SNMMI Procedure Standard for Bone Scintigraphy 4.0

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The Society of Nuclear Medicine and Molecular Imaging (SNMMI) is an international scientific and professional organization founded in 1954 to promote the science, technology, and practical application of nuclear medicine. Its 18,000 members are physicians, technologists, and scientists specializing in the research and practice of nuclear medicine. In addition to publishing journals, newsletters, and books, the SNMMI also sponsors international meetings and workshops designed to increase the competencies of nuclear medicine practitioners and to promote new advances in the science of nuclear medicine.

The SNMMI will periodically define new standards/guidelines for nuclear medicine practice to help advance the science of nuclear medicine and to improve the quality of service to patients. Existing standards/guidelines will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated. Since February 2014, the SNMMI guidelines have been referred to as procedure standards. Any practice guideline or procedure guideline published before that date is now considered an SNMMI procedure standard.

Each standard/guideline, representing a policy statement by the SNMMI, has undergone a thorough consensus process in which it has been subjected to extensive review. The SNMMI recognizes that the safe and effective use of diagnostic nuclear medicine imaging requires specific training, skills, and techniques, as described in each document.

The SNMMI has written and approved these standards/guidelines to promote the use of nuclear medicine procedures with high quality. These standards/guidelines are intended to assist practitioners in providing appropriate nuclear medicine care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the SNMMI cautions against the use of these standards/guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by medical professionals taking into account the unique circumstances of each case. Thus, there is no implication that an approach differing from the standards/guidelines, standing alone, is below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the standards/guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the standards/guidelines.

The practice of medicine involves not only the science but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these standards/guidelines will not ensure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these standards/guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

Bone scintigraphy is one of the most common functional imaging procedures performed in a nuclear medicine department. It is a sensitive diagnostic test for detection of both benign and malignant osseous abnormalities. Radionuclide bone scans can detect altered metabolic activity much earlier than structural changes appear on anatomic radiographs or cross-sectional imaging such as CT and MRI. Following radiopharmaceutical injection, the tracer accumulation is dependent upon both blood flow and osteoblastic activity. In general, there is increased vascularity and bone remodeling in most benign or malignant bone conditions, and this is often seen as an area of increased tracer uptake on bone scans. However, conventional bone scintigraphy can have limitations. One limitation is

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decreased sensitivity regarding osteolytic lesions such that it is not a reliable test to assess the disease burden in patients with osteolytic metastases. Another potential limitation is inaccurate localization of a bony abnormality. The addition of SPECT or SPECT/CT can help overcome this and improve diagnostic accuracy. Combined SPECT/CT also provides both functional and structural anatomic information. In general, for further specific comprehensive information about ^{99m}Tc- and ^{18}F-NaF–based hybrid imaging, the recommended reading includes SNMMI and European Association of Nuclear Medicine (EANM) practice guidelines for sodium-fluoride PET/CT bone scans, SNMMI Procedure Guideline for SPECT/CT Imaging, and EANM practice guidelines for bone scintigraphy.

II. GOALS

The goal of this procedure standard is to assist nuclear medicine practitioners in recommending and performing bone scintigraphy and in interpreting and reporting the results.

III. DEFINITIONS

Bone scintigraphy is the general term for a diagnostic study used to evaluate the distribution of osteoblastic activity in the body, whether this activity is benign, malignant, or physiologic. There are 4 types of bone scintigraphy:

- Whole-body bone planar scintigraphy is performed to obtain anterior and posterior static images of the entire axial and appendicular skeleton.
- Limited-area skeletal planar scintigraphy (also called spot-view imaging) is performed to obtain additional views after whole-body imaging or as initial imaging over a specific area of interest.
- Multiphase bone scintigraphy (also called 3-phase) usually includes blood flow/vascular images (phase 1), immediate blood pool/soft-tissue images (phase 2), and delayed/skeletal images (phase 3). Phase 1 is a dynamic sequence of planar images of the area of interest obtained as the radiopharmaceutical is injected. Phase 2 includes one or more static planar images of the area of interest immediately after the flow phase and within 10 min after injection of the tracer. Phase 3 images are usually acquired 2–4 h after injection. If necessary, images may be acquired after an additional delay (sometimes referred to as phase 4) up to 24 h later.
- SPECT imaging (with or without integrated CT) is performed to obtain additional tomographic delayed images of a portion of the skeleton.

IV. COMMON CLINICAL INDICATIONS

Common clinical indications for bone scintigraphy include:

- Skeletal metastatic disease and staging (e.g., neuroblastoma or cancers of the prostate, breast, lung, or kidney)
- Primary bone tumors (benign and malignant)
- Occult or stress fractures and shin splints
- Osteomyelitis
- Avascular necrosis
- Arthritides
- Complex regional pain syndrome (formerly called reflex sympathetic dystrophy)
- Bone infarction
- Bone graft viability
- Bone pain that is otherwise unexplained
- Evaluation of distribution of osteoblastic activity before radionuclide therapy
- Accidental and nonaccidental trauma
- Further evaluation of skeletal abnormalities incidentally found on other types of imaging studies
- Prosthetic hardware complications
- Heterotopic ossification
- Paget disease
- Fibrous dysplasia
- Hypertrophic osteoarthropathy
- Bone manifestations of sickle cell disease
- Temporomandibular joint disorders

V. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

Bone scintigraphy should be performed by, or under the supervision of, a physician specialized in nuclear medicine and certified by the appropriate accrediting boards.

B. Technologist

Bone scintigraphy should be performed by a qualified registered or certified nuclear medicine technologist. Refer to the *Performance Responsibility and Guidelines for the Nuclear Medicine Technologist* for further details. In Europe, refer to the *European Qualifications Framework level 6:* EANM benchmark document on nuclear medicine technologists' competencies.

C. Medical Physicist

The medical physicist should be involved in the aspects of protocol/image acquisition and processing as necessary. In addition, acquisition should be performed as recommended by the manufacturer.

VI. PROCEDURE/SPECIFICATIONS OF THE EXAMINATION

Also see the SNMMI Procedure Standard for General Imaging.

A. Study requisition

The requisition should include all clinical information about the patient necessary for correct coding of the study. The requisition should also indicate the ability of the patient to cooperate, if there is need for mild sedation or analgesia, and whether the patient needs to be accompanied by a guardian. Any medications the patient is currently taking should also be noted. Any recent trauma or surgery is also useful information to include.

B. Patient preparation and precautions

1. Pre-arrival and patient instructions

   The rationale for and details of the procedure should be explained to the patient in advance. Any questions should be answered, and if available, written information provided.

   Unless contraindicated, patients should be well-hydrated and drink two or more 8-ounce glasses of water between the time of radiopharmaceutical injection and the time of delayed imaging. In order to promote excretion and minimize radiation exposure, patients should also drink additional fluids and void frequently for at least 24 h after the injection. In addition, patients should empty their bladder frequently between the injection and delayed imaging, including immediately before the scan.

2. Information pertinent to the procedure

   Relevant clinical information should be obtained, including current symptoms; pertinent physical findings; history of fracture/trauma, osteomyelitis, cellulitis, edema, arthritis, neoplasm, or metabolic bone disease; and any functional limitations. Information on any relevant recent imaging studies should also be obtained, including scintigraphic imaging, especially bone scans and imaging with radiopharmaceuticals such as ^{18}F-NaF, ^{18}F-FDG, ^{131}I, ^{67}Ga, ^{111}In, or ^{99m}Tc-sulfur colloid, and anatomic imaging studies such as conventional radiography, CT, or MRI.

   If the patient has received any prior therapy that may affect the results of bone scintigraphy (e.g., antibiotics, corticosteroids, chemotherapy, radiation therapy, diphosphonates, and/or iron therapy), this should be noted, as should any history (and the date) of orthopedic surgery (including the type, presence, and location of implants and any complications) or nonorthopedic surgery (e.g., ileal conduit). Anatomic or functional abnormalities of the urinary tract should also be noted as well as any relevant laboratory results (e.g., prostate-specific antigen in patients with prostate cancer).

3. Precautions

   The technologist should determine whether any female patient of childbearing age is pregnant, and if so, should confer with the ordering/requesting team service to confirm that the procedure is medically necessary and cannot be deferred until after pregnancy and breastfeeding. Per the International Commission on Radiological Protection, ^{99m}Tc-labeled radiopharmaceuticals do not require any change in breastfeeding (unless ^{99m}Tc-NaO_4 is present). Nevertheless, it may be recommended that the patient delay breastfeeding for a minimum of 4 h after receiving a ^{99m}Tc-labeled radiopharmaceutical, and many institutions have the patient delay breastfeeding for 24 h.

   Drugs that may interfere with bone scintigraphy include aluminum-containing compounds, corticosteroids, iron, methotrexate, nifedipine, hematopoietic growth factors, androgen deprivation therapy drugs, estrogens, bisphosphonates, those that interfere with osteoblastic function, nephrotoxic chemotherapy, and E-amino caproic acid. Bone scintigraphy may still be performed while the patient is taking any of these drugs if clinically indicated. However, if a prior bone scan was thought to be non-diagnostic because of interference from one of these medications, the scan should be deferred until the medication can be stopped long enough to minimize interference.

C. Radiopharmaceuticals

Several ^{99m}Tc-labeled radiopharmaceuticals from the bisphosphonate family are available for bone scintigraphy. These include methylene diphosphonate, hydroxyethylene diphosphonate, and 2,3-dicarboxypropane-1, 1-diphosphonate.

1. Characteristics

   ^{99m}Tc decay is by isomeric transition with emission of 140.5-keV γ-rays. The half-life is 6.02 h. ^{99m}Tc-labeled radiopharmaceuticals attach to the bone surface by chemisorption (attachment to hydroxyapatite crystals in bone and calcium crystals in mitochondria). Approximately 50%–60% of diphosphonate tracers attach to bone by 3–4 h after administration. Uptake of diphosphonate tracers in bone is enhanced by increased osteoblastic activity and increased blood flow. The primary excretion route is renal with approximately 70% clearance by 6 h. Clearance is typically delayed in patients with renal impairment.

2. Administration

   Administration is typically intravenous but can also be performed through an indwelling intravenous catheter or butterfly needle if necessary.

   The administered activity is usually 500–1,110 MBq (~13–30 mCi) for adults but may be increased to 11–13 MBq/kg (300–350 μCi/kg) for markedly obese adults. For children, the administered activity is based on body weight according to the guidelines of the European Association of Nuclear Medicine (EANM)/SNMMI Pediatric Dosage Harmonization Working Group. The typical pediatric dose is 170–210 MBq (~4–6 mCi), with a minimum of 20–40 MBq (0.5–1.0 mCi) and a maximum not exceeding the maximum for a healthy adult.

   Bone radiopharmaceuticals are subject to oxidation. Care should be taken to avoid introducing air into the vial and/or syringe. Quality control testing should be performed before administration (see the SNMMI Procedure Standard for the Use of Radiopharmaceuticals).

D. Protocol/image acquisition and processing

The energy window should be centered at 140 keV with a window width of between 15% and 20%.

1. Phase 1 images

   If flow images are acquired, the camera should be positioned over the region of interest before radiopharmaceutical injection. The acquisition computer should be programmed to acquire approximately 30–60 images at 1–3 s/frame. When digital images are acquired, blood flow images may be obtained in a 64 × 64 or greater matrix.
2. Phase 2 images

   Blood pool images should be acquired for approximately 3–5 min/image immediately after the flow phase and within 10 min after injection of the tracer. After 10 min, activity may appear in the skeleton. Blood pool images are usually obtained in a 128 × 128 or greater matrix and with a count density of approximately 300,000 counts per image (150,000–200,000 counts per image may be adequate for the extremities).
3. Phase 3 images

   Routine delayed images are usually obtained from 2 to 4 h after injection of the tracer to allow it to clear from the soft tissues.

   When whole-body scanning is used for routine delayed imaging, the count rate (usually of the anterior chest) should be determined before image acquisition, and the scanning speed should be adjusted so that the images contain more than 1.5 million total counts. The views are anterior and posterior and are usually obtained in a 256 × 1,024 or greater matrix. Whole-body scanning can be accomplished with multiple overlapping images or with continuous images.

   When spot views are used as the primary method of acquiring the routine delayed images, the areas covered by the spot views must overlap so that the entire skeleton is imaged. The recommended counts per region are 500,000–1 million for the thorax and abdomen, 250,000–400,000 for the skull and large joints, and 150,000–250,000 for distal extremities. More counts should be obtained when the field of view is larger. A 128 × 128 or 256 × 256 matrix can be used.

   An additional delay in imaging (6- to 24-h) will result in a higher target-to-background ratio and may permit better evaluation of the pelvis if it was obscured by bladder activity on the routine delayed images. An additional delay may also be particularly helpful in patients with renal insufficiency or urinary retention.

   A pinhole collimator may be used if very high-resolution images of a specific area are necessary. This use is more common in imaging of infants, children, and small structures. Approximately 75,000–100,000 counts should be obtained for pinhole-collimator views. Zoom magnification or a converging collimator may also be used to improve visualization.

   Other views (e.g., lateral, oblique, or tangential) and special views (e.g., frog-leg views of the hips or sitting-on-detector [caudal] views of the pelvis) may be obtained when necessary.
4. Pelvic images/interventions

   The pelvis can be difficult to evaluate when there is overlying bladder activity. In patients with pelvic symptoms, one or more of the following additional views may better evaluate the pelvis: images repeated immediately after voiding, sitting-on-detector (caudal) or oblique images, lateral images, 24-h delayed images, and images acquired immediately after bladder catheterization (which should be reserved for patients in whom visualization of the pelvis is essential).

   Single or multiple rapid (5–10 min/acquisition) SPECT images are preferred to avoid artifacts caused by changes in bladder activity. Bladder artifacts are exaggerated in the plane in which the SPECT acquisition begins and ends. Beginning a dual-head SPECT acquisition with the camera heads in the left and right lateral positions—or a single-head acquisition with the camera head in the posterior position—will help reduce bladder-filling artifact.
5. SPECT and SPECT/CT

   The increased contrast and diagnostic sensitivity and specificity of SPECT and SPECT/CT may help to better characterize the presence, location, and extent of disease in some patients. The acquisition should be performed as recommended by the camera manufacturer.

   Typical SPECT acquisition and processing parameters for a dual-head γ-camera are a 180° detector head orientation, a 360° circular orbit, 60–120 stops, a 64 × 64 or greater matrix, and 10–40 s/stop. An equivalent total number of counts should be acquired if continuous acquisition is used. Three-dimensional iterative ordered-subsets expectation maximization is the typical reconstruction algorithm, with typically 3–5 iterations and 8–10 subsets. Corrections are made for attenuation, scatter, and resolution recovery. Postprocessing usually includes application of a gaussian filter (width at half maximum, 4–10 mm) or a Butterworth filter (conventional parameters of 10.0.5).

   In SPECT/CT, the CT portion is for anatomic localization/attenuation correction and is performed before the SPECT portion using a multi-slice spiral or flat-panel/cone-beam CT scanner (currently up to 64 slices) with a low milliampere-seconds setting to decrease the patient radiation dose. The recommended SPECT parameters are the same as above. The CT parameters typically include a 512 × 512 matrix, a tube voltage of 80–130 kV, an intensity–time product of 2.5–300 mAs (depending on the anatomy being imaged), and application of a high-resolution filter to the final image. A single SPECT/CT field of view is usually 40 cm, and several separate or contiguous fields of view can be used. Fused 3-dimensional SPECT/CT images are usually displayed as 2-dimensional orthogonal (axial, coronal, and sagittal) and maximum-intensity projections.

E. Interpretation criteria

Bone scans are sensitive for detecting skeletal disease but with relatively low specificity, and these studies must be interpreted in light of other information. Reported bone scintigraphy findings should narrow the differential diagnosis as much as possible, and a further, more definitive study should be recommended if needed or if the differential diagnosis is broad. Information that will help in the interpretation includes the patient's history and the results of physical examination, other tests, and findings from previous imaging studies.

An increase in radiopharmaceutical uptake, compared with normal bone, indicates increased osteoblastic activity. The differential diagnosis is long but can be narrowed in light of the pattern of uptake (focal or diffuse), location, and number of findings.

A decrease in uptake intensity or number of abnormalities in comparison with a previous study often indicates improvement and may be secondary to therapy (e.g., radiation or chemotherapy). On the other hand, an increase in uptake intensity or number of abnormalities may indicate progression of disease or a flare response to therapy, caused by increased osteoblastic activity at sites of bone repair.

Focal decreased uptake (i.e., focal area of photopenia) without adjacent increased activity is often caused by benign conditions such as attenuation, artifacts, and absence of bone (e.g., surgical resection). There are some cases where decreased uptake can also represent metastatic disease.

Diffuse increased soft-tissue uptake can be caused by renal failure, dehydration, a shortened interval between injection and imaging, post-trauma, or use of the wrong energy window for image acquisition. Focal increased soft-tissue uptake can be caused by localized infection or inflammation, trauma, infarction, and soft-tissue metastasis, particularly from mucinous primary lesions. Diffuse decreased soft-tissue uptake can reflect a superscan (diffusely increased uptake in bone) or result from a prolonged interval between injection and imaging (focal or diffuse uptake).

Interpretation errors may be caused by urinary contamination or diversion reservoirs; injection artifacts; prosthetic implants, radiographic contrast material, or other attenuating artifacts that might obscure normal structures; homogeneously-increased bony activity (e.g., a superscan); patient motion; increased collimator-to-patient distance; imaging too soon after injection before optimal clearance of the tracer from soft tissues; and restraint artifacts caused by soft-tissue compression. Of note, the technologist should note when there is possible radioactive urine contamination, clean the area with soap and water, and then repeat the examination without contaminated clothing.

Additional sources of interpretation error include prior administration of a higher-energy radionuclide (^{131}I, ^{67}Ga,^{111}In) or of a ^{99m}Tc tracer that accumulates in an organ that may obscure or confound skeletal activity; radioactivity extraneous to the patient; incomplete imaging of the entire bony skeleton; radiopharmaceutical degradation; changes in bladder activity during pelvic SPECT; purely lytic lesions; pelvic lesions obscured by bladder activity; renal failure; and myositis ossificans.

VII. DOCUMENTATION/REPORTING

For general recommendations on all nuclear medicine reports, see the SNMMI Procedure Standard for General Imaging and the American College of Radiology Practice Guideline for Communication: Diagnostic Radiology.

A. Indications

The report should briefly summarize the reason for the examination, the clinical problem, any pertinent medical or surgical history, the results of any relevant laboratory tests or prior imaging studies, and any treatments that may interfere with bone uptake.

B. Technique

The report should include the nonproprietary name of the radiolabeled bisphosphonate and describe the injection site and scanning protocol. If the technologist has injected the patient, this should be documented, including the dose, time, location, and whether the injection was uncomplicated. The scanning protocol should describe any of the following that are used: flow images, blood pool images, delayed images, SPECT or SPECT/CT images (the radiation dose from the CT portion should be stated), and additional intervention images.

C. Findings

The report should include the location and character of any abnormal uptake (abnormally increased, abnormally decreased, abnormal bony or soft-tissue pattern); a comparison with the results of prior imaging studies (if pertinent or available; this comparison—or notation that prior studies are not available—is a quality measure of the Physician Quality Reporting System); and any pertinent additional CT findings (if CT was performed with SPECT).

D. Impression

The impression should include conclusions, diagnoses, or differential diagnoses to answer questions posed by the referring clinician or team, any recommendations for further work-up, and an indication to contact the referring physician or service per local radiologic communication requirements (to include the contact information).

VIII. EQUIPMENT SPECIFICATION

A single- or dual-head-camera may be used. A low-energy, high-resolution parallel-hole collimator is preferable, but a low-energy all-purpose collimator may also be used. An ultra-high-resolution collimator may be used for delayed images.

IX. QUALITY CONTROL AND IMPROVEMENT

See the SNMMI Procedure Standard for General Imaging for general recommendations.

TABLE 1
Radiation Dosimetry in Adults

Radiopharmaceutical	Administered activity (MBq)	Critical organ (bladder)	Effective dose
^{99m}Tc-phosphates (intravenous)	500–1,110	0.047 (mGy/MBq)	0.0049 (mSv/MBq)
		34.8 (mGy/740 MBq)	3.6 (mSv/740 MBq)
		52.2 (mGy/1,110 MBq)	5.4 (mSv/1,110 MBq)

Values for normal bone uptake and normal renal function are from *Radiation Dose to Patients from Radiopharmaceuticals*. London, U.K.: ICRP; 1988:215. ICRP report 53. See also Weber DA, Makler PT Jr, Watson EE, Coffey JL, Thomas SR, London J. MIRD dose estimate report no. 13: radiation absorbed dose from technetium-99m-labeled bone imaging agents. *J Nucl Med*. 1989;30:1117–1122.

TABLE 2
Radiation Dosimetry in Children (5 y old)

Radiopharmaceutical	Administered activity (MBq)	Critical organ (bladder)	Effective dose
^{99m}Tc-phosphates (intravenous)	170–210	0.11 (mGy/MBq)	0.012 (mSv/MBq)
		18.7 (mGy/740 MBq)	2.0 (mSv/740 MBq)
		23.1 (mGy/1,110 MBq)	2.5 (mSv/1,110 MBq)

Values for normal bone uptake and normal renal function are from *Radiation Dose to Patients from Radiopharmaceuticals*. London, U.K.: ICRP; 1988:215. ICRP report 53. See also Weber DA, Makler PT Jr, Watson EE, Coffey JL, Thomas SR, London J. MIRD dose estimate report no. 13: radiation absorbed dose from technetium-99m-labeled bone imaging agents. *J Nucl Med*. 1989;30:1117–1122.

X. SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

See the SNMMI Procedure Standard for General Imaging for general recommendations.

XI. RADIATION SAFETY IN IMAGING

See the SNMMI Procedure Standard for General Imaging for general recommendations.

It is the position of SNMMI that exposure to ionizing radiation should be at the minimum level (as low as reasonably achievable) needed to obtain a diagnostic examination. Radiation dosimetry in adults and children is presented in Tables 1 and 2, respectively.

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XIV. APPROVAL

The Board of Directors of the SNMMI approved version 4.0 at the SNMMI Annual Meeting in June 2018. Version 3.0 was approved on June 20, 2003.