Annals of Nuclear Medicine Vol. 19, No. 7, 627–631, 2005

Assessment of the solid-state gamma camera to depict axillary sentinel lymph nodes in breast cancer patients

Mariko GOTO, Chio OKUYAMA, Takao KUBOTA, Yo USHIJIMA and Tsunehiko NISHIMURA

Department of Radiology, Graduate School of Medical Science, Kyoto Prefectural University of Medicine

Purpose: The solid-state gamma camera is now commercially available offering the advantages of a compact and portable system, currently used mainly in the cardiac region. We evaluate the ability of the solid-state gamma camera to depict axillary sentinel lymph nodes (SLNs) in breast cancer patients. ***Materials and Methods:*** Preoperative SLN lymphoscintigraphy (LSG) was performed in 19 patients with breast cancer using the solid-state gamma camera. Immediately thereafter, we performed a second LSG using a single detector Anger-type gamma camera, and compared the findings from the two cameras. ***Results:*** Concordant results were obtained in 12 (63%) patients with both cameras. In 4 (21%) patients, axillary SLNs were correctly identified only with the solid-state gamma camera. In these patients, the distance between the SLN and the radiopharmaceutical injection site was closer than that of patients who had concordant results ($p = 0.001$). ***Conclusion:*** We can depict correctly axillary SLNs with the solid-state gamma camera in comparison with the Anger-type gamma camera. This technique would be useful for assessing SLNs in breast cancer patients.

Key words: breast cancer, sentinel lymph node, solid-state gamma camera

INTRODUCTION

SENTINEL LYMPH NODE BIOPSY for patients with breast cancer is a less invasive technique for evaluating the status of the axillary lymph nodes.[1–11] Lymphoscintigraphy (LSG) using a radiopharmaceutical has been widely accepted for depicting the sentinel lymph node (SLN) in breast cancer. The solid-state gamma camera 2020tc Imager™ (Digirad, California, USA) is a multi-crystal scintillation camera, and each matrix is separated by a septum and semiconductor elements one connected to each matrix. High signal-to-noise (S/N) ratio images can be obtained. In addition, the weight of the equipment is reduced, which makes it easy to move. The 2020tc Imager™ has been clinically applied in the cardiac region, but no report of this imaging system to depict the status of axillary SLNs in breast cancer patients has yet appeared in the literature.[12–15] Because of the ideal characteristics of the solid-state gamma camera, we considered that is should be able to detect axillary SLNs more precisely than the conventional gamma camera. In the present study, we evaluated the ability of the solid-state gamma camera to depict the status of SLNs in breast cancer patients.

Received February 24, 2005, revision accepted July 14, 2005.

For reprint contact: Mariko Goto, M.D., Department of Radiology, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, 465 Kajiicho, Kawaramachi Hirokoji, Kamigyo-ku, Kyoto 602–8566, JAPAN.

E-mail: gomari@koto.kpu-m.ac.jp

MATERIALS AND METHODS

Selection of patients

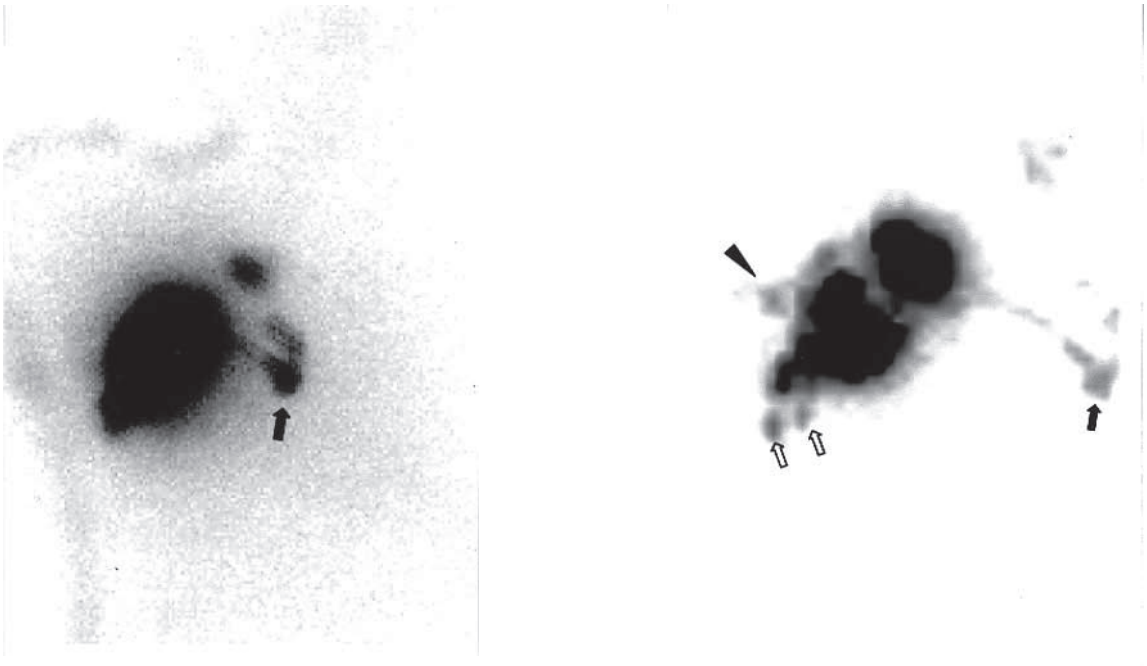
Nineteen consecutive females with a total of 21 breast cancers, who had clinically negative axilla, were enrolled in our study. Two patients had double lesions each on a unilateral breast. The mean age of the patients was 49 years (range, 36–84 years).

A preoperative diagnosis was obtained with the aid of a physical examination, mammography, ultrasonography, computed tomography, and fine-needle aspiration cytology or a core biopsy. The tumor was situated in the upper outer quadrant in 7 tumors, the lower outer quadrant in 3, the upper inner quadrant in 8, the lower inner quadrant in 2, and in the central part of the breast in 1. The clinical stage was T1 in 9 tumors, T2 in 6, T3 in 1, and Tis in 5. The histologic diagnosis of the primary tumor was

Table 1 Patient characteristics and scintigraphic findings

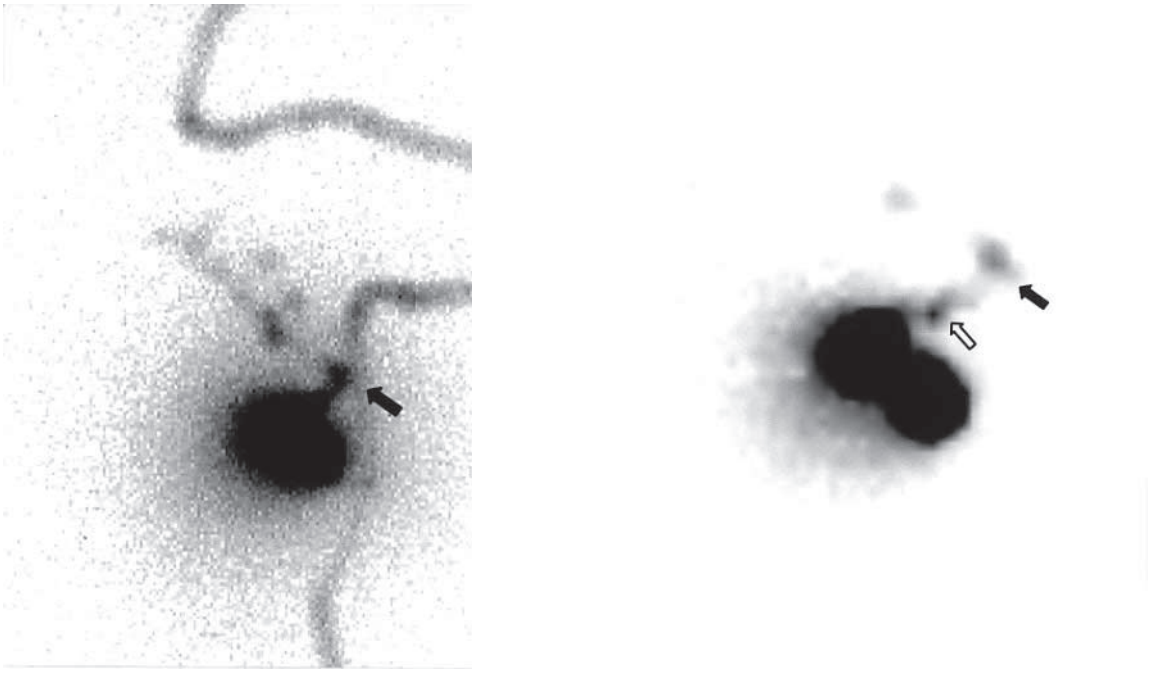
Patient No.	Age (y)	Primary Tumor				Depiction of SN		Distance of SN-injection site (cm)
		Location	Side	Size (cm)	Histology	Solid-state	Anger type	
1	36	LOQ	Left	1.8	DCIS	correct	correct	4
		LOQ	Left	1.8				
2	49	UIQ	Left	2.6	IDC	correct	correct	5.7
3	44	UIQ	Right	3.9	IDC	correct	ND	1.2
4	41	C	Left	1.8	IDC	correct	ND	0.8
5	43	UOQ	Right	2.6	IDC	correct	correct	11.4
		UOQ	Right	1.5				
6	47	UIQ	Left	1.9	IDC	correct	correct	4.1
7	47	LOQ	Left	2.5	IDC	correct	correct	5.3
8	50	LIQ	Right	1.4	DCIS	correct	correct	6.5
9	47	UOQ	Left	2.7	ILC	ND	ND	
10	61	UIQ	Left	3.3	DCIS	correct	incorrect	0.8
11	54	UOQ	Left	1.6	IDC	correct	correct	2.7
12	48	UIQ	Right	2	DCIS	correct	correct	0.8
13	57	LIQ	Left	2	IDC	ND	ND	
14	46	UIQ	Left	3	IDC	correct	correct	3.3
15	47	UOQ	Left	2	IDC	correct	correct	1
16	67	UIQ	Right	1.9	IDC	correct	ND	1.6
17	38	UIQ	Left	1.8	IDC	correct	correct	5.5
18	50	UOQ	Left	7.2	ILC	correct	correct	5.1
19	60	UOQ	Left	0.9	IDC	ND	ND	

SN: Sentinel node, C: Central part of breast, LIQ: Lower inner quadrant, LOQ: Lower outer quadrant, UIQ: Upper inner quadrant, UOQ: Upper outer quadrant. DCIS: Ductal carcinoma *in situ*, IDC: Invasive ductal carcinoma, ILC: Invasive lobular carcinoma. correct: The axillary SN was identified on LSG. incorrect: An axillary lymph node was detected, however not the correct. ND: The axillary hot spot could not detected.



A **B**

Fig. 1 A 44 y.o. patient with cancer of the right breast. A: LSG on the Anger-type gamma camera. The internal mammary chain was depicted (*arrow*), but no axillary hot spot. B: LSG on the solid-state gamma camera. The axillary SLN could be detected near the hot spot of the tracer injection site (*arrowhead*). The intramammary lymph nodes were also detected (*open arrow*).



A B

Fig. 2 A 61 y.o. patient with cancer of the left breast. A: LSG on the Anger-type gamma camera. The axillary SLN was detected (*arrow*). B: LSG on the solid-state gamma camera. An axillary hot spot nearer to the tracer injection site was identified in a sequential series (*open arrow*).

invasive ductal carcinoma in 13 patients, ductal carcinoma *in situ* (DCIS) in 4, and invasive lobular carcinoma in 2. All patients met the inclusion criteria and written informed consent forms were prospectively included in this study.

Imaging and SLN biopsy

On the day of surgery, LSG was performed on each patient to delineate the lymphatic drainage and mark the location of the draining nodes. Technetium-99m-diethylenetriamine pentaacetic acid human serum albumin (^{99m}Tc-HSAD) (Nihon Medi-Physics Co., Nishinomiya, Japan) was prepared in 4 m*l* 0.9% normal saline. Three or four injections of the radiopharmaceutical, typically 0.3 m*l* each, were placed around the tumor, either subcutaneously or intradermally. The average of the administered dose was 185 MBq (range, 135–235 MBq).

Immediately after injection, the arms on the patients' affected sides were fixed in a 90-degree abducent position. First, images were obtained using the solid-state gamma camera with the movable detector placed anterior to the patients' axillae. The mobility of the detector was of great advantage in achieving direct contact with the target area. A low energy high-resolution collimator was attached, and data collection was conducted for 15–20 minutes. Immediately thereafter, patients underwent a second imaging using the conventional single detector Anger-type gamma camera (GCA 901A, Toshiba, Tokyo, Japan), equipped with a low-energy, high-resolution collimator. Oblique planar images were obtained in 10–15 minutes. The location of the sentinel node was marked on the skin with indelible ink.

About one hour after tracer injection, total mastectomy or breast-conserving surgery was performed after sentinel node biopsy. Just before surgery, 2% patent blue dye was injected subareolarly to a volume of 2.0 m*l*. Breast massage was used in all patients. The sentinel node was identified and harvested after careful dissection of blue lymphatic vessels and detection of radioactivity with a gamma-ray detection probe (Navigator GPS*, Tyco, USA). We compared the sentinel node as detected intraoperatively with the image of the same SLN from each camera.

Statistical analysis

Statistical significance was determined with the paired Welch's t-test for the differences in the tumor size and the distance of the SLN-injection site in paired images. The distance of the SLN-injection site means the distance from the closest site of the radiopharmaceutical tracer injections to the depicted axillary SLN. A p value of less than 0.005 indicated significance.

RESULTS

Table 1 summarizes our results. We could depict an axillary hot spot on LSG with the solid-state gamma

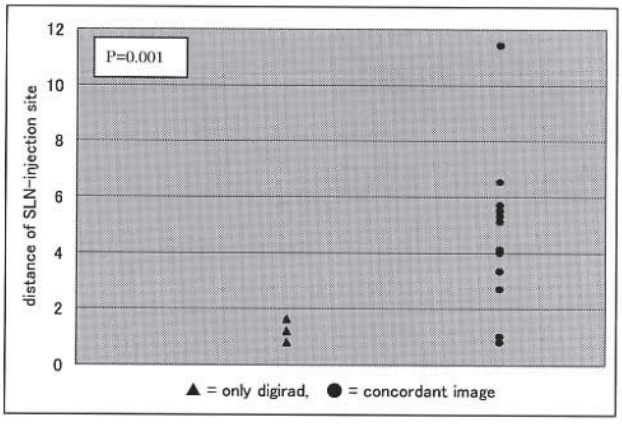


Fig. 3 In a case where the axillary SLN was correctly identified with the solid-state gamma camera, the distance between the SLN and the tracer injection site was significantly nearer than that in other patients in whom the images were concordant with both camera systems. (p = 0.001)

camera in 16 (84%) of 19 cases. With the Anger-type gamma camera, an axillary hot spot was depicted in 13 cases (68%). Six patients had drainage to both the axilla and nonaxillary basins on both images: to the internal mammary chain in one patient, to the infraclavicular fossa in four, and to the internal mammary chain and the infraclavicular fossa in one. Three patients (14%) had no visualized axillary hot spot on either image. However, an axillary SLN could be intraoperatively identified with blue dye and handheld gamma-ray detection probe in all three cases. All the axillary hot spots visualized on LSG with the solid-state gamma camera could be localized with blue dye or the handheld gamma-ray detection probe. We could identify the same axillary lymph node as SLN in 12 (63%) cases with both the solid-state gamma camera and the conventional Anger-type gamma camera. In 4 (21%) of 19 patients (Table 1, No. 3, 4, 10, 16), correct axillary SLN was identified only with the solid-state gamma camera. Three of the four tumors were located in the upper inner quadrant, one in the central. Two of the four patients had only internal mammary drainage with or without infraclavicular drainage, and one had no visualized hot spot on LSG with the conventional Anger-type gamma camera (Fig. 1). The nearer axillary hot spot of a sequential series was identified by the solid-state gamma camera (Fig. 2), in 1 patient. In four patients in whom the axillary SLN was identified with the solid-state gamma camera only, the distance between the SLN and the tracer injection site was significantly nearer than that in patients in whom the images were concordant on both camera systems (p = 0.001) (Fig. 3). There were no significant differences between the difference on the paired images and the tumor size (p = 0.28).

No patients had axillary sentinel node metastasis, and no further axillary lymph node dissection was performed. The median follow-up period was 29 months with a maximum follow-up time of 32 months, during which time no axillary recurrence was observed in any of the patients.

DISCUSSION

Preoperative LSG is often performed for the purpose of visualizing the SLN location before operation. The value of LSG for breast cancer is still a matter of debate,[16,17] but we consider that adequate imaging is clinically useful for sentinel node biopsy, because a surgeon can tailor incision planning based on knowledge of the location and number of sentinel or secondary nodes. In addition, LSG is most useful for revealing the pattern of drainage across the entire lymphatic system, identifying uptake in multiple nodes or detecting 'remote' SLNs, that is, internal mammary or infraclavicular nodes.

Technetium-99m-sulfur colloid and technetium-99m-colloidal albumin are usually used for SNB. In the present study, however, we used ^{99m}Tc-HSAD, because ^{99m}Tc-HSAD has faster kinetics than either of the particulate agents and provided the benefit of better definition of the lymph draining vein. Because of its small particle size, ^{99m}Tc-HSAD can permeate the lymphatic vessels rapidly, resulting in a good identification rate of axillary SLNs only a few minutes after tracer injection. This depiction rate is in line with previous reports using other radiopharmaceuticals,[4,18] and ^{99m}Tc-HSAD is considered to be acceptable for lymphatic mapping in breast cancer.[19]

The solid-state gamma camera used in the study does not require vacuum tubes, and uses CsI (Tl) as the scintillant and a silicon photodiode. Because CsI (Tl) has a higher density and atomic number than NaI (Tl), it detects gamma rays with higher sensitivity. Each module is partitioned into 4,096 individual elements of 3.2 × 3.2 mm in area, and this camera has a field-of-view of 20.8 × 20.8 cm, thus providing the basis for a compact, lightweight and portable system. The detector element has its own signal processing chain and can address individual photon events. This type of movable camera can therefore be used under emergency conditions in coronary care or intensive care units.

In this study, in four patients (21%) the axillary SLN was correctly identified by only the solid-state gamma camera, especially when the distance from the tracer injection site was closer to the SLN (p = 0.001). In these four cases, although the axillary SLN was correctly detected when the solid-state gamma camera was used for the first set of images, we could not detect these hot spots with the Anger type gamma camera. Two possible explanations for the difference in imaging ability between the two camera systems can be considered. The first explanation is the higher S/N ratio of the solid-state gamma camera. Because each detector has its own signal processing chain, we can obtain images with a higher S/N ratio than that obtained from conventional scintillation cam-

eras. Because of this, the problem of "shine through" from the injection site is supposed to be lower, and we can identify SLNs closer to the hot spot of the tracer injection site. A second explanation is that the equipment is reduced in weight and it is compact, which makes it easy to move. The arm which supports the detector has a large range of movement, so that the axillary SLN count can be collected with the detector oriented closer to patients'axilla from the anterior aspect. When these explanations are taken into account, the solid-state gamma camera was more useful than Anger type gamma camera for the depiction of axillary SLNs, especially for those SLNs close to the injection site.

In conclusion, the accuracy of lymphatic mapping is of utmost importance now that axillary node dissection is not usually performed in patients who have breast cancer but have negative sentinel nodes. We confirmed that count collection was highly efficient and the axillary SLNs were correctly detected with the solid-state gamma camera. This technique would be useful for assessing SLNs in breast cancer patients.

REFERENCES

1. Fisher B, Redmond C, Fisher ER, Bauer M, Wolmark N, Wickerham DL, et al. Ten-year results of a randomized clinical trial comparing radial mastectomy and total mastectomy with or without radiation. *N Engl J Med* 1985; 312: 674–681.
2. Giuliano AE, Kirgan DM, Guenther JM, Morton DL. Lymphatic mapping and sentinel lymphadenectomy for breast cancer. *Ann Surg* 1994; 220: 391–401.
3. Giuliano AE, Jones RC, Brennan M, Statman R. Sentinel lymphadenectomy in breast cancer. *J Clin Oncol* 1997; 15: 2345–2350.
4. Krag D, Weaver D, Ashikaga T, Moffat F, Klimberg VS, Shriver C, et al. The sentinel node in breast cancer—a multicenter validation study. *N Engl J Med* 1998; 339: 941–946.
5. Motomura K, Inaji H, Komoike Y, Kasugai T, Nagumo S, Noguchi S, et al. Sentinel node biopsy in breast cancer patients with clinically negative lymph-nodes. *Breast Cancer* 1999; 6: 259–262.
6. Motomura K, Inaji H, Komoike Y, Kasugai T, Noguchi S, Koyama H. Sentinel node biopsy guided by indocyanine green dye in breast cancer patients. *Jpn J Clin Oncol* 1999; 29: 604–607.
7. Motomura K, Inaji H, Komoike Y, Hasegawa Y, Kasugai T, Noguchi S, et al. Combination technique is superior to dye alone in identification of the sentinel node in breast cancer. *J Surg Oncol* 2001; 76: 95–99.
8. Giuliano AE, Haigh PI, Brennan MB, Hansen NM, Kelley MC, Ye W, et al. Prospective observation study of sentinel lymphadenectomy without further axillary dissection in patients with sentinel node—negative breast cancer. *J Clin Oncol* 2000; 18: 2553–2559.
9. Roumen RM, Kuijt GP, Liem IH, van Beek MW. Treatment of 100 patients with sentinel node—negative breast cancer without further axillary dissection. *Br J Surg* 2001; 88: 1639–1643.
10. Schrenk P, Hatzl-Griesenhofer M, Shamiyeh A, Waynad W. Follow-up of sentinel node negative breast cancer patients without axillary lymph node dissection. *J Surg Oncol* 2001; 77: 165–170.
11. Chung MA, Steinhoff MM, Cady B. Clinical axillary recurrence in breast cancer patients after a negative sentinel node biopsy. *Am J Surg* 2002; 184: 310–314.
12. Raff W, Sialer G, von Segesser L, Pfeiffer A, Turina M, von Schulthess GK. Perioperative myocardial perfusion scintigraphy at rest with technetium 99m methoxyisobutylisonitrile before and after coronary bypass operations. *Eur J Nucl Med* 1991; 18: 99–105.
13. Kjoller E, Nielsen SL, Carlsen J, Nielsen F, Moller JT, Hvid-Jacobsen K, et al. Impact of immediate and delayed myocardial scintigraphy on therapeutic decisions in suspected acute myocardial infarction. *Eur Heart J* 1995; 16: 909–913.
14. Tausig A, Knesewitsch P, Brinkbaumer K, Tatsch K, Hahn K. Is a low dose Tc-99m-MIBI protocol suitable for first-pass RNV? *Nucl Med Commun* 2000; 21: 965–970.
15. Kumita S, Tanaka K, Cho K, Sato N, Nakajo H, Toba M, et al. Assessment of left ventricular function using solid-state gamma camera equipped with a highly-sensitive collimator. *Ann Nucl Med* 2003; 17: 517–520.
16. McMasters KM, Wong SL, Tuttle TM, Carlson DJ, Brown CM, Dirk Noyes R, et al. Preoperative lymphoscintigraphy for breast cancer does not improve the ability to identify axillary sentinel lymph nodes. *Ann Surg* 2000; 231: 724–731.
17. Burak WE Jr, Walker MJ, Yee LD, Kim JA, Saha S, Hinkle G, et al. Routine preoperative lymphoscintigraphy is not necessary prior to sentinel node biopsy for breast cancer. *Am J Surg* 1999; 177: 445–449.
18. Cox CE, Pendas S, Cox JM, Joseph E, Shons AR, Yeatman T, et al. Guidelines for sentinel node biopsy and lymphatic mapping of patients with breast cancer. *Ann Surg* 1998; 227: 645–653.
19. Imoto S, Murakami K, Ikeda H, Fukukita H, Moriyama N. Mammary lymphoscintigraphy with various radiopharmaceuticals in breast cancer. *Ann Nucl Med* 1999; 13: 325–329.