Overview

The Bone Mineral Study depicts the distribution of bone mineral metabolism throughout the skeleton. In addition, rapid serial images during the first pass of the radiopharmaceutical through the circulatory system may be obtained to demonstrate regional perfusion.

Indications

1. **Whole body scan:**
   - Cancer (1-3)
   - Musculoskeletal pain
   - Fracture
   - Paget’s disease (15)
   - Metabolic bone disease
   - Abnormal x-ray
   - Elevated alk. phos.
   - Arthritis

2. **Three phase scan:**
   - Osteomyelitis (4-6)
   - Reflex sympathetic dystrophy (13,14)
   - Avascular necrosis
   - Musculoskeletal Injury (7-11)
   - Joint disease

3. **SPECT:**
   - For pain or abnormality of:
     - Lumbosacral spine
     - Skull or facial bones
     - Selected cases of hips, knees, thoracic spine, cervical spine, extremities, ankles, hands, and feet

4. **Limited:**
   - Use when specifically ordered to evaluate pain or abnormality in a limited area.

*Exams ordered for indications which are not listed above need to be discussed with the Nuclear Medicine Physician.

Examination Time

Initially: 15 minutes for injection of the radiopharmaceutical; 25 minutes for the perfusion and blood pool component of a three phase study.

2-4 hours later: 1 hour for routine image acquisition, but as long as 2 hours if SPECT or extensive spot views are needed.
**Patient Instructions**

No special preparation is required. Patients may take medications and eat before coming in.

Patients should drink plenty of fluid (2 or more 8oz. glasses of water) starting the morning of the study and continuing from the time of injection until imaging (16).

Notify outpatients that there will be at least a three hour delay between injection and scanning. During that time, the patient may leave the hospital, or may wait in one of the hospital waiting rooms or in the cafeteria.

Ask the patient about any recent radiology exams. Bone scans should not be scheduled for 48 hours after barium enema or UGI studies.

**Lab / Image Correlation**

If test is ordered for an abnormal lab (increased alkaline phosphatase, PSA, calcium, etc.) request the value if available.

Obtain outside films and reports of all prior nuclear medicine studies, and of any outside studies whenever correlation is specifically requested.

When bone scan is ordered for an abnormal x-ray done elsewhere, obtain a copy of the radiology report, and request that the patient bring the x-rays if possible.

**Equipment & Energy Windows**

Gamma camera: Large field of view, preferably with dual heads.

Collimator: Low energy, high resolution, parallel hole. Pinhole in select cases: Children, small structures requiring imaging.

Energy window: 20% window centered at 140 keV.

Matrix: Flow 128x128
Blood pool 256x256
Delayed 256x256
SPECT 64x64

**Radiopharmaceutical, Dose, & Technique of Administration**

Radiopharmaceutical (17,18):
- Tc-99m-methylene diphosphonate (MDP).
- Tc-99m-hydroxymethylene diphosphonate (HMDP).
Dose: 20 mCi

Technique of administration:
   Routine study: Standard intravenous injection.
   Three Phase: Bolus intravenous injection.

**Patient Position & Imaging Field**

Patient position: Supine (prone position can be used if patient cannot lie supine).

Imaging field: Entire body.

**Acquisition Protocol – Routine Study (17)**

Begin image acquisition 3-4 hours following injection of the radiopharmaceutical.

Have the patient empty his/her bladder immediately before image acquisition.

Remove all metal objects and breast prostheses before scanning.

Note the presence of any non-removable appliances (colostomy or ileostomy bags, breast implants, etc.) in writing on the requisition. Ask patients with ileal loop to bring a fresh collection bag, to be placed just before scanning.

If activity in the urinary bladder after voiding or during SPECT of the pelvis interferes with specific structures being evaluated, the nuclear medicine physician may request straight catheterization, to be done by an RN.

**Moving acquisition protocol (Whole Body):**

1. Whole body images should contain >1.5 million counts.
2. Acquire ANT and POST images from the head to the bottom to the feet. (If a single head camera is being used, only ANT images of the lower extremities may be acquired.)
3. Acquire static “spot” images as indicated.

**Static acquisition protocol (Whole Body):** Only if whole body scanner is not available.

1. Acquire an ANT image of the chest for 5 minutes (approximately 500-750 K counts), note the time required for acquisition.
2. Using the same acquisition time used for the ANT chest image acquire ANT and POST images of the rest of the torso and head, and ANT images of the extremities (arms may be omitted).

**Spot view protocol:**
1. See tables below to determine acquisition time and counts.
2. For prostate cancer always perform a TOD view or obliques (have patient empty bladder).

Limited studies protocol

1. To evaluate joint pain (e.g., hip, knee) images must include the joint above and below the symptomatic joint (i.e., “pelvis south”). See tables below to determine acquisition time and counts.
2. Oblique views must be obtained of any symptomatic sites.

Optional Maneuvers

Three phase bone scan (4):
1. Routinely used when the clinical question is reflex sympathetic dystrophy, infection in the extremities, stress fracture, avascular necrosis, or primary bone tumor.

Note: For patients with suspected osteomyelitis or reflex sympathetic dystrophy, obtain flow, blood pool, and delayed spot images with both the suspected region and the contralateral body part in the field of view (Three Phase Bone Imaging). For RSD, two "orthogonal" (i.e., at 90 degrees, such as a plantar and a lateral of the foot) views should be obtained of the affected extremity. Delayed images of the feet or hands should be made 3 to 6 hours after injection.

2. The patient position and field of view depend on the area of interest. Always attempt to include both sides of the body, e.g. both legs or both hands, so that the normal side can be used for comparison.

3. The radiopharmaceutical is administered as a bolus. To obtain flow images of the arms or hands, place a reseal in a proximal vein in the arm opposite the symptomatic side; then wait 10 minutes before proceeding with injection.

4. Acquire serial images for 5 seconds each for 80 seconds (16 frames) starting at the time of injection.

5. Immediately acquire a blood pool image for approximately 5 minutes. (The number of counts will depend on the body part being imaged and other factors.)

6. Have the patient return in 3-4 hours for the delayed images; follow the acquisition protocol for delayed images given above.
Special views:
1. Images of the scapula with the arm abducted (POW) and adducted can be used to differentiate activity in the scapula and underlying ribs (24).
2. The TOD view (tail on detector) is useful for separating otherwise superimposed structures around the pelvic ring. The view is obtained with the patient sitting over the head of the camera (25).
3. Small structures may be magnified with a 2 mm pinhole collimator (26).

NOTES / PRECAUTIONS:
When residual activity is seen at the site of injection, mark it “injection site” on at least one film to prevent subsequent confusion with bone lesions. If a large amount of residual activity is present, evaluate image quality. Shield the injection site during imaging.

In mastectomy patients, inject the opposite arm whenever possible.

If a whole body scanning system is not available, image the whole body with 5 minute spot images. All views must overlap so no areas will be missed. The anterior image set must include the shoulders, arms, legs, and feet. Acquire symmetrically positioned right and left anterior images of the arms with elbows bent, including the shoulders; the hands may be excluded. Posterior images may exclude the arms and the legs below mid femurs.

Data Processing

SI joint ratios:
If evaluation of the sacroiliac joints is requested: Acquire a posterior pelvis image. Using the computer select a horizontal slice, three pixels in height, that passes through the sacrum and both SI joints. For each joint, calculate the ratio of maximum profile counts over the joint to maximum profile counts over the sacrum.

<table>
<thead>
<tr>
<th>Spine, Ribs, Clavicles</th>
<th>Standard Projections</th>
<th>Optional Projections</th>
<th>Image Time</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>Ant. and post. (done with W/B) LPO, RPO (include T-12 to coccyx)</td>
<td>RAO or LAO for hot focal spots on ant. aspect of the vertebrae. Ant. delay (see comments) Post. Delay (see comments)</td>
<td>5 min.</td>
<td>Seated spine views preferred if patient cooperative. Blurred ant. l/s spine due pt. Leg, abd., do ant. delay. Use block under pt’s legs to open vertebrae spaces, if there is no separation on post l/s spine on W/B. Use wedge and chair to reduce movement to steeper obliques, to demonstrate post elements or post vertebrae. Abn. Kidney? (get good kidney hx). Bring H2O to patients to drink during interview.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Lumbar flow for osteoma, diskitis infection or specific requesting flow.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-spine</td>
<td>Post LPO or RPO (to show ant. vertebral aspects)</td>
<td>Angled post view (see comments)</td>
<td>5 min.</td>
<td>For a kyphotic patient, do an angled upright post. View (note area of pa… and angle accordingly).</td>
</tr>
<tr>
<td>3-ph T-spine</td>
<td>Flow – post. Imm. – RPO or LPO</td>
<td></td>
<td>5 min.</td>
<td>3-ph done for osteomyelitis.</td>
</tr>
<tr>
<td>Sternum</td>
<td>Flow – ant. Imm. – ant. LAO or RAO</td>
<td></td>
<td>5 min.</td>
<td>Do an oblique to determine if there is a hot spot seen on the sternum or T-spine. For a hot sternoclavicular joint, do either one ant. oblique or one post. Oblique. Note any CABG surgery on bone hx sheet.</td>
</tr>
<tr>
<td>Ribs</td>
<td>Ant. and post. Obliques of affected side</td>
<td>Lateral view for lateral chest wall pain</td>
<td>5 min.</td>
<td>Rib views done for fractures or lesions.</td>
</tr>
<tr>
<td>Clavicles</td>
<td>Ant.</td>
<td>5.min.</td>
<td>Do good ant. view, angled if necessary, if W/B camera is far from patient.</td>
<td></td>
</tr>
</tbody>
</table>
## UPPER EXTREMITIES

<table>
<thead>
<tr>
<th></th>
<th>Standard Projections</th>
<th>Optional Projections</th>
<th>Image Time</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fingers</strong></td>
<td>Ventral, lateral, Flow</td>
<td>Lateral view for finger lesions</td>
<td>5 min.</td>
<td>Use positioning block for lateral views and immobilization.</td>
</tr>
<tr>
<td><strong>Hands/wrists</strong></td>
<td>Palmar, medial Flow – palmar</td>
<td>Radial deviation</td>
<td>5 min.</td>
<td>Wait 10-15 min. before injection. Note: Include wrists on hand views. Immobilize with tape and sandbags, ulna deviation for scaphoid, and radial deviation for pisiform or triquetrum area. Inject in opposite vein of symptoms. Inject in antecubital vein area, when possible.</td>
</tr>
<tr>
<td><strong>Forearms/elbows</strong></td>
<td>Dorsal, medial Flow – dorsal</td>
<td>Medial views for bilateral forearms, use positioning block</td>
<td>5 min.</td>
<td>Dorsal – palms up and immobilized. Medial – elbow 90° and pt’s palm parallel to pt’s chest. Include thumb on both elbow and forearm view.</td>
</tr>
<tr>
<td>Shoulder joints</td>
<td>Flow (ant.) shoulders</td>
<td>If hot spot is in the glenoid fossa, do the glenoid fossa view</td>
<td>5 min</td>
<td>Inject in opposite arm, pt. Supine, palms up. Check post. View on W/B. If OK, do only ant. view on single head camera, and angle camera close to shoulders.</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------</td>
<td>-------------------------------------------------------------</td>
<td>-------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Scapulas</td>
<td>Post. View</td>
<td>P.O.W. view, to clear hot spots from rib. If pt. Is round shouldered, angle camera parallel to pt’s shoulders</td>
<td>5 min</td>
<td>Scapula parallel to camera.</td>
</tr>
</tbody>
</table>
## LOWER EXTREMITIES

<table>
<thead>
<tr>
<th>Standard Projections</th>
<th>Optional Projections</th>
<th>Image Time</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bilateral feet</strong> (toes and metatarsals)</td>
<td>For toes only – get good plantar on affected side. Flow Plantar Plantar imm. 90° of affected side (med. Or lat.) for metatarsal area)</td>
<td>5 min.</td>
<td>Remove pt’s socks and shoes. Place pads between toes. Record lesion on foot picture. Unwrap any dressing, if necessary for localization.</td>
</tr>
<tr>
<td><strong>Tarsals And heel</strong></td>
<td>Flow Plantar Plantar imm. Medial or lateral of affected side Delayed views: Dorsal view Plantar view Medial view (affected side) Lateral view</td>
<td>5 min.</td>
<td></td>
</tr>
<tr>
<td>Ankle Details</td>
<td>Imaging Details</td>
<td>Duration</td>
<td>Additional Notes</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
<td>----------</td>
<td>------------------</td>
</tr>
<tr>
<td>Flow ant. or post. (where pain is located) Ant. or post. Imm. Imm. Medial or lateral of affected side</td>
<td>5 min.</td>
<td>Post. View – toes pointed up.</td>
<td></td>
</tr>
<tr>
<td>Hips (see pelvis also) Hips only if orders by Dr. indicate this, or r/o loose hip prosthesis and there is no hx of CA or osteoporosis</td>
<td>Ant. flow Ant. imm. Imm. Lateral (if pain below the trochanter) Imm. Post (if pain is in sacral area) Ant., post</td>
<td>5 min.</td>
<td>Tape pt’s feet for ant. flow, imm., delay. Include as much of the pelvis as possible. Do large pts on single-head cameras, when possible, and angle camera to hips. If soft tissue contamination does not overly the bone, do not do extra view. T.O.D. if pt’s bladder obscures pubic rami</td>
</tr>
<tr>
<td>Lower legs</td>
<td>Standard Projections</td>
<td>Optional Projections</td>
<td>Image Time</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Ant. flow of both legs with toes pointed, if possible (feet taped together). 90° immediate view of affected side (lateral or medial). Delays – ant. both legs – medial, lateral of affected side (include entire tibia, fibula).</td>
<td>5 min.</td>
<td>Post view only if evaluating posterior abnormality. Include entire tibia/fibula.</td>
<td></td>
</tr>
</tbody>
</table>
### Knees

| | Ant. flow both knees. Ant. immediate 90° affected side medial or lateral. Delays – ant. both knees – medial, lateral of affected side. | 5 min. | Feet taped. No post view of knees unless history indicates. Patient is seated on a chair for medial and lateral Views. |

### SKULL AND C-SPINE

<table>
<thead>
<tr>
<th></th>
<th>Standard Projections</th>
<th>Optional Projections</th>
<th>Image Time</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td>Anterior, posterior Right or left lateral 3-phase – posterior flow for ostitis, anterior flow otherwise Immediate lateral (affected side) Immediate posterior</td>
<td>Vertex for midline of skull if not shown on lateral (slight oblique if lateral doesn’t show area)</td>
<td>5 min.</td>
<td><em>Vertex – immobilizer patient with tape lateral of affected side</em></td>
</tr>
<tr>
<td>C-Spine</td>
<td>Posterior (next to camera) Lateral right and left</td>
<td>5 min.</td>
<td>No anterior views. Do patient supine if he/she can not turn head for lateral views.</td>
<td></td>
</tr>
<tr>
<td>Standard Projections</td>
<td>Optional Projections</td>
<td>Image Time</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------</td>
<td>-------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>Pelvis (do W/B also)</td>
<td>Ant. flow L-4 down If pain in coccyx or sacrum, do post. Flow</td>
<td>Coccyx pain LPO, RPO (heavy patients) Lat (thin patients) Cranial caudal vein or T.O.D. to separate bladder from pubic rami</td>
<td>5 min.</td>
<td>Have patients void before imaging. Tape patient’s feet for ant. flow, imm. And delays. Elderly osteoporotic patients, do pelvis first, then W/B if possible. Pain in pubic area, see optional views. If bladder obscures sacrum, do LPO, RPO or rt, lt lat.</td>
</tr>
</tbody>
</table>

**SPECT TOMOGRAPHIC IMAGING PROTOCOL**: Routine for low back pain, and are used in other selected situations (evaluations of the skull and facial bones, pelvis, hips, and knees) (19-22):

1. Image acquisition parameters: See table below.

2. Data processing: Siemens workstation
   a) reconstruct transverse, sagittal, and coronal images.
   b) filter using Weiner or Butterworth.

For uniformity in the archive, use the following labels:

- Skull
- Face
- LS-Spine
- Pelvis
- Hips
- Knees
- T-spine
**BONE SPECT ACQUISITION**

<table>
<thead>
<tr>
<th>Label</th>
<th>SP6/SP6-HR</th>
<th>AG/CardiaL</th>
<th>Helix/Varicam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Last, first</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isotope</td>
<td>Tc-99m</td>
<td>Tc</td>
<td>Tc</td>
</tr>
<tr>
<td>Energy</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Window</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Dose (mCi)</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collimator</td>
<td>45</td>
<td>4</td>
<td>45, 46</td>
</tr>
<tr>
<td>Zoom</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Frame Size</td>
<td>128</td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>Patient Orient</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center XY</td>
<td>0,0</td>
<td>0,0</td>
<td>0,0</td>
</tr>
<tr>
<td>Angle Range</td>
<td>360</td>
<td>360</td>
<td>180</td>
</tr>
<tr>
<td>Angle Step</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Step Shoot</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Frame Time</td>
<td>30</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Elliptical</td>
<td>Yes</td>
<td>N</td>
<td>Contour</td>
</tr>
</tbody>
</table>

SPECT/CT Siemens processing

- In Category drop down select skeletal
- Double click SPECT PROC icon
- In Tomo Reconstruction tab verify
  - Iterative Reconstruction is being used
  - OSEM 2D is being used to process
  - 4 subset are processing
  - 10 iterations are processing
  - Gaussian filter set to 8.0

- Changs Attenuation Correction
  - coefficient 0.15
- Automatic Contours
- Projection Angle 2
- Edge Strength 0.5
- Background Threshold 5
- Slice Averaging Gaussian # of slice 1
- In 3D Orientation tab verify image is centered and adjust if needed
- In Flexible Display tab adjust slices in transverse, coronal, and sagittal tabs across top of screen
- Send to Dr. reading station and PACS

**Principle Radiation Emission Data – Tc-99m (31)**

Physical half-life = 6.01 hours.

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Mean % per disintegration</th>
<th>Mean energy (keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma-2</td>
<td>89.07</td>
<td>140.5</td>
</tr>
</tbody>
</table>

**Dosimetry – Tc-99m-MDP/Tc-99m-HMDP (32,33)**

<table>
<thead>
<tr>
<th>Organ</th>
<th>rads/25 mCi</th>
<th>mGy/925 MBq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bladder wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 hour void</td>
<td>3.25</td>
<td>32.5</td>
</tr>
<tr>
<td>4.8 hour void</td>
<td>7.75</td>
<td>77.5</td>
</tr>
<tr>
<td>Kidneys</td>
<td>1.00</td>
<td>10.0</td>
</tr>
<tr>
<td>Bone total</td>
<td>0.88</td>
<td>8.8</td>
</tr>
<tr>
<td>Liver</td>
<td>0.80</td>
<td>8.0</td>
</tr>
<tr>
<td>Red marrow</td>
<td>0.70</td>
<td>7.0</td>
</tr>
<tr>
<td>Testes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 hour void</td>
<td>0.20</td>
<td>2.0</td>
</tr>
<tr>
<td>4.8 hour void</td>
<td>0.28</td>
<td>2.8</td>
</tr>
<tr>
<td>Ovaries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 hour void</td>
<td>0.30</td>
<td>3.0</td>
</tr>
<tr>
<td>4.8 hour void</td>
<td>0.43</td>
<td>4.3</td>
</tr>
<tr>
<td>Total body</td>
<td>0.16</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**References**


Normal Findings


This procedure adheres to ACR Standards 2002-2003.

JSM
PROTOCOL/01-1
Rev. 6/1/2016