Bone Scintigraphy

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1. Introduction

Bone scintigraphy is a diagnostic imaging technique used to evaluate the distribution of active bone formation in the skeleton using a radioactive tracer. Bisphosphonate molecules labeled with technetium-99m (^{99m}Tc) exhibit favourable tracer characteristics with good localization in the skeleton after intravenous injection. Tracer deposition occurs in proportion to local blood flowand bone remodelingactivity (dependent on osteoblast-osteoclast activity). Unbound tracer is rapidly cleared from surrounding soft tissues.
Most pathological bone conditions, whether of infectious, traumatic, neoplastic or other origin, are associated with an increase in vascularization and local bone remodeling. This accompanying bone reaction is reflected on a bone scan as a focus of increased radioactive tracer uptake. Bone scintigraphyis a sensitive technique that can detect significant metabolic changes very early, often appearing several weeks before they become apparent on conventional radiological images. In addition, the technique provides an overview of the entire skeleton with relatively mode stradiation exposure.
The introduction of hybrid SPECT-CT bone imaging has added sensitivity and specificity as well as complexity to this technique, increasing the need for standardization and experience.

2. Methodology

This guideline is heavily based upon, and in large parts copied from, a preliminary draft of the upcoming EANM guideline on bone scintigraphy. The EANM guideline is based on corresponding guidelines from the Society of Nuclear Medicine and Molecular Imaging (SNMMI) and on previous versions of the European Assiciation of Nuclear Medicine (EANM) guidelines. This guideline is also based on available scientific literature on the subject and made applicable to the Dutch situation.

3. Indications

The indications for bone scintigraphy are numerous and can generally be classifiedinto three distinct clinical scenarios: for analysis when a specific bone disease is present or suspected, to explore unexplained symptoms, or for the metabolic assessment of the skeleton prior to start of therapy. Conversely, bone scintigraphy is not indicated in a number of specific conditions, e.g. due to limitations of the technique in a specific disease context or lack of clinical impact of imaging results. Non-exhaustive examples of both indications and non-indications are outlined below:

3.1 Bone scan is indicated when bone disease is present or suspected

Oncology: breast- and prostatecancer, (cautious analysis of lung-and renal cancer), bone tumours and bone dysplasia, paraneoplastic syndromes (hypertrophic pulmonary osteoarthropathy, algodystrophy, polymyalgia rheumatica, poly(dermato)myositis, osteomalacia, etc.

Rheumatological and osteoarticular infections: osteomyelitis, septic arthritis, spondylodiscitis or spondylitis, septic loosening, avascular necrosis, osteoarthritis, complex regional pain syndrome type I, Tietze's syndrome (costochondritis), Paget's disease.
Orthopaedics, sports & traumatology: periostitis i.e. shin splints, enthesopathies: plantar fasciitis, achilles tendinitis or bursitis, spondylolisthesis (acute or subacute), radiological occult fractures. Insufficiency fractures: osteoporotic vertebral fractures, sacral fracture, femoral head or neck fractures, tibial plateau fractures, tarsal or metatarsal fractures, etc, pseudoarthrosis (non-unions), periarticularexostosis, viability of bone graft).
Paediatrics: osteochondritis of the hip (Legg-Calve-Perthes disease) transient synovitis of the hip, osteoid osteoma, battered child syndrome, bone infarction (sickle cell disease, thalassemia).

3.2 Bone scan may be indicated to explore unexplained symptoms
Sub acute or chronic musculoskeletal or bone pain with normal clinical examination and radiographs. Further exploration of abnormal biochemical (e.g. phosphate or calcium metabolism) or radiological findings.

3.3 Bone scan may be indicated for metabolic assessment prior to start of therapy
Assessment of bone remodelling prior to radionuclide therapy (^{223}Ra, ^{89}Sr, ^{153}Sm-EDTMP, ^{186}Re-HEDP) as palliative treatment for painful bone metastases. Evaluation of the activity of arthropathies prior to synovectomy or before infiltration with corticosteroids of facet joints. Evaluation of osteoblast activity in (suspected) Paget's disease before starting bisphosphonates. Assessment of benign or malignant vertebral compression fracture prior to vertebroplasty or kyphoplasty.

3.4 Specific Indications for SPECT-CT imaging
- The indications for SPECT-CT imaging in daily clinical practice are broad and include (non-exhaustive list):
- Oncology: in abnormal planar scintigraphy to increase lesion localization or in normal planar scintigraphy and high suspicion of pathology to increase sensitivity
- Suspected traumatic injuries of the axial or appendicular skeleton
- Assessment of lesions in the tarsal or carpal small bones, particularly after trauma
- Suspicion of axial or peripheral osteoid osteoma
- Assessment of the spine and sacro-iliac joints in rheumatic disorders
- Diagnosis of osteonecrosis and bone infarction
- Diagnosis of infectious lesions, such as osteomyelitis and spondylodiscitis (complemented with infection imaging)
- Diagnosis of tendinitis
- Evaluation of painful prosthesis
- Evaluation of residual pain after orthopaedic surgery on the axial or peripheral skeleton
- Assessment of malignant or pseudo-malignant lesions
- Exploration of extra-skeletal pathology or uptake

3.5 Bone scan may not be the preferred investigation in the following conditions
Bone lesions with known inconsistent scintigraphic findings: Plasmacytoma, multiple myeloma, chordoma, Ewing's sarcoma.
Benign bone lesions and incidentalomas when adequately characterized by radiological imaging: Bone island, uncomplicated haemangioma, osteitis condens ans ilii, non-ossifying fibromas, asymptomatic enchondroma of the long bones, ganglion cyst, asymptomatic Paget's disease.
Symptomatic degenerative joint disease well characterized on radiological imaging, adequately diagnosed based on pain and a well performed clinical examination.

Bone scintigraphy may not, in general, be the preferred imaging modality in the conditions listed above. Nonetheless, the specific clinical context must be taken into account when determining whether or not there is an indication.

4. Relation to other diagnostic procedures
There is only one substitute technique for visualisation of bone remodeling activity and that is ^{18}F-Fluoride. This technique is superior in almost every way e.g. faster blood clearance, two-fold higher uptake in bone, superior resolution of PET vs SPECT (2 mm vs 6 mm). The main disadvantage is the radiation dose. For ^{18}F-Fluoride this is typically 10 mSv, whereas for ^{99m}Tc-HDP/MDP this is 3 mSv. A second disadvantage of this technique is costs. Depending on local differences both availability and costs may vary, influencing the choice for ^{18}F-sodium fluoride. Conventional X-ray images and CT will show the net effect of increased osteoblastic and/or osteoclastic activity through increased sclerosis (dominance of osteoblastic activity) or osteolysis (dominance of osteoclastic activity). However, this is revealed in a much later stage of a disease compared to a bonescan. Also, it is standard protocol to image the entire skeleton, which is cumbersome to do with conventional X-ray images and may produce a high radiation burden with CT. With recent low dose settings being applied in diagnostic CT imaging the latter argument is no longer valid.
MRI is usually preferedfor characterisation of bone lesions, because of its capability to also characterise soft tissue tumour components of bone lesions. However MRI and bone scans allow visualisation of different types of lesions. The two techniques lead to divergent lists of differential diagnoses and are therefore often complementary. As a screening tool for tumours the bonescan is challenged by ^{18}F-FDG PET-CT (and ^{18}F/^{11}C-Choline PET-CT). These modalitiesshare the benefit of imaging the entire body in a single acquisition. However, ^{18}F-FDG PET-CT has the clear advantage of imaging any tissue with potential tumour burden. Visualisation of extra-osseous tumour deposits on bonescans is limited to sparse situations where soft tissue tumours contain calcifications. The relatively high radiation dose for ^{18}F-FDG PET-CT is a disadvantage: typically 7 mSv for ^{18}F-FDG PET-CT and 3 mSv for ^{99m}Tc-HDP/MDP. Also, there is a difference in price which make bonescans the preferred choice from a cost-effectiveness point of view in situations with a high probability for presence of bone metastases (certain types of tumours with higher prevalence of bone metastases or certain types of complaints suggesting bone metastases).

5. Medical information nessecary for planning

The written or electronic request form should provide sufficient information to demonstrate the medical necessity of the investigation. This should include current signs and symptoms, relevant history (skeletal surgery, trauma, or recent radiation or chemotherapy), and the specific reason for the investigation or provisional diagnosis. Outpatients should also bring the results of other relevant investigations that have already been performed (laboratory, radiological and scintigraphic).

6. Radiopharmaceutical

Tracer:	bisphosphonates are used for performing bone scintigraphy: hydroxymethylenediphosphonate (HMDP or HDP) and 2,3-dicarboxypropane-1,1-diphosphonate (DPD)
Nuclide:	^{99m}Tc decays by isomeric transition with a half life of 6,02 h to ^{99}Tc by emitting 140,5 keV gamma rays

6.1 Pharmacokinetics

The radiolabeled bisphosphonates are incorporated into the surface of hydroxyapatite crystals in proportion with local bone vascularization and osteoblastic activity. After intravenous administration, the plasma clearance of bisphosphonates is biexponential. It is also a function of skeletal uptake and urinary elimination. Four hours after injection, approximately 60% of the injected amount will be fixed to the skeleton, the unbound fraction (34%) is excreted in the urine, and only 6% remains in circulation. Tracer elimination through the gastro-intestinal tract is insignificant. Maximum bone accumulation is reached 1 h after tracer injection and remains practically constant up to 72 h. Clearance of activity from the surrounding soft tissue shows a somewhat slower continuous course that reaches a more optimal bone-soft tissue-ratio between 2 and 3 h.

6.2 Radiopharmaceutical preparation and storage

The bisphosphonates listed above are commercially available, in the form of sterile non-pyrogenic powder, ready for labeling with ^{99m}Tc. Preparation is done in accordance with the manufacturer's procedures. Vials containing the sterile non-pyrogenic lyophilisate should be stored at 4 to 8°C or room temperature, as required by the manufacturer. These kits can be used until the expiry date of the batch (one to two years after the date of manufacture). After labeling, the preparation should be kept between 4 and 8°C, or at room temperature, depending on brand used, and remains stable for eight hours. Because the radiopharmaceutical is susceptible to oxidation, introduction of air into the multidose vial should be avoided.

6.3 Administered activity

The mode of administration is intravenous injection. For bone scintigraphy, the average activity administered by a single intravenous injection should be 500 MBq (300-740 MBq) (8-20 mCi). The administered activity usually ranges between 8 to 10 MBq/kg for adults. Less activity may be used when equipment with higher detector sensitivity or resolution is available, thereby producing similar image quality. For markedly obese adult patients, the administered activity may be increased to 11-13 MBq/kg. If the injected activity falls outside these recommended limits for clinical reasons, any deviation from

this interval should be kept as small as possible. Practitioners could be required to justify administration of activities greater than local or national DRLs.
In children, the EANM recommendations suggest a baseline activity of 35 MBq for ^{99m}Tc-bisphosphonates (with a minimum of 40 MBq) that should be adjusted based on the class of the radiopharmaceutical (class B) and the weight of the child (see the online dosage calculator on the EANM site).

7. Radiation safety

7.1. Pregnancy / lactation

For women of childbearing age, it is necessary to verify the absence of pregnancy. Pregnancy is a strong contra-indication for elective imaging. If medically warranted, radiation exposure should be delayed until after both pregnancy and breastfeeding. Evaluation by other techniques such as ultrasound or MRI is preferred.
According to ICRP 106 there is no need to interrupt breastfeeding, but due to possible free ^{99m}Tc pertechnetate it is advisable to interrupt the feeding for 4 hours

7.2 Radiation exposure

The estimated adsorbed radiation dose to a person is 0,0057 mSv/MBq. For the estimated adsorbed radiation dose to various organs in healthy subjects following administration of ^{99m}Tc-labelled phosphates and phosphonates see ICRP publication 80.

7.3 Radiation protection

Staff radioprotective measures follow the recommendations for good practice (lead castle, syringe shields, wearing gloves during tracer preparation and injection, etc.). The exposure of caregivers on hospital wards is usually very low. Based on the biokinetic model of the tracer (ICRP publication 53) and the dose rate constant of ^{99m}Tc it can be calculated that under extreme conditions (using a fictitious pointsource model with a minimum distance of 20 cm based on a 30 cm circumferential diameter of a (thin) patient and an estimated tissue shielding based on the half-value thickness of water for ^{99m}Tc and an exposure duration of maximum 1h (for instance prolonged performance of an ultrasound or surgery of the truncus) directly (after 15 min transfertime) following injection of a dose of 500 MBq) the effective dossage for a caregiver does exceeds 0,01 mSv (the maximum tollerated per incidence exposure for a radiological worker by Dutch law). For the same distance and exposure duration this will drop below 0,01 mSv after 3 h. Alternatively for a distance of 30 cm (bronchoscopy / surgery of the limbs) after 1 h. Under all circumstances the radiation dose will not exceed 0,1 mSv (the maximum tolerated per incidence exposure for a member of the public by Dutch law).
One should wear disposable gloves for personal care in the 24 h following the administration of radiopharmaceuticals labeled with technetium. Urine and faeces are disposed of into the toilet. Pads, catheters, and containers should be handled with gloves. Hospital waste management accepts materials free of radioactivity only. Therefore all solid waste from hospitalized patients should be collected during three days and kept in storage for a further four days to allow sufficient radioactive decay. For the patient's family no special measures are required. In case of an erroneous tracer administration to a patient for whom the radiopharmaceutical was not intended, it is recommended that the patient is sufficiently hydrated and encouraged to urinate

frequently, in order to limit the radiation dose to the bladder and pelvis. No special radioprotective measures are required in case of a patient's death.

8. Patient preparation/essentials for procedure

8.1 Preparation

When making an appointment, the patient should be informed of how the investigation is performed and of its estimated duration. Also, it should be explained that the patient may eat and drink. Patients should be informed of the need to report pregnancy, any delay in menstrual cycle, or active breastfeeding. An information leaflet and/or display in the waiting room of the nuclear medicine service must be available, and all information should preferably be accessible through the website of the institution. Prior to tracer injection, the nuclear medicine physician or technologist must explain the purpose of the investigation as well as both the expected benefits and disadvantages, and provide answers to any remaining questions. The patient is informed of how the investigation will be performed (e.g. multiple planar acquisitions, additional SPECT-CT, etc), taking into account the specific clinical problem. Unless contraindicated, patients should be well hydrated and instructed to drink at least 0,5 l of water between the time of injection and delayed imaging, and to void their bladder frequently. Drinking a large amount of fluid during the 24 h after radiopharmaceutical administration should also be encouraged. Relevant information that may assist in interpretation of imaging findings are checked with the patient, including:

- History of fractures, trauma, osteomyelitis, cellulitis, oedema, peripheral artery disease, arthritis, neoplasms, metabolic bone disease, or limitation of function
- Current symptoms and physical findings
- History of recent scintigraphy, especially with ^{131}I, ^{67}Ga, or ^{111}In
- Results of prior imaging studies and laboratory results
- History of therapy that might affect the results of bone scintigraphy (see precautions)
- History and dates of prior orthopaedic surgery (e.g. presence and location of prosthetic implants)
- History of anatomical or functional renal/urinary tract abnormalities
- Contraindications for hydration

At this time, an assessment should be made of the physical condition of the patient and whether current symptoms (e.g. pain, immobility, etc) may hamper optimal image acquisition. For patients with severe pain, an appropriate analgaesic strategy should be implemented in consultation with the treating/referring physician. In addition, the scanning parameters may be adapted to accommodate the patient (see image acquisition).

8.2 Possible drug interactions

The main drugs that may interfere with the quality of the scintigraphic images are:

- Androgen deprivation therapy for prostate cancer (bicalutamide, estrogens), because of increased mammary tracer uptake in case of gynaecomastia
- Bone modifying agents (including bisphosphonates and denosumab), because of reduced skeletal tracer uptake
- Corticosteroids, because of reduced skeletal tracer uptake, reduced tracer uptake at fracture sites

- Haematopoietic growth factors, because of increased spinal tracer uptake, possible increased tracer uptake in the appendicular skeleton
- Iron, because of increased renal tracer uptake, increased tracer uptake at site of intramuscular injection, diffuse hepatic tracer uptake
- Methotrexate, because of diffuse hepatic tracer uptake
- Nephrotoxic chemotherapy, because of increased renal tracer uptake
- Nifedipine, because of reduced skeletal tracer uptake

9. Acquisition and processing

9.1 Planar and whole-body acquisitions

For the vascular phase of the investigation, the camera is centered on the area of interest. The dynamic acquisition of 30 to 60 images with a duration of one to two seconds each and with a matrix of 64x64 or 128x128 pixels, is started simultaneously with the intravenous tracer injection.

The early and late planar images are focused on one or more region(s).The early images are acquired between one and ten minutes after intravenous injection of ^{99m}Tc-labeled bisphosphonate. The acquisition time should be three to five minutes with a matrix size of 128x128 or 256x256. Delayed images are usually acquired three to five hours after injection of the radiolabeled bisphosphonate using a predefined duration (four to ten minutes) or number of counts, with a matrix size of 256x256. When using a predefined number of counts, at least 700.000 to 1.000.000 counts are required for scanning the thoraco-abdominal region, 250.000 to 400.000 counts for the large joints and skull, and 150.000 to 250.000 for the distal joints.

A pinhole collimator can be used to complete the investigation by acquiring high resolution planar views of a small area, particularly in infants and children. A total count of 50.000 to 100.000 is recommended. If a pinhole collimator is not available a second best solution is to acquire an image with at least a 256x256 matrix and zoom with a maximum zoomfactor of 2. Acquisition duration should be 4 times longer then for a standard acquisition using a zoomfactor of 2 to retain similar counts per pixel. By this means a pixel size of 1,2 mm is achieved in stead of 2,4 mm. For a modern gammacamera with a center field-of-view system resolution without scatter (scatter correction) of 7,5 mm FWHM at 10 cm a pixel size of 2,4 mm is sufficient to achieve a required pixel size of one third of the systerm resolution in FWHM to retain maximum resolution information. In the eighties empirical research also showed no benefit in increasing pixelation beyond a pixel size of 2,5 mm. This was however established with cameras with a center field-of-view system resolution of 9 mm FWHM at 10 cm. This can be corrected to a lowerlimit of 2,1 mm pixelsize for a modern gamma camera based on the slightly improved system resolution. Also, for acquisitions where the camera is specifically positioned close to and centered on an area of interest the distance can be less then 10 cm and loss of resolution can occur based on anti-aliasing effect of a too small sample size.

The acquisition of whole-body images is routinely performed. Exceptions may include localized symptoms or patient specific factors (children, patients with severe pain, claustrophobic patients) or specific indications with a localized area of interest (imaging of joint protheses, avascular necrosis, assessment of growth activity in the mandibular condyle). The recommended scanning speed is 25 to 30 cm per minute for early phase images (if applicable) and 10 to 15 cm per minute for delayed acquisitions. The image format is 1024x256 or 2048x512. The whole-body images can be processed with a spatial filter to improve pixel to

pixel variation. In children it is common to perform multiple planar acquisition, rather than whole-body images, because children are more likely to move during acquisition. Movement-artefacts are more likely to occur with longer scanning time as is the case with whole-body imaging.
Image acquisitions between 6 and 24 h after injection can be useful in case of poor visualization of the skeleton (e.g. renal insufficiency), for specific anatomical regions (e.g. the pelvis in case of urinary retention), in older patients with impaired bone metabolism (osteoporosis, osteomalacia). Usually, the goal of these images is to detect stress fractures, osteitis, osteomyelitis, or bone metastases.
Planar images do not require particular processing. It should be noted that current digital gamma cameras and workstations allow for changing the range of image contrast and the use of non-linear grayscales (the gamma setting), improving the diagnostic value of the images. In addition, this allows for choosing the optimum contrast when printing images or making sawescreens on behalf of the requesting clinician without access to a common PACS. Relative image quantification may be performed on certain areas.

9.2 SPECT and SPECT-CT acquisitions
SPECT-CT images may follow the whole-body acquisition, to assist in localising anomalies seen on the whole-body images and to improve lesion contrast.
SPECT-CT images are acquired using a hybrid camera that combines a gamma camera and a multi-slice spiral or flat panel/cone beam CT (currently with 1, 2, 4, 6, 8, 10, 16, 40 or 64 slices). The acquisition protocols are specific to each type of machine.
For SPECT, there are usually 60 or 64 projections covering the entire 360° range, with each lasting 10 to 30 sec. The acquisition matrix size is 128x128. Reconstructions are performed using an iterative ordered subset expectation maximization algorithm (OSEM), including classical corrections for attenuation and scatter, and nowadays also resolution recovery. The parameters used for reconstruction may vary between centres, but must permit a good image resolution while maintaining adequate noise levels (using post-processing).
Typically, 3 or 5 iterations are necessary and 8 to 10 subsets. Post-processing is usually performed using a Gaussian filter (width at half-maximum of 4 to 10 mm), or a Butterworth filter (conventional parameters = 10/0,5). Novel reconstruction algorithms, including multimodal reconstruction, are being introduced and can be used alternatively.
The parameters used by the three main hybrid camera manufacturers are shown in Table 3.

Table 1. Parameters from the three main hybrid camera manufacturers.

Manufacturer	General Electric	Philips	Siemens
Reconstruction algorithm	OSEM 3D	OSEM 3D	OSEM 3D
Attenuation and scatter correction	Yes	Yes	Yes
Resolution recovery	Evolution	Astonish	Flash 3D
Parameters	Iterations3 Subsets 10 Butterworth filter (10/0,5)	Iterations3 Subsets 10 Hanning filter (threshold 1,73)	Iterations5 Subsets 8 Gaussian filter (4mm)

The CT is performed immediately before or after the SPECT acquisition. The image matrix size is 512x512, with a tube voltage of 80-130 kV and intensity-time product of 2,5 to 300 mAs, depending on the anatomical region that is being scanned and the dose reduction software that is used. For optimal resolution the Field-of-View for the reconstruction should be decreased as much as possible. This will spread the 512x512 mm matrix over a smaller area. The pitch can range from 1 to 2 mm and the slice thickness is generally 0,33-2,0 mm for scanning extremities and 0,33 to 5 mm for the spine. For 3D viewing based on a single transaxial series it is advisable to keep the slice thickness at or below 2,0 mm to avoid stepartifacts in the coronal and sagital views. If experiencing to much noise with these thin slice reconstructions the viewing software can be used to create thicker slices dynamically. However, these will allways be of lesser quality compared to a direct reconstruction of the same slice thickness. This is something to take into account when selecting the appropriate intensity-time product. The final volume is obtained after applying a high resolution filter. The SPECT-CT acquisition may span a single field of view (FOV), usually covering a region of 40 cm, or can include multiple contiguous or separate FOVs.

9.3 Adapting scan parameters

These suggested imaging parameters may be adapted depending upon the patient's specific clinical condition (e.g. pain due to bone metastases, vertebral fractures, loosening prosthesis, etc). In such circumstances, shortening the duration of the investigation by decreasing the time interval between injection and imaging, reducing acquisition time, or increasing the activity administered can be considered.

9.4 Selecting the appropriate image acquisition technique

- *Sequential planar acquisitions* are used in the assessment of various diseases: infectious or inflammatory diseases, trauma, malignancy or pain syndromes affecting the extremities.
- *Whole body bone scintigraphy* is routinely used in oncology and other settings.
- *Pinhole collimator acquisitions* are preferably reserved for studies in children, and in particular for scanning smaller osseous structures such as the hands, wrists, feet, ankle and the hips (osteochondritis, aseptic necrosis, fractures).
- *Hybrid SPECT-CT imaging* is indicated for the assessment of equivocal lesions on planar bone scintigraphy or localised pain syndromes with normal findings on planar scintigraphy, in particular in the staging of malignancies that have a tendency to metastasize to bone. SPECT-CT can also be used to assess multiple equivocal benign lesions in the axial or appendicular skeleton, in order to increase specificity and diagnostic certainty. It is also of added value to evaluate more complex 3-dimensional osseous structures such as the skull, pelvis, wrist, mid- and hind-foot and ankle.

9.5 Equipment specifications

Planar acquisitions (early and late) and whole-body bone scans are made on a gamma camera with low energy, high resolution parallel-hole collimators. The spectrometric window is centered on the photon peak of ^{99m}Tc (140 keV) and the width is generally set at 15%.

10. Interpretation

10.1. Normal distribution of radiolabeled bisphosphonates

Correct image interpretation requires detailed knowledge of the normal distribution of radiobisphosphonates. Particular attention should be paid to symmetry and homogeneity of tracer uptake. Image quality should be assessed before reporting scan findings (figure 1).

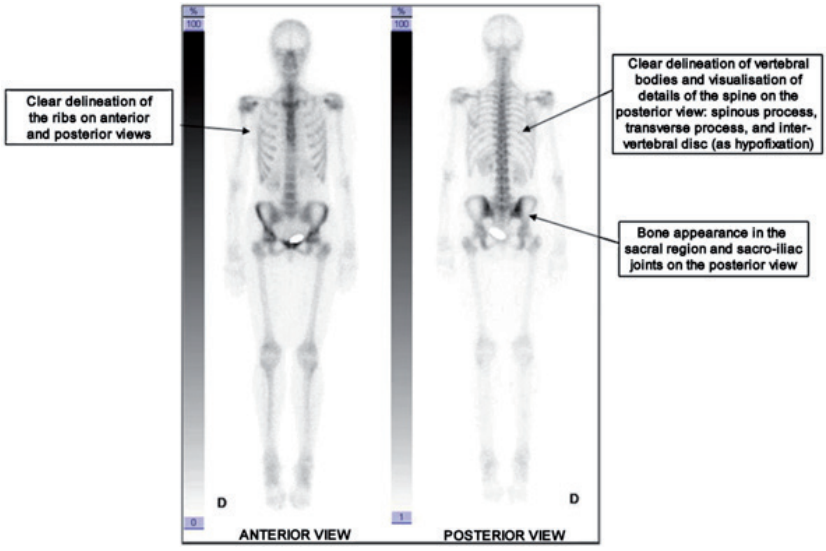

Figure 1. Normal whole body scan. Scintigraphic criteria allowing assessment of the quality and interpretability of a whole body scan.

Increased skeletal uptake, whether focal or diffuse, can be objectively assessed by comparing to the contralateral bone or soft tissue. The localisation, size, shape, intensity, and number of abnormal findings should be described.

Some osteolytic skeletal laesions are seen as a region of reduced tracer uptake, either surrounded by a rim of increased tracer deposition or, conversely, with a punched-out appearance. Bone scintigraphy has a low sensitivity for purely osteolytic lesions (e.g. multiple myeloma).

Lesions detected on bone scintigraphy can take an extended time to normalize, reflecting the protracted course of bone healing which may take multiple months. Therefore, it is rarely useful to repeat the investigation within 4 to 6 months.

An increase in the intensity or the number of foci on scans performed less than 6 months apart may represent disease progression, but can also be associated with a flare phenomenon after therapy

The renal system and urinary tract are normally visualized. Both diffuse and focal tracer uptake can occur in soft tissue. Diffusely increased soft-tissue uptake can be caused by drug interference, failed ^{99m}Tc labeling, severe osteoporosis, renal failure, dehydration, or an insufficiently long interval between tracer injection and image acquisition. Conversely, reduced or absent tracer uptake in soft tissue may be caused by excessive avidity of the osteoblasts populating the axial skeleton, resulting in a "superbonescan" appearance or

excessively long interval between tracer injection and imaging.
Clinical data should be taken into account when interpreting skeletal or joint abnormalities.

10.2. Sources of error

Focal soft tissue hot spots have a wide range of causes (table 2) and may lead to an incorrect diagnosis of skeletal disease on planar imaging. Attenuation artefacts caused by metal objects or motion artefacts are generally obvious. The same holds true for tracer extravasation at the injection site due to (partly) paravenous injection.
The most common artefacts are related to urinary tracer contamination. This may be due to dilatation,stasis or an anatomical variant of the urinary tract, especially after urological surgery, or due to contamination during urination.

Causes of increased uptake in striated muscle
Repeated intramuscular injections of iron supplements
Haematoma/necrosis/sickle cell anaemia
Rhabdomyolysis (mechanical, toxic, electrical, …)
Muscular abscess
Primary tumours (rhabdomyosarcoma, other sarcomas)
Metastases of solid tumours
Poly(dermato)myositis (many causes)
Severe renal insufficiency/hypercalcemia/malignant calcinosis/multiple myeloma
Myositis ossificans

Table 2. Causes of increased uptake in striated muscle.

Bone lesions may be purely or predominantly lytic and therefore barely visible on planar bone scintigraphy, particularly when <2 cm: multiple myeloma, infarction, osteonecrosis, haemangioma, lytic bone metastases. These artefacts and sources of error can generally be intercepted with an additional SPECT-CT acquisition or with a planar image of higher resolution and greater count statistics.

11. Report

The study report must include the following information. A brief summary of the reason for the investigation, the clinical context, the medical and/or surgical history, all relevant blood results, radiological findings, and any treatment that may target or interfe with the osteoarticular system.
Technical information should include the model and optionally the installation date of the camera, the international non-proprietary name (INN) of the radiobisphosphonate, the injected activity in MBq, the site and time of injection, the time of image acquisition, the scanning protocol used (early phase, late phase, SPECT-CT images), the different image acquisitions, the dose length product (DLP) and computed tomography dose index (CTDI) if SPECT-CT is performed.
Also, any specific patient preparation must be reported (e.g. analgesics, anxiolytics, catheter, etc.), in addition to any incidents during imaging or technical limitations of the investigation.
The description of the different images acquired during the investigation includes details of early phase images, specific late phase images, and whole-body acquisitions.
When hybrid SPECT-CT imaging is performed, the description of osteo-articular structures

focuses on the SPECT images and the SPECT-CT fusion images.
Any skeletal anomalies that are seen only on the CT part of the investigation, are also reported. Likewise, other relevant non-skeletal pathology detected on the CT images is mentioned. Software based assessment of bone abnormalities can assist in reporting, but should not replace assessment by a nuclear medicine physician.
The conclusion of the report answers the question posed by the requesting clinician and mentions any associated diagnoses. A differential diagnosis is given when non-specific findings are present on scintigraphy or hybrid imaging. Whenever possible mention the likelihood of the listed diagnoses.
When in doubt or when further work-up is required, the nuclear medicine physician may suggest additional tests (e.g. blood tests, imaging, biopsy, etc.).
If life or limb threatening conditions are found, it is the nuclear medicine physician's responsibility to contact the requesting clinician and organise further care.

12. Literature

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