Combined SPECT/CT bone scintigraphy; a superior technique for diagnosis of benign and malignant conditions in the spine.

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Learning objectives

To show the benefits of SPECT/CT versus planar imaging and CT alone in the diagnosis of both benign and malignant conditions.

In this poster we will describe in detail the new combined SPECT/CT scanners and relevant acquisition protocols. We will also present imaging findings of benign and malignant conditions of the spine, which can be definitively diagnosed with SPECT/CT. In addition we will describe the limitations of this technique, radiation dose burden and suggest algorithms to guide its use in clinical practice.
Background

Planar bone scintigraphy and CT are well established techniques in the diagnosis of benign and malignant conditions of the spine. However, both techniques have limitations that frequently lead to further tests being required for definitive diagnosis. The recent development of 3D reconstruction methods in SPECT/CT scanners has improved the sensitivity and specificity of these techniques with no significant increase in imaging time or patient dose.

Bone scintigraphy is one of the most commonly performed studies in a nuclear medicine department. It is frequently performed for the staging of known malignancies. Secondary metastasis are the most common bone tumours occurring in 30-70% of all cancer patients with breast cancer, prostate cancer and lung cancer being the most common causes[1]. 90% of metastatic bone lesions occur in the axial skeleton with the spine being the most common site(39%)[2]. Bone scintigraphy has been shown to be very sensitive in detecting skeletal metastasis[3], playing a role in assessing bulk of disease, treatment response and on occasion to guide biopsies. Isolated lesions on bone scintigraphy are often equivocal with the difference between trauma, degenerative change and tumour being difficult to diagnose. In the past, extra plain radiographic, computed tomographic and magnetic resonance studies would have been required for diagnosis, however with recent technological advances and a vogue for fusion of anatomical and functional diagnostic studies, SPECT/CT is finding a role for itself at the forefront of this diagnostic quandary. A recent study by Ndlovu et al. of 42 patients with equivocal skeletal lesions on planar scintigraphy showed a significant reduction in the proportion of patients with equivocal lesions after SPECT/CT, 14% compared with 48%( P=0.0015) and that the accuracy of SPECT/CT on a lesion-wise basis was also significantly better, 92% compared with 67%(P<0.0001)[4].
**Fig. 0:** 64 year old male with widespread bony metastatic disease. Diagnosis can be made in this instance on planar scintigraphy, however the SPECT/CT provides much more anatomical and functional information.

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The first commercial SPECT/CT scanner was the Hawkeye system produced by GE Healthcare (Haifa, Israel). The x-ray system operated at 140kVP with a tube current of only 2.5mA, this resulted in a significantly lower radiation dose than would be delivered using a conventional scanner (by a factor of 4-5). The result was inferior quality CT images secondary to both the lower dose and the poorer axial resolution. It must however be realised that the CT component was initially developed as a means of attaining a better quality attenuation map for use with the emission data[5]. While technological advances have meant that diagnostic quality CT can be performed if required, it is not often necessary as the bone imaging on low dose CT is adequate for accurate diagnosis of spinal lesions.

We have reviewed all the SPECT/CT studies carried out in our institution for the last 9 months. These were primarily carried out on patients with known malignancies for either symptomatic evaluation or screening purposes. As this is an educational exhibit we have selected a few cases to illustrate the diagnostic benefits attained with combined SPECT/CT acquisition.

All patients were scanned on a Philips Bright View XCT scanner. This combines a flat panel based volume CT with Coplanar SPECT imaging.

The injected activity of the technetium-99m-MDP from the bone scan was between 600-750 Mbcq and this was combined with a low dose CT using the scanning parameters of 120kV and 20mA. Three beds of CT are acquired (14cm each) in 1mm slices. Each bed/segment takes 12s to acquire. The matrix size is 512 x 512 and the reconstruction algorithm used is iterative reconstruction (3D OSEM - ordered subset expectation maximisation) implemented with distance dependent resolution modelling (proprietary name Astonish).

The SPECT/CT scan takes approximately 17 minutes to perform, less than 1 minute for the CT component and 16 minutes for the SPECT. The SPECT timing alters with size of body part being imaged.

In our department the images are reported by physicians with dual certification in radiology and nuclear medicine, which is typical of the practice of nuclear medicine and PET in Ireland. In addition the scans are performed by technologists with training in general radiography and nuclear medicine, many of who have completed certification in CT. We do not use intravenous or oral contrast. The contrast resolution of the cone-beam
CT is poor and contrast would not add significant information. If the clinical indication justifies the use of contrast, we perform the CT on a diagnostic scanner and fuse the SPECT scan with this, if needed.

SPECT and CT are very sensitive for osseous metastatic disease but non-specific. Both modalities, when reported in isolation, frequently report a suspicion of osseous metastatic disease but require another examination for confirmation. We have found that SPECT/CT permits a very high degree of confidence in confirming or excluding metastatic disease without resort to a second examination.

Case 1

A 55 year old female with a history of high risk node positive breast cancer who underwent left mastectomy 3 years prior presented with acute onset severe back pain. Whole body bone scintigraphy demonstrated lesions in the spine. Although this was highly likely to be metastatic disease, potentially degenerative changes could have resulted in some of these findings. SPECT/CT demonstrated that the hot spots on the bone scan matched to lytic lesions at T10 and L3. Six months later she went onto have an MRI for progressive lower limb neurology which illustrated progressive disease.
**Fig.** Case 1: Planar scintigraphy, illustrating abnormal uptake in the thoracic and lumbar spine.

**References:** Radiology, St James' Hospital - Dublin /IE
**Fig.**: Case 1: Planar, SPECT and SPECT/CT images Confirming lytic lesions in T10 and L3 in a 55 year old female with prior breast cancer.

**References:** Radiology, St James' Hospital - Dublin /IE
Case 2

A 57 year old male recently diagnosed with prostate cancer, presented for staging bone scan. Again, whole body bone scintigraphy is abnormal with a pattern suspicious for metastasis. In this group of patients, degenerative disease is ubiquitous and frequently mimics metastatic disease. In this case we see that the CT component SPECT/CT illustrated an isolated sclerotic metastasis to the T10 vertebral body. Although, this
strongly suggested by the whole body imaging, the scintigraphic pattern can be mimicked by benign disease (see case 3). We now routinely do SPECT/CT of the lumbar spine in this group of patients.

Fig.: Case 2: Isolated abnormality in thoracic spine on planar scintigraphy

References: Radiology, St James' Hospital - Dublin /IE
**Fig.**: Case 2: Planar, SPECT and SPECT/CT confirming sclerotic metastasis to T10.  
**References**: Radiology, St James’ Hospital - Dublin /IE
Fig.: Case 2: CT component showing T10 sclerotic lesion.

References: Radiology, St James’ Hospital - Dublin /IE

Case 3

A 63 year old male with hormone resistant Prostate cancer presented with back pain. Whole bone scintigraphy was strongly suspicious for metastatic disease at L4, however on review of the SPECT/CT images it was clear that the uptake was due to a superior endplate fracture. This case provides a nice contrast to case 2. Traditionally we are taught that isolated tracer uptake in a vertebral body in a patient with a known malignancy has
roughly a 50% chance of being a metastasis. In case 2 and Case 3, we can see how SPECT/CT improves the clinician's specificity in confirming or rejecting metastasis.

**Fig.**: Case 3: Suspicious abnormality in L4 in a male with hormone resistant Prostate cancer

**References:** Radiology, St James' Hospital - Dublin /IE
Fig.: Case 3: Planar scintigraphy, SPECT and SPECT/CT show this lesion represents a superior end-plate fracture of the L4 vertebral body. This case may well have been a false positive on Planar scintigraphy and SPECT alone.

References: Radiology, St James' Hospital - Dublin /IE
Fig.: Case 4: L4/L5 Facet joint hypertrophy on SPECT imaging

*References:* Radiology, St James' Hospital - Dublin /IE

**Case 4**

A 74 year old male with recently diagnosed adenocarcinoma of the prostate presented for a staging bone scan. Whole body imaging demonstrated increased tracer uptake in the posterior elements of L5. This a common finding in patients of this age and is very difficult to interpret with confidence. Both degenerative and metastatic disease can have this appearance. SPECT/CT confirmed that this uptake was related to large osteophyte at the L4/L5 intervertebral disc level.
Fig.: Case 5: abnormal uptake in lumbar spine

References: Radiology, St James' Hospital - Dublin /IE
**Fig.**: Case 5: SPECT/CT shows that the abnormal uptake corresponds to a large osteophyte.

**References:** Radiology, St James’ Hospital - Dublin /IE

**Case 5**

A 74 year old female with a past history of ovarian carcinoma and serosal liver deposits presented with acute lower back pain. Uptake in the lumbar region correlated with L4/5 and L5/S1 facet joint hypertrophy. The uptake identified in the sacral region had no CT
correlate. In this instance the CT was useful in excluding neoplastic pathology and she was felt to have an acute sacral stress fracture.

**Fig.**: Case 6: Abnormal uptake in the lumbo-sacral region

**References**: Radiology, St James’ Hospital - Dublin /IE
Fig.: Case 6: SPECT/CT shows facet joint hypertrophy at the L4/L5 and L5/S1 level. There is also abnormal uptake in the right sacrum.

References: Radiology, St James' Hospital - Dublin /IE
Fig.: Case 6: CT shows no lesion in the sacrum. Thus the abnormal signal intensity likely relates to a sacral stress fracture.

References: Radiology, St James' Hospital - Dublin /IE

There are limitations with SPECT/CT. As with all forms of imaging, orthopaedic hardware will reduce the sensitivity of the study with failure to accurately detect subtle lesions in a periprosthetic distribution. Diffuse bone marrow disease will be missed and as a low dose CT is used soft tissue lesions associated with bony abnormalities may not be as easy to visualise.
Conclusion

In our department we have found SPECT/CT bone scintigraphy to be especially useful in patients with prostate cancer. These patients frequently have degenerative disease in the spine that can result in false positive diagnosis of metastatic disease. We now routinely perform SPECT/CT of the lumbar spine in all prostate cancer patients except those with obvious diffuse metastatic disease on their whole body image.

SPECT/CT is also routinely performed in cases where there is a clinical suspicion of degenerative or inflammatory disease in the spine. For other patients, a SPECT/CT is performed after review of the whole body image. We have also found SPECT/CT very useful in assessing degenerative disorders of the feet, as a guide for steroid injection and a way of monitoring the results of surgery. The fusion of the metabolic data and CT give both the radiologist and referring clinician a high degree of confidence in the result.

SPECT/CT bone scintigraphy is a powerful new technique, which combines the functional information from bone scintigraphy with high resolution anatomical information from CT to provide more information than is available from each modality on its own, providing, in many cases, a 'one-stop-shop' for assessments of disorders of the spine.
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References


