The skeleton is a metabolically active organ that undergoes continuous remodelling throughout life. Normal healthy bones are dynamic structures with inherent basal levels of turnover sustained by balanced osteoblastic and osteoclastic activity. Increased bone turnover (ie osteoblastic activity) is the central mechanism of attempts at bone healing in case of any insult, whether it is benign or malignant.

Radionuclide 99mTc-MDP is a tracer that gets adsorbed into bone in proportion to bone turnover and thus provides an "osteoblastic map" of the entire skeleton. 99mTc-MDP planar bone scintigraphy has historically been employed in regular staging and re-staging of many cancers as well as for answering specific questions in orthopaedics. Many malignancies, eg breast, prostate, lung, thyroid and renal cell carcinomas, have a tendency to metastasise to bone.

Most bone metastases, even when they are predominantly osteolytic, show some degree of increased bone turnover, thereby making them appear as "hotspots" compared to the background skeletal uptake. Similar increased bone turnover can be seen in other non-malignant causes of bone insult, eg infection, degenerative disease, fractures etc. This makes bone scintigraphy a sensitive modality for detection of all such lesions and disease processes.

The major limitation of this functional technique has been its limited specificity. Single photon emission computerised tomography (SPECT) imaging improves the sensitivity and accuracy of prediction of skeletal lesions by virtue of increased lesion contrast and provision of tomographic information. However, a substantial number of skeletal lesions remain equivocal, due to limited spatial resolution of the technique and lack of precise anatomical localisation. Integrated SPECT/CT systems have become available recently, which provide co-registered functional and structural data allowing precise anatomical localisation and characterisation of the underlying disease process by virtue of morphological CT characteristics. It is important to note that accurate diagnosis of both benign as well as malignant disease is equally important for patient management. In many cases, such interpretation can be binary to subsequent patient management.

Routine use of SPECT/CT has a radiation burden which may be deemed as unjustifiable, although there are some early data to support this approach. Due consideration is required for appropriate use of this technology, with additional steps being taken to reduce patient dose to as low as is practicable. A normal tracer distribution on planar bone scan usually makes the use of SPECT/CT unnecessary. Although in many cases the correct diagnosis can be derived from planar bone scans, SPECT/CT is necessary to make the correct diagnosis in case of undefined lesions. We have used the following criteria at our institution for the last few years to add limited low dose SPECT/CT where required to improve diagnostic accuracy (figure 1).

### Bone SPECT/CT in malignant bone disease

Accurate characterisation of bony metastatic disease is of high clinical importance in staging, management and prognosis of cancer patients (figure 2). Spine and pelvis have traditionally been difficult areas to interpret accurately on planar and SPECT imaging. These are also the most common sites of metastatic involvement, being rich in red marrow content. These areas are also frequent sites of co-existing pathology, eg degenerative disease, compression fractures etc. SPECT/CT allows accurate characterisation of spinal lesions into benign and malignant disease. This results in significant reduction of equivocal reports and improved diagnostic confidence.

CT is perceived to be superior to MRI in detecting subtle bone destruction, which can prove to be invaluable in clinching accurate diagnosis. MRI is widely accepted to be the most sensitive modality for detection of vertebral metastases as it is able to detect early bone marrow replacement. SPECT is quite sensitive in picking up subtle increased osteoblastic activity associated with early metastatic disease. Not infrequently, increased uptake on SPECT may not have a definite abnormal CT correlate in early metastatic involvement. The reason for this is that in early phase, the osteoblastic process may not as yet be so well-established to be detectable as macroscopic sclerosis on CT. In such cases, it may be prudent to seek correlation with MRI.

Comparison studies of fused SPECT/CT versus SPECT alone or side-by-side correlation of scintigraphic and CT images in oncology patients have shown improved diagnostic confidence in differentiating malignant from benign bone lesions for the fused SPECT/CT cohort. Strobel et al showed 100% specific diagnosis being made with SPECT/CT in the series consisting of 37 patients with 42 lesions. This was in comparison with 64% specific diagnoses being made with planar scintigraphy and 86% with SPECT alone. Horger et al in their series showed 92% indeterminate lesions on SPECT being accurately characterised with SPECT/CT in 44 patients with 52 total indeterminate lesions.

### Bone SPECT/CT in benign bone disease

There are increasingly accumulating data about the use of SPECT/CT for diagnosis and management of benign bone conditions, eg trauma, wrist pain, low back and hip pain, following orthopaedic surgery of ankle and feet, infection, knee pain and for guiding sites for bone biopsy. Even-Sapir et al published their experience in using low dose SPECT/CT in 76 non-oncological patients with non-specific findings on planar imaging. SPECT/CT allowed a final diagnosis to be made in 58% (49/85) of lesions and 59% (45/76) of patients with no requirement for additional imaging. It also guided additional imaging in another 30% (23/76) of patients.

Solitary and occasionally scattered few foci of uptake in the ribs are a common finding on planar bone scans. Many of these patients do not have any recalled history of significant trauma. SPECT/CT has the capability to characterise undisplaced or subtle fractures accurately in ribs and elsewhere (figure 3).

In the extremities, SPECT/CT can accurately localise subtle fractures not visible on planar x-rays. The anatomical information available allows accurate surgical management. It is also possible to make other specific diagnoses, eg impingement syndromes, osteochondral defects etc.
In case of low backache and hip pain, SPECT/CT allows determination of definite metabolically active sites of degenerative and facet joint disease.\(^\text{10}\) It allows accurate differentiation of anatomically close separate disease sites, eg costovertebral joint osteoarthritis vs interfacet joint osteoarthritis, which allows precise targeting for treatment. A similar example is patients with coexistent chronic osteoporotic vertebral collapse and interfacet joint osteoarthritis. Besides showing typical degenerative disease involving the hip joint, SPECT/CT may show specific diagnoses, eg femoral acetabular impingement syndrome, avascular necrosis of femoral head, fracture of degenerative subchondral cyst, unrecognised impacted fracture of the femoral neck, sacral insufficiency fracture etc, as the cause of a patient’s low backache and hip pain (figure 4).

SPECT/CT can be helpful in localisation and characterisation of causes of knee pain such as osteoid osteoma, loosening of knee replacement prosthesis, maltracking of patella, osteochondral defects etc.

In the setting of suspected bone infection, SPECT/CT can be performed in addition to a triple phase planar bone scan and can significantly improve diagnostic accuracy, eg post-operative, diabetic foot etc. Both the functional and structural components of the study are helpful in determining the presence or absence of infection, ie uptake extending into the bone and evidence of bone rarefaction or destruction on CT.\(^\text{11}\) This examination can be undertaken first with an additional labelled white cells scan, if required.

**Conclusion**

There is a rapidly accumulating evidence base for use of SPECT/CT in bone imaging, both in oncology and non-oncology settings. This technique significantly improves diagnostic accuracy when compared to planar bone scintigraphy and SPECT imaging alone.

**References**


**Figure 1**

Criteria for addition of SPECT/CT to planar bone scan.

1. Indeterminate uptake not clearly metastatic or due to degenerative disease. Acquire separate acquisitions, if foci of uptake are far apart.
2. No recent suitable imaging within previous eight weeks allowing direct side-by-side comparison. No scan anticipated within the coming week which would cover the area of uptake.
3. Exercise lower threshold for obtaining SPECT/CT tailored to clinical information/specific tumour type, eg sternal uptake in breast cancer, spine/pelvis/upper femoral uptake in prostate cancer, specific area of bone pain provided by requester.
4. Repeat SPECT/CT only if appearances on planar bone scan have changed and metastatic disease is not known before.
5. Get medical opinion, especially when in doubt. Involvement of more experienced senior radiographer colleagues is also encouraged.
6. For extremities and for Paget’s disease, perform plain x-rays unless specifically asked to undertake SPECT/CT.
7. Continue with current established practice of obtaining plain x-rays to assess for risk of fracture in long bones with metastatic involvement (if not already included within SPECT/CT field).
Figure 2
A 55-year-old lady with breast cancer was referred for a staging scan. Sternal uptake confirmed to be due to lytic metastatic disease on SPECT/CT (see red cross hair).

Figure 3
A 72-year-old man with lung cancer. Presented with right hip pain. SPECT/CT showed an unrecognised impacted fracture of right neck of femur (see red cross hair). Patient confirmed recent history of trauma on specific subsequent inquiry. There is also degenerative disease affecting right shoulder joint, sinus disease and dental disease in the left mandible.
Figure 4
An 80-year-old lady with previous history of breast cancer. She attended to have a re-staging bone scan triggered by severe backache. SPECT/CT demonstrated the extensive spinal uptake to be due to advanced degenerative disease along with a sacral insufficiency fracture (see red cross hair), with no evidence of malignant bone disease.