SCINTIGRAPHY OF THE SKELETAL SYSTEM
THE “BONE SCAN”

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THE BONE SCAN

The premise

The bone scan is the most sensitive study for the detection of bone disease which may be located anywhere in the body and whether the patient has symptoms or not.
THE BONE SCAN

Can we always rely on the bone scan?

- A **normal or negative** bone scan excludes bone disease

  [occasionally a negative bone scan may not exclude disease (some tumors)]

- An **abnormal or positive** bone scan shows bone disease

  [a positive bone scan may be an old problem (old fractures)]
The patient had persistent Pain 2 months after an Accident. He had a negative work up (X-rays). They suspected him a pretender to extract money from insurance. Finally they sent him for a Bone Scan.

RIB FRACTURE from motor vehicle accident (MVA)
99mTc-MDP or HEDP BONE SCAN in Children and Adults

INDICATIONS

• Malignant Tumors: Primary and Metastatic
• Benign Bone Tumors: Osteoid Osteoma
• Trauma: Occult Fractures, Domestic Violence/Abuse
• Infection: Osteomyelitis, Arthritis
• Metabolic diseases: Paget’s, Bone (Avascular) Necrosis
• Soft Tissue diseases: Myositis Ossificans
• Unexplained bone Pain
RADIOPHARMACEUTICALS FOR BONE SCAN

(a “suitable for scintigraphy” radioisotope of Calcium does not exist)

CURRENTLY IN USE:

99m Tc-phosphate Compounds

NEW DEVELOPMENTS:

Use PET/CT imaging with $^{18}$FNa (Sodium Fluoride) for bone scan
**BONE SCAN METHODOLOGY**

$^{99m}$TcMethylene (MDP) or Hydroxyethylene (HDP) Diphosphonate (20-30 mCi, adults 1-30 mCi children, based on weight)

Over 3-4 hrs MDP (HDP) is **accumulated in the bones** and in the lesions proportional to Blood Flow and to Osteoblastic Activity.

**Excretion of remainder** in the urine and this Clears the background.

**Sufficient skeletal-to-soft tissue ratio** at 3-4hr for Planar and Tomo.
Hydration and bladder emptying (catheterization if needed)

Sufficient waiting period post injection to clear BKG

Adequate renal function is needed, otherwise delay scanning

Immobilization (sedation) of the patient

Statistically Enough Counts 500kCts-1MCts (least 100kCts)

Total Body imaging (multifocality, referred pain)
NORMAL BONE SCAN: The “Sweep”
NORMAL BONE SCAN: Multiple “Spots”
NORMAL BONE SCAN: AGE PATTERN

Child

Young Adult
NORMAL BONE SCAN: AGE PATTERN

Tc-99m-MDP BONE SCAN

Mature Adult

Older overweight Person
Regional Hyperactivity may be due to:

a) Normal bone growth and remodeling

b) Increased Blood Flow (trauma, heterotopic ossification)

c) Reactive osteoblastic activity (active infections, tumors)

d) Reparative bone process (healing fractures, tumors, infections)

e) Hyper-metabolic activity (metabolic disorders)

They induce an increase in blood flow and osteoblastic activity, which enhance Ca / Phosphate local accretion into the hydroxyapatite matrix
TYPICAL "HOT" SPOT BONE SCANS
METASTATIC PROSTATE CANCER

METASTATIC PROSTATE CANCER - Tc-99m-MDP BONE SCAN

FRACTURES - Tc-99m-MDP BONE SCAN
Exceptionally, some lesions, although they destroy the bone, they don’t generate bone reaction. This prevents osteoblastic reactivity and results in FN studies. Such non-active lesions may appear as cold spots on the scans.
Metastasis: “Cold” Lesion

Patient with Breast and Esophageal Cancer s/p Rad. Tx
Cold Spots may be caused by:

a) **Malignant Tumors**
   - Lung (2-4%)
   - Breast (5%)
   - Renal (10%)
   - Neuroblastomas (bone marrow mets)
   - Thyroid (most cases)
   - Multiple Myeloma (most cases)

b) **Bone Abscesses** (they are surrounded by activity)

c) **Bone ischemia** (AVN, sickle cell, etc.)

d) **Hemangiomas** (normal or decreased activity)
Metastasis: “cold” Lesion
Prostate Cancer
Some very aggressive Skeletal lesions induce Bone Reaction around them = Hot Spots and, centrally, they are Cold Spots on the scans
Metastases: “HOT” and “COLD” Lesions

Prostate Cancer
1) Planar (3 hr) Total Body Study
   a) with or without **Tomographic** Study (increases sensitivity)
   b) or **Pinhole** Collimator (high resolution) views

2) Triple Phase Study (blood flow/blood pool/late phases)
   (Differentiates Soft Tissues infection/inflammation from Skeletal lesions)
TRIPLE PHASE BONE SCAN

(Differentiates Soft Tissues infection/inflammation from Skeletal lesions)
TRIPLE PHASE BONE SCAN

NORMAL STUDY

Tc-99m-MDP BONE SCAN PLANAR (TRIPLE PHASE)

FLOW POSTERIOR

BLOOD POOL POSTERIOR ANTERIOR DELAYED ANTERIOR

35yo female with pain and a lytic lesion in left fibula
TRIPLE PHASE BONE SCAN

CELLULITIS in a diabetic patient

flow  blood  pool  delayed
TRIPLE PHASE BONE SCAN

ACUTE OSTEOMYELITIS in a diabetic patient

flow

blood pool

delayed
BONE SCAN TOMOGRAPHY
SPECT
(Single Photon Emission Computed Tomography)

Increased Sensitivity in the lumbar spine by 20% to 50%
BONE SCAN TOMOGRAPHY
THREE DETECTOR SPECT CAMERA
INDICATIONS FOR BONE SPECT SCANS

1. Complex Bony Structures, such as skull and pelvis
2. Unexplained Bone Pain with normal planar studies
3. Precise Localization of a known abnormality
4. Improved Correlation with CT and MRI
5. Soft-Tissue v/s bony uptake (i.e., kidney from bone)
NORMAL BONE SCAN STUDY

FLOW STUDY

PLANAR IMAGES
NORMAL BONE SCAN STUDY

TOMOGRAPHY SPECT

VOLUME/REPROJECTION SPECT
Young patient with Back Pain
THE VALUE OF SPECT

Sacroiliitis:

The planar image is normal

The SPECT showed the lesion
Patient with pain on the right side of the face
THE VALUE OF SPECT

TMJ Inflammation

A Normal SPECT study

PLANAR Negative(?)

SPECT Positive
PINHOLE COLLIMATOR IMAGES

improves resolution of complex bony structures
PINHOLE COLLIMATOR
NORMAL PINHOLE OF THE HIPS

Hip pain; R/o aseptic necrosis
QUALITY CONTROL
Patient with thyroid cancer, had treatment with RAI recently
BARIUM ATTENUATION
BONE SCAN

INTERPRETATION NEEDS INFORMATION

Why you need the Bone Scan?

Indication(s) for the study

Patient Profile, Diagnosis, Therapy

Patient history, symptoms, signs,

Findings on other studies
BONE SCAN

INTERPRETATION: ISSUES TO ADDRESS

Reading of the Bone Scan issues:

- Quality control
- Skeletal lesions (multifocality, size, number, intensity)
- Need for SPECT and Volume Display
- Soft tissue abnormalities
- Comparison with previous Bone Scans
- Correlation with Other imaging modalities
- Answer the questions asked by referring physician
  - “Positive, Negative, Inconclusive”
ACUTE OSTEOMYELITIS IN CHILDREN

THE BONE SCAN
A 5 yo child with fever and swelling of the right knee

3 days duration
ACUTE OSTEOMYELITIS IN A CHILD
The Bone Scan is more sensitive than Radiographs

On Admission

X-rays were negative

On Admission

Two foci of osteomyelitis

15 days Later

Lytic lesion
5 yo child with congenital Immunodeficiency
Recent fever and blood culture positive
R/O Osteomyelitis
Osteomyelitis of ribs

Normal epi/metaphysial activity
Newborn from a HIV+ mother
Has fever, leukocytosis and redness in the arm

R/O Osteomyelitis
Osteomyelitis in a Newborn

Scalp Injection Site

A good quality bone scan is diagnostic of Osteomyelitis in the newborn despite publications claiming otherwise.
14mo with low back pain and recent history of otitis media
Evaluate for Infection
Diskitis of the Lumbar Spine

Notice that two lines of hyperactivity are present
DISKITIS; PINHOLE IMAGE

BONE SCAN

GALLIUM
ACUTE OSTEOMYELITIS

TRIPLE PHASE BONE SCAN

Differentiates Soft tissue from skeletal lesions

The Bone Scan is more sensitive than Radiographs
58 yo Diabetic Lady with ulcer in the L tibia
R/O Osteomyelitis
Osteomyelitis: The Delayed hyperactivity in the lesion is focal and of relatively equal or greater intensity than the corresponding Early hyperactivity.
ACUTE OSTEOMYELITIS IN CHILDREN

THE CONTRIBUTION OF GALLIUM-67 SCAN

High Sensitivity for Acute and Chronic Lesions
SEPTIC ARTHRITIS

BONE SCAN
overexposed

GALLIUM
ACUTE OSTEOMYELITIS

THE CONTRIBUTION OF LEUKOCYTE SCAN

$^{111}\text{In}$ or $^{99m}\text{Tc}$-HMPAO WBC SCAN

High Specificity for Acute Osteomyelitis
INFECTION LOCALIZATION: OSTEOMYELITIS
BONE SCAN AND LABELED-WBC SCAN

Hand Auto-transplanted; r/o Osteomyelitis
In Serial Studies after effective treatment and no symptoms

**Cellulitis:** Bone Scan becomes Normal

**Osteomyelitis:** The Focal Hyperactivity persists long
( repair of the damaged bone)

**Arthritis:** Non-specific diffuse activity in the region of the joint remains for long (synnovial changes)
EVOLUTION OF TREATED OSTEOMYELITIS
in a 6 year old boy

24 hours
1 week
1 month
2 months
6 months ant
6 months post
SEPTIC ARTHRITIS

Arthritis: Non-specific diffuse activity in the region of the joint remains for long (synovial changes)
The Bone Scan is more Sensitive than Radiographs (hyperemia and osteoblastic activity v/s calcium loss)

Fractures appear earlier on bone scan and last longer and It is easy to recognize them
BONE SCAN

TRAUAMA - FRACTURES

TOTAL BODY PLANAR study (multifocality, referred pain)

SPECT for head, spine, pelvis, or if planar study negative

Accidents: MVA, Falls, Occupational, Osteoporotic

Sports: Stress Fractures, Extension / Flexion Fractures, Direct Injury to / Fractures of bones

Intentional: Child Abuse, Domestic Violence in Adults

Iatrogenic: Surgery, Resuscitation, Physical Therapy
In non-osteoporotic patients, less than 65 y/o, 95% of fractures become **visible** on bone scans **within 24 hours**

In older patients, 95% of fractures are detectable on bone scan in **72 hours**

The bone scan Remains **positive** for months to **many years**
RIB FRACTURE from motor vehicle accident (MVA)

Persistent pain 2 months after MVA and negative work up
Lung Cancer s/p resection of left Pancoast tumor
R/O bone metastasis
FRACTURES and TUMOR

Tumor Involvement

Degenerative Disease

Surgical Trauma: Sternotomy and Rib Fractures
FRACTURES from Fall and Resuscitation
99mTc-MDP or HEDP BONE SCAN in CHILD ABUSE

FRACTURES
ROLE OF BONE SCAN IN EVALUATION OF CASES SUSPECTED OF CHILD ABUSE

1. To detect recent fractures non detectable by radiography (3-5 days)

2. To detect old fractures in patients with burns and other findings suggesting abuse

The bone scan is more sensitive than radiographs because it detects increased osteoblastic activity and increased local blood pool.
99mTc-MDP or HEDP BONE SCAN in CHILD ABUSE
A child is brought in the ER for “trauma from falling”
Cigarette burns raised suspicions of child abuse.
No acute fractures were present
FRACTURES: CHILD ABUSE
Multiple Fractures
FRACTURES: SEVERE CHILD ABUSE
Multiple Fractures
SPORTS FRACTURES
OCCULT FRACTURE: Triple Phase and Pin Hole

Baseball player with pain in the hand and normal radiographs

3 HR PLANAR IMAGES

Recent fracture of the HAMULUS OF THE HAMATE BONE
Patient on Steroids for long time
Now with back pain following fall

Evaluate for fractures
IATROGENIC FRACTURES

Compression Fractures of Spine: planar v/s SPECT

Left Ribs Fractures

Anything in the Spine?
Patient with a history of chiropractic maneuver
BONE TUMORS

Primary benign and malignant

Metastatic bone tumors
THE BONE SCAN

$^{99m}$Tc-Methylene (or Hydroxyethylene) Diphosphonate (MDP or HDP) 20-30 mCi, Imaging Total Body (or SPECT)

INDICATIONS IN ONCOLOGY

Primary Bone Tumors: Extend of tumor, multifocality, metastases, recurrence

Skeletal Metastasis: The most sensitive, easily performed, inexpensive total body imaging modality for early detection and follow up of asymptomatic skeletal metastasis
PRIMARY BONE TUMORS
24 yo male with a painful lesion in the left calf
X-rays showed a lucent lesion with peripheral reaction
DIAGNOSIS: OSTEOID OSTEOMA

The flow study showed hyperemia

Central hyperactivity
Peripheral fading
OSTEOID OSTEOMA: PINHOLE COLLIMATOR

PIN HOLE COLLIMATOR
PARALLEL HOLE COLLIMATOR
21 yo with biopsy proven Osteosarcoma of the right proximal tibia
Evaluate for metastases
OSTEOSARCOMA
(osteoblastic=hot lesion)

EWING’S SARCOMA
(cold lesion + bone reaction)

No bone metastasis present
OSTEOSARCOMA

SINGLE FOCUS

MULTIFOCAL (METASTATIC)

LUNG METASTASIS

amputation
OSTEOSARCOMA.
recurrent
25 yo male with biopsy proven Ewing’s sarcoma

Evaluate for bone metastases
EWING’S SARCOMA
(cold lesion + bone reaction)
METASTATIC BONE TUMORS
STRATIFICATION BY BONE SCAN

1. Bone Scan
   - Lesion
     - X-ray
       - Metastasis
       - Benign disease
2. Normal
   - No further investigation
   - CT or MRI
     - Metastasis
     - Normal
     - ? Biopsy
Multiple Myeloma: “COLD” Lesion
7yo boy with recurrent Neuroblastoma
Evaluate for Bone metastasis
METASTATIC NEUROBLASTOMA
NEUROBLASTOMA METS AND RESOLUTION FOLLOWING THERAPY
5 year old child with Neuroblastoma:
Evaluation for bone metastasis
BONE SCAN: SOFT TISSUE FINDINGS
CALCIFIED TUMORS
NEUROBLASTOMA

Neuroblastoma with calcifications
Injection site
Small Neuroblastoma Calcified
59 yo Lady with Breast Tumor: R/O Bone Metastasis
BONE SCAN:
SOFT TISSUE FINDINGS:
CALCIFIED TUMORS
BREAST CANCER
LIVER METASTASES

Calcified Liver Metastases
DJD
Two females with history of Breast Cancer
Evaluation for bone metastasis
METASTATIC BREAST CANCER
DETERIORATION OF THE DISEASE

Early Disease

Advanced Disease
71 yo male with prostate cancer and PSA 250
Evaluate for bone metastasis
Body, head, proximal extremities full with metastases

distal extremities spared (no metastases)
SUPERSCAN

Metastatic Prostate Cancer

Not Every Bone is hyperactive

In Metabolic Disorders Every bone is hyperactive
HYPERPARATHYROIDISM

Tc-99m-MDP BONE SCAN PLANAR
FOLLOW UP STUDIES
Metastatic Prostate Cancer

EFFECT OF THERAPY: TAMOXIFEN 6mo

Before Therapy

After 6mo Tamoxifen
METASTATIC LUNG CANCER

Metastasis with Orthopedic Significance

62yo male with lung cancer
METASTASIS FROM ESOPHAGEAL CANCER
LYMPHOMA OF THE SKELETON
FDG-PET/CT

Bone metastasis
Bone metastasis 2 months later
BONE SCAN

SOFT TISSUE FINDINGS

Often useful Information
HETEROTOPIC OSSIFICATION
(MYOSITIS OSSIFICANS)

Occurs in Paraplegic or Quadriplegic patients soon after rehabilitation therapy begins (may be related to muscle trauma).

Muscles develop inflammation which leads to new bone formation.

Clinically inflammatory findings appear around the joints and Laboratory evidence of inflammation is found (increased ESR etc)

May be treated if confirmed early, otherwise needs surgery

The Bone Scan can establish the diagnosis early

(Increased Blood Flow and Blood Pool and delayed bone activity)
HETEROTOPIC OSSIFICATION
(MYOSITIS OSSIFICANS)

Phase 1:
Increase in blood flow+pool only

Phase 2
Increase in blood flow+pool greater than in delayed activity

Phase 3
Increase in blood flow+pool equal to the delayed activity

Phase 4
Increase in blood flow+pool less than in delayed activity

Phase 5
Increase in delayed activity only
Quadriplegic patient with evidence of soft tissue inflammatory reaction (left hip and left shoulder)

Evaluate for Heterotopic Ossification
HETEROTOPIC OSSIFICATION PHASE 3

Increased Delayed Activity

Increased Blood Flow and Blood Pool activity

Periodontal + Fractures

Increased Delayed Activity
Quadriplegic with clinical inflammatory findings around the hips
HETEROTOPIC OSSIFICATION Phase 4-5
HETEROPTOPIC OSSIFICATION in a Non-Paralyzed Patient
HETEROPTOIC OSSIFICATION in a Non-Paralyzed Patient
HETEROPTOPIC OSSIFICATION in a Non-Paralyzed Patient
12yo girl with “pelvic pain”, to evaluate for traumatic or inflammatory bone lesion: Triple bone study
17 week Pregnancy

Placenta visualized
Two patients for evaluation for metastatic bone disease
Final Diagnosis: Kidney and Bladder Tumors

Renal Tumor (SOL)

Pelvic Tumor (SOL)
Patient with liver cancer.
R/O bone metastasis

History of cirrhosis
Ascites

Renal Space Occupying Lesion
Back pain
R/O Osteomyelitis of the spine/pelvis
Rib Fracture

Bowel Visualization (Sestamibi Previous Day)

Renal Transplant
Breast Cancer
R/O metastatic bone disease
Bowel Visualization / Free Tc-99m

Urine Contamination
SKELETAL BENIGN DISORDERS
A 55 yo woman under evaluation for Metastatic breast cancer.
PARS DEFECT (SPONDYLOLISTHESIS and FRACTURE):
Is it centered behind the posterior margin of a vertebral body
Patient with metastatic bone tumors and painful left hip prosthesis
BONE SCAN

METABOLIC DISORDERS

Paget’s disease

Hypertrophic Pulmonary Osteoarthropathy

Hyperparathyroidism

Fibrous Dysplasia

Aseptic Necrosis

Sickle Cell Disease

Bone Marrow expansion
55 yo male with history of Prostate Cancer
R/O bone metastasis
Paget’s Disease of the left first Rib
Degenerative Joint Disease of the cervical spine
PAGET’S DISEASE AND PROSTATIC METASTASIS
HYPERTROPHIC PULMONARY OSTEOARTHRITIS
HYPERPARATHYROIDISM

Tc-99m-MDP BONE SCAN PLANAR
Patient is a 6yo boy with right hip pain for 2 weeks
History of trauma of the head and the left upper extremity
25 yo patient with Sickle Cell Disease
R/O Osteomyelitis of the left proximal tibia
Sickle Cell Disease

Calcified Spleen

Bone Infarct
Pain in the heels, left more than right: R/O Infection or fracture
OSSIFYING TENDONITIS

Triple Phase and Multiple Views

No Increased blood flow or Blood Pool

Increased delayed activity
FIBROUS DYSPLASIA
Metastatic to Bones Lung Cancer
F/U bone scan S/P therapy
RADIATION EFFECT
Port included
Thoracic Spine, Ribs, Lung, Heart

Multiple Bone Metastatic Foci

Port on the lumbar spine
BONE SCANNING: Metastasis
BONE SCANNING: Metastasis
METASTATIC LUNG CANCER: FDG-PET and BONE SCAN

Results of Therapy show better on FDG-PET

Before therapy bone metastases show better on the FDG-PET

Baseline Studies

Bone Scans

surgery

FDG/PET Scans

12 months later

PERSISTENT REACTION

THERAPY

REMISSION

46 yo with surgically removed carcinoma of the lung and lumbago
$^{18}$FNa-PET BONE SCANNING:
**18FNa-PET BONE SCAN v/s 99mTc-MDP-SPECT**

Chronic stress to the spine: Additional information by 18F-PET

18F-PET (50µCi/kg)

99mTc-MDP-SPECT (50µCi/kg)
**18FNa-PET BONE SCAN v/s 99mTc-MDP-SPECT**

25 y.o. rower: stress to costovertebral junctions

18F-PET
(50µCi/kg)

99mTc-MDP-SPECT
(50µCi/kg)
Visual presentation of each lesion:
the same semi-quantitative grading was applied to both studies