

A Portable γ -Camera for Intraoperative Detection of Sentinel Nodes in the Head and Neck Region

Lenka Vermeeren¹, Renato A. Valdés Olmos¹, W. Martin C. Klop², Alfons J.M. Balm², and Michiel W.M. van den Brekel²

¹Department of Nuclear Medicine, Netherlands Cancer Institute–Antoni van Leeuwenhoek Hospital, Amsterdam, The Netherlands; and ²Department of Head and Neck Surgery and Oncology, Netherlands Cancer Institute–Antoni van Leeuwenhoek Hospital, Amsterdam, The Netherlands

We introduced and evaluated a portable γ -camera for intraoperative visualization of sentinel nodes in the head and neck region.

Methods: Planar lymphoscintigraphy and SPECT/CT were performed after peritumoral injection of ^{99m}Tc-nanocolloid in 25 patients (head and neck melanoma or oral cavity carcinoma). Sentinel nodes were localized intraoperatively with a portable γ -camera and a hand-held γ -probe. The portable γ -camera was used to determine the distribution of remaining radioactivity after excision of the sentinel nodes. **Results:** The portable γ -camera visualized all 70 preoperatively identified sentinel nodes. Sentinel nodes at difficult sites could be localized more efficiently, and in 6 patients, 9 additional nodes (1 tumor-positive) were identified with the portable γ -camera after excision. **Conclusion:** Intraoperative identification of sentinel nodes in the head and neck region with a portable γ -camera is feasible and might lead to detection of more sentinel nodes.

Key Words: sentinel lymph node biopsy; gamma cameras; head and neck neoplasms

J Nucl Med 2010; 51:700–703

DOI: 10.2967/jnumed.109.071407

Sentinel node biopsy in the head and neck region is challenging because of the presence of several vital structures and unpredictable lymphatic drainage. For melanoma, sentinel node biopsy is often less successful in the head and neck (1,2), with higher false-negative results (3,4). Intraoperative detection of the sentinel nodes is usually guided by a γ -probe. Unfortunately, the signal of the injection area can cause difficulty in localizing nearby sentinel nodes, and deeply located sentinel nodes may be missed because of tissue attenuation. Patent blue is commonly used as an additional tracer of lymphatic flow. However, patent blue

migrates quickly and sentinel nodes in the head and neck region are less frequently stained blue (5). A recently introduced portable γ -camera can detect radioactive hot spots by visualization of the tracer signal on screen (6,7). In cases of urologic tumors, this camera was able to visualize and localize sentinel nodes during operation and confirm if they had accurately been removed (8).

The current feasibility study evaluated the use of a portable γ -camera in the head and neck area. We report on our first experience and analyze if the portable γ -camera leads to detection of more sentinel nodes.

MATERIALS AND METHODS

Patients

After giving informed consent to participate in the study, 25 consecutive clinically and radiologically node-negative patients underwent sentinel node biopsy for a tumor in the head and neck region. Fifteen patients were treated for a melanoma (Breslow thickness ≥ 1.0 mm or Clark invasion level \geq IV) and 10 for an early-stage oral cavity carcinoma (T1–2N0). The mean age of the patients was 60 y (range, 39–79 y).

Preoperative Imaging

The radiopharmaceutical, ^{99m}Tc-nanocolloid (GE Healthcare), was injected peritumorally, intracutaneously (melanoma), or submucosally (oral cavity carcinoma), in 4 deposits of 0.1 mL. The mean injected dose was 72 MBq (1.9 mCi). Dynamic planar lymphoscintigraphy was performed for 10 min, and 5-min static images were acquired 10 min and 2 h after injection. SPECT (128 \times 128 matrix, 60 frames, 25 s/frame) and CT (130 kV, 40 mAs, B30s kernel) were acquired after the delayed static images, using a SymbiaT hybrid camera (Siemens).

Direct-draining nodes on dynamic lymphoscintigraphy and the first nodes in each station on early planar lymphoscintigraphy were considered to be the sentinel nodes. Nodes appearing later in the same stations were considered to be second-echelon nodes. If late images or SPECT/CT showed additional hot spots proximal to the injection area or on a side with no other drainage or with previous drainage, these were also considered sentinel nodes. The levels of the sentinel nodes were marked on the skin, with the help of an external cobalt source.

Received Oct. 7, 2009; revision accepted Jan. 15, 2010.

For correspondence contact: Renato A. Valdés Olmos, Department of Nuclear Medicine, Netherlands Cancer Institute–Antoni van Leeuwenhoek Hospital, Plesmanlaan 121, 1066 CX Amsterdam, The Netherlands.

E-mail: r.valdes@nki.nl

COPYRIGHT © 2010 by the Society of Nuclear Medicine, Inc.

Surgical Procedure

Fifteen of the patients underwent surgery 18–24 h after injection (the next morning), and the other 10 patients underwent surgery the same afternoon (<6 h after injection). Radioguided sentinel lymphadenectomy was assisted by a hand-held γ -probe (Neoprobe; Johnson & Johnson Medical) and a portable γ -camera (Sentinella, S102; Oncovision). This camera is equipped with a pinhole collimator and a CsI(Na) continuous scintillating crystal. The field of view is 4×4 cm when the distance to the imaging plane is 3 cm, and 20×20 cm when the collimator is placed at a distance of 15 cm. The intrinsic spatial resolution of the camera is 1.8 mm, and the extrinsic spatial resolution is 7 and 21 mm for distances of 3 and 15 cm, respectively. Detection sensitivity depends on the distance from the detector to the imaging plane, being 19,135 and 1,111 cpm/MBq for distances of 3 and 15 cm, respectively. More technical details can be found in the report of Sanchez et al. (6).

Before incision, the sterile-wrapped detector was placed 5–15 cm above the marked sentinel node levels to provide an overview of all the nodes in relation to the injection area (Fig. 1). At least 1 overview image (acquisition time, 1 min) was made. Concurrently, the location of each sentinel node was determined by placing the laser pointer exactly above the sentinel node signal. Acquisition continued until certainty was reached about the location of the node, and the time to visualization was recorded. After excision of the nodes, a new image was acquired and compared on-screen with the image before excision. The acquisition time was at least 1 min, and the camera was placed at the same position and distance as for the image acquired before excision. If hot spots remained near the injection area or near previously marked sentinel node levels, these nodes were regarded as additional sentinel nodes and removed. Nodes that were preoperatively defined as second-echelon nodes were left in situ.

RESULTS

A median of 3 sentinel nodes per patient was visualized (mean, 2.8; range, 1–7) on preoperative images, and all were visualized on the screen of the portable γ -camera intraoperatively. Superficial nodes with strong tracer uptake were depicted within 10 s. Deeply located and radioactively weak nodes took 30–50 s to visualize. All sentinel nodes were visualized within 1 min.

Eight of the 70 sentinel nodes were in difficult locations: near the injection area, next to another sentinel node, or deep within the parotid gland. These nodes could be localized more efficiently with the addition of the portable γ -camera.

In a separate case, a preoperatively visualized node that could not be found with the probe could be excised after localization with the portable γ -camera.

With imaging after excision, 9 additional radioactive nodes were identified in 6 patients. These were regarded as possible sentinel nodes and removed. These 9 nodes had not been visualized preoperatively. One additional sentinel node was discovered behind the injection area in neck level II, after removal of the primary lesion. Additional nodes were removed because substantial radioactivity remained after excision of a sentinel node in the other 5 patients (Fig. 2).

One (parotid) sentinel node was clearly visualized with the portable γ -camera but was not excised because of the risk of damaging the facial nerve.

Six patients had 1 tumor-positive sentinel node on pathologic examination. One of these positive nodes was an additional node that had not been separately identified on preoperative images but was identified with postexcision imaging.

DISCUSSION

Several portable and hand-held mini γ -cameras have been developed to provide intraoperative visualization of radiotracers (6,9,10). These cameras can give an overview of all radioactive hot spots within the surgical field. This overview can be compared with preoperative images to localize nodes and distinguish between first and higher echelons. In the example of Figure 3, the procedure could have been performed with the probe only, but the availability of both preoperative images and intraoperative images provided detailed information on the anatomic location of each sentinel node.

The overview before incision can also be compared with images obtained after the sentinel nodes (Fig. 2) and primary lesion have been excised, to detect additional sentinel nodes that had been overshadowed. In our series, this type of comparison led to excision of an additional sentinel node in 24% of the patients (including 1 positive node). In some cases, intense tracer uptake at the site of the sentinel node on preoperative images corresponds to a cluster of sentinel nodes. Imaging after excision of the first hot node can reveal the remaining sentinel node. Another reason for visualization of more sentinel nodes

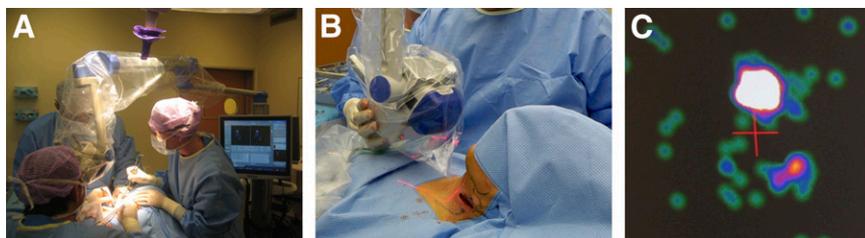


FIGURE 1. Surgeon positions sterile-wrapped head of camera (A) above surgical field using laser pointer (B). On screen of γ -camera, sentinel node is visualized just cranial to red cross of laser pointer, and second-echelon node is visualized caudal to cross of laser pointer (C). Head of portable γ -camera can be placed above sentinel nodes to

exactly localize each node (C). When head of camera is placed farther from patient, entire surgical field can be visualized, providing overview of injection area and all radioactive nodes.

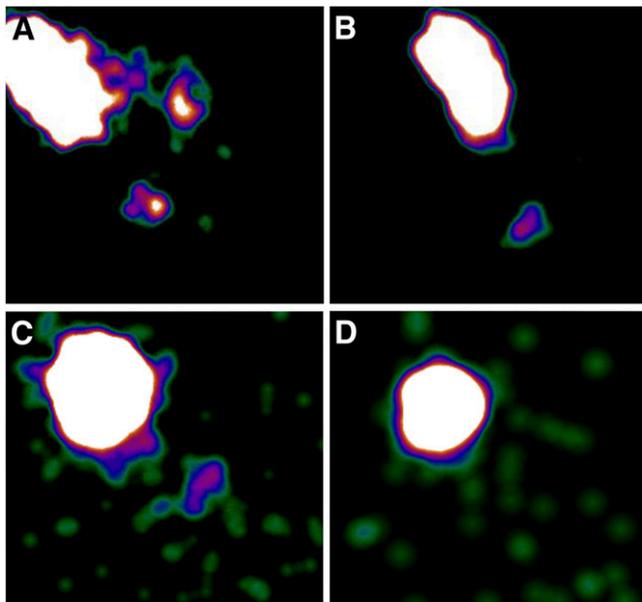


FIGURE 2. Postexcision imaging in 2 patients. In patient with melanoma of left cheek, portable γ -camera images show injection area and 2 sentinel nodes before incision (A). Both sentinel nodes could be removed with help of portable γ -camera and γ -probe. Postexcision imaging showed remaining radioactivity at site of excision of most caudal sentinel node (B). This hot spot had not been separately visualized on preoperative images. Because substantial remaining radioactivity was visualized near injection area, this additional hot spot was considered to be sentinel node instead of second-echelon node. Because its location allowed for easy removal, it was excised. All sentinel nodes appeared to be tumor-negative. In another patient with temporal melanoma, cluster of 2 sentinel nodes was visualized caudal to injection area (C). After excision of 2 radioactive nodes, only background radioactivity and radioactivity at site of injection remained (D), confirming adequate sentinel node excision. No nodal metastases were found on pathologic examination.

intraoperatively might be that more tracer has accumulated because of the longer time from injection to imaging. Although the portable γ -camera enabled detection of these nodes, they might also have been found by more extensive exploration with the γ -probe.

In our experience, weakening of the radioactive signal is limited, and intraoperative imaging takes less time if patients undergo surgery in a 1-d protocol. With sufficient measuring time, the portable γ -camera enables detection of weak hot spots.

The γ -camera can also be used to adjust skin marks intraoperatively, because the locations of nodes in a patient's definite surgical position may slightly differ from the preoperatively marked location.

Furthermore, if there is difficulty localizing a preoperatively found sentinel node, the γ -camera may be able to show the surgeon where the node is located. In our population, 11% of the nodes were localized more efficiently in this manner. In addition, a node that could not be found

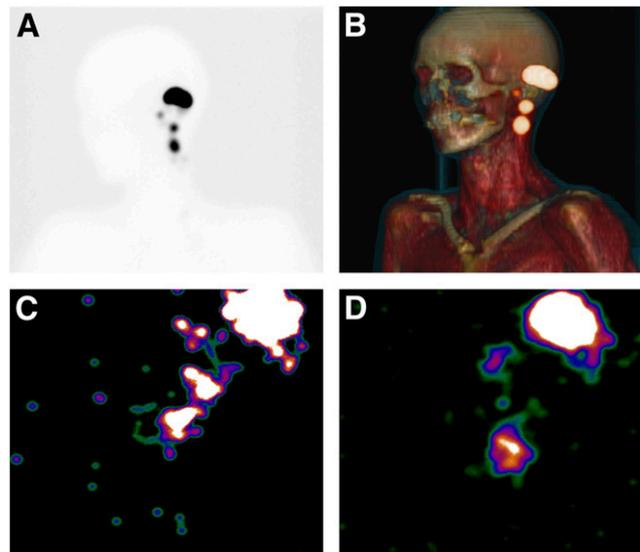


FIGURE 3. Comparison of preoperative images with intraoperative images. In patient with melanoma cranial to left ear, lateral planar lymphoscintigraphy after 2 h (A) showed 2 hot spots caudal to injection area and weak preauricular hot spot. All 3 hot spots had already been visualized on dynamic scans and on static planar images after 15 min. On 2-dimensional and 3-dimensional (B) SPECT/CT fusion, 2 sentinel nodes were localized just ventral to sternocleidomastoid muscle and 1 preauricular sentinel node was localized within upper part of parotid gland. In concordance with SPECT/CT, intraoperative images before incision showed injection area and 3 sentinel nodes in same relation to each other (C). After excision of first sentinel node, portable γ -camera showed remaining sentinel nodes (D), which were then localized and removed.

with the probe could also be excised. In the latter case, attenuation had probably prevented the probe from picking up the signal, whereas the node could be visualized and localized by continuous counting with the portable γ -camera.

Few authors have reported on their first experience with intraoperative localization of lymph nodes using these cameras (7,8,10–14). Motomura et al. showed that lymphoscintigraphy of sentinel nodes in breast cancer can reliably be reproduced in the operating room using a solid-state γ -camera (11). Kopelman et al. achieved exact intraoperative localization of sentinel nodes with a portable γ -camera in 9 pigs (7), whereas Mathelin et al. were able to localize sentinel nodes with a portable γ -camera in 11 breast cancer patients (12). Mathelin et al. could also successfully estimate the depth of the nodes preoperatively with this camera (12). Scopinaro et al. demonstrated that more nodes were removed when the hand-held γ -camera was used intraoperatively in addition to the γ -probe in breast cancer patients, and operation time was significantly shorter (13). Aarsvod et al., on the other hand, reported a longer operation time when an intraoperative γ -camera was used (14). We could not compare operation length, since the portable γ -camera was used in all patients. Acquiring intraoperative images takes

only a few minutes, but if more nodes are found and excised because of intraoperative imaging, the procedure is likely to be prolonged. A recently published study from our institute showed the possibility of separate visualization of different radiotracers with the portable γ -camera, enabling the use of an iodine-source pointer as a guide for laparoscopic sentinel node seeking (8).

Because the γ -camera provides only a 2-dimensional view, the depth of nodes can be visualized only when the detector is turned and positioned at the side of the patient. This problem could be solved using a system with 2 separate detectors, although it would reduce the working space of the surgeon. Possibly in the future an integrated system that combines preoperative SPECT/CT images with intraoperative γ -camera guidance will enable intraoperative 3-dimensional navigation (15). Additionally, if reliable tumor-specific radiotracers were to be developed, a portable γ -camera could be able to guide excision of only the tumor-positive nodes (16).

CONCLUSION

Intraoperative visualization of sentinel nodes with a portable γ -camera is feasible and might improve intraoperative detection of sentinel nodes in the head and neck region. Sentinel nodes close to the injection area can be visualized. Determination of postexcision radioactivity might lead to detection of more sentinel nodes. Further research is warranted to assess the exact value of additional intraoperative imaging in these patients.

ACKNOWLEDGMENTS

For cooperation on the treatment of oral cavity carcinoma, we thank Remco de Bree and Géke B. Flach (VU University Medical Center, Amsterdam).

REFERENCES

1. Tanis PJ, Nieweg OE, van den Brekel MW, Balm AJ. Dilemma of clinically node-negative head and neck melanoma: outcome of "watch and wait" policy, elective lymph node dissection, and sentinel node biopsy—a systematic review. *Head Neck*. 2008;30:380–389.
2. Jansen L, Koops HS, Nieweg OE, et al. Sentinel node biopsy for melanoma in the head and neck region. *Head Neck*. 2000;22:27–33.
3. Nowecki ZI, Rutkowski P, Nasierowska-Guttmejer A, Ruka W. Survival analysis and clinicopathological factors associated with false-negative sentinel lymph node biopsy findings in patients with cutaneous melanoma. *Ann Surg Oncol*. 2006;13:1655–1663.
4. Carlson GW, Page AJ, Cohen C, et al. Regional recurrence after negative sentinel lymph node biopsy for melanoma. *Ann Surg*. 2008;248:378–386.
5. Chao C, Wong SL, Edwards MJ, et al. Sentinel lymph node biopsy for head and neck melanomas. *Ann Surg Oncol*. 2003;10:21–26.
6. Sanchez F, Fernandez MM, Gimenez M, et al. Performance tests of two portable mini gamma cameras for medical applications. *Med Phys*. 2006;33:4210–4220.
7. Kopelman D, Blevis I, Iosilevsky G, et al. Sentinel node detection in an animal study: evaluation of a new portable gamma camera. *Int Surg*. 2007;92:161–166.
8. Vermeeren L, Valdés Olmos RA, Meinhardt W, et al. Intraoperative radio-guidance with a portable gamma camera: a novel technique for laparoscopic sentinel node localisation in urological malignancies. *Eur J Nucl Med Mol Imaging*. 2009;36:1029–1036.
9. Schillaci O, D'Errico G, Scafè R, et al. Sentinel node detection with imaging probe. *Tumori*. 2002;88(suppl):S32–S35.
10. Mathelin C, Salvador S, Bekaert V, et al. A new intraoperative gamma camera for the sentinel lymph node procedure in breast cancer. *Anticancer Res*. 2008;28:2859–2864.
11. Motomura K, Noguchi A, Hashizume T, et al. Usefulness of a solid-state gamma camera for sentinel node identification in patients with breast cancer. *J Surg Oncol*. 2005;89:12–17.
12. Mathelin C, Salvador S, Huss D, Guyonnet JL. Precise localization of sentinel lymph nodes and estimation of their depth using a prototype intraoperative mini gamma-camera in patients with breast cancer. *J Nucl Med*. 2007;48:623–629.
13. Scopinaro F, Tofani A, di Santo G, et al. High-resolution, hand-held camera for sentinel-node detection. *Cancer Biother Radiopharm*. 2008;23:43–52.
14. Aarsvod JN, Greene CM, Mintzer RA, et al. Intraoperative gamma imaging of axillary sentinel lymph nodes in breast cancer patients. *Phys Med*. 2006;21(suppl 1):76–79.
15. Wendler T, Hartl A, Lasser T, et al. Towards intraoperative 3D nuclear imaging: reconstruction of 3D radioactive distributions using tracked gamma probes. *Med Image Comput Assist Interv*. 2007;10:909–917.
16. Aderson RS, Eifert B, Tartt S, King P. Radioimmunoguided surgery using indium-111 capromab pentetide (PROSTASCINT) to diagnose supraclavicular metastasis from prostate cancer. *Urology*. 2000;56:669.