

Radionuclide SPECT/CT in oncology

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Introduction

Radionuclide imaging employs radiolabelled tracers in the investigation of suspected cancer, subsequent staging, response assessment and the assessment of recurrence. Highly specific tracers, that target cellular receptors and metabolic pathways, are used in investigating patients with known or suspected cancers.

Radionuclide imaging techniques have superior sensitivity compared to anatomic techniques and provide functional/metabolic information. However historically, nuclear medicine studies have suffered from reduced specificity, which is partly related to difficulties with localisation and characterisation. The combination of single photon emission computed tomography (SPECT) and computed tomography (CT) into a single study, providing both functional and structural information in a single event, can assist localisation and the integration of the anatomical features can improve specificity, therefore improving diagnostic confidence. The technical advances fusing diagnostic CT with multiple detector SPECT systems have developed significantly over the last decade and the evidence for its routine use in oncology is evolving.

SPECT/CT: sentinel lymph node biopsy

Sentinel lymph node biopsy (SLNB) is a technique, commonly used in patients with melanoma and breast cancer. Currently the indications for SLNB are expanding and it has applications in gynaecological, penile, testicular, prostate and oropharyngeal cancers. Conventional radio-nuclide SLNB with ^{99m}Tc-nanocolloid is performed by acquisition of dynamic and delayed static images after injecting the radiopharmaceutical around the lesion. However, limitations/pitfalls of planar technique include false negative and false positive results.¹⁻³ Common false negative results are caused by:

- lymph node lying close to the injection site can be missed;
- sentinel node with little radioactivity, and;

- two lymph nodes lying close to each other/overlapping giving the appearance of a single node.³

False-positive findings can be due to:

- second-tier nodes, lymphangioma or lymphatic lakes reported or mistaken for a sentinel nodes and;
- radioactive skin contamination.³

Current evidence favours the use of ^{99m}Tc-nanocolloid SPECT/CT to overcome these limitations.^{1,2,4} The authors favour using SPECT/CT in addition to dynamic imaging. Several studies have shown that SPECT/CT can improve sensitivity with more SLNs identified than with conventional dynamic and delayed planar alone.¹ Additional potential advantages include:

- improved localisation;
- change in surgical approach;
- identification of false positives (contamination or spill over from the injection site);
- detection of additional nodes in obese breast cancer patients^{1,2,4} (**figure 1, table 1**).

SPECT/CT: thyroid cancer

Diagnostic and therapeutic radioiodines are used in the management of patients with thyroid cancer. ¹³¹I sodium iodide is a widely used radiotracer for therapeutic purposes. Following thyroidectomy, planar imaging can be challenging for precise localisation of tracer uptake, primarily due to a lack of anatomical landmarks,⁵ and occasionally physiological uptake can be misinterpreted as residual or recurrent disease. Several studies have reported the limitations of ¹³¹I whole body scanning, with the need for subsequent correlative imaging or diagnostic procedures. The addition of SPECT/CT imaging improves anatomical localisation and can provide additional information, which leads to changes in final diagnosis/interpretation.⁵⁻⁹ The major advantages of SPECT/CT in thyroid cancer are summarised in **table 1**. In general, the use of SPECT/CT may be useful in patients with:

- tracer uptake outside the thyroid bed;
- equivocal tracer activity in the thyroid bed;
- negative whole body radioiodine scan in patients with rising thyroglobulins (Tg)⁵⁻⁹ (**figure 2**).

SPECT/CT: neuroendocrine tumours

Radionuclide SPECT and PET imaging in neuroendocrine tumours is supported by several different radiotracers such as ¹¹¹In-pentetreotide, ¹²³I-metaiodobenzylguanidine (¹²³I-MIBG), ⁶⁸Ga-DOTA, fluorine-18-fludeoxyglucose (¹⁸F-FDG) and fluorine-18-L-dihydroxyphenylalanine (¹⁸F-DOPA). Local use can vary depending on the clinical scenario and availability. Differentiating physiological uptake from pathology, accurate localisation and characterisation of suspected lesions can be improved with SPECT/CT compared to planar or SPECT (**figure 3**). Perri et al (n=81) reported ¹¹¹In-DTPA-octreotide SPECT/CT to provide greater diagnostic accuracy than SPECT for both patient-based analysis and lesion-based analysis.¹⁰ In addition, the number of equivocal results with SPECT/CT was relatively lower when compared with SPECT. Overall, lesion localisation was better with SPECT/CT than SPECT alone (95% vs 46%).¹⁰ Castaldi et al (n=54) reported improved anatomical localisation in 37% of patients and altered patient management in 26% by ¹¹¹In-DTPA octreotide SPECT/CT.¹¹ In a retrospective analysis, Rozovsky et al have reported ¹²³I-MIBG SPECT/CT to provide additional information in 53% of the studies in patients with pheochromocytoma and

neuroblastoma.¹² Overall, similar results have been published supporting the use of SPECT/CT in evaluating patients with neuroendocrine tumours and the advantages are summarised in **table 1**.¹⁰⁻¹²

SPECT/CT: malignant bone disease

Radionuclide bone scans (99mTc-MDP) are used in the assessment of benign and malignant bone disease. It is a sensitive test for detecting bone pathology/abnormalities before anatomical/structural changes are evident. However, in patients with cancer increased tracer uptake is not specific for bone metastases. Degenerative disease is common in the elderly oncology population and can coexist with or mimic metastasis and lead to false positive diagnosis.¹³ In particular for spinal imaging, radionuclide bone SPECT provides better localisation of areas of increased tracer uptake than planar imaging. However, in our experience SPECT alone is often insufficient to provide a definitive diagnosis and complementary anatomical imaging is often required. Radionuclide bone SPECT/CT is reported to be useful in assessment of indeterminate bone lesions noted on both planar and SPECT imaging (**figures 4 and 5**). The majority of the data reported in the literature supports the use of SPECT/CT routinely, as SPECT/CT can help classify equivocal lesions as benign or malignant, therefore increase specificity, accuracy and diagnostic confidence.¹³⁻¹⁷

Conclusion

SPECT/CT provides accurate localisation and characterisation of abnormalities seen on the conventional whole body scans. There is increasing evidence to support the use of SPECT/CT in oncology. Integrated diagnostic imaging with simple but specific algorithms may help clinicians use SPECT/CT effectively in oncology.

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Clinical applications	Advantages of SPECT/CT over conventional radionuclide imaging (planar or SPECT)
Sentinel lymph node biopsy	<ol style="list-style-type: none"> 1. Better visualisation and localisation of lymph nodes 2. Detection of additional basins of drainage and identification of extra-axillary nodes in patients with breast cancer 3. Improves surgical planning 4. Identification of false positives
Thyroid cancer	<ol style="list-style-type: none"> 1. Improves diagnostic confidence and decreases indeterminate cases 2. Superior lesion localisation 3. Alters staging/changes risk stratification and assists/modifies clinical management 4. Unnecessary therapy is avoided
Neuroendocrine tumours	<ol style="list-style-type: none"> 1. Useful in differentiating pathological from physiological tracer uptake 2. Improves surgical planning 3. Improves lesion localisation and characterisation 4. Increases diagnostic confidence
Cancer patients with indeterminate bone scan findings	<ol style="list-style-type: none"> 1. Improves specificity and reduces equivocal results 2. Accurate localisation and characterisation 3. Increases diagnostic confidence

TABLE 1
Summary of SPECT/CT in oncology.¹⁻¹⁷

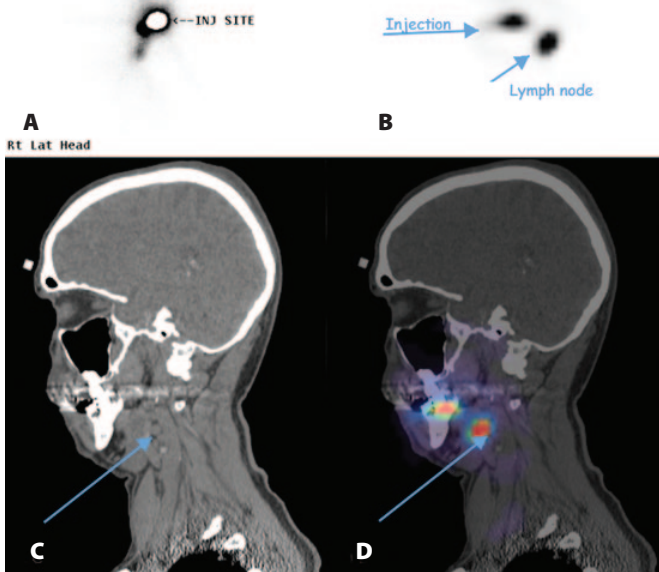


Figure 1
Squamous cell cancer of the tongue: ^{99m}Tc -nanocolloid was injected around the ulcer (right lateral tongue). Dynamic and planar images were acquired. (A) On the planar image, there is a focal area of increased tracer uptake on the right side of the neck close to the injection site. (B-D) On the SPECT/CT images the focal increased tracer uptake on the right side of the neck corresponds to a level 2 lymph node. SPECT/CT helped in precise localisation.

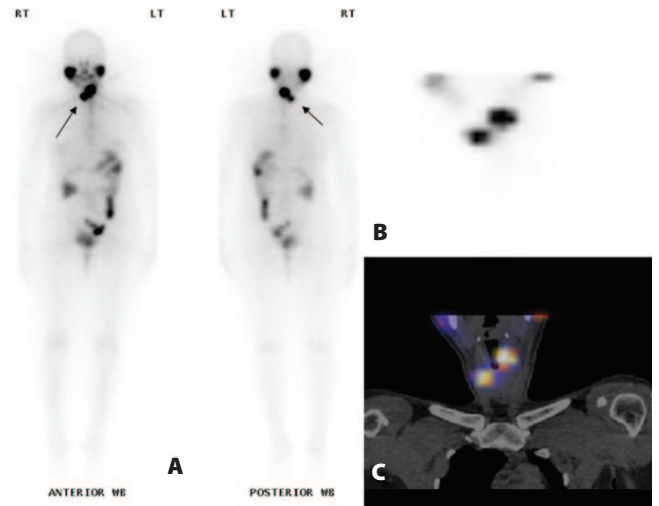


Figure 2
Differentiated thyroid cancer, post total thyroidectomy: (A) ^{131}I whole body scan and (B,C) SPECT/CT post therapy shows two focal areas of increased iodine uptake noted within the neck, compatible with good iodine uptake within the remnant thyroid tissue in the neck. On the whole body scan the uptake in the neck was suggestive of a thyroid remnant with a possible lymph node. However, SPECT/CT helped in correctly localising the uptake in thyroid remnant only, with no lymph nodes.

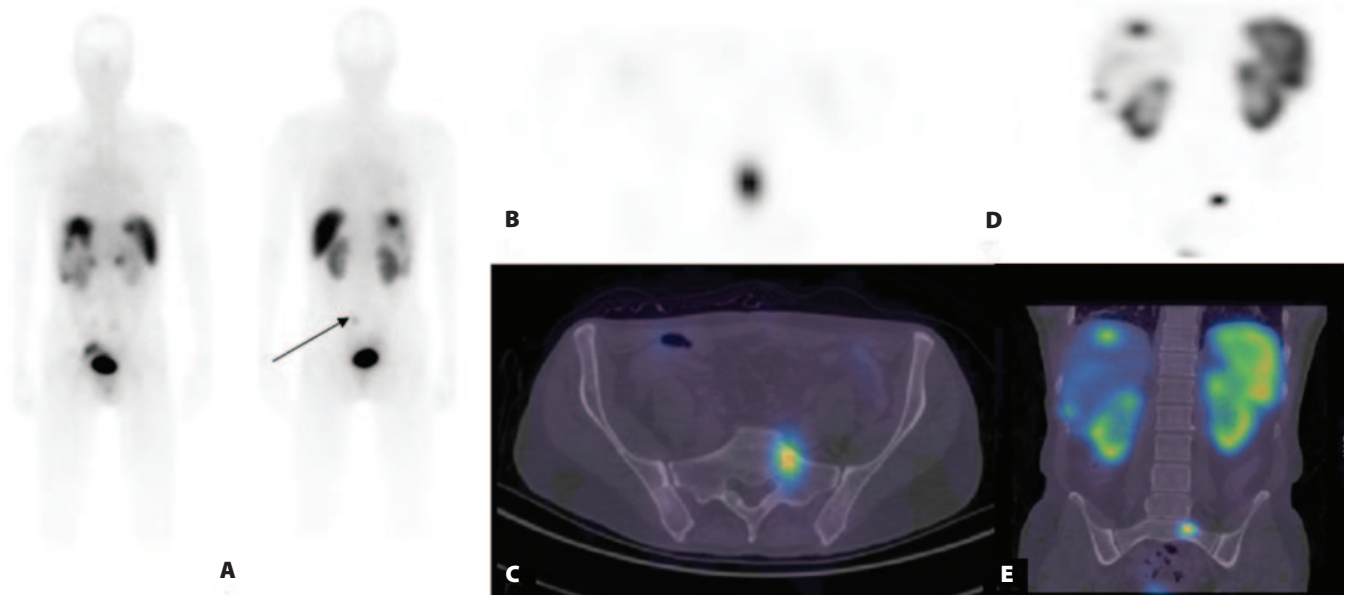


Figure 3
Metastatic neuroendocrine tumour: ^{111}In -octreotide scan. There are multiple foci of increased tracer uptake within the liver, which is in keeping with known liver metastases. Further, a focal area of increased tracer uptake is noted in the abdomen (arrow) on the left side posteriorly, which corresponds to a sacral metastasis on the SPECT/CT images.

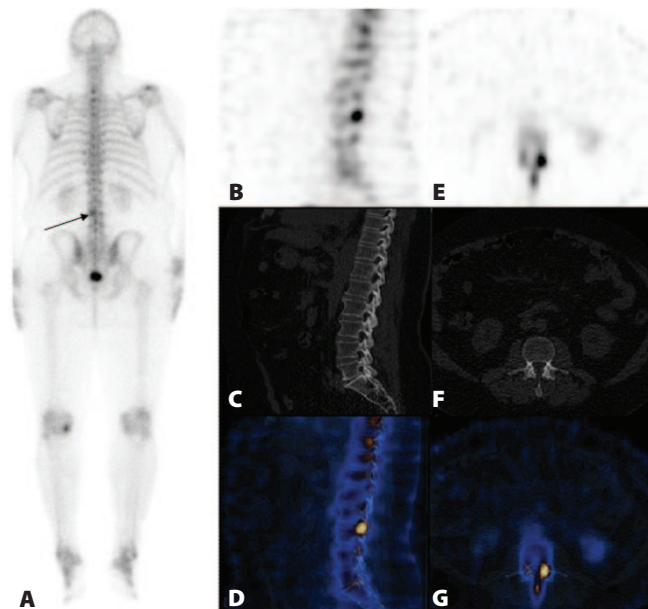


Figure 4
Prostate cancer with back pain. 99mTc-MDP bone scan. (A) On the whole body image there is a focal area of increased tracer uptake seen involving the left lateral aspect of L2/3 vertebra posteriorly (arrow). (B-G) On the SPECT/CT images of thoraco/lumbar spine, the focal uptake at L2/3 vertebrae corresponds to a left-sided facet joint, consistent with facet joint disease. Bone metastasis was excluded.

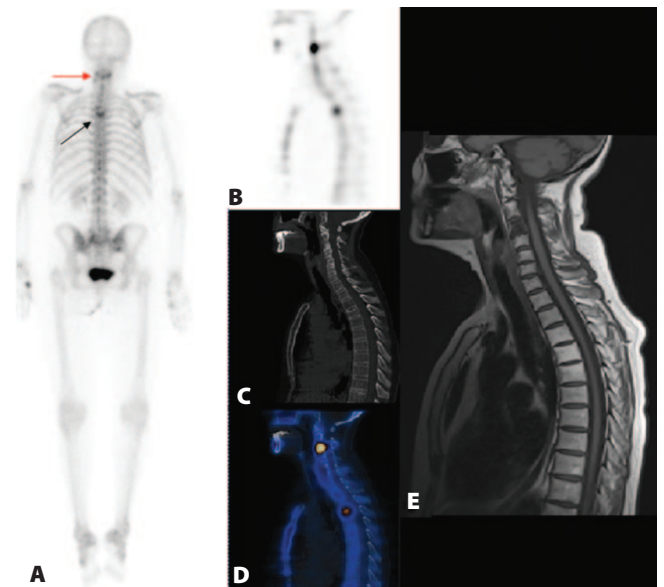


Figure 5
Lung carcinoma. 99mTc-MDP bone scan. (A) On the whole body scan (posterior view), there is increased uptake of tracer in the cervical (red arrow) and thoracic spine (black arrow). (B-D) On SPECT/CT the increased abnormal activity in the cervical spine is localised to a sclerotic C3 vertebra. There is further increased activity in the T4 vertebral body, which shows partial collapse. The scan confirms malignant infiltration of C3 vertebra. Increased activity with collapse of T4 vertebra morphologically favours osteoporosis. (E) MRI shows diffuse signal change within the C3 vertebral body consistent with a metastasis.