Nuclear Medicine

Bone & Joints
Bone Scan

V. R. Dabbagh, M.D.
Professor; Nuclear Medicine
Nuclear Medicine Research Center (NMRC)
Mashhad University of Medical Sciences (MUMS)
Bone Scan

Tracer: $^{99m}$Tc-MDP
Bone Scan

Sensitive but not Specific

- **Clinical applications**
  - Bone metastases,
  - Primary bone tumors,
  - Trauma and fractures, Stress fractures,
  - Osteonecrosis,
  - Osteomyelitis,
  - Prosthesis evaluation,
  - Metabolic bone disease,
  - Arthritis,
Figure 4. 15 years old boy with low back pain of one month duration. Bone scan revealed prominent activity in both SIJs which is more prominent in the left side. Finding was consistent with sacroiliitis.

Figure 5. 13 years old child with low back pain of 2 months duration; bone scan revealed prominent activity within left iliac bone suggestive of aggressive bone pathology. Biopsy revealed primary malignant Ewing sarcoma.
Bone scan

- Scan pattern
  - Increased Uptake
  - Defect - cold lesion
  - Super-scan (spread malignancies) - diffusely increased uptake
Bone Metastases
Lung cancer – cold lesion
Bone Metastases

Superscan: Disseminated bone metastases secondary to prostatic cancer
3-phase Bone Scan

- **Flow phase**
  - 2-5 Sec Frames: 1 minute

- **Blood Pool phase**
  - 5 minutes post injection

- **Delayed phase**
  - 2-4 hr

- **Maybe added:**
  - Fourth phase: 24-hr
  - Enhances specificity
Different Applications of BS

- Diagnosis & Localization of the source of complaints (pain, ...)
- Detection of complications (complicated simple bone cyst; .....)
- Additive value in localization of more lesions and determination of the number of the lesions
- Bone, joint and soft tissue infection
- Vascular disorders (Paget’s disease, AVN, bone infarction, ...); Displastic disorders; Specific extra-osseous lesions
- Complications of Trauma
SPECT/CT

- The fusion of simultaneously acquired SPECT and CT allows
  - a precise anatomical localization of the scintigraphic findings
  - possible to identify not only if a lesion is hypermetabolic but also which part of the lesion is more or less hypermetabolic
  - Usefulness for diagnosis in correlation with radiographic findings
Benign and maligantant Musculoskeletal Disease

- BS: valuable, due to
  - its high negative predictive value
  - fast whole-body evaluation
BS in Malignancy
Extra-skeletal Malignancies

- **Initial staging:** Metastatic skeletal survey
- **Detection of areas at risk for pathological fractures**
- **Therapy management:**
  - Protocol monitoring: Response to chemotherapy and decision to change therapy
  - Radiation therapy: Treatment field planning and response to radiation therapy
Neuroblastoma: Bone Metastasis
PRIMARY MALIGNANT BONE DISEASE

In assessment of extension of the lesions or metastatic involvement

- Osteosarcoma
- Ewing Sarcoma
- Chondrosarcoma
- Rhabdomyosarcoma
- ............
Osteosarcoma and Ewing’s sarcoma

- **Typical indications for BS:**
  - initial staging
  - evaluating the response to treatment.
Ewing Sarcoma

Blood Pool

Delayed Bone images
Osteosarcoma

A 16-year-old boy with pain in the upper left tibia diagnosed as primary osteogenic sarcoma of the left femur.

Bone scan reveals disseminated bone and lung metastases.
Chondrosarcoma may be suggested from the bone scan appearance where there is a metaphyseal area arising from the proximal physis of the left tibia and showing non-homogeneous intense increased uptake of isotope but rather areas with absent activity surrounded by areas of increased activity.
Primary Benign Bone Tumors

In metabolic characterization, diagnosis, localization, complications and determination of the number of lesions

- Osteoid Ostemoa
- Osteoblastoma
- Chondroblastoma
- Osteochondroma
- Aneurysmal Bone Cyst
- Giant Cell Tumor (Osteoclastoma)
- Adamantinoma (Ameloblastoma)
- Enchondroma
- Simple (Unicameral) Bone Cyst
- Osteoma
- Miscellaneous
Aneurysmal Bone Cyst tumor
Diagnosis & Localization of the source of complains (pain,...)
Osteoid Osteoma (Case I & II)

Leg pain
No diagnosis on radiographic images

Double intensity sign
Similar appearances can be interpreted as traumatic or stress fracture, if the patient presents relevant history of trauma
Osteoblastomas and osteoid osteoma
SPECT/CT BS can be considered as “the one-stop shop” for the diagnosis of OO

- Translucent nidus with the surrounding bone sclerosis on CT,

- with a nidus-corresponding very “hot” spot on the BS and surrounding diffuse mildly increased tracer uptake
SPECT/CT of an 18-year-old girl with pain at the left leg and X-ray femoral hyperostosis. SPECT/CT MIP image (a) shows a focal high uptake, localized at the hyperostotic focus (b, fused images). Bone window CT images (c) demonstrate a less dense area in between, the nidus of an osteoid osteoma, later confirmed by a targeted CT scan (d)
Osteoid Osteoma
Additive value in localization of more lesions

And

Determination of the Number of the lesions
A 17 year old boy with swelling of the left knee.

Radiography of the knee suggested osteochondroma; however, Whole body scan shows abnormal increased uptake of isotope in the left upper humerus as well as in the distal left femur and left foot.
Benign Bone Disease (Other than tumors)

- Bone, joint and soft tissue infection

- Vascular disorders (Paget’s disease, AVN, bone infarction,...)

- Displastic disorders
Infection
&
Inflammation
Osteomyelitis

1) Plain films
   - Initial procedure

2) Radionuclide imaging: image the entire skeleton
   - Bone Scan (TPBS)
   - Gallium Scan
   - Labeled Leukocyte Scan: WBC Scan ($^{111}$In or $^{99m}$Tc-WBC scan)
   - FDG-PET
   - $^{99m}$Tc-Ciprofloxacin (Infecton)
   - Tc$^{99m}$-UBI

3) Magnetic Resonance Imaging (MRI)
4) Probe to Bone
Acute osteomyelitis

- 3-phase BS are abnormal very early in the course of disease, as images depict
  - Increased blood flow, increased capillary permeability (blood pool image), and
  - increased bone uptake in the late scan
Three-Phase Bone Scan: Cellulitis without Bone Infection

blood pool  posterior whole body bone scan

V.R.Dabbagh; DSNMC; www.DSNMC.ir
A 12-month-old girl who was acutely unwell and was not moving her lower limbs

Case Diagnosis:
Acute osteomyelitis of the right tibia.
Anterior image of the lower limbs shows increased uptake throughout the diaphysis and metaphysis of the right tibia extending down to the distal epiphyseal plate.
A 19-year-old man with previous history of penetrating trauma to the right ankle was referred for three-phase bone scan because of redness in the ankle and purulent discharge from the old ulcer.

The scan shows focal increased uptake of isotope in the epiphysial area of the distal right tibia as well as in the posterior aspect of the talus. Slight increased uptake in the most of the small bones of the right foot is due to reactive hyperemia.
Three-phase bone scintigraphy (TPBS)

- Highly sensitive: as early as 24-48 hours after onset
- In patients without prior bone changes: for osteomyelitis
  - 94% sensitive
  - 85%-95% specific
- Adequate
  - Specificity
  - Efficient
  - Cost-effective
Three-phase bone scintigraphy (TPBS)

- **In patients with complicating conditions:**
  - 95% sensitive,
  - 30% specific.

- **Main benefit of BS: exclude osteomyelitis:**
  unequivocally normal

- **Combined with other modalities:**
  - Gallium, $^{111}$In-WBC, Tc99m-UBI or TC99m-Ciprofloxacin:
    Improve specificity
A 9-year old boy presented with recurrent lower extremities pain and discomfort lasting for two years. In every period, symptoms vanished after several weeks.
Chronic recurrent multifocal osteomyelitis (CRMO)

- BS represents an important asset in its diagnosis,
Discitis and spondylodiscitis

SPECT increases the sensitivity of scintigraphy for the diagnosis of diskitis and vertebral osteomyelitis. It is an essential part of the examination whenever spinal infection is considered likely and planar imaging is normal.
Dysplastic disorders
Fibrous Dysplasia (two cases)

A 16 years old girl

A 6 years old boy
Arthritis
&
Alteration of Vascularity
Multifocal Arthritis

Whole body scans show abnormal increased uptake of isotope around the left ankle and small bones of the left foot as well as increased uptake of isotope in the right hip (posterior view only) and also around the right elbow.

A 6-year-old boy with septicaemia who refused to walk.
Septic arthritis

Three-Phase Bone Scan:

- Increased activity in the blood pool phase
- Increased activity in the both sides of joint
SPECT of the left hip:
Is extremely helpful for demonstrating photopenia: AVN
Transient Synovitis

Bone Scan: May be either normal or show increased activity
Transient Synovitis

Bone Scan: May be either normal or show increased activity
Right Femoral Head AVN

3 month later
Legg-Perthes disease

right hip

left hip
Traumatic & Athletic injuries
subtle bone lesions like spondylolysis or stress fractures are identified with BS.
Bilateral Calcaneal Stress Fracture
Stress Fracture: A 17-year-old girl, professional runner. She complained pain at the left leg severely hampering her daily practice. The whole-body bone scan (a) showed the bilateral presence of an uptake at the insertion of adductory muscles. SPECT/CT better demonstrates the findings involving the cortical bone, with no bone abnormalities.
Fracture of the right cuboid bone
Fractures of the medial cuneiform bones of the left foot
SPECT: Spondylolysis
SPECT: Spondylolysis
Enthesopathies
Shin-splints
Bilateral Plantar Fascitis

History of bilateral heel pain with normal radiography