Value of SPECT/CT for Sentinel Lymph Node Localization in the Parotid and External Jugular Chain

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Abstract

Objective. Preoperative single-photon emission computed tomography/computed tomography (SPECT/CT) imaging may aid in the localization of sentinel lymph nodes (SLNs) in cutaneous head and neck malignancy and has been rigorously evaluated for deep cervical lymph nodes. The purpose of this study was to assess the sensitivity, specificity, and positive predictive value (PPV) of SPECT/CT for preoperative localization of nodal basins superficial to the sternocleidomastoid muscle, with comparison to deep nodal basins of the neck.

Study Design. Retrospective review.

Setting. Tertiary care center.

Subjects and Methods. SPECT/CT images obtained preoperatively for patients undergoing SLN biopsy for cutaneous head and neck malignancy between June 2015 and June 2016 were reviewed by a blinded nuclear medicine physician and head and neck surgeon. SPECT/CT imaging was compared to intraoperatively determined SLN location via gamma probe. Sensitivity, specificity, and positive and negative predictive values were determined and compared for superficial (external jugular [EJ] and parotid) nodes vs level II nodes.

Results. Fifty-three patients were included in the study. Most had cutaneous melanoma (69.8%). The PPV of EJ-parotid node identification by SPECT/CT imaging was 85.7%, specificity was 88.9%, and sensitivity was 69.2%. Comparatively, the PPV for level II nodes was 76.9%, specificity was 50%, and sensitivity was 85.7%. No significant difference in SPECT/CT predictive value was identified between EJ/parotid and level II node identification (P > .05).

Conclusion. SPECT/CT imaging has strong specificity and positive predictability for preoperative localization of SLN superficial to the sternocleidomastoid muscle in cutaneous head and neck malignancy. SPECT/CT imaging may be a useful radiographic aid for preoperative SLN mapping in this patient population.

Keywords

single-photon emission computed tomography, SPECT, sentinel lymph node, SLN, sentinel lymph node biopsy, SLNB, external jugular, parotid, cutaneous malignancy, cutaneous, head and neck

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Head and neck cutaneous malignancy presents a unique challenge for sentinel lymph node (SLN) mapping due to variable and unpredictable drainage patterns. Various techniques have been used to identify lymph node basins, starting with blue dye injection pioneered by Morton and colleagues1 in the 1990s. The evolution of lymphatic mapping has progressed from dye injection to lymphoscintigraphy and handheld gamma probes, with single-photon emission computed tomography/computed tomography (SPECT/CT) constituting the newest mapping adjunct.2 SPECT/CT is a multimodal imaging technique combining lymphatic drainage radioactive identification through injection of nuclear medicine particles, with anatomic detail obtained from concurrent CT.2 The images are fused to aid in preoperative localization of sentinel nodes by yielding a 3-dimensional map of the nodal basin of interest as well as tissue attenuation correction and adjustment for gamma ray signal scatter. SPECT/CT localization is improved over lymphoscintigraphy alone, which has historically provided...
poor preoperative mapping in the head and neck region due to the lack of anatomical reference points and details on nodal depth. Three-dimensional intraoperative SPECT/CT has been shown to optimize incision planning and reduce operative dissection time.6

SPECT/CT has been previously been demonstrated to provide clear benefits in the identification of SLNs for head and neck cutaneous malignancy.7 However, the predictive value for SPECT/CT for superficial head and neck nodal basins, such as the parotid and external jugular chain, has not been previously studied. Distinguishing between these 2 regions can dramatically improve operative efficiency by guiding incision placement and surgical approach. This has the potential to decrease operative morbidity by avoiding areas that do not contain sentinel nodes and by decreasing operative times. The purpose of this study was to assess the sensitivity, specificity, and positive predictive value (PPV) of SPECT/CT for preoperative localization of nodal basins superficial to the sternocleidomastoid muscle, with comparison to deep nodal basins of the neck.

Methods

Patient Selection

A retrospective review of 53 patients with cutaneous head and neck malignancy with clinically and radiographically N0 neck disease who underwent SLN biopsy with preoperative SPECT/CT imaging between June 2015 and June 2016 was performed. All tumor histologies were included to permit global analysis of SPECT/CT for preoperative localization of sentinel nodes in superficial nodal basins among patients with cutaneous head and neck malignancy. Approval from the Human Subjects Committee of the Massachusetts Eye and Ear Institutional Review Board was obtained.

SPECT/CT Imaging

SPECT/CT images were acquired preoperatively using previously described methods.8 Images were reviewed retrospectively in a blinded fashion by a head and neck surgeon (K.S.E.) and radiologist/nuclear medicine physician (Y.W). Nodal groups were defined by the Imaging-Based Nodal Classification system described by Som et al and identified as follows: intraparotid, tail of parotid, external jugular chain, level IIa/b, level III, level IV, level V, submandibular, submental, suboccipital, supraclavicular, or postauricular. Positive nodes were defined as sites of contrast uptake, separate from the primary lesion, that localized to a specific nodal level. Patients without any positivity beyond the primary site were excluded.

SLN Biopsy

SLN biopsy (SLNB) was performed by the senior author using previously described methods.8 Intraoperative SLNs were identified by gamma probe positivity as detected by a gamma ray detection probe (Navigator GPS; Dynasil Products, Watertown, Massachusetts). The total gamma ray probe count over 10 seconds was recorded for each node harvested. Lymph nodes were defined as sentinel nodes when gamma ray probe count was at least 10% of the hottest node, as previously established.10 The nodal location was defined by the classification scheme published by the Academy of Otolaryngology—Head and Neck Surgery.

Statistical Analysis

Statistical measures of performance for SPECT/CT imaging included calculation of sensitivity, specificity, PPV, and negative predictive value (NPV) by nodal drainage basin. Drainage basins superficial (external jugular [EJ] or parotid) and deep (level IIa/b) to the sternocleidomastoid (SCM) were primarily assessed. Level IIa/b was selected a priori for comparison given its proximity to superficial basins and possibility for overlap with traditional lymphoscintigraphy. For the purposes of predictive value calculation, intraoperative SLN location, as measured by gamma ray probe detection, was considered the “gold standard.” Measures of predictive value were compared between level II vs EJ or parotid nodal basins. Receiver operator curves were generated to assess sensitivity/specificity of SPECT/CT for detection of deep and superficial nodal basins. The χ² test was used to test for statistical significance, which was defined by an α threshold of .05. All data manipulation and statistical testing were performed using STATA (v13.0; StataCorp, College Station, Texas).

Results

A total of 53 patients underwent SLNB with preoperative SPECT/CT for cutaneous head and neck malignancy during the study period and were included in the analysis. All patients had positive nodes on SPECT/CT beyond the primary site. Mean (SD) patient age was 66.8 (13.4) years. Most patients were diagnosed with melanoma (n = 37, 69.8%), and the most common primary site was the scalp (n = 11, 20.8%) (Table 1).

Nodal location as assessed by intraoperative vs SPECT/CT identification is listed in Table 2. The sensitivity of SPECT for sentinel lymph nodal basins superficial to the sternocleidomastoid muscle (EJ or parotid) was 69.2%, specificity was 88.9%, and PPV was 85.7%. Comparatively, for level II nodes, the sensitivity was 85.7%, specificity was 50.0%, and PPV was 76.9% (Table 3). There was no significant difference in these measures by nodal subsite (Table 3).

Receiver operator curves were generated for level II and EJ/parotid basins. The area under the curve was greater for level II vs EJ or parotid nodal identification (0.68) (Figure 1 and Figure 2).

Representative SPECT/CT images demonstrating the ability to distinguish superficial and deep location of sentinel nodes are shown in Figure 3.

Discussion

SPECT/CT is a valuable tool for preoperative mapping of SLNB in head and neck cutaneous malignancy. Traditional
lymphoscintigraphy alone has less utility in the head and neck region because of the variable drainage patterns, dense, overlapping lymphatic networks, and proximity of nodal basins to the primary site. The gamma probe is a useful intraoperative tool that may guide surgical dissection when hot areas are in distinctly different regions and thereby guide incision placement and initial dissection. However, when areas are overlapping, such as the tail of parotid, EJ, and level II, the gamma probe is not as helpful. Indeed, the presence of the facial nerve, spinal accessory nerve, and hypoglossal nerves in these regions creates the potential for significant morbidity. Fortunately, for experienced head and neck surgeons performing SLNB, these risks are low. However, SPECT/CT may offer another adjunct to improve identification and safe dissection in these regions. Whereas prior studies have globally assessed performance measures for SPECT/CT in all areas of the head and neck, the primary objective of this study was to assess the utility and predictability of SPECT/CT for SLNB mapping superficial to the sternocleidomastoid muscle.

For external jugular and parotid nodes, SPECT/CT had greater specificity (89%) than sensitivity (69%). Therefore, if SPECT/CT demonstrates a positive node, the surgeon can be confident that the node is a true SLN. However, if SPECT/CT does not identify a positive node (negative test), then there is a chance a sentinel node is present despite not being apparent on the scan. For level II nodes, sensitivity and specificity were reversed, with a sensitivity of 86% and a specificity of 50%. Therefore, if SPECT/CT does not identify a positive node (negative test), there is a high likelihood that a sentinel node is indeed absent. However, if SPECT/CT demonstrates a positive node, it may represent a false positive. The PPV of EJ/parotid nodes was 86% with an NPV of 75%, while level II nodes exhibited a PPV of 77% and an NPV of 64%. The relatively high PPVs indicate if SPECT/CT demonstrates a node with radiotracer uptake, it is likely to be found within that basin in the operating room.

These results compare favorably to prior studies of SPECT/CT for cutaneous malignancy SLN mapping.

### Table 1. Patient Demographics, Tumor Histology, and Primary Site (N = 53).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>66.8 (13.4)</td>
</tr>
<tr>
<td>Tumor histology, No. (%)</td>
<td></td>
</tr>
<tr>
<td>Merkel cell</td>
<td>4 (7.5)</td>
</tr>
<tr>
<td>Melanoma</td>
<td>37 (69.8)</td>
</tr>
<tr>
<td>SCCa</td>
<td>12 (22.6)</td>
</tr>
<tr>
<td>Primary site, No. (%)</td>
<td></td>
</tr>
<tr>
<td>Scalp</td>
<td>11 (20.8)</td>
</tr>
<tr>
<td>Cheek</td>
<td>8 (15.1)</td>
</tr>
<tr>
<td>Ear</td>
<td>8 (15.1)</td>
</tr>
<tr>
<td>Temple</td>
<td>8 (15.1)</td>
</tr>
<tr>
<td>Forehead</td>
<td>7 (13.2)</td>
</tr>
<tr>
<td>Neck</td>
<td>4 (7.5)</td>
</tr>
<tr>
<td>Nose</td>
<td>2 (3.8)</td>
</tr>
<tr>
<td>Periocular</td>
<td>2 (3.8)</td>
</tr>
<tr>
<td>Lip</td>
<td>2 (3.8)</td>
</tr>
<tr>
<td>Postauricular</td>
<td>1 (1.9)</td>
</tr>
</tbody>
</table>

Abbreviation: SCCa, squamous cell carcinoma.

### Table 2. Intraoperative Node Location Identification vs SPECT/Computed Tomography Imaging Localization by Nodal Basin for All Patients (N = 53).

<table>
<thead>
<tr>
<th>Neck Location</th>
<th>Intraoperative Node, No.</th>
<th>SPECT Imaging, No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Not Present</td>
</tr>
<tr>
<td>Level II (IIa or IIb)</td>
<td>35</td>
<td>18</td>
</tr>
<tr>
<td>EJ or parotid</td>
<td>26</td>
<td>27</td>
</tr>
</tbody>
</table>

Abbreviations: EJ, external jugular; SPECT, single-photon emission computed tomography.

### Table 3. Sensitivity, Specificity, PPV, and NPV for SPECT/CT Imaging by Site for All Patients (N = 53), with P Value Comparison for Each Measure between Level II and EJ/Parotid SPECT/CT Positivity.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Level II, %</th>
<th>EJ or Parotid, %</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>85.7</td>
<td>69.2</td>
<td>.588</td>
</tr>
<tr>
<td>Specificity</td>
<td>50.0</td>
<td>88.9</td>
<td>.243</td>
</tr>
<tr>
<td>PPV</td>
<td>76.9</td>
<td>85.7</td>
<td>.788</td>
</tr>
<tr>
<td>NPV</td>
<td>64.3</td>
<td>75</td>
<td>.760</td>
</tr>
</tbody>
</table>

Abbreviations: EJ, external jugular; SPECT/CT, single-photon emission computed tomography/computed tomography; NPV, negative predictive value; PPV, positive predictive value.
Remenschneider et al\textsuperscript{8} demonstrated that in all head and neck cutaneous subsites, the sensitivity, specificity, PPV, and NPV for SPECT/CT were 73\%, 92\%, 54\%, and 96\%, respectively. These findings were notable for a high NPV, indicating that when head and neck nodal basins do not have uptake of SPECT/CT, they are unlikely to contain SLNs. These results have important implications for incision planning and determination of nodal basin dissection in the search for SLNB.

Previous work determined the high utility of SPECT/CT in identifying SLNs for particular subsites, including the cheek, scalp, eyelid, and ear. The concordance of intraoperative with SPECT/CT findings ranged from 50\% to 68\%.\textsuperscript{8} Notably, these studies have demonstrated that SPECT/CT is able to narrow down the basin or a basin within one adjacent level 92\% of the time.\textsuperscript{8} SPECT/CT may therefore be most useful in predicting the location of the “hottest” node, as was identified in this study. This allows for more precise and faster dissection in specific basins demonstrating uptake on SPECT/CT.

SPECT/CT has been studied in the context of periparotid SLN mapping in head and neck melanoma.\textsuperscript{11} In prior reports, CT data provided clear localization to differentiate level II vs periparotid nodes.\textsuperscript{11} This imaging data changed incision planning in 57\% of patients. In addition, another sentinel node was identified 29\% of the time with the addition of SPECT/CT over traditional lymphoscintigraphy, and all of these were in the parotid tail or level II region.

Improved surgical planning and operative efficiency with SPECT/CT have been demonstrated in prior studies. Klop et al\textsuperscript{12} found SPECT/CT affected surgical planning and outcome in 20\% of head and neck melanoma cases. Jensen et al\textsuperscript{13} retrospectively analyzed 137 patients, with up to 64\% of surgical incisions being affected by SPECT/CT localization. Veenstra et al\textsuperscript{14} studied melanoma from all body sites, with head and neck melanoma patients having 50\% of their surgical planning changed based on SPECT/CT, higher than any other site on the body. Mean operative time was reduced by an average of 64 minutes with effective incision planning and direct dissection to nodes identified on SPECT/CT.\textsuperscript{15} Improvement of operative efficiency has been reported to amount to an average of $4000 savings per case.\textsuperscript{16}

These data, combined with our findings, suggest SPECT/CT is useful for preoperative localization of SLN lateral to the sternocleidomastoid muscle in cutaneous head and neck malignancy. Future studies should continue to investigate operative efficiency and cost differences for SPECT/CT compared to traditional planar lymphoscintigraphy.

Limitations of this study include small sample size and retrospective study design. In addition, there is heterogeneity in primary subsite location and tumor histology, which may influence radiotracer absorption. The primary objective of this study was to assess SPECT/CT as a tool for nodal localization regardless of tumor histology or location, but future studies should account for these potential confounders in a stratified analysis. Of note, the benefit of SLN mapping among patients with cutaneous squamous cell carcinoma has not yet been proven. Surgical and radiographic definitions for lymph node basins may differ slightly, but the primary objective was to assess nodal identification superficial to the sternocleidomastoid muscle, which is a reliably identified landmark both surgically and radiographically. Future studies may compare the accuracy of SLNB for EJ/parotid nodes with other neck levels as single-level comparison may introduce bias.

**Conclusion**

SPECT/CT has a strong specificity and positive predictability for preoperative localization of SLN lateral to the sternocleidomastoid muscle in patients with cutaneous head and neck malignancies. Level II nodes and parotid nodes can often be difficult to discern from one another or from a close primary site, and anatomical detail rendered by the CT is valuable. SPECT/CT may also improve incision planning and reduce operative time. SPECT/CT imaging may be a useful radiographic aid for preoperative SLN localization.

\textbf{Figure 2.} Area under the curve for level II nodal basin identification by single-photon emission computed tomography/computed tomography. ROC, receiver operator characteristic.

\textbf{Figure 3.} Preoperative axial single-photon emission computed tomography/computed tomography images demonstrating radiotracer uptake within distinct nodal basins superficial (thin arrow) and deep (thick arrow) to the sternocleidomastoid muscle.
mapping in appropriate patients with head and neck cutaneous malignancy.

**Author Contributions**

Rosh K. V. Sethi, study conception and design, acquisition, interpretation and analysis of data, drafting of manuscript, final approval; Nicholas B. Abt, study conception and design, acquisition, interpretation and analysis of data, drafting of manuscript, final approval; Aaron Remenschneider, study conception and design, drafting of manuscript, final approval; Yingbing Wang, study conception and design, acquisition, interpretation and analysis of data, drafting of manuscript, final approval; Kevin S. Emerick, study conception and design, acquisition, interpretation and analysis of data, drafting of manuscript, final approval.

**Disclosures**

**Competing interests:** None.

**Sponsorships:** None.

**Funding source:** None.

**References**


