SPECT AND PET FOR OSTEOMYELITIS IMAGING

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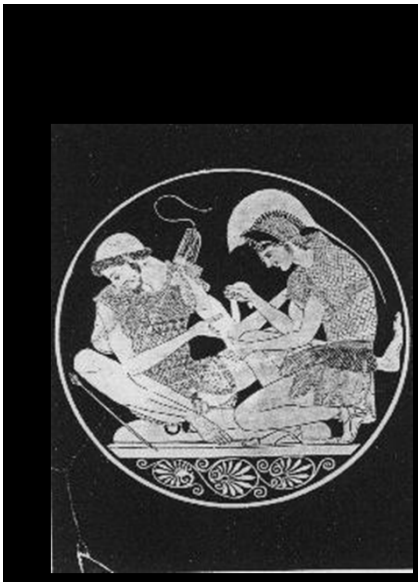
SPECT AND PET IN OSTEOMYELITIS

- Definition, prevalence and classification
- Pediatric versus Adult osteomyelitis
- Imaging in acute osteomyelitis
- Imaging in chronic osteomyelitis
  - General
  - Diabetic foot

Osteomyelitis: Definition

- Infection of
  - bone (osteo)
  - and bone marrow (myelitis)
- Aetiology
  - Mostly bacterial,
  - Occasionally fungal



Osteomyelitis

- Subdivided clinically into:
  - Pediatric versus Adult
  - Hematogenous vs. Direct spread
  - Duration: acute , subacute chronic
  - Special cases IVDA , Sickle cell

Prevalence of osteomyelitis

• Children	1/5000
• Sickle cell patients	3.6/1000
• Post puncture wound to foot	16/100
• Neonates	1/1000
• Post puncture wound to foot in diabetics	30-40/100

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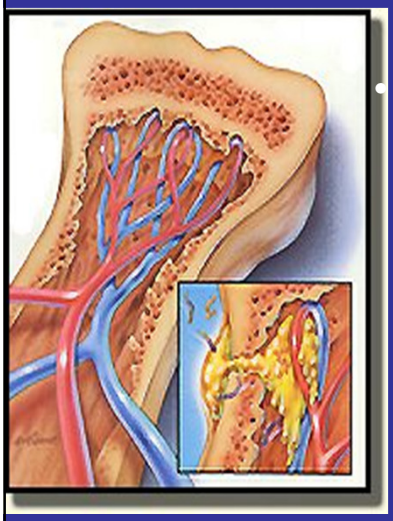
Pediatric Osteomyelitis

- >> Hematogenous spread
  - Involved micro-organisms:
    - Staph Aureus,
    - Streptococcus,
    - H. Influenzae,
    - Coliforms)
- >>long bones: tibia, humerus, femur.
- >>>acute
  - (tumor, rubor, calor, dolor, immobilization)
- << direct (Skin lesion extension) to bone
  - spina bifida, quad.

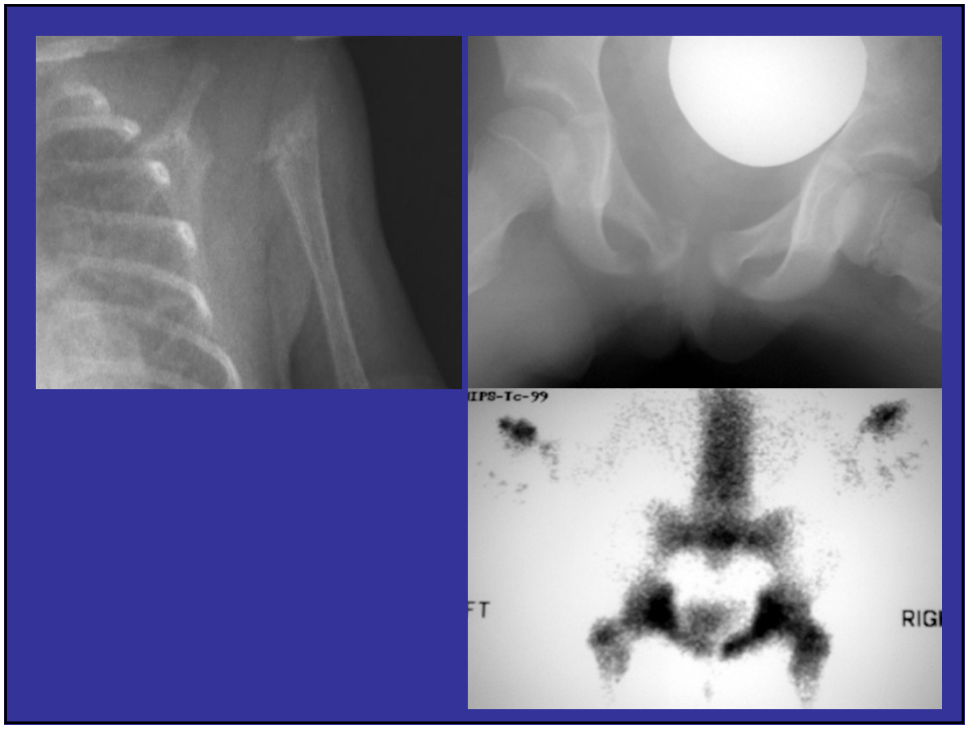
Pediatric Osteomyelitis:

- Special cases
  - Sickle cell disease:
    - Osteomyelitis of the long bones
    - Often due to salmonella sp.
  - Teenagers:
    - Osteomyelitis of the long bone and joint infections
    - GC

Why the long bones?

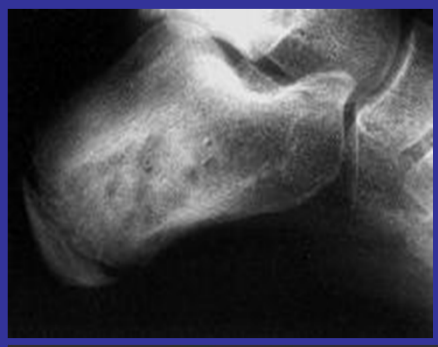


Non-anastomosing capillary ends of nutrient arteries form sharp loops under the growth plates and enter large venous sinusoids where the blood flow is slow and turbulent, trapping the organisms



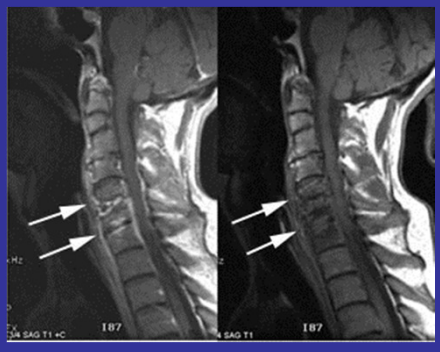
Adult Osteomyelitis

- >> Direct extension of infection to the bone from a skin ulceration, leading cause of amputations
- >Direct inoculation to the bone from an open/contaminated fracture, or during ORIF, post-op TKA, THA
- >>>subacute and chronic
  - Localized pain, drainage, deformity, instability
- <<Hematogenous seeding from IVDA



Adult Osteo. additional features:

- IVDA: Hematogenous seeding site more likely to be spine or pelvis only occasionally to the long bones



Acute Osteo	Sub-Acute Osteo	Chronic Osteo
•Begins with marrow edema, cellular infiltration and vascular engorgement •May progress to necrosis and abscess formation •Spread within the intramedullary cavity → extension through cortex by Havers and Volkman's canals → subperiosteal space → periosteum → soft tissues •Rupture of joint space → septic arthritis	• Occurs in abnormal bone or after inadequate antibiotics •Localized pyogenic process •Commonly appears as a well-defined osteolytic metaphyseal lesion (Brodie's abscess) with a sclerotic margin that fades peripherally (fuzzy sclerotic margin) •S. aureus is most common pathogen	• Occurs after inadequate tx or in pts with altered immunity •Distinguishing feature is necrotic bone surrounded by granulation tissue •Interruption of blood supply → necrosis → devitalized bone fragments (sequestra) •A thick sheath of new periosteal bone can develop around the sequestra (involucrum) •Fistula tract formation •Sharp interface between normal and diseased marrow

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FDG PET(-CT) IMAGING IN ACUTE OSTEOMYELITIS

- Diagnosis of acute osteomyelitis based upon clinical history, clinical appearance, biochemical and conventional imaging is mostly straightforward

no need for complexe nuclear medicine techniques

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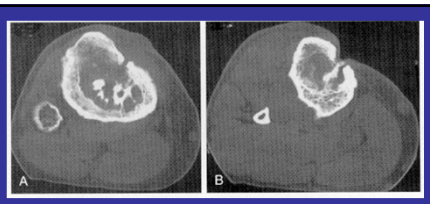
Conventional Radiography

- Modality of choice for initial evaluation
- Advantages
  - Inexpensive
  - Exclude other conditions
  - May help guide further work-up
- Disadvantages
  - Often normal for the first 10 to 21 days of infection
  - Sensitivity: 43-75%
  - Specificity: 75-83%

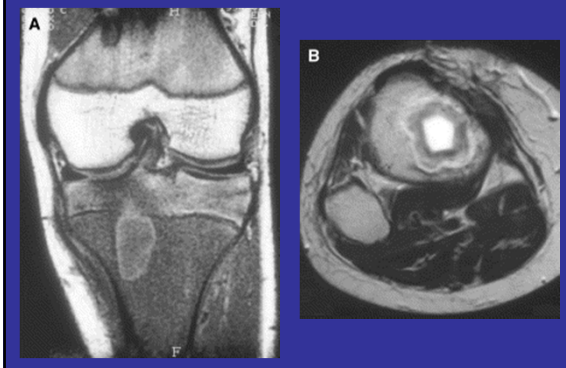
CT Imaging



- Advantages:
  - Best method to detect small foci of intraosseous gas, areas of cortical erosion or destruction, tiny foreign bodies, involucrum and sequestration formation
  - Good for evaluation of chronic osteomyelitis: cortical thickening, sclerosis, fistula draining
  - Good for identifying abnormalities that must be fixed at surgery (sequestra, involucra, fistula)
  - Can be used to guide aspirations and bone biopsies
- Disadvantages
  - Sensitivity and specificity not clearly established
  - Lower sensitivity than MRI
  - Limited assessment of bony parts with metalic implants due to beam hardening artifact

Subacute MRI Findings

- Brodie's abscess
  - (intraosseous abscess, internal wall covered by granulation tissue)



16 y/o with Brodie's abscess. T1 weighted image of the knee (A) demonstrates the double line effect, a focal area of low signal with alternating bands of high and low signal. Axial T2 weighted image of the proximal tibia at the same level (B) demonstrates a region of high-intensity surrounded by alternating bands of low signal and high signal.

■Subacute osteo is often confused with tumor (osteosarcoma, Ewing)

Chronic MRI Findings

- In both subacute and chronic osteomyelitis, a peripheral area of low-signal intensity (the rim sign) on all pulse sequences is visualized. Corresponds to fibrous change or reactive bones.
  - Reported in 93% of patients with chronic osteomyelitis and in less than 1% of patients with acute.
- Usual appearance of high T2 signal in marrow may be absent. Instead, there are areas of devascularized fibrotic scaring which are low intensity signal onT1 and T2 images.
- Predominant bone sclerosis with cortical thickening
- Sinus tracts, sequestra, soft tissue abscesses
- Sharp interface between normal and abnormal marrow

Sensitivity and Specificity of MRI in Osteomyelitis

*Adapted from Restrepo et al, 2003

Reference	Sensitivity%	Specificity%	Location
Modic, 1986	96	92	Spine
Unger,1988	92	96	Multiple
Yuh, 1989	100	89	Foot
Wang, 1990	99	81	Foot
Erdman, 1991	98	75	Multiple
Zynamon,1991	100	78	Foot
Weinstein,1993	100	89	Multiple
Morrison, 1995	82	80	Foot
Mazur, 1995	97	92	Multiple
Morrison,1998	84-96	78-88	Foot
Haung, 1998	98	89	Hips/Pelvis

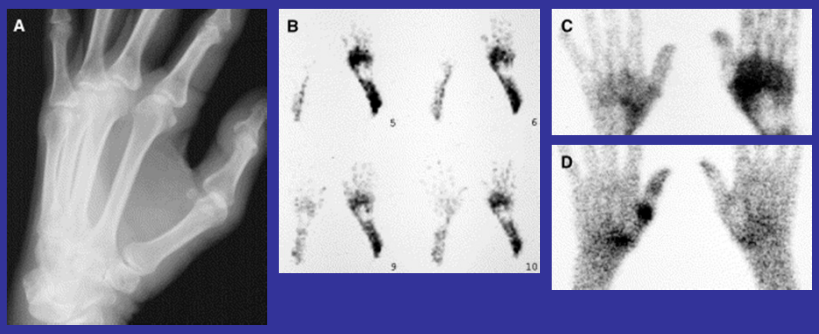
Nuclear Medicine Imaging

- Four types of studies may be used:
  - Bone Scan
  - Gallium Scan
  - White Blood Cell Scan
  - FDG PET imaging
- General Advantages
  - Can image patients with prostheses without interference
  - Easier for pediatric patients (pts usually don't need sedation)
  - Multiple foci of disease can be demonstrated
  - Sensitivity and Specificity similar to MRI
- General Disadvantages
  - Limited spatial resolution
  - Less ability to delineate complex anatomy
  - Circulatory compromise can interfere with study

Bone Scan

- 3-phase bone scan performed after injection of methylene diphosphonate (MDP)
- Immediate, 15 minute and 3-4 hour images are obtained.
- Abnormal findings for osteo include:
  - Increased flow activity
  - Blood pool activity
  - Positive uptake on 3 hour images
- High sensitivity for osteomyelitis
  - Sensitivity 73 to 100%
- Specificity for osteo decreases when other conditions are simultaneously present → recent trauma, surgery or diabetes
  - Specificity: 73% to 79% but as low as 38% with complicating conditions

Bone Scan Image



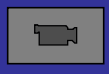
Patient with a history of puncture wound at the base of the thumb. Plain radiograph (A) of the hand is normal. Three phase bone scan (B–D) demonstrates increased flow of radiotracer to the soft tissues and increased uptake in the bone consistent with osteomyelitis involving the base of the first metacarpal bone.

Gallium Scan

- Imaging preformed 24 to 48 hours after injection of Gallium
- Relatively high sensitivity
  - Sensitivity: 25% to 80%
- Specificity similar to bone scan
  - Occasional false positives from fractures, tumor uptake
  - Specificity: 67%
- Image quality may not be as good as the bone scan and it takes longer
- Marked excretion through the GI tract

White Blood Cell Scan

- Indium –labeled WBC or HMPAO-labeled WBC
- Accumulation at sites of inflammation
- Compared to HMPAO, the Indium-labeled has:
  - Higher radiation dose to pt
  - Takes 24 hours to perform
  - Images with extensive noise
  - Sensitivity of 90%, Specificity of 78%
- Compared to Indium, the HMPAO-labeled has:
  - Lower radiation dose to pt
  - Same day study and result
  - Better image quality
  - Similar sensitivity and specificity
- Both types are superior to bone scan when imaging patients with complicating conditions
  - Specificity increases to 80% to 90%
- Difficult to distinguish between acute, chronic or partially tx infection



Increased Specificity with WBC Scan Compared to Bone Scan

Patient with a history of trauma and possible osteomyelitis at the level of the right ankle. Bone scan (A) demonstrates increased uptake in the posterior calcaneus. White blood cell scan (B) is normal and excludes the possibility of osteomyelitis. The increased uptake on the bone scan could be explained from prior trauma.

FDG PET(-CT) IMAGING

- First study
  - N= 22 pts
  - Suspected chronic osteomyelitis
  - FDG-PET
    - sens 100%, spec 87.5%, accuracy of 90.9%
  - 2 false positives: 1 tibial non-union, 1 osteotomy
  - Final diagnosis was made by surgical exploration or clinical follow-up during a 1-year period
- Second study:
  - FDG appears to normalize rapidly following traumatic or surgical fractures as fibroblast predominate in normally healing bone

Zhuang et al, Clin Nuc MEd 2000, Exclusion of chronic osteomyelitis with 18F-FDG PET imaging

Zhuang et al, EJNMI 2003, Rapid normalization of osseous FDG-uptake following traumatic or surgical fractures

FDG PET(-CT) IMAGING IN CHRONIC OSTEOMYELITIS

Fluorine-18 fluorodeoxyglucose-positron emission tomography: a highly accurate imaging modality for the diagnosis of chronic musculoskeletal infections

- Prospectively
- n = 60: 33 central skeleton, 27 peripheral skeleton; 35 pts had surgery in past 2 years
- histopathological studies or microbiological culture (18 patients) or on clinical findings after at least six months of follow-up (42 patients)
- **Results:**
  - 25 pts infection, correctly identified
  - 35 pts no infection
  - 4 false false-positive findings;
    - in 2: surgery < 6 months prior to the study

PET	Sensi	Speci	Accuracy
Whole group	100%	88%	93%
Central skeleton	100%	90%	94%
Peripheral skeleton	100%	86%	93%

- **Conclusions:**
  - 18F- FDG-PET is highly accurate as a single technique for the evaluation of chronic musculoskeletal infections.
  - Especially valuable in the evaluation of the central skeleton, where white blood-cell scans are less useful.
  - Simplicity and high degree of accuracy: the potential to become a standard technique for the diagnosis of chronic musculoskeletal infections.

De Winter et al, J Bone Joint Surg; 2001, 83-A: 651-660

FDG PET(-CT) IMAGING IN CHRONIC OSTEOMYELITIS

	Pooled sensi	CI	Pooled speci	CI
PET	96%	88-99	91%	81-95
Bone scintigraphy	82%	70-89	25%	16-36
Leuko scintigraphy	61% Perif 84%-axial 21%		77% Perif 80%-axial 60%	63-87
Bone and leukocyte scinti	78%	72-83	84%	75-90
MRI	84%	69-92	60%	

Conclusions:

1. FDG-PET has the highest diagnostic accuracy for confirming or excluding the diagnosis of chronic osteomyelitis.
2. Leukocyte scintigraphy has an appropriate diagnostic accuracy in the peripheral skeleton, but FDG-PET is superior for detecting chronic osteomyelitis in the axial skelet.

Termaat et al, Bone Joint Surg Am 2005;87:2464-71 The accuracy of diagnostic imaging for the assessment of chronic osteomyelitis: systematic review and meta-analysis

FDG PET(-CT) IMAGING IN CHRONIC OSTEOMYELITIS

- Conclusions
  - High sensitivity and specificity values for chronic osteomyelitis with FDG-PET
  - Negative FDG-PET : excludes presence of the disorder

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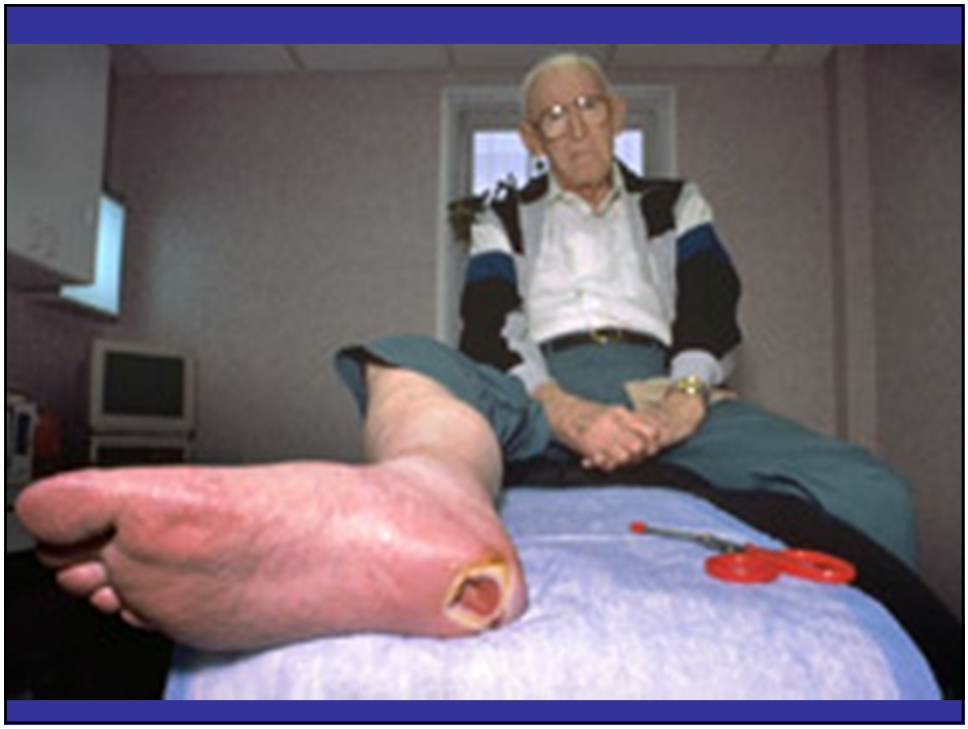

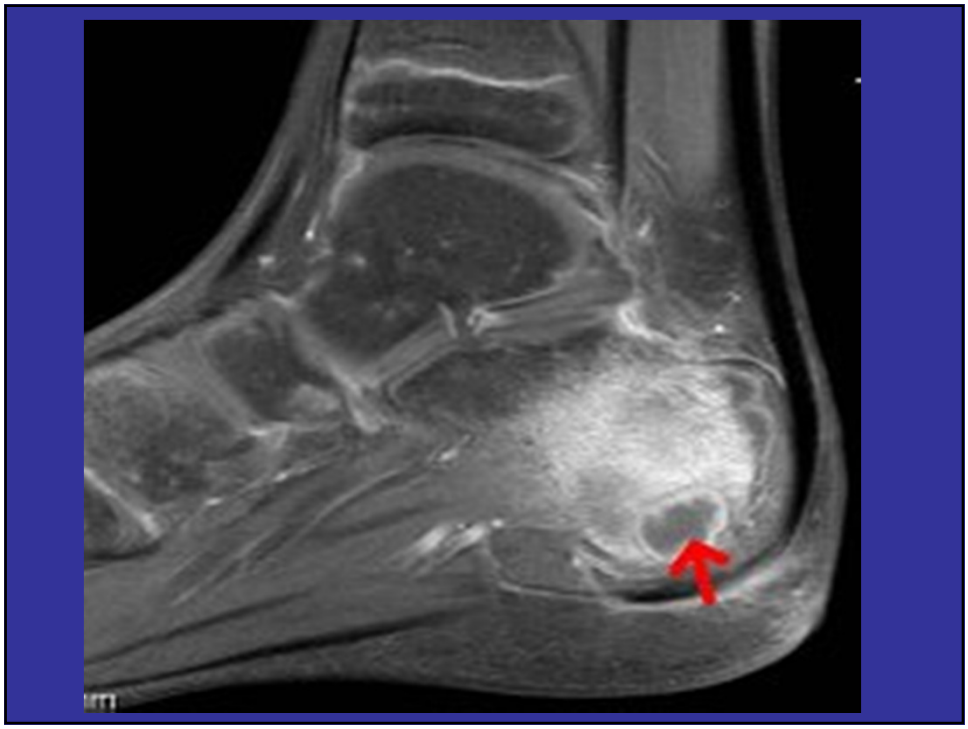

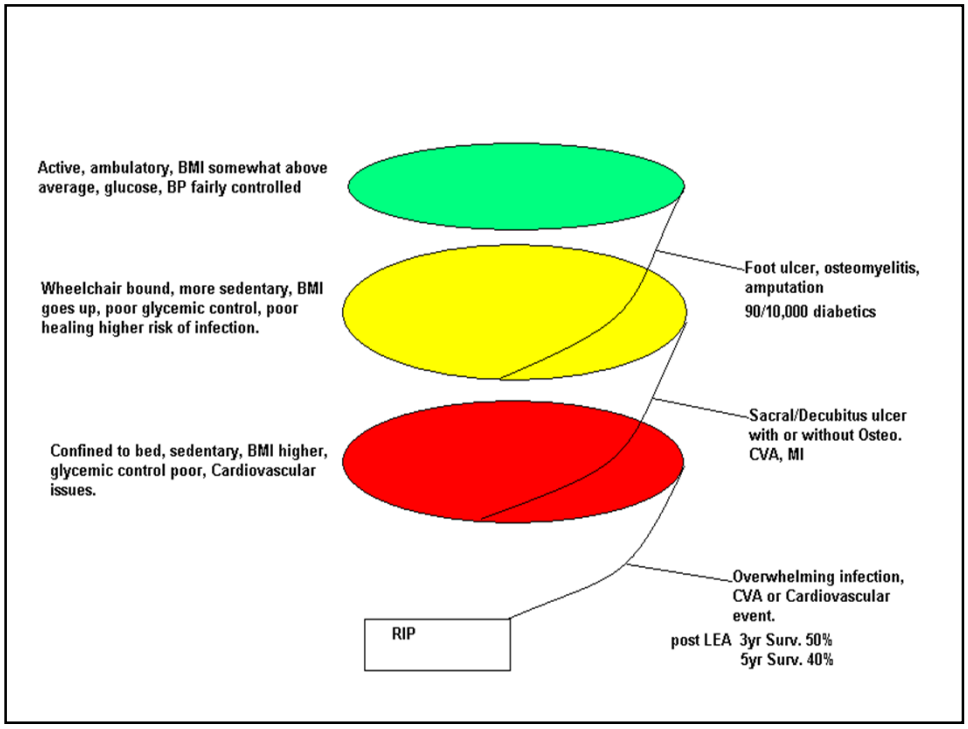

DIABETIC FOOT

- Early detection leads to treatment (antibiotics) and decreases amputation rate
- Bone marrow edema and contrast enhancement on MRI are
  - not specific for osteomyelitis
  - Occur in several other non-infectious diseases (stress fractures, necrosis and neuropathy)
- Bone biopsy: gold standard, risk of iatrogeneous infection!
- Radionuclide study of choice: labelled leucocyte imaging: accuracy 80%, less performing for the midfoot: due to marrow proliferation in Charcot joints: add colloid!!

FDG PET(-CT) IMAGING IN DIABETIC FOOT

- Keidar et al, The diabetic foot: intial experience with 18F-FDG PET/CT (J N Med 2005; 46:444-9)
  - FDG PET highly accurate in differentiation between osteomyelitis and soft-tissue infection
  - 1 out of 18 sites false positive due to osteoarthropathy misinterpreted as osteomyelitis
  - FDG PET/CT can be used for diagnosis of diabetes-related infection

- Schwegler et al, Unsuspected osteomyelitis is frequent in persistent diabetic foot ulcer and better diagnosed by MRI than by 18F-FDG PET or 99m Tc-MOAB (Int Med 2008;263:99-106)
  MRI (6/7) more sensitive than FDG-PET (2/7) for diagnosing diabetic pedal osteomyelitis
  - N = 20 pts, 7 had histopathological proof of osteomyelitis
  - MRI correct in all cases
  - Only if MRI is inconclusive, conventional radionuclide imaging or FDG-PET/CT might help in the diagnosis of osteomyelitis

FDG PET(-CT) IMAGING IN DIABETIC FOOT

Nuclear medicine and diabetic foot infections

- Bone scan as screening test or localization
- Labeled leukocyte imaging
  - Sensi range: 72%-100%
  - Speci range: 67%-98%
  - Accuracy 99mTc or 111 In: similar
- SPECT-CT: to be investigated, probably useful in mid and hind foot
- FDG-PET and PET/CT: limited results and inconclusive

Palestro and Love, Semin Nucl Med. 2009 Jan;39(1):52-65