portion of the right femur.

CT scan

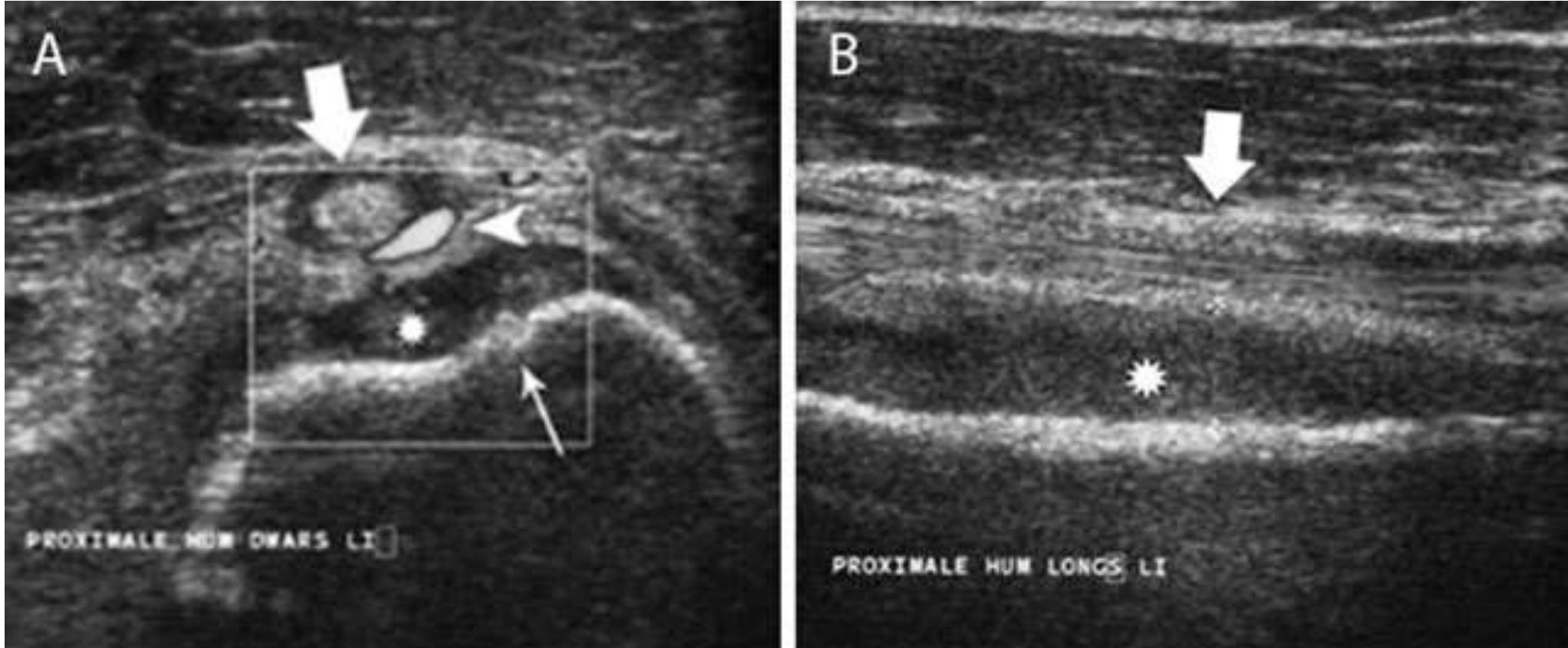


Radiographic appearance of devitalized bone (sequestra) in anteroposterior and lateral radiographs (panels A and B, respectively) and computed tomography (panel C) in a 13-year-old boy who developed femoral osteomyelitis and septic arthritis of the knee as complications of methicillin-resistant *Staphylococcus aureus* septic shock.



Coronal image of chronic osteomyelitis showing cortical thickening of proximal humerus (arrow)

Ultrasound



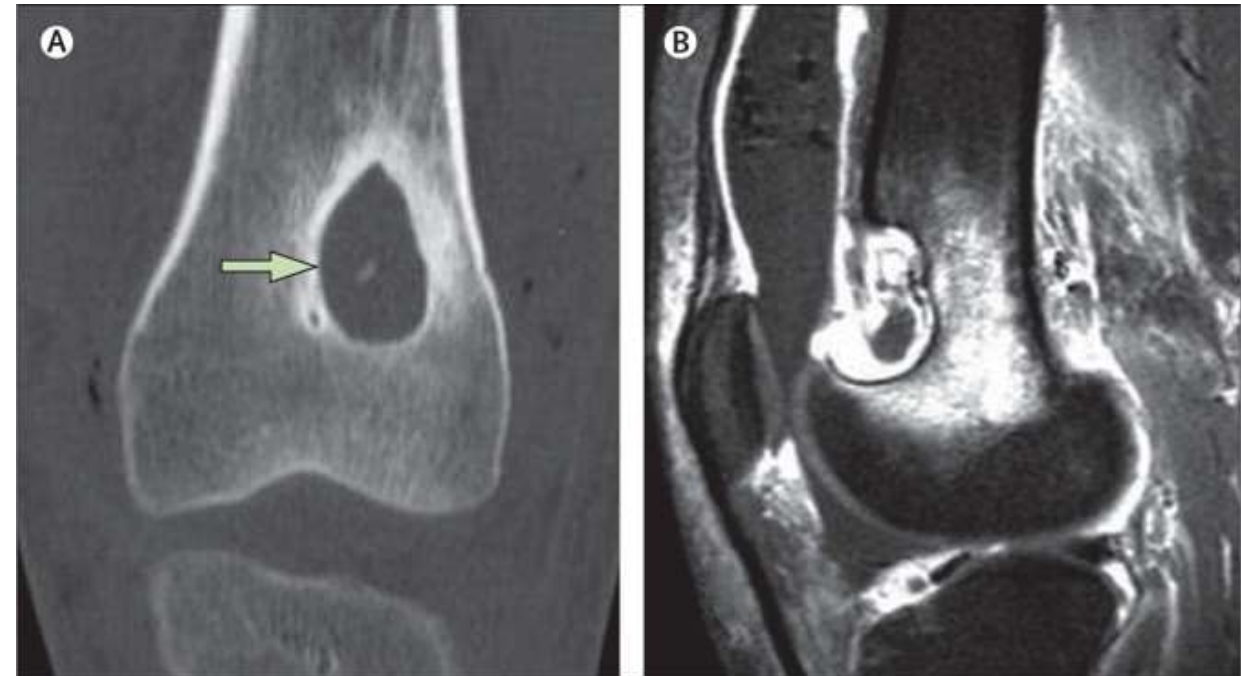
Acute childhood osteomyelitis of the proximal humerus on ultrasound. Transverse (a) and longitudinal (b) ultrasound images of the proximal humerus. Note focal thinning of the humeral cortex (thin white arrow) on the axial images in keeping with a cortical penetration of the infection causing subperiosteal pus collection (asterisk). There is also increased Doppler signal (white arrow head) within the synovium of the long head of the biceps tendon (large white arrow).

Complications

- Extension of infection into the soft tissue (eg, pyomyositis), common in young infants.
- Septic arthritis if infection spreads to the joint space (more common with infections of the proximal humerus and femur) or with hematogenous delivery of organisms to the joint space.
- Abnormal bone growth (angular deformity, shortening, or overgrowth) with involvement of the physis and epiphysis.
- Subperiosteal abscess.
- Brodie abscess.
- Pathologic fracture.
- Multifocal infection.
- Osteonecrosis (avascular necrosis) of the femoral head.
- Collapse or complete destruction of one or more vertebral bodies, which may be associated with kyphosis or spinal cord compression.
- Devitalized bone (sequestra) and cutaneous fistulae.
- Chronic osteomyelitis (radiographic evidence of devitalized bone and ≥ 2 weeks of signs and symptoms of bone inflammation) occasionally occurs in a child who has longstanding musculoskeletal complaints that are not recognized as osteomyelitis.

Brodie abscess

- The lesion is named after Sir Benjamin Collins Brodie (1783-1862), who initially described a chronic inflammatory process affecting the tibia without acute precipitating factors in the 1830s.
- It is an intraosseous abscess related to a focus of subacute or chronic pyogenic osteomyelitis.
- It has a protean radiographic appearance and can occur at any location and in a patient of any age.
- It might or might not be expansile, have a sclerotic or nonsclerotic border, or have associated periostitis.



Sclerosing osteomyelitis of Garré

- It was first described by Carl Garre in 1893
- It is a specific type of chronic osteomyelitis.
- It mainly affects children and young adults.
- It typically affects the mandible and is commonly associated with an odontogenic infection resulting from dental caries.
- A localized overgrowth of bone on the outer surface of the cortex. This mass of bone, which is supracortical but subperiosteal, is smooth, fairly calcified, and is often described as a duplication of the cortical layer.



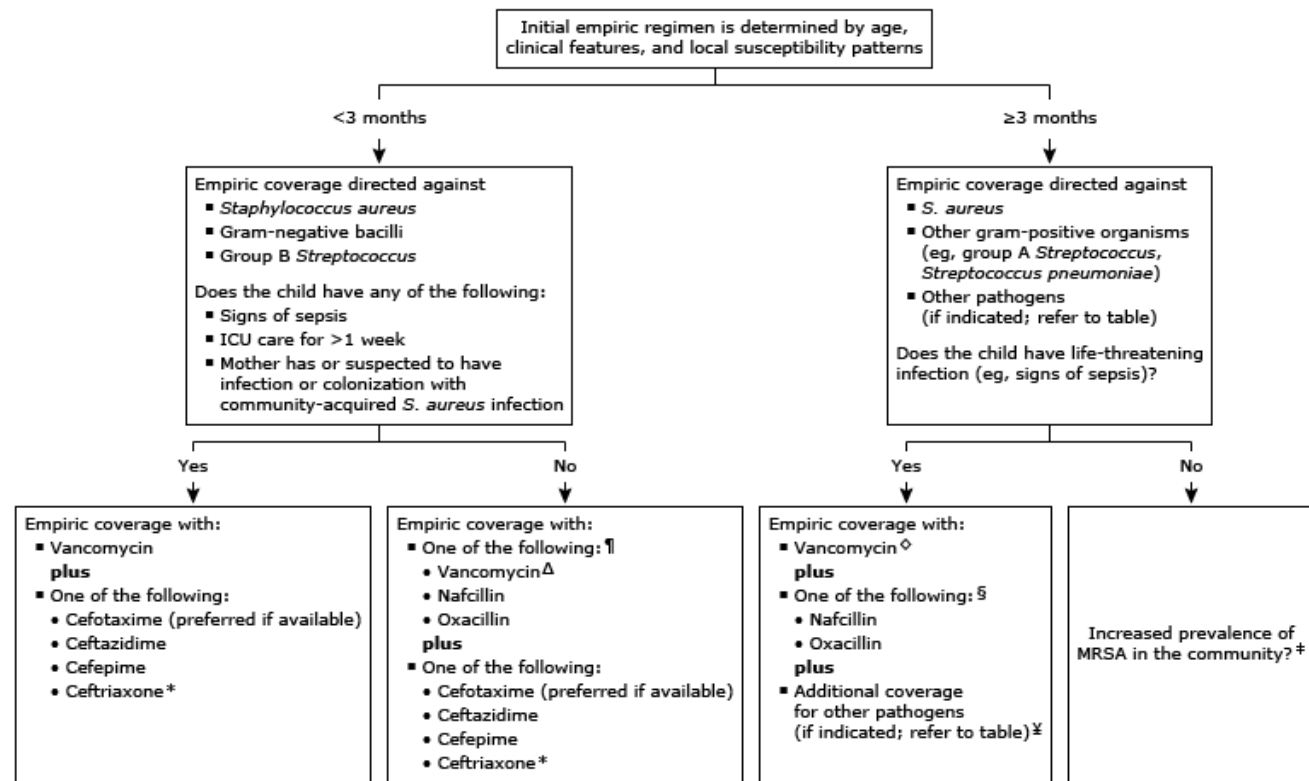
Albuminose osteomyelitis

- Rare form of chronic osteomyelitis
- Not represented in the international literature
- Caused by S.Aureus of low virulence
- Clinical signs are not intensive
- Bone inflammation (usually femur) is non-purulent with appearance of protein-rich serous (albuminose) exudate
- The lesion is usually limited by cortical bone with periosteum reaction and elevation of wide length
- One or several zones of lytic lucency in the cortical bone without sequestration



Management

- For most children with clinical features compatible with osteomyelitis empiric antimicrobial therapy should be started, even if the initial radiograph is normal. Characteristic features of osteomyelitis are not usually apparent on radiographs until 10 days after symptom onset, and advanced imaging (MRI, scintigraphy) may not be immediately available or feasible.
- Initial antimicrobial therapy for acute hematogenous osteomyelitis usually is administered parenterally.
- The empiric regimen is determined by the most likely pathogens and antimicrobial susceptibilities based on epidemiologic factors including the child's age, clinical features, and organisms prevalent in the community:
 - Infants <3 months: 3-gen cephalosporins (cefotaxime, ceftazidime, ceftriaxone, cefepime) plus anti-staphylococcal agent (usually vancomycin or nafcillin/oxacillin)
 - Children ≥ 3 months: cefazolin, nafcillin/oxacillin, clindamycin, or vancomycin, depending upon the local prevalence of community-associated MRSA and the susceptibility of CA-MRSA to clindamycin. It may be necessary to add empiric coverage for pathogens other than *S. aureus* when clinical or laboratory features suggest a specific pathogen.



Population	Potential pathogens	Additional empiric therapy
▪ Age 6 to 36 months and in day care or history of oral ulcers before onset of musculoskeletal symptoms	<i>Kingella kingae</i>	▪ Cefazolin if child is not improving as expected and is receiving vancomycin or clindamycin
▪ Incomplete Hib immunization in a child <2 years from area with low rates of Hib immunization**	Hib	▪ Cefotaxime or ceftriaxone
▪ Sickle cell disease¥ ▪ Reptile or amphibian exposure ▪ Gastrointestinal symptoms	<i>Salmonella</i>	▪ Cefotaxime or ceftriaxone
▪ Chronic granulomatous disease¥	Unusual organisms (eg, fungi, filamentous bacteria, gram-negative bacteria)	▪ Cefotaxime or ceftriaxone
▪ Recent GI surgery or complex urinary tract anatomy	Enteric gram-negative organisms	Either: ▪ A third or fourth generation cephalosporin (eg, cefotaxime, ceftriaxone, cefepime), or ▪ An aminoglycoside (eg, gentamicin)
▪ Injection drug user	<i>Pseudomonas aeruginosa</i>	▪ Ceftazidime

Management

- The antimicrobial regimen can be tailored to a specific pathogen when culture and susceptibility results are available.
- Children whose cultures remain negative and improve with empiric therapy usually are continued on the same parenteral regimen on which they improved, followed by an oral regimen with a similar spectrum

Pathogen	Parenteral agents	Oral agents
<i>Staphylococcus aureus</i>		
Methicillin-susceptible	Cefazolin Nafcillin Oxacillin	Cephalexin Cloxacillin (not available in the United States) Dicloxacillin Clindamycin*
Methicillin-resistant		
Clindamycin-susceptible	Vancomycin Clindamycin	Clindamycin
Clindamycin-resistant [¶]	Vancomycin Linezolid Daptomycin ^Δ	Linezolid
<i>Streptococcus agalactiae</i> (Group B <i>Streptococcus</i>)	Penicillin	Oral therapy not suggested in infants
<i>Streptococcus pyogenes</i> (Group A <i>Streptococcus</i>)	Penicillin Ampicillin	Penicillin Amoxicillin
<i>Streptococcus pneumoniae</i> (Pneumococcus)		
Penicillin-susceptible	Penicillin	Penicillin Amoxicillin
Penicillin-nonsusceptible	Cefotaxime Ceftriaxone Clindamycin* Linezolid	Clindamycin* Linezolid
<i>Kingella kingae</i>	Penicillin Cefazolin Cefotaxime Ceftriaxone	Penicillin Cephalexin Cefixime
<i>Haemophilus influenzae</i> type b	Cefotaxime Ceftriaxone Cefuroxime	Amoxicillin (if susceptible) Cefixime

Management

- In children with acute hematogenous osteomyelitis who are receiving appropriate and effective antimicrobial therapy, clinical improvement usually occurs within 3 to 4 days.
- Clinical and laboratory improvement is indicated by:
 - Resolution of fever
 - Decreased pain and erythema or swelling
 - Decrease in peripheral WBC (if initially elevated) and a drop in CRP of ≥ 50 percent every two to three days
- Clinical and laboratory improvement suggests that the diagnosis and choice of antimicrobial therapy are correct; continued improvement may be an indication for outpatient therapy.

Management

- Lack of improvement or worsening may indicate development of a complication requiring surgical intervention (eg, abscess, sinus tract, sequestra), thromboembolism, ineffective antimicrobial therapy (eg, unusual or resistant pathogen, polymicrobial infection, insufficient dose), or a diagnosis other than osteomyelitis.
- Additional evaluation may include ESR/CRP, WBC count, plain radiography, and aggressive attempt to isolate fastidious and unusual pathogens.
- Adjustments to antimicrobial therapy may be necessary.

Management

- Antimicrobial therapy should be administered for a minimum of **4 weeks**.
- Before discontinuing antimicrobial therapy, recheck the CRP and the ESR, and we do not stop therapy if either is abnormal.
- Also generally obtain a radiograph to make sure there are no new bone lesions (eg, abscess, sequestra), even if there is no clinical evidence of treatment failure.
- Oral antibiotics may be used to complete the course of therapy for acute osteomyelitis in children older than one month who have unequivocal improvement (eg, afebrile for ≥ 48 hours, decreased pain and erythema or swelling, normalization of WBC count, consistent decrease in CRP).

Indications for surgery

- Drainage of subperiosteal and soft tissue abscesses and intramedullary purulence
- Debridement of contiguous foci of infection
- Excision of sequestra (ie, devitalized bone)
- Failure to improve after 48 to 72 hours of antimicrobial therapy

Surgical drainage of hematogenous osteomyelitis



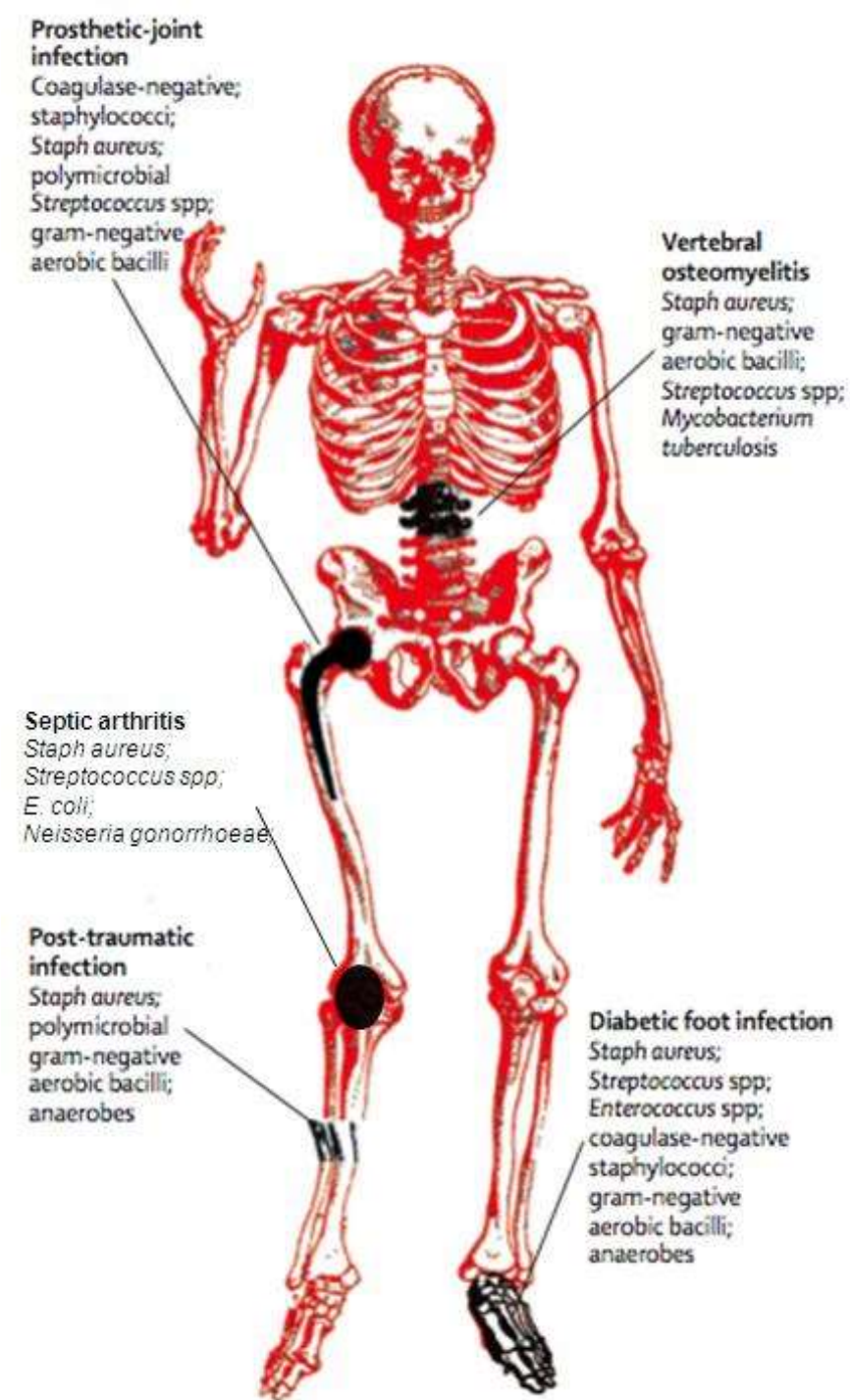
Chronic osteomyelitis

- Chronic osteomyelitis is defined by signs and symptoms of bone inflammation for at least **2 weeks** and radiographic evidence of **devitalized bone**.
- Chronic osteomyelitis typically is described in patients with inadequate duration of therapy, but patient-specific etiologic and anatomic factors also play a role.
- Chronic osteomyelitis is uncommon with current principles of management of acute hematogenous osteomyelitis.
- Diagnosis of chronic osteomyelitis requires bone biopsy for culture and histopathologic confirmation.
- Bone biopsy also may be necessary to exclude other conditions that may have similar radiographic appearance, including nonbacterial osteomyelitis (eg, chronic recurrent multifocal osteomyelitis), Langerhans cell histiocytosis, large cell lymphoma, or primary bone tumors.
- Treatment of chronic osteomyelitis involves removing devitalized bone and long-term administration of antibiotics.
- Repeated surgical debridement and bone grafting often are necessary.



Osteomyelitis in adults

- Non-hematogenous osteomyelitis:
 - Younger adults: trauma and surgery
 - Older adults: contiguous spread of infection to bone from adjacent soft tissues and joints (such as in the setting of diabetic foot wounds or decubitus ulcers)
 - Risk factors:
 - poorly healing soft tissue wounds (including decubitus ulcers),
 - presence of orthopedic hardware,
 - diabetes,
 - peripheral vascular disease,
 - peripheral neuropathy
- Hematogenous osteomyelitis
 - Vertebral, pelvic, long bones
 - Risk factors:
 - endocarditis,
 - presence of indwelling intravascular devices (eg, vascular catheters, cardiovascular devices) or orthopedic hardware,
 - injection drug use,
 - hemodialysis,
 - sickle cell disease



Non-hematogenous osteomyelitis in adults

- Nonhematogenous osteomyelitis may be polymicrobial or monomicrobial.
- *Staphylococcus aureus* (including MRSA), coagulase-negative staphylococci, and aerobic gram-negative bacilli are the most common organisms.
- Other pathogens including corynebacteria, fungi, and mycobacteria have also been implicated.

Acute non-hematogenous osteomyelitis in adults

- Acute osteomyelitis typically presents with gradual onset of symptoms over several days.
- Patients usually present with dull pain at the involved site, with or without movement.
- Local findings:
 - tenderness,
 - warmth,
 - erythema,
 - swelling
- Systemic symptoms: fever, rigors
- Patients with osteomyelitis involving the hip, vertebrae, or pelvis tend to manifest few signs or symptoms other than pain



Chronic non-hematogenous osteomyelitis in adults

- Chronic osteomyelitis may manifest as pain, erythema, or swelling, sometimes in association with a draining sinus tract; fever is usually absent.
- Chronic osteomyelitis may also present with intermittent flares of pain and swelling.
- **The presence of a sinus tract is pathognomonic of chronic osteomyelitis.**



Patient presented with a discharging sinus and surrounding cellulitis over the distal tibia, 13 months following a closed distal tibia fracture that was surgically managed

Chronic non-hematogenous osteomyelitis in adults

- Patients with diabetes and chronic osteomyelitis may present with atypical findings.
- Diabetics who develop cutaneous ulcers often develop osteomyelitis before exposed bone is present on exam.
- **If a diabetic foot ulcer is larger than 2 cm² or if exposed bone is present, osteomyelitis is highly likely.**
- Probing to bone with a sterile blunt metal tool should be included in the initial assessment of diabetic patients with infected pedal ulcers.
- A positive result consists of detection of a hard, gritty surface.



Chronic non-hematogenous osteomyelitis in diabetic foot



Hematogenous osteomyelitis in adults

- **Hematogenous osteomyelitis is usually monomicrobial: *S. aureus* is the most commonly isolated organism.**
- Aerobic gram-negative rods are identified in up to 30% of cases.
- Among injection drug users, hematogenous osteomyelitis due to *P. aeruginosa* and *Serratia marcescens* has been described.
- Among immunosuppressed patients, hematogenous osteomyelitis due to *Aspergillus* spp has been described.
- Hematogenous osteomyelitis due to beta-hemolytic streptococci is relatively rare (<1 percent of cases).
- Other less common pathogens include *Mycobacterium tuberculosis*, *Candida* spp, *Bartonella henselae*, *Coccidioides immitis*, and *Cutibacterium* (formerly *Propionibacterium*) *acnes*

Hematogenous osteomyelitis in adults

- Clinical manifestations of hematogenous osteomyelitis mirror those of nonhematogenous osteomyelitis.
- Typical locations:
 - **Vertebral osteomyelitis:** back or neck pain, with or without fever.
 - **Sternoclavicular osteomyelitis:** anterior chest wall swelling, pain, and tenderness
 - **Pelvic osteomyelitis:** severe pain and fever above affected bones (sacroiliac zone, pubis) is not obligatory, long time from trauma/surgery to onset.
 - **Long-bone osteomyelitis:** some present subacutely with low-grade fever and vague pain at the site of infection, while others present acutely with high fever, sharp pain, and swelling over the involved site.

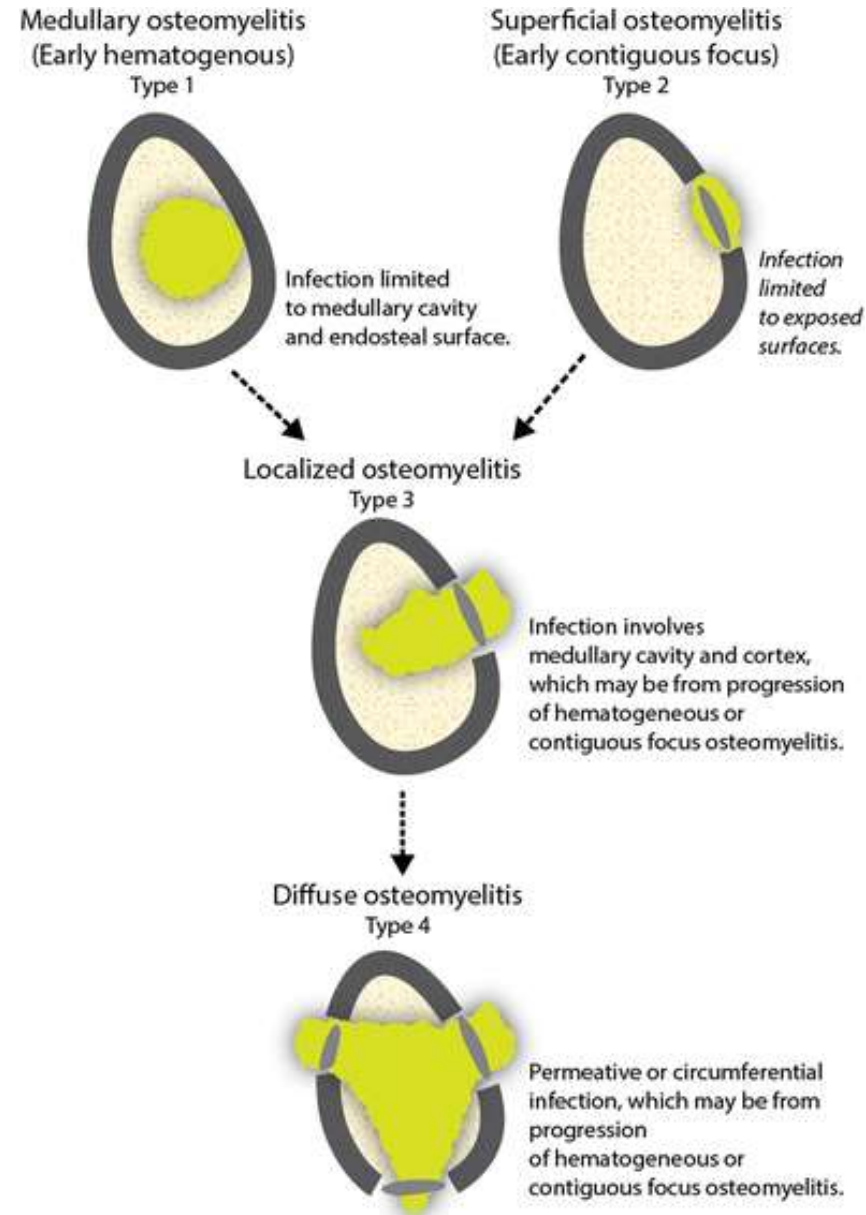
Diagnosis

- Nonhematogenous osteomyelitis should be suspected in the setting of new or worsening musculoskeletal pain, particularly in patients with poorly healing soft tissue or surgical wounds adjacent to bony structures, in patients with signs of cellulitis overlying previously implanted orthopedic hardware, and in patients with traumatic injury (including bite and puncture wounds). It should also be suspected in diabetic patients with ulcers that probe to bone.
- Hematogenous osteomyelitis should be suspected in the setting of new or worsening musculoskeletal pain, particularly in the setting of fever and/or recent bacteremia. Vertebral osteomyelitis is the most common form of hematogenous osteomyelitis in adults.

Diagnosis

- **The diagnosis of osteomyelitis is established via culture obtained from biopsy of the involved bone.**
- A diagnosis of osteomyelitis may be made in the following circumstances:
 - Clinical and radiographic findings typical of osteomyelitis + positive blood cultures with a likely pathogen (*Staphylococcus aureus*).
 - Bone histopathology consistent with osteomyelitis without positive culture.
 - Suggestive clinical and typical radiographic findings + persistently elevated inflammatory markers.

Classification of long bone osteomyelitis



Treatment

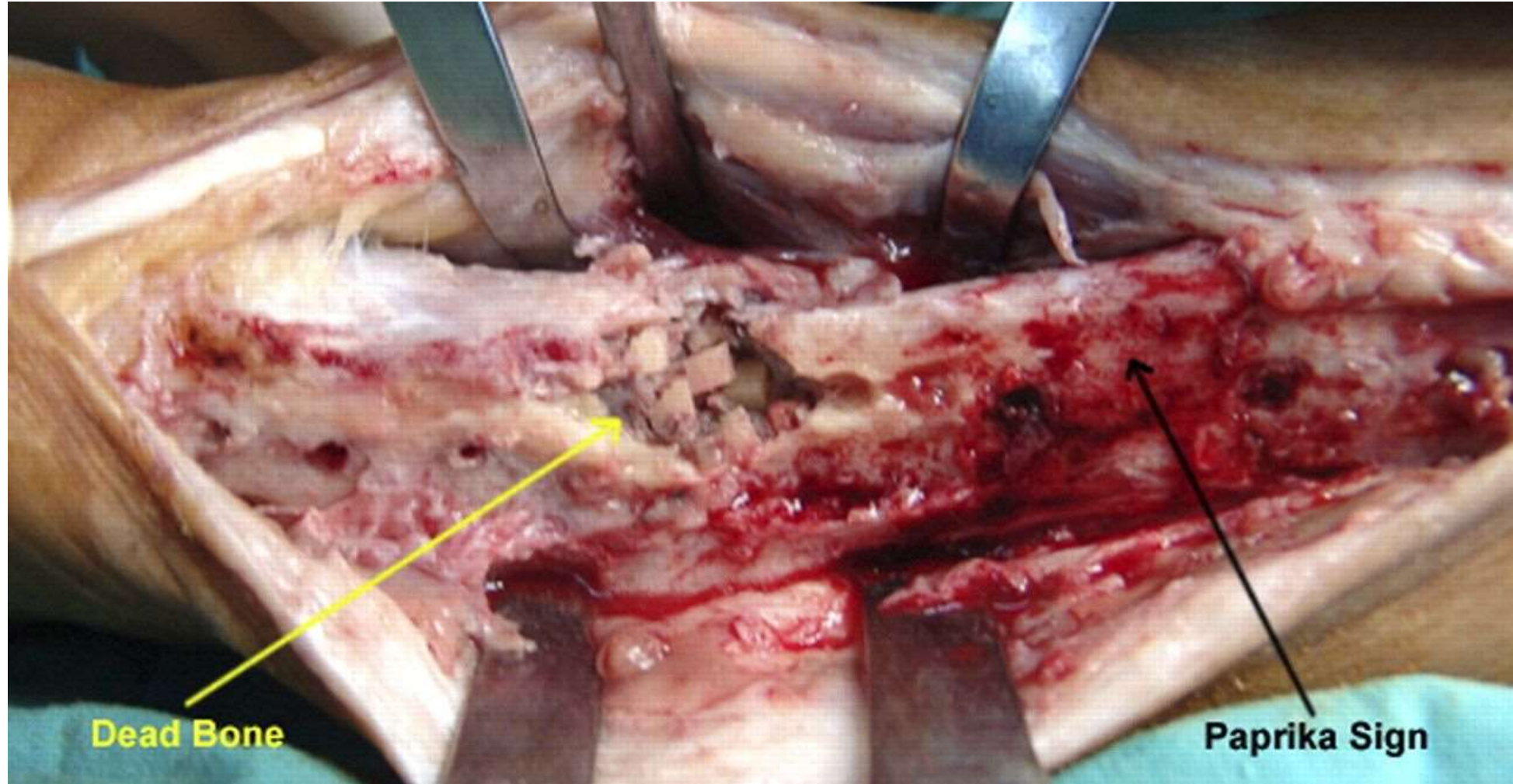
- For non-hematogenous osteomyelitis antibacterial therapy according to the bacterial culture and sensitivity should be continued for at least **6 weeks**, starting with parenteral and switching to oral:
 - Longer duration of treatment:
 - Residual infected bone that could not be completely removed
 - Retained orthopedic hardware
 - Shorter duration of treatment:
 - No residual infected bone
 - Amputation
- For non-hematogenous osteomyelitis empiric antibacterial therapy should include activity against MRSA and aerobic gram-negative bacilli for at least **4 weeks**

ctious agent	Antibiotic regimen	Dosing
Empiric therapy	Vancomycin PLUS a third- or fourth-generation cephalosporin (such as ceftriaxone, ceftazidime, or cefepime)	As summarized below
Pathogen-specific therapy		
Staphylococci, methicillin susceptible*	Nafcillin	2 g IV every 4 hours
	Oxacillin	2 g IV every 4 hours
	Cefazolin	2 g IV every 8 hours
	Flucloxacillin	2 g IV every 6 hours
	Ceftriaxone¶	2 g IV every 24 hours
Staphylococci, methicillin resistant*	Regimen of choice:	
	VancomycinΔ	Loading dose [◊] : 20 mg/kg Initial maintenance dose and interval determined by nomogram [§] : typically 15 to 20 mg/kg every 8 to 12 hours for most patients with normal renal function Subsequent dose and interval adjustments based on AUC-guided or trough-guided serum concentration monitoring [¥]
	Alternative regimens:‡	
	Daptomycin†	6 to 10 mg/kg IV once daily
	Teicoplanin (where available)**,*¶¶	12 mg/kg IV every 12 hours for 3 to 5 doses, followed by 12 mg/kg once daily
Staphylococci, adjunctive agents*	Rifampin	300 to 450 mg orally twice daily
	Fusidic acid (where available)**	500 mg orally 3 times daily
Gram-negative organisms	Ciprofloxacin ^{ΔΔ,◊◊,§§}	750 mg orally twice daily or 400 mg IV every 12 hours; if treating Pseudomonas, increase IV dose to 400 mg IV every 8 hours
	Levofloxacin ^{◊◊,§§}	750 mg orally or IV once daily
	Ceftriaxone ^{¥¥}	2 g IV every 24 hours
	Ceftazidime ^{◊◊}	2 g IV every 8 hours
	Cefepime ^{◊◊}	2 g IV every 8 to 12 hours
	Ertapenem ^{¥¥}	1 g IV every 24 hours
	Meropenem ^{◊◊}	1 g IV every 8 hours
Enterococci ^{‡‡}	Monotherapy regimens:	
	Ampicillin	12 g IV every 24 hours, either continuously or in 6 equally divided doses
	Aqueous crystalline penicillin G	20 to 24 million units IV every 24 hours, either continuously or in 6 equally divided doses
	VancomycinΔ	20 mg/kg loading dose, then 15 mg/kg IV every 12 hours, not to exceed 2 g per dose
	Daptomycin†	6 to 10 mg/kg IV once daily
	Teicoplanin (where available)**,*¶¶	12 mg/kg IV every 12 hours for 3 to 5 doses, followed by 12 mg/kg once daily
	Combination therapy regimen:	
	Ampicillin	12 g IV every 24 hours, given either continuously or in 6 equally divided doses
	PLUS	
	Ceftriaxone	2 g IV every 12 to 24 hours
Streptococci, penicillin sensitive	One of the following:	
	Aqueous crystalline penicillin G	20 to 24 million units IV every 24 hours, either continuously or in 6 equally divided doses
	Ampicillin	12 g IV every 24 hours, either continuously or in 6 equally divided doses
	Ceftriaxone	2 g IV every 24 hours
	VancomycinΔ	20 mg/kg loading dose, then 15 mg/kg/dose IV every 12 hours, not to exceed 2 g per dose, initially
<i>Cutibacterium</i> (formerly <i>Propionibacterium</i>) <i>acnes</i> ^{‡‡}	One of the following:	
	Aqueous crystalline penicillin G	20 million units IV every 24 hours, either continuously or in 6 divided doses
	Ceftriaxone	2 g IV every 24 hours

Surgical debridement

- Surgical debridement for management of osteomyelitis consists of removal of necrotic material and culture of involved tissue and bone.
- A satisfactory soft tissue envelope overlying the site of infection must be re-established for successful treatment, either via direct closure or flap coverage.
- In the setting of dead or injured bone and/or infected fluid collections, surgical debridement (and revascularization, in some cases) is a cornerstone of therapy.
- Surgical debridement also allows placement of local antimicrobials, either applied directly to the site of infection or mixed with absorbable (eg, calcium sulfate) or nonabsorbable (eg, polymethyl methacrylate cement) carriers.

Surgical debridement



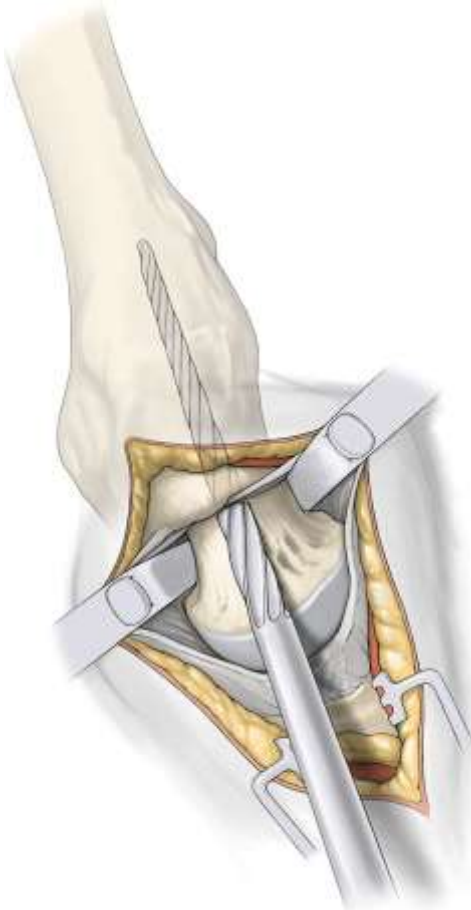
Surgical debridement



Different surgical techniques for treating chronic osteomyelitis

Surgical technique	Advantages	Disadvantages
Conventional reaming of the IM canal	• Clearance of intramedullary sepsis	• Risk of fracture • Risk of bleeding • Need for fenestration of the distal diaphysis to allow drainage of the irrigation fluids
Reamer/Irrigator/Aspirator (RIA) technique	• Clearance of intramedullary sepsis • Less traumatic than convectional reaming	• Risk of fracture • Risk of bleeding
Antibiotic-impregnated cement spacers/cement nails / antibiotic beads	• Slow release of high concentrations of antibiotics, avoiding their systemic effects • Easy to mix - form into various shapes and sizes • Cement nails can provide some stability to associated fractures	• Lack of biodegradability in some carriers / need for two-stage procedures • Concern that they can act as a foreign body, therefore harbouring infection • Increased risk of antibiotic resistance
Primary bone grafting / bone graft substitutes	• Single-stage procedure • Superior osteoconductivity and osteoinductivity of the bone graft	• Confined to small defects / limited availability of bone graft • Risk of early resorption / highly depends on the soft tissue bed • Risk of relapse of infection • Graft incorporation is slow and unreliable • Donor site morbidity
Bioactive glass	• Anti-microbial, osteoconductive and angiogenic properties	• Depends on good soft-tissue coverage

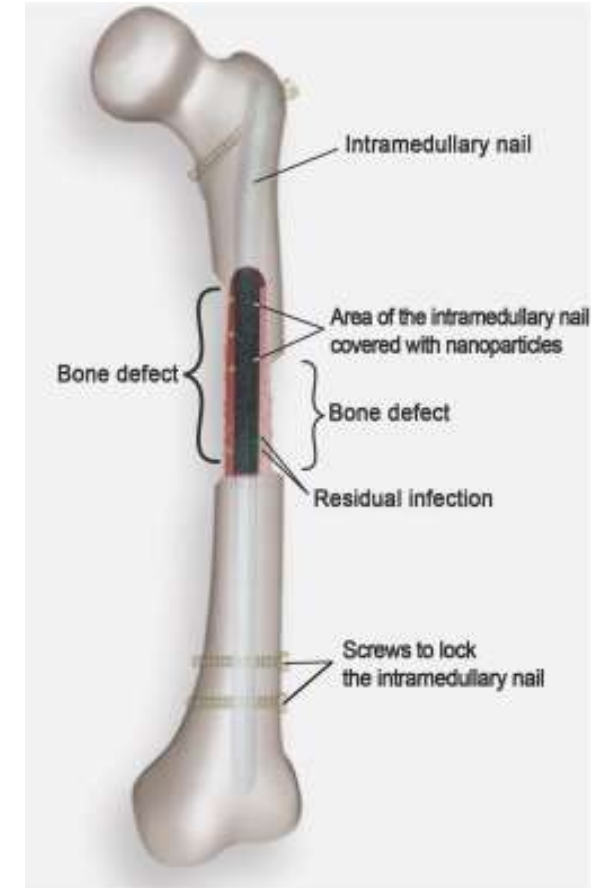
Different surgical techniques for treating chronic osteomyelitis



Conventional reaming of the IM canal

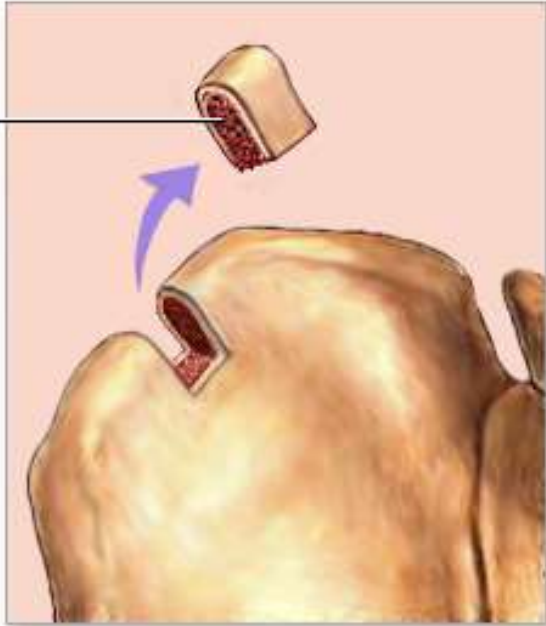


Reamer/Irrigator/Aspirator (RIA) technique



Antibiotic-impregnated cement spacers/cement nails

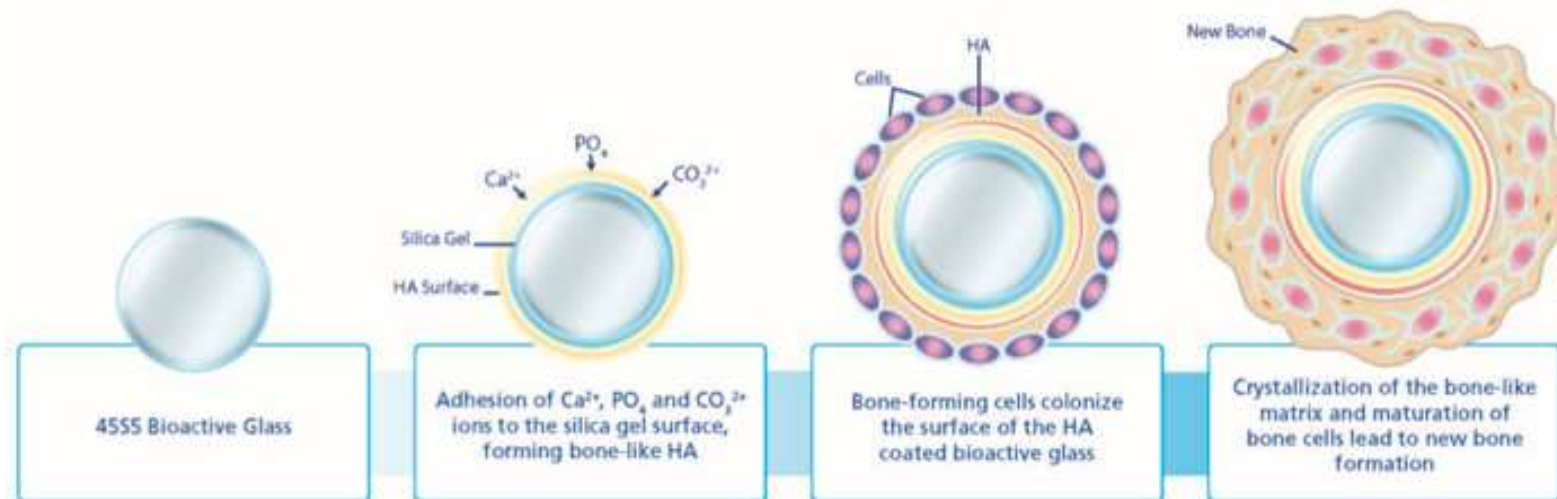
Different surgical techniques for treating chronic osteomyelitis



Primary bone grafting / bone graft substitutes

Bioactive glass

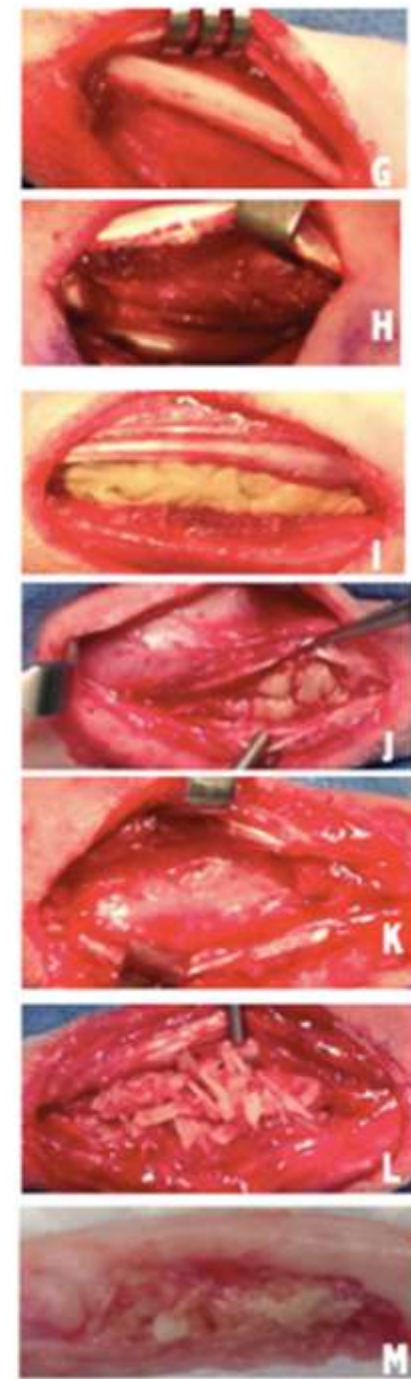
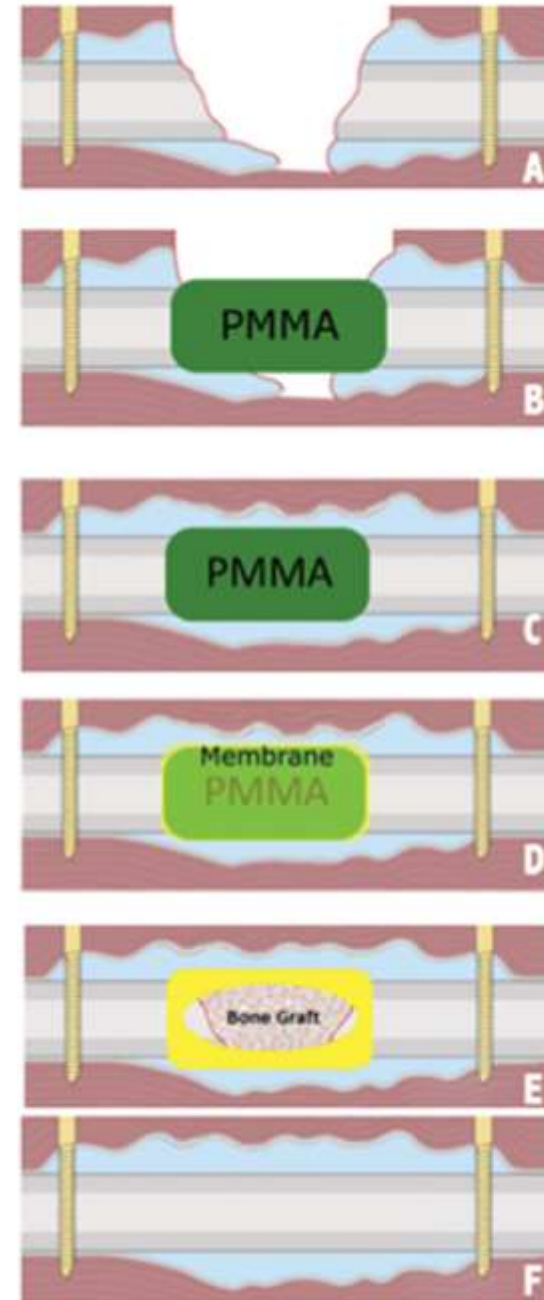
- The bioactive process that leads to bone bonding has been described through reactions at the glass surface:
 - sodium ions from the glass are exchanged for acid ions (H^+ and H_3O^+) in the adjacent tissue, leading to formation of silanol ($SiOH$) groups at the glass surface.
 - Repolarization then leads to an SiO_2 rich layer.
 - This is followed by migration of Ca^{2+} and PO_4^{3-} groups to the surface and crystallization, thereby creating a hydroxyapatite on top of the Si-rich layer.
 - In a final step, cell interaction with the hydroxyapatite layer initiates the bone forming pathway.
- The antibacterial properties can be explained by an initial rapid rise in pH of the bioglass, seen as high as 11.65 in body fluid studies.
- Additionally, in vitro studies demonstrated angiogenic properties of the bioactive glass.



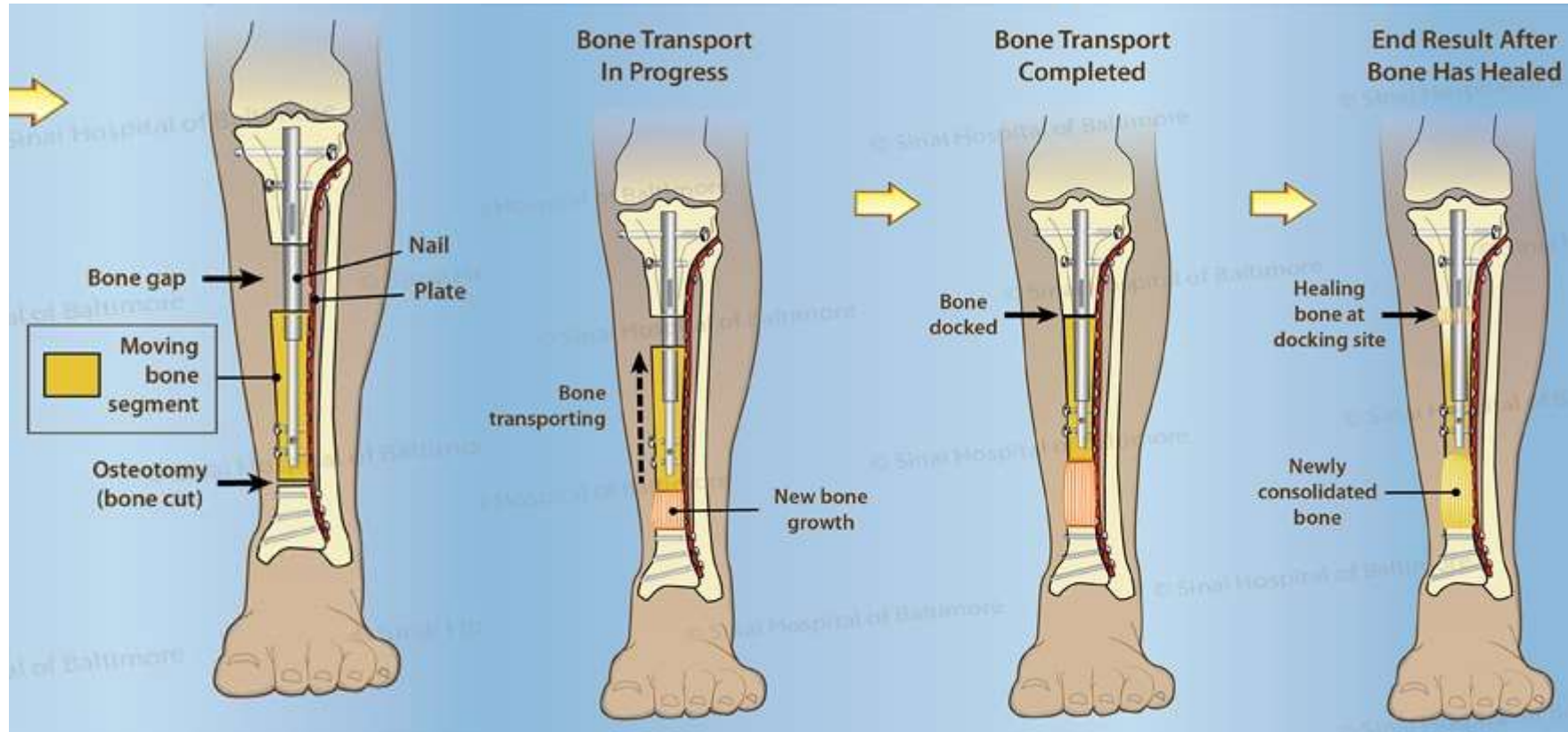
Surgical technique	Advantages	Disadvantages
Induced membrane (Masquelet) technique	- Combines the advantages of antibiotic-impregnated cement spacers with those of delayed bone grafting - The induced membrane is highly vascularised, rich in growth and osteoinductive factors - Offers a confined space for the application of the bone graft	- Two-stage procedure - Increased risk of antibiotic resistance - Limited availability of bone graft - Can be associated with prolonged healing and recovery time
Circular external fixation devices and bone transport	- Increased blood flow in the area of corticotomy - Minimally-invasive nature	- Distraction is often limited because of the neurovascular bundle contracture - Can be associated with pain for distraction > 2 cm - Pin-site complications - Need for specialised equipment - Need for re-interventions
Local flaps	Transfer of well-vascularised tissue that aids wound and bone healing	- Limited by pedicle length - Donor-site morbidity
Vascularised free flaps	Transfer of well-vascularised tissue that aids wound and bone healing	- Donor-site morbidity - Need for microsurgical anastomoses - Limited by peripheral artery disease - Prolonged operating time - High risk of early complications / risk of graft failure
Megaprosthesis	- Restores limb function quickly - No need for harvesting bone ‘One-shot’ surgery	- Risk of residual infection and early loosening - Risk of dislocation - Risk of revision surgery
Amputation	- Early mobilization - One shot surgery	- Soft tissue reconstruction procedures - Compromised function - Regular revisions of the prosthetic limb

Induced membrane (Masquelet) technique

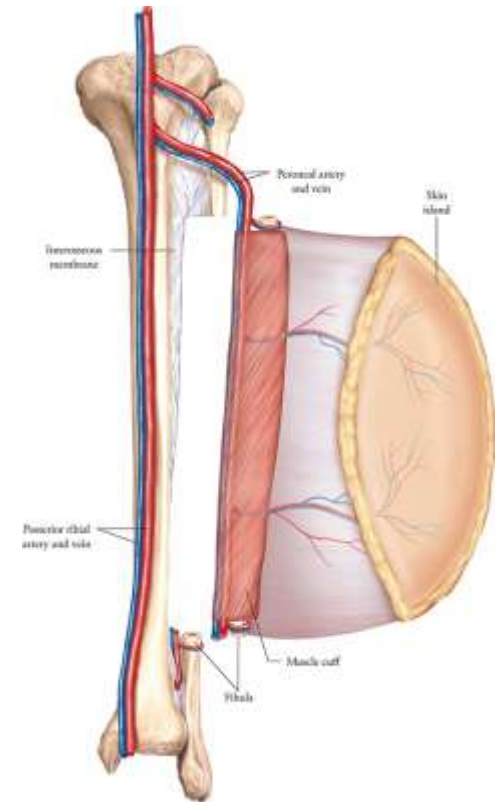
- Debridement in the presence of necrotic bone, infection, or tumor must be meticulous, preserving neurovascular structures and healthy soft and bone tissue.
- A polymethylmethacrylate (PMMA) cement spacer is implanted in the created bone defect covering the void uniformly.
- Bridging fixation of the osseous defect, performed with either external or internal fixation methods, and soft tissue reconstruction in the presence of soft-tissue defects are necessary at this stage.
- The second stage includes removal of the cement spacer, preservation of the membrane, repeat debridement of the bone edges, insertion of autologous bone graft (ABG), and closure of the membrane containing the graft without tension.



Different surgical techniques for treating chronic osteomyelitis

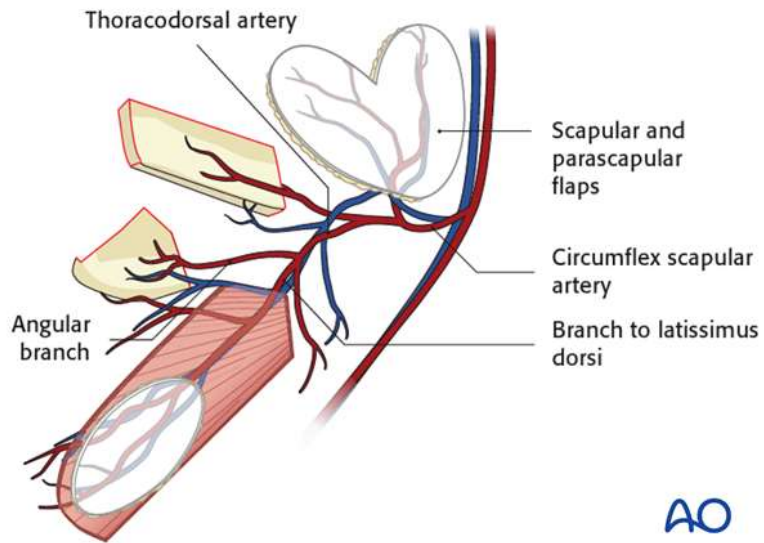


Bone transport



Local flaps

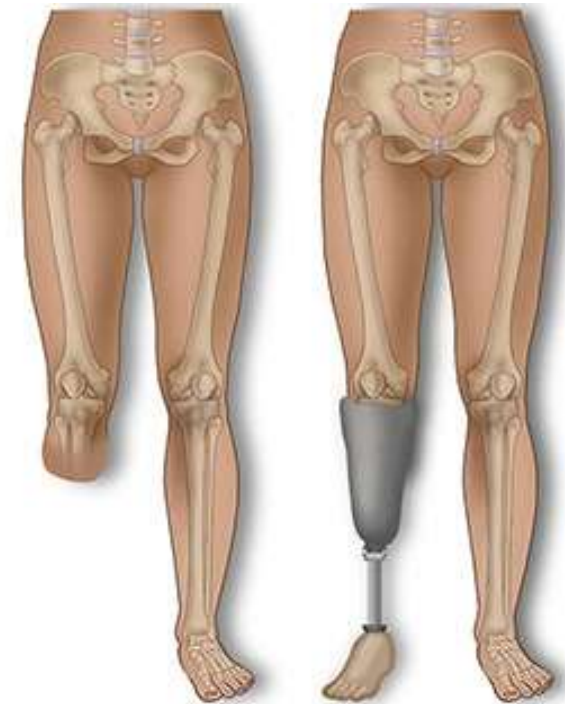
Different surgical techniques for treating chronic osteomyelitis



Vascularised free flaps



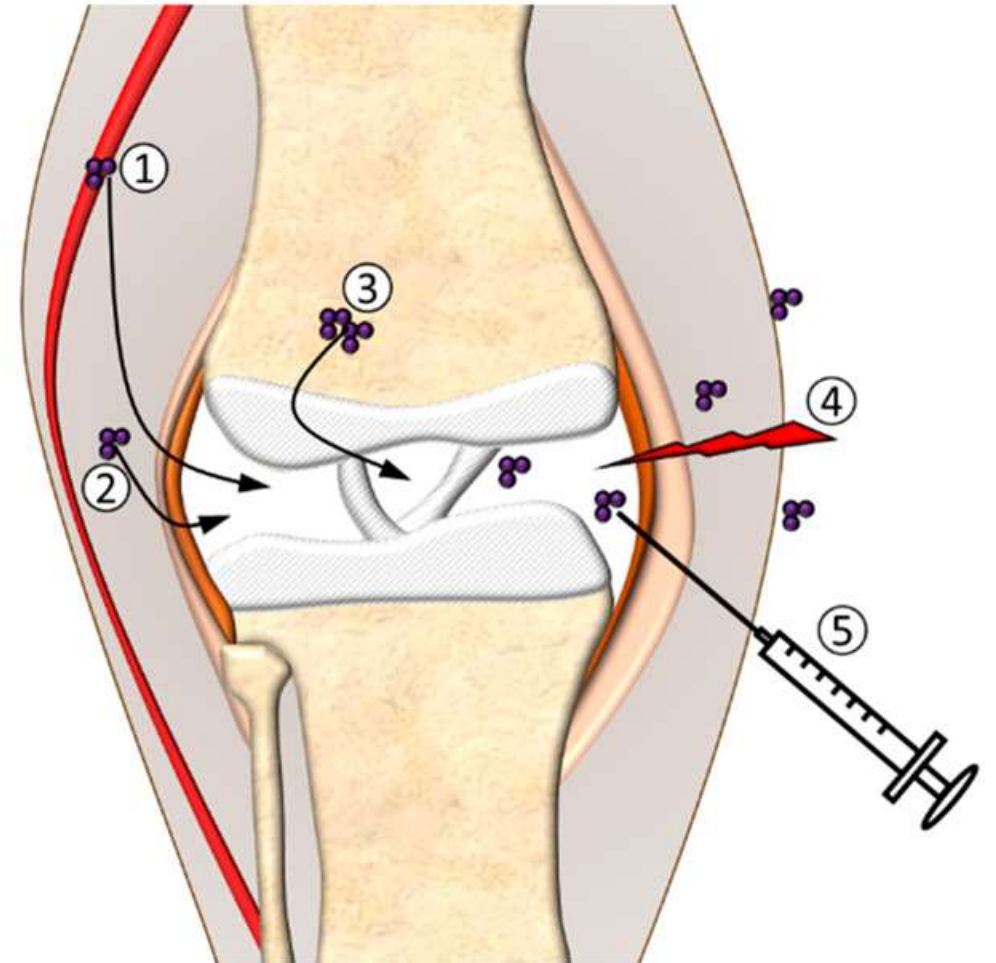
Megaprosthesis



Amputation

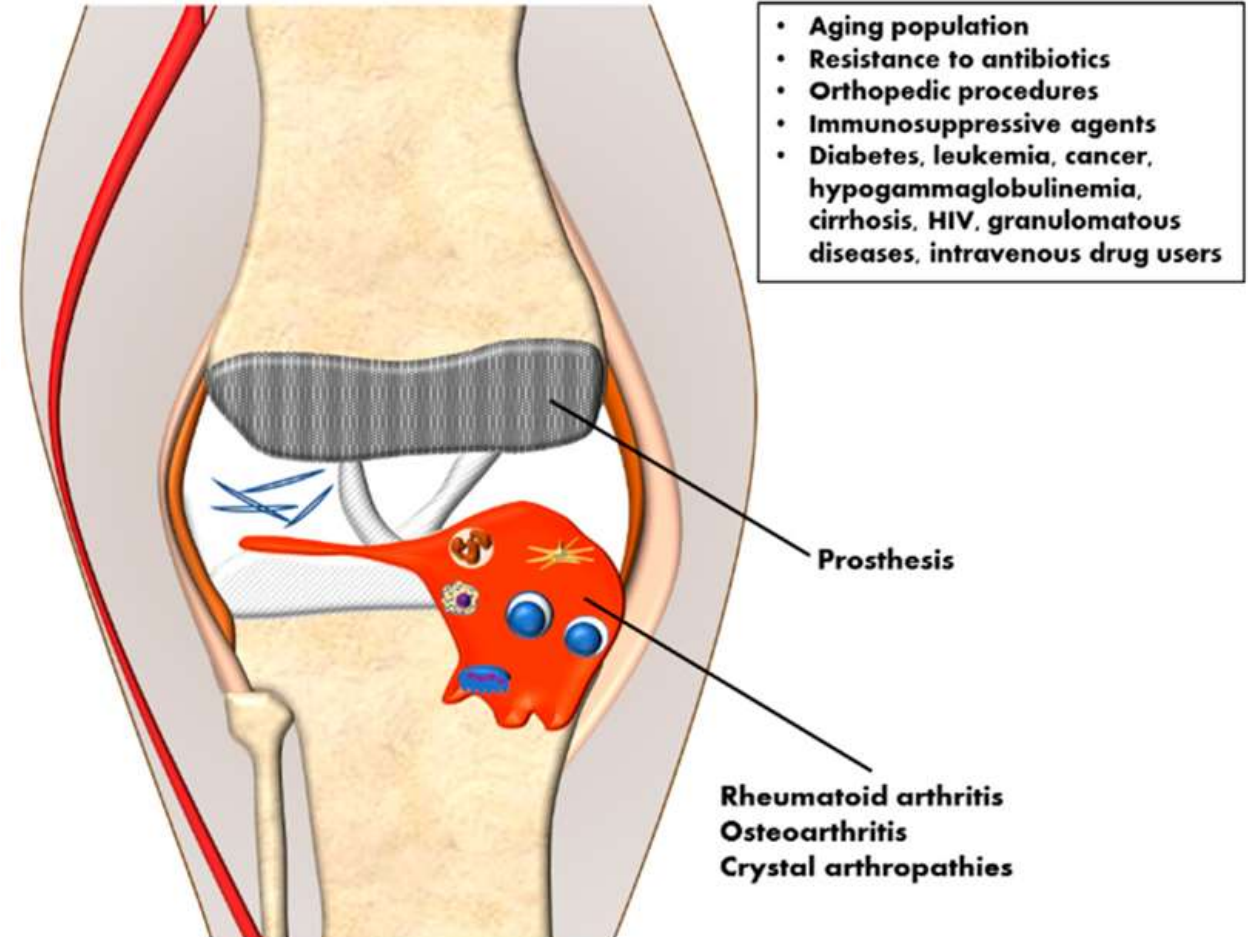
Septic arthritis

- Septic arthritis refers to infection in a joint.
- It is usually caused by bacteria but can also be caused by other microorganisms.
- Most commonly, septic arthritis arises via hematogenous seeding.
- It may also develop as a result of direct inoculation of bacteria into the joint.
- Rarely, septic arthritis develops via extension of infection into the joint space from adjacent tissues.
- It can be broadly classified into three groups:
 - Non-gonococcal arthritis,
 - Gonococcal arthritis,
 - Others.



Risk factors

- Advance age
- Pre-existing joint disease
- Recent joint surgery or injection
- Skin or soft tissue infection
- Intravenous drug use
- Indwelling catheters
- Immunosuppression (including diabetes)



Causes of infectious arthritis

Organism	Clinical clues
<i>Staphylococcus aureus</i>	Healthy adults, skin breakdown, previously damaged joint (eg, rheumatoid arthritis), prosthetic joint
Streptococcal species	Healthy adults, splenic dysfunction
<i>Neisseria gonorrhoeae</i>	Healthy adults (particularly young, sexually active), associated tenosynovitis, vesicular pustules, late complement deficiency, negative synovial fluid culture and Gram stain
Aerobic gram-negative bacteria	Immunocompromised hosts, gastrointestinal infection
Anaerobic gram-negative bacteria	Immunocompromised hosts, gastrointestinal infection
Brucellosis	Zoonosis
Mycobacterial species	Immunocompromised hosts, travel to or residence in an endemic area
Fungal species (<i>Candida</i> species, sporotrichosis, <i>Cryptococcus</i> , blastomycosis, coccidioidomycosis)	Immunocompromised hosts
Spirochete (<i>Borellia burgdorferi</i>)	Exposure to ticks, antecedent rash, knee joint involvement
<i>Mycoplasma hominis</i>	Immunocompromised hosts with prior urinary tract manipulation



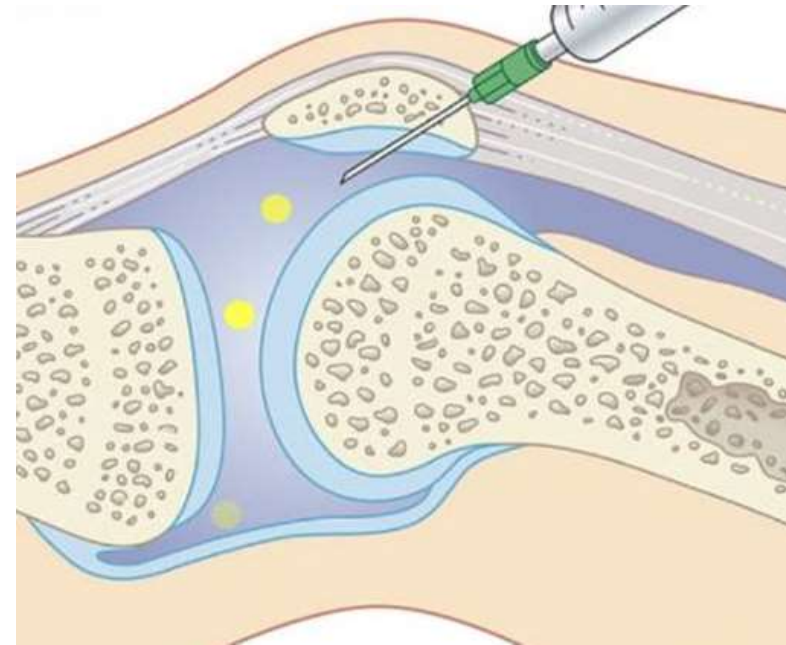
Clinical manifestations

- Monoarticular arthritis:
 - Knee >50%;
 - Wrists,
 - Ankle,
 - Hip
- **Joint pain**
- Fever
- Swelling, erythema, and warmth
- Infected joints demonstrate an effusion associated with limited active and **passive** range of motion

Diagnosis

- Blood test
- Radiographic imaging
- MRI
- CT
- Ultrasound
- **Synovial fluid with bacterial culture**

Measure	Normal	Noninflammatory	Inflammatory	Septic	Hemorrhagic
Volume, mL (knee)	<3.5	Often >3.5	Often >3.5	Often >3.5	Usually >3.5
Clarity	Transparent	Transparent	Translucent-opaque	Opaque	Bloody
Color	Clear	Yellow	Yellow	Yellow	Red
Viscosity	High	High	Low	Variable	Variable
White blood cell, per microL	<200	0 to 2000	>2000*	>20,000 [†]	Variable
Polymorphonuclear leukocytes, percent	<25	<25	≥50	≥75	50 to 75
Culture	Negative	Negative	Negative	Often positive	Negative



Diagnosis



Radiographs of the left knee reveal an erosive process involving the tibiofemoral and patellofemoral joints with an associated effusion and subcutaneous soft tissue edema



Irregularity of the right femoral epiphysis as well as abnormal marrow signal of the right femoral epiphysis and opposing acetabular surface displaying low signal in T1 and bright signal in STIR/T2 FATSAT due to marrow edema. There is loss of joint space at the superior aspect of right hip joint with moderate joint effusion.

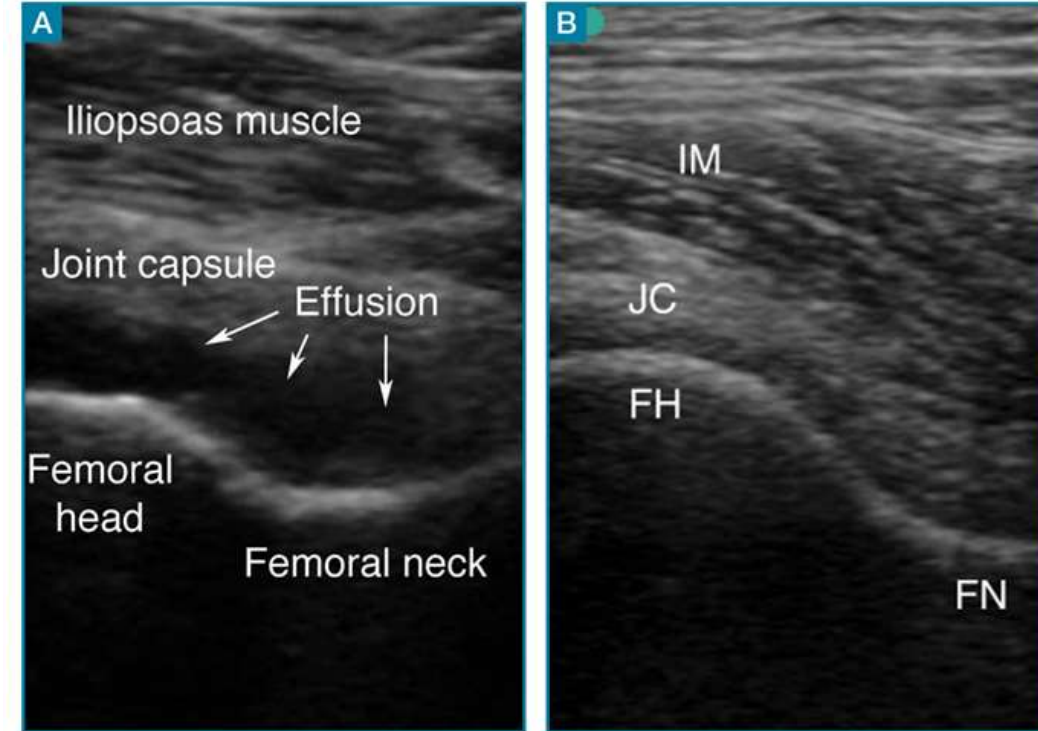


Figure 2. (A) Ultrasound image of a right hip displays the femoral head, femoral neck, iliopsoas muscle, and joint capsule with a concurrent effusion. (B) Ultrasound image visualizing normal hip anatomy.

Treatment

- Drainage:
 - Aspiration
 - Arthroscopy
 - Arthrotomy
- Antibiotics
- Immobilization

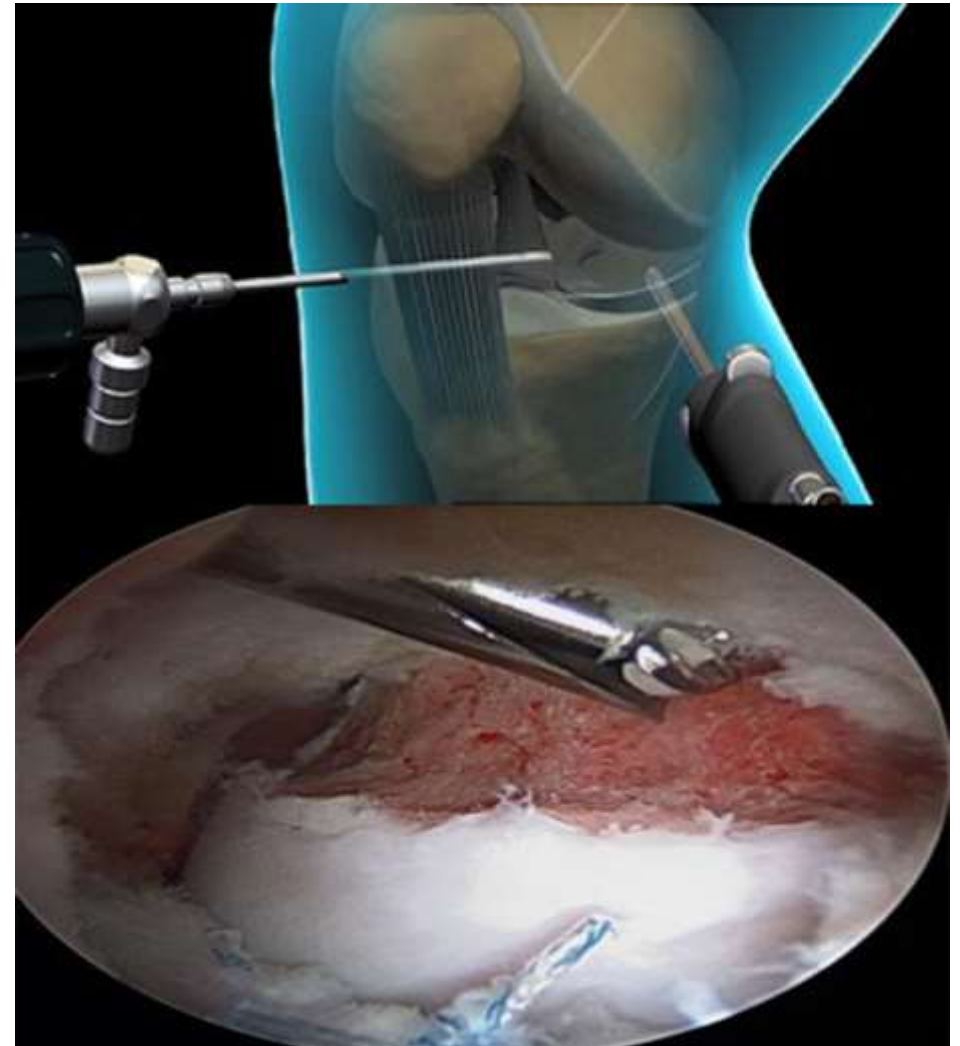
Needle aspiration

- Knee joint
- Ankle joint
- Elbow joint
- Wrist joint



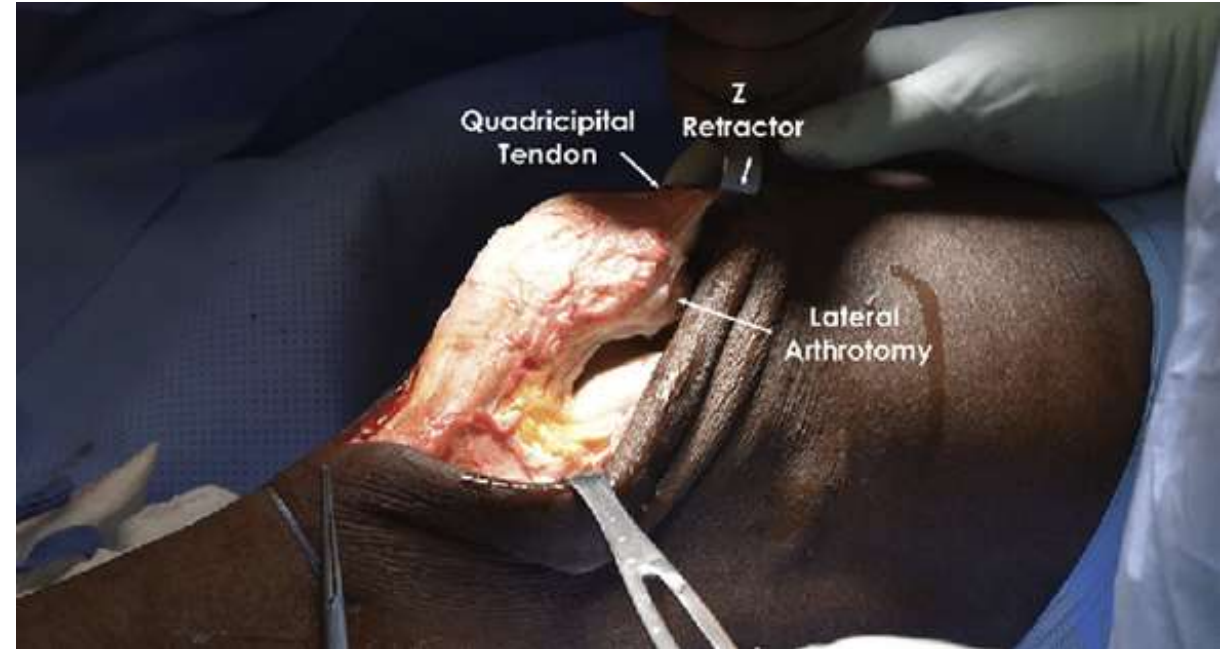
Arthroscopic drainage

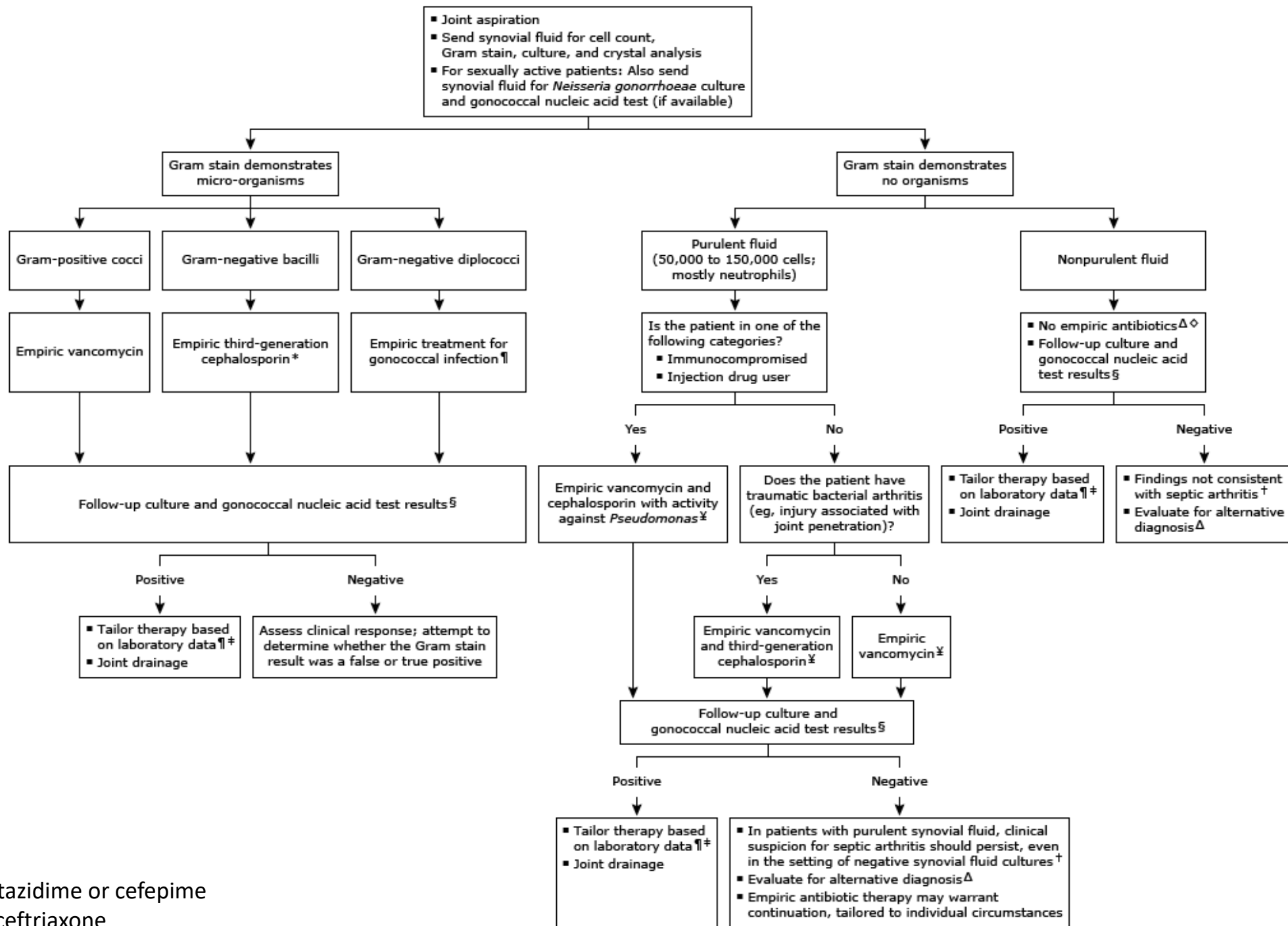
- Shoulder joint
- Hip joint
- Difficult-to-access joints (e.g. sternoclavicular joint)



Arthrotomy & Surgical drainage

- Needle aspiration/arthroscopy are inadequate
- Suspected penetrating trauma, foreign body
- Persisting joint effusion after 7 days of aspiration





P. Aeruginosa: ceftazidime or cefepime
 N. Gonorrhoeae: ceftriaxone

Antibiotic therapy

Duration:

- *S. aureus*, NO concomitant bacteria, NO endocarditis: initial 14 days parenterally + 7-14 days orally
- *S. aureus* + concomitant bacteria, NO endocarditis: 4 weeks parenterally
- Fluoroquinolone-sensitive bacteria: initial 4-7 days parenterally + 14-21 days orally
- Difficult-to-treat bacteria: 3-4 weeks parenterally