

GUIDELINES FOR BONE SCINTIGRAPHY IN CHILDREN

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Under the Auspices of the Paediatric Committee of the European Association of Nuclear Medicine

I Purpose

The purpose of this guideline is to offer the nuclear medicine team a framework, which could prove helpful in daily practice. This guideline contains information related to the indications, acquisition, processing and interpretation of bone scintigraphy in children. The present document is inspired by the desire of EANM and American Society of Nuclear Medicine to have guidelines for most nuclear medicine procedures. However this guideline contains information more specifically adapted to the European practice. This guideline summarises the views of the Paediatric Committee of the European Association of Nuclear Medicine. It should be taken in the context of 'good practice' of nuclear medicine and local regulations.

II Background Information and Definition

Since the introduction of ^{99m}Tc labelled polyphosphates, bone scintigraphy has become a widely accepted method for the evaluation of bone disease in children. High quality images are important and require immobilisation and correct positioning of the child as well as optimised equipment. Two or three phase bone scintigraphy is routinely used. Additional techniques such as pinhole images or SPECT can be helpful in special circumstances. Due to the age dependent differences of bone metabolism in the developing skeleton, the interpretation of bone scanning in children is more difficult than in adults and requires knowledge of the appearances of the maturing skeleton⁽¹⁹⁾.

Bone scintigraphy has a high sensitivity in the early detection of pathological bone metabolism indicating bone disease. Traditional x-ray techniques, which describe morphological changes, are less sensitive at the beginning of the disease process. A negative bone scan usually rules out significant bone disorders with a high degree of certainty. In special cases follow-up studies can give additional information about the response to treatment and prognosis. To improve the specificity of bone scintigraphy a combined interpretation of scintigraphy and X-ray is recommended.

III Common Indications

Bone scintigraphy is indicated whenever skeletal pathology is suspected⁽¹⁶⁾.

Main clinical indications are:

A. Infection or Inflammation (1,4,5,14,15,20,22,23,33,40,42,44)

- acute osteomyelitis versus soft tissue inflammation
- subacute and chronic osteomyelitis
- septic arthritis complicating osteomyelitis
- aseptic arthritis

B. Bone Tumours (2,10,11,27,30,41,43)

- benign bone tumours
- malignant bone tumours
- tumourlike lesions such as Langerhans histiocytosis
- bone metastases

C. Aseptic Necrosis (6,7,9,13,26,34,35,38,42,48)

- Legg-Calve-Perthes disease
- aseptic necrosis other than Legg-Calve-Perthes disease and bone infarct
- sickle cell disease

D. Traumatic Bone Disease (3,8,18,25,29,42,47,50)

- equivocal x-ray findings after trauma
- stress fractures
- child abuse (battered child syndrome)
- polytrauma
- complications of fractures and therapy

E. Sudeck's atrophy (42)

- reflex sympathetic dystrophy

F. Bone Scintigraphy Guided Surgery (42)

- e.g. osteoid osteoma

G. Bone Dysplasia (42)

- e.g. Camurati-Engelmann disease

H. Other Clinical Situations in Paediatrics (17,24,32,39,42)

- pain possibly due to bone pathology
- the child with a limp or backache
- child refusing to stand or to use one limb
- fever of unknown origin

Contra indications:

There are no contra indications.

IV Procedure

A. Information about Previous Examinations relevant to this Procedure

All previous bone scans should be available for review to ensure that sufficient time has elapsed since the previous study (depending on the disease). Also the current radiographs and CT or MRI scans, if relevant, should be available for comparison.

B. Patient Preparation

B.1 With Appointment

The parents and the child should receive information about the procedure itself and especially the waiting time between injection and bone scintigraphy as well as the probable duration of the actual scan.

B.2 Preparation of the Patient prior to the Injection

On arrival in the department a local anaesthetic cream can be used; it should be applied at least 60 minutes before the injection ⁽³¹⁾. The entire procedure should be explained to child and parents. In babies and smaller children a special explanation about the necessity of having a quiet patient for the 3-hour images is important. In most cases sedation for the delayed images is not necessary. In a minority of cases when, despite all efforts no co-operation is possible, then sedation might be needed ⁽³⁷⁾.

All children should be encouraged to drink especially during the time between injection of tracer and delayed imaging. This frequently results in voiding spontaneously with little need to insist on voiding. This will result in a lower radiation burden.

B.3 Co-operation / Immobilisation / Sedation

Especially for the 3-hour images the child has to lie absolutely still. Up to an age of 2 - 3 years it is most convenient if the child sleeps during the imaging procedure. Most babies and little children do sleep after lunch and it is recommended to schedule the 3-hour images in the normal daytime sleeping period. Co-operative parents are of great help in these cases. For older children a nice surrounding, entertainment during the imaging procedure and an appropriate attitude towards the child work most effectively for immobilisation. The use of a vacuum mattress and/or sand bags with Velcro straps can support the fixation, but one has to make sure that the distance between child and collimator is not increased by the fixation material.

Sedation is usually not required for a technically satisfactory examination, but in some patients who cannot or do not want to co-operate mild sedation might be necessary. The safest drug then is intranasal or per-rectal midazolam, which will help reduce extreme anxiety. Nevertheless, if sedation is used, it must follow local hospital guidelines. When sedation is used the child will have oral fluid intake restricted and will also not micturate spontaneously; under such circumstances a bladder catheter may be necessary, especially to visualise the pelvis adequately.

C. Precautions

Nil

D. Radiopharmaceutical

D.1 Radionuclide

Technetium-99m (^{99m}Tc)

D.2 Pharmaceutical:

Polyphosphates

MDP (Methylene diphosphonate)

HMDP or HDP (Hydroxymethylene diphosphonate)

DPD (Diphosphonopropanedicarboxylic acid)

D.3 Dose Schedule

Minimal dose: 40 MBq

Recommended maximal dose: 500 MBq

Administered dose should be scaled on a body surface area basis ⁽³⁶⁾.

D.4 Injection Technique:

Position patient: supine.

For a three-phase study start the computer simultaneously with the injection of the tracer.

For a two-phase study start the computer immediately after the tracer injection.

In a one-phase study the injection can be done adjacent to the camera or even in another room.

D.5 Radiation Burden

This is dependent on the age of the child.

For a new-born receiving ^{99m}Tc MDP the effective dose equivalent is 0,11 mSv/MBq. It decreases with the age (0,042 mSv/MBq - 1 year of age; 0,021 mSv/MBq - 5 years of age; 0,014 mSv/MBq - 10 years of age and 0,0089 mSv/MBq - 15 years of age).

The estimated radiation dose is highest for the bone surfaces (1,6 mGy/MBq in a new-born) and the urinary bladder wall (0,4 mGy/MBq in a new-born). This values decrease to 0,076 mGy/MBq (bone surfaces) and 0,042 mGy/MBq (urinary bladder wall) in a 15-year-old child ^(12,46,49).

The radiation burden is calculated on the assumption of a 3-hour bladder void. If oral fluid intake is encouraged with subsequent more rapid bladder emptying, then the above radiation doses will be reduced.

E. Image Acquisition

Depending on clinical question the bone scintigraphy is performed as a one-, two- or three-phase study.

First Phase: The images of the first phase (started with the injection of the radiopharmaceutical) show the arterial blood flow to the region of interest.

Second Phase: The second phase (30 - 120 sec after injection) is the blood pool phase.

Third Phase: The images of the third phase (2 - 4 h post-injection) reflect osteoblastic bone activity.

E.1 Position of Detector

The highest quality images are obtained by having the child as close as possible to the camera face, if possi-

ble on the camera face. A special table -if available- with an aperture for the collimator will allow imaging of the patient lying directly on the collimator. For SPECT studies a small table should be used which will allow the smallest radius of rotation of the camera to achieve the highest resolution.

E.2 Collimators

The radionuclide angiography and the blood pool images are obtained with a low energy all-purpose collimator (LEAP) or a low energy high-resolution collimator (LEHR). For the 3-hour images a low energy high- or ultra-high-resolution collimator (LEHR or LEUHR) should be used. Magnified images with better resolution of small parts e.g. hips, hands or feet can be obtained by using a single aperture pinhole collimator⁽⁴⁵⁾. The resolution of the pinhole collimator is inversely related to the diameter of the aperture (2 - 5 mm). The closer the pinhole to bone the greater the magnification.

E.3 Positioning of the Child

It is recommended to do all imaging with the child lying down. Exceptions include imaging of hands or elbows in bigger children where the child may do better sitting in front of the horizontal camera with the lower forearms positioned directly on the collimator. The child may also sit on the mother's or father's lap if required.

In a lying position, imaging of the skull in lateral position should include the arm of the same side.

Oblique views of the ribs can be taken in a lying position with the camera rotated to an oblique angle.

For adequate visualisation of hips, knees and fibula, the feet should be turned inward with the toes close together (radiographic neutral position).

To detect lesions in the feet, images in the plantar, dorsal and lateral projections are required.

If a child has problems to lie still for any reason or there is a need for differentiation e.g. of activity in the renal pelvis or in the ribs, spot images of the spine or thorax can be acquired in a sitting position.

E.4 Views

There is debate as to the usefulness of the first phase study; these guidelines do however recommend acquisition of the first phase especially in children with primary malignant bone tumours or clinical suspicion of localised bone disease.

In patients with multifocal bone disease blood pool images of the entire skeleton (either spot images or whole body technique) should be done immediately after the injection of the radiopharmaceutical.

Images of the entire skeleton should be obtained in all cases 2 - 4 hours after injection in anterior and posterior view either as static images (up to the age of 4 - 5 years) or in whole body technique, even if the pathology is localised at one site.

Attention: When a localised abnormality is seen, images of this area in two planes are essential; this is especially important with whole body scanning.

Unusual images of the skull, spine and pelvis require SPECT⁽²⁸⁾. In addition in all children who have symptoms related to the spine, SPECT might be useful particularly for accurate localisation of lesions, which have been detected on planar images^(24,32,39). In the presence of localised clinical symptoms but normal planar images SPECT may also be useful. Although there is little data to support the use of SPECT when the planar images of the spine are normal, there is an increasing feeling that the possibility of missing pathology is much reduced by incorporating SPECT of the spine in the examination of children who are suspected of benign disease affecting the spine.

Pinhole images are required for adequate examination of all small parts of the skeleton, e.g. hip, wrist and ankle^(41,45).

A radionuclide side marker should always be used to identify the extremities.

E.5.1 Computer Acquisition Set Up - Radionuclide Angiography

dynamic study (64x64 or 128x128 matrix): over 30 - 60 seconds; 1-2 seconds per frame

E.5.2 Computer Acquisition Set Up - Blood Pool Images

These should be completed within the first minutes after the injection.

static images (256 x 256 matrix): 50-100 kcounts for hands, feet and knees
300 - 500 kcounts for the skull, thorax, spine and pelvis

whole body images (256 x 1024 matrix) : scan speed 30 cm/min or total imaging time 10 minutes

E.5.3 Computer Acquisition Set Up - Bone Scan Images

2 - 4 hours post-injection start imaging with empty bladder, if possible and perform pelvis imaging as soon as possible after micturition.

static images (256 x 256 matrix) : 50 - 100 kcounts for hands and feet
100-200 kcounts for the knees
300 kcounts for the skull
500 kcounts for thorax, spine and pelvis.

whole body images (256 x 1024 matrix):

scan speed 8 cm/min from 4(5) - 8 years
scan speed 10 cm/min from 8 - 12 years
scan speed 12 cm/min from 12 - 16 years
scan speed 15 cm/min over the age of 16 years
or total imaging time 30 minutes

E.5.4 Computer Acquisition Set Up - SPECT

SPECT (128x128 matrix recommended): technique depends on the type of camera system

E. 5.5 Computer Acquisition Set Up - Pinhole Images

pinhole images (256x256 matrix) : two views (affected site and contralateral site)
600 - 900 seconds per image
or
100 kcounts for the non-affected site and the identical acquisition time
for the affected site for a better comparison

F. Interventions

In children who cannot empty their bladder for any reason a bladder catheter may be necessary, especially to visualise the pelvis adequately.

G. Processing

The processing of the images should be done before the child has left the department.

Reframe dynamic images to 2 or 3 second images.

SPECT processing: check for movement; use a filter, which moderately increases the contrast and does not smooth the data too much. Details are depending on the camera and computer interface used. Reconstruct transverse, sagittal and coronal slices relating to the body axis. In some cases (e.g. lower spine) a reangulation relating to the organ axis might be necessary. The slice thickness should be equal to the resolution of the camera system.

H. Hard Copy Output

1. series of images of the radionuclide angiography.
2. blood pool images and 3-hour images of whole skeleton from anterior and posterior, including spot images.
3. SPECT display transverse, coronal and sagittal.

I. Interpretation / Reporting / Pitfalls and Normal Variants

Normal appearances of the paediatric skeleton include clear visualisation of the growth plates best seen at the knees. Increased or decreased bone metabolism is always shown as an increased or decreased uptake of the radiotracer. Interpretation of the images should always be done with the knowledge of the results of X-ray, Ultrasound and MRI and clinical history (e.g. a long phase of immobilisation can lead to a decreased bone uptake of the radiotracer; similarly in sympathetic reflex dystrophy the painful limb is generally the hypoactive one). The knowledge of the normal appearance of the skeleton in different age groups is important. Another pitfall is a lack of increased uptake in osteomyelitis with increased intraosseous pressure and therefore reduced perfusion.

Pitfalls can be caused by contamination with radioactive urine, as well as movement of the child or inadequate positioning e.g. asymmetrical positioning of the thorax.

A thorough knowledge of possible normal variants like the age dependent ossification e.g. of hand, foot, skull and sternum or the normal synchondrosis of the posterior pubic ramus ⁽²¹⁾, reduces the risk for false positive statements. The "shining through" of the activity from the costo-chondral junctions on the posterior view of the thorax should not be mistaken for multiple rib fractures.

J. Quality Control

The child must be in a straight and symmetrical position for all images if possible (depending of the child's condition). The separate visualisation of the epiphyseal plates of tibia and fibula as well as radius and ulna are criteria for a high quality bone scintigraphy. The quality of the bone scan can also be judged by the sharp appearance of the epiphyseal plates of femora, tibiae and fibulae.

For a good visualisation of the pelvis the bladder should be empty.

The vertebrae and ribs should be clearly recognised one by one.

V Issues requiring further clarification

Nil

VI Consise bibliography

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