Hybrid SPECT/CT: Enhancing Nuclear Medicine

- SPECT/CT combines the anatomic details seen in CT images with functional information from single photon emission computed tomography (SPECT) nuclear imaging by acquiring both sets of images on the same scanner.
- SPECT/CT scans provide better anatomic localization of lesions than standard nuclear medicine images.
- SPECT/CT is primarily used in oncologic applications, but can be applied to a broad range of nuclear medicine procedures.
- In selected cases, SPECT/CT can provide better diagnostic accuracy than either modality alone.

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**Table 1. Comparison of PET/CT and SPECT/CT Applications at MassGeneral Imaging**

<table>
<thead>
<tr>
<th>PET/CT</th>
<th>SPECT/CT</th>
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</thead>
<tbody>
<tr>
<td>CT is integral part of study</td>
<td>CT is selective adjunct to SPECT</td>
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<tr>
<td>Diagnostic CT may be included</td>
<td>Only non-diagnostic CT included</td>
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<tr>
<td>CT can be used for attenuation correction</td>
<td>CT can be used for attenuation correction</td>
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<tr>
<td>Primarily used for imaging FDG metabolic activity (glucose analog)</td>
<td>Used for imaging a variety of physiologic uptake markers</td>
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In many cases, localization of the source of radioactivity can be achieved using side-by-side comparisons of separately acquired SPECT and CT images, or with the use of co-registration software. However, co-registration is much more straightforward when SPECT and CT are combined in a single scanner because the patient remains in the same position during the acquisition of both sets of images. Automated software can accurately co-register the SPECT and CT data to create fused SPECT/CT images, in a manner analogous to PET/CT, resulting in images that show the focal point of tracer uptake and good anatomical detail. However, there are significant differences between PET/CT and SPECT/CT (Table 1). SPECT/CT is useful in selected cases where there is a need for precise localization, for example, in regions with complex anatomy, such as in the abdomen and in the head and neck. In addition, the CT data can be used to correct for attenuation inherent in the SPECT data, in some cases providing a more accurate rendering of the actual tracer distribution.

Clinical Applications of SPECT/CT

Established oncological applications of SPECT/CT include the evaluation of a variety of tumors, such as neuroendocrine tumors, adrenocortical tumors, and parathyroid tumors. Many neuroendocrine tumors express somatostatin analogs, which can be detected by SPECT using radiolabeled somatostatin receptors such as $^{111}$In-pentetreotide. Scintigraphic imaging using this agent has a high sensitivity (80-100%), but its specificity is reduced because of physiological uptake of radioactivity and the difficulty of precise anatomical localization. Because SPECT/CT provides anatomical information, it can increase specificity and improve localization of tracer uptake, which can have a direct impact on patient management.
Figure 1. A) Axial image from diagnostic CT performed without intravenous contrast demonstrates soft tissue nodule adjacent to the adrenal gland in a patient with neurofibromatosis. B) Coronal image from an adrenal protocol CT again demonstrates the lesion, which was shown to have enhancement characteristics similar to that of the spleen, suggesting that it could represent an unusual splenule.

Tumors that produce catecholamines, such as pheochromocytomas and neuroblastomas, can be successfully imaged with radiolabeled guanethidine analogs, such as $^{123\text{I}}$-metaiodobenzylguanidine (MIBG). However, the interpretation of scintigraphic images can be confounded by physiological uptake, which can be better identified with SPECT/CT. For example, in a limited series of patients with biochemically or clinically suspected pheochromocytoma, SPECT/CT has been shown to add incremental diagnostic value by identifying sources of physiological tracer uptake. In cases of neuroblastoma, CT or MRI is used initially to assess the primary tumor and its potential resectability. MIBG scintigraphy is commonly used for disease staging to guide management, assessment of treatment response, and detection of disease recurrence. SPECT/CT improves tumor localization, especially when tumors are found adjacent to organs with physiological MIBG uptake, such as the heart, liver, and kidneys.

Parathyroid adenomas are the most common cause of primary hyperparathyroidism. Accurate localization of the tumor is essential to minimize surgical procedures. This is usually accomplished with the aid of SPECT, using $^{99\text{Tc}}$-methoxyisobutylisonitrile (MIBI), and high-resolution sonography. However, in selected patients with thyroid nodules, ectopic adenomas, or distorted neck anatomy from previous surgery, SPECT/CT has an incremental value for tumor localization.

Another oncologic application of SPECT/CT is in selected patients undergoing lymphoscintigraphy. Lymph node staging is integral for treatment planning for a number of cancers. A combination of lymphoscintigraphy using a $^{99\text{Tc}}$-sulfur colloid injected intradermally prior to surgery and mapping with dye during surgery is a common approach to finding sentinel lymph nodes (SLN). Localization with CT may facilitate surgical planning and can increase detection rates. Anatomic co-registration using SPECT/CT can be beneficial for SLN detection in the pelvis, the mediastinum, and particularly in the head and neck region. In a pilot study of patients with melanoma, SPECT/CT enabled the detection of SLNs in a number of patients with negative planar scintigraphy examinations. Other studies have found that SPECT/CT improved SLN identification and/or localization of SLNs associated with head and neck tumors, and breast cancer. SPECT/CT is also superior to planar scintigraphy for detecting SLNs in patients with a body mass index over 25. In other patients undergoing lymphoscintigraphy, such as for truncal or extremity melanoma, conventional imaging is typically sufficient, as SPECT/CT does not appear to add substantial diagnostic information.

On occasion, SPECT/CT can be valuable for differential diagnosis. One example is shown here (Figures 1-3) in which uptake of $^{99\text{Tc}}$-sulfur colloid demonstrated that a soft tissue nodule adjacent to the adrenal gland represented a splenule.

**The SPECT/CT Examination**

Patients receive an injection of a radiotracer either the same day as the SPECT/CT examination (for example, $^{99\text{Tc}}$-MIBI, $^{99\text{Tc}}$-sulfur colloid) or the day before the SPECT/CT examination (for example, $^{111\text{In}}$-pentetreotide). At the start of the examination, the patient is positioned comfortably on the imaging table and is asked to stay motionless for the duration of the imaging procedure. The SPECT/CT scan starts with a low-dose CT scan of the region of interest, which provides sufficient anatomic detail for localization purposes and for attenuation correction, if needed. The SPECT examination is performed immediately after the CT examination is completed and takes 10-30 minutes, depending on the body part being imaged.
Figure 2. SPECT/CT imaging was performed with technetium-99m sulfur colloid liver and spleen imaging agent and low-dose, non-diagnostic localizing CT. A) The sulfur colloid SPECT image demonstrates ectopic tracer uptake medial to the spleen (arrow), which corresponds precisely to the soft tissue nodule on B) low dose CT and C) on SPECT/CT fusion image.

Figure 3. Coronal images from the SPECT/CT correlate well with the diagnostic coronal CT (Figure 1B). The presence of sulfur colloid uptake within the nodule confirms that it represents a splenule.

Note that the CT scan in SPECT/CT is not of diagnostic quality and is performed as an adjunct to the nuclear images. This is an important difference between the techniques used for SPECT/CT and PET/CT. With PET/CT, a full diagnostic CT scan can be performed on the same scanner in addition to the PET images.

The radiation exposure for a SPECT/CT scan is about 47 mrem, or 0.47 mSv for an abdomen nondiagnostic localization and attenuation correction scan, in addition to the exposure from the nuclear medicine tracer. The half-life of the radionuclide commonly used in SPECT (99mTc, 123I, 111In) ranges from 6 hours to 2.8 days. They are effectively fully decayed within ten half-lives after their administration.

**Scheduling**

SPECT/CT is currently available on a single scanner located on the main campus. At this time, it is not being used for nuclear cardiology examinations. Nuclear imaging examinations may be scheduled online through Radiology Order Entry (http://mghroe/) or by calling 617-724-9729 (XRAY). A nuclear medicine specialist will choose whether to perform planar scintigraphy, SPECT, or SPECT/CT.

**Further Information**

For further questions on SPECT/CT, please contact Edwin L. Palmer, MD, Director of Clinical Nuclear Medicine (617-726-8350).

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References


