Original article

Contribution of the portable gamma camera to detect the sentinel node in breast cancer during surgery

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A B S T R A C T

Aim: To show our experience using the portable gamma camera during surgery in the detection of the sentinel node in breast cancer.

Material and methods: A total of 46 women diagnosed with breast cancer were included. This study was carried out by means of the periareolar intradermal injection. Planar images and SPECT/CT were acquired. On the following day, the sentinel nodes were localized intraoperatorically with a portable gamma camera and a gamma probe. Images of the axilla in anterior and lateral projections were acquired before and after extraction of all the sentinel nodes.

Results: The images acquired with the portable gamma-camera during the operation showed no activity in all the patients after the removal of the sentinel nodes. In four out of the 46 cases, the portable gamma camera provided relevant information during the procedure (it detected a sentinel node in two cases in which it had not been detected prior to the surgery and it oriented the surgeon in the localization of low activity nodes when the probe screening had been negative).

Conclusions: The intraoperative portable gamma camera to detect the sentinel node in breast cancer patients is useful in order to ensure, independent of the surgeon that all the sentinel nodes have been removed. It can also help guide the surgeon in the event of a single low activity sentinel node.

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Aportación de una gammacámara portátil en la localización intraoperatoria del ganglio centinela en el cáncer de mama

R E S U M E N

Objetivo: Mostrar nuestra experiencia en el uso de una gammacámara portátil en la localización intraoperatoria del ganglio centinela en el cáncer de mama.

Material y métodos: 46 mujeres diagnosticadas de cáncer de mama fueron incluidas. Se realizó inyección periareolar intradérmica del radiotrazador. Se obtuvieron imágenes planares y SPECT-TAC. El día siguiente se emplearon una sonda y una gammacámara portátil para la detección del ganglio centinela intraoperatorio. Se tomaron imágenes en las proyecciones anterior y lateral de la axila antes y después de la extracción del ganglio centinela.

Resultados: Las imágenes obtenidas intraoperatoriamente no mostraron actividad en todos los pacientes después de la extracción de todos los ganglios centinela. En cuatro de los 46 casos la gammacámara dio información importante (en dos casos localizó ganglios no detectados en las imágenes prequirúrgicas y en otros dos orientó al cirujano en localizar ganglios de baja actividad cuando el rastreo con sonda fue negativo).

Conclusiones: El uso de la gammacámara portátil intraoperatoria en la localización del ganglio centinela en cáncer de mama es útil para asegurar, con independencia del cirujano, que todos los ganglios han sido extirpados. Puede guiar además al cirujano en la localización de ganglios de baja actividad.

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Introduction

Imaging and diagnosis by imaging are increasingly more present in the operating rooms with laparoscopic surgery, interventional radiology, and intraoperative robots, among other techniques. Nowadays, Nuclear Medicine has a role in the world of surgery with the implementation of the sentinel lymph node technique. Up to now the images obtained in breast cancer have been obtained presurgically (conventional scintigraphy and/or SPECT/CT) with intraoperative localization achieved with the aid of presurgical images and the gamma probe. In the present study we aimed to apply the intraoperative use of a portable gamma camera to this technique. The portable gamma camera and the use of intraoperative images have shown to be useful in several fields: cerebral blood flow scintigraphy as a tool in the diagnosis of encephalic
Fig. 1. Planar images (a) and SPECT-CT (b) performed the day before surgery, showing two deposits interpreted as sentinel lymph nodes (red arrows) and injection points (green arrow). First intraoperative image (c) depicting three sentinel lymph nodes (red arrows). After the removal of the three lymph nodes (d), no activity was observed on the intraoperative image. The intraoperative image detected one lymph node more than the presurgical images. The technique was negative for malignancy. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

dead,1 surgical treatment of primary hyperparathyroidism,2 the ROLL technique,3 sentinel lymph node in breast cancer,4–6 sentinel lymph node in urological tumors via laparoscopy,7 sentinel lymph node in head and neck tumors (melanomas)8 and even in the control of the administration of chemotherapy treatment of malignant melanoma or sarcoma in isolated extremities.9 The aim of this study was to determine the contribution of the use of intraoperative images to the sentinel lymph node technique in breast cancer.

Material and methods

We performed a prospective study in 46 patients diagnosed with breast cancer who attended our department to undergo the sentinel lymph node technique. Women diagnosed with stages T1 and T2 breast cancer without clinical evidence of lymph node involvement (N0) and with no evidence of distant metastasis (M0) were included in the study. The exclusion criteria included pregnant patients, those with evidence of lymph node involvement, multicentric tumors, patients receiving adjuvant chemotherapy and patients with distant metastasis (M1). Age of patients ranged between 37 and 88 years with a mean age of 62.15 years and a standard deviation of ±14 years. Of these 46 women, 15 presented the lesion in the right breast and 31 in the left.

Injection protocol

We used 4 syringes with 99mTc-nanocolloid (Nancol®), a maximum particle diameter of 80 nm, an activity of 37 MBq and a volume of 0.2 ml each 24 h prior to surgery. For the administration of the radiotracer 4 intradermic periareolar injections were made.

Protocol of image acquisition

The images were acquired 60–90 min after the injection of the radiotracer. We performed 3 studies: one planar scintigraphy immediately after the SPECT-CT study and images were obtained with the portable gamma camera during the surgery the following day. No delayed planar images were obtained (Figs. 1–3). For the planar images we used a conventional double-head gamma camera (Sofha Camera DST; Sofha Medical Vision International, Bue Cedex, France) with low energy and ultra-high resolution collimators (LEUHR). The energy peak was of 140 keV ± 10%. A matrix of 128 × 128 was used with a zoom of 1.0. Ten-minute planar images were obtained in two projections, one anterior and one lateral to the side of the lesion with the patient in supine position and the hands behind the head. Transmission images with 57Co were not used. In addition, the lymph nodes observed on the screen were marked on the skin of the patient in both anterior and lateral projection. For the SPECT-CT study we used the equipment composed of a double-head gamma camera with a low dose X-ray tube (Infinia Hawkeye®, General Electric Medical System, Milwaukee WI, USA) with low energy and high resolution collimators (LEHR). Scatter correction was performed. A SPECT study was acquired with a matrix of 128 × 128, zoom 1.0 and a 360° rotation with 60 images of 20 s (one image every 6°) in step and shot mode. Two types of emission image reconstruction were used: reconstruction by filtered retroprojection and iterative reconstruction.
A prefiltration was used with a Hann filter (frequency 0.9, order 0.0) and a post-filtration also with a Hann filter (frequency 0.9, order 10.0). The parameters of reconstruction by defect were Ordered Subset Expectation Maximization/Maximum Likelihood Expectation Maximization (OSEM/MLME) iterative reconstruction with 2 iterations and a maximum of 10 subsets. Scatter correction was applied to both images and attenuation correction by CT was only applied to iterative reconstruction. The CT was acquired in a helicoidal mode with a pitch of 1.9, an interval of 4.42 mm, a matrix of $512 \times 512$ and energy of 2.5 mA and 140 keV. We used a portable gamma camera (Sentinella S102, GEM imaging, Valencia, España) for the images in the operating room. This camera has a scintillation crystal CsI(Na) of $4 \times 4$ cm and a photomultiplier tube (Hamamatsu H8500). To obtain the images we connected a pinhole collimator with an aperture of 2.5 mm to the gamma camera. The gamma camera also has a laser pointer which is useful for positioning in the operating room. It has two lines which cross over the patient in the center of the field of acquisition which is also reflected in the image obtained allowing the operator to identify the center in both the surgical field and in the image acquired. This allows optimization of camera-surgical field alignment from all angles. One-minute images of the injection points and skin marks were obtained in anterior and lateral projection at an approximate distance of 15 cm. When the surgical conditions required, images were performed with a lesser distance between the camera and the area of interest with the aim of increasing the sensitivity, diminishing the size of the field of acquisition and more precisely localizing any radiotracer deposit. After the excision of each lymph node new images were made in anterior and/or lateral projection to confirm the absence of activity in the previous location of the lymph node. In the presence of residual activity or any other deposit, the search for new sentinel lymph nodes was continued with the probe.

**Surgery**

First, the tumor was removed. Once removed the search for the sentinel lymph node was initiated using a gamma probe (Europrobe, Eurorad, Strasbourg, France) with a cadmium telluride crystal (CdZnTe) of $5 \times 5 \times 3$ mm designed for medium energies (20–170 keV). Following extirpation of the sentinel lymph nodes residual activity in the surgical bed was measured with the gamma probe and an image in anterior and/or lateral projection (according to what was considered to be more sensitive) with the portable gamma camera, with the search being considered as finalized when the activity with the probe was minimum and no activity was observed in the images. The lymph node with the greatest activity and all the nodes with activity above 10% of their activity (cps) were removed. Thereafter, the nodes were analyzed by the Department of Anatomy Pathology.

**Results**

A total of 86 sentinel lymph nodes were removed in the 46 patients, corresponding to a mean of 1.86 nodes per patient. In
Fig. 3. SPECT-CT image performed the day before surgery (a) showing two sentinel lymph nodes (red arrows). Image in anterior projection with portable gamma camera (b) in which two sentinel lymph nodes are observed (red arrows). Following extirpation of the first lymph node a scan is made with the probe which is negative. A new image was made (c) demonstrating the persistence of activity (red arrow). An exhaustive search was made with the probe in the zone indicated by the image and a second lymph node was localized. On removal of the second lymph node a last image was made in which no deposits suggesting the presence of more lymph nodes were observed (d). The lymph nodes extirpated were negative for malignancy. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

39 of the patients (85%) the sentinel lymph node(s) were negative for malignancy. Sentinel lymph nodes were localized in 100% of the patients. A total of 83 sentinel lymph nodes were localized in the presurgical images at axillary levels I and II. The images obtained with the portable gamma camera following extirpation of the sentinel lymph nodes did not show residual activity in any of the patients. That is, the procedure was not finished until a negative intraoperative image was obtained; thus, the 83 nodes visualized were removed plus another three which are described below.

In two of the 46 cases (4%) an image compatible with the presence of a lymph node was observed after scanning with a negative gamma probe after removal of at least one sentinel lymph node. A more exhaustive search was performed in these two cases in the region indicated in the image, removing the lymph node (with a count greater than the 10% of the sentinel lymph node in both cases) and checking for the absence of residual activity with both the probe and the gamma camera. In both cases all the sentinel lymph nodes were negative for malignancy. In the two cases of the last sentinel lymph node removed; this node had already been identified in the SPECT-CT.

In two of the 46 cases (4%) more lymph nodes were observed in the operating room images than those observed in the planar images and/or in the SPECT-CT. In one of the cases the sentinel lymph node was positive for malignancy, although another two removed previously had also been positive. In one of the cases two lymph nodes had been identified in the presurgical images (planar and SPECT-CT) and three were detected in the intraoperative image. In the other case there were three presurgical (planar and SPECT-CT) and five intraoperative images. In two of the 46 cases (4%) the sentinel lymph node was not observed with the portable gamma camera in vivo but, once the lymph nodes were excised with the aid of the gamma probe, the lymph node was observed ex vivo. The mean extra intervention time was 10 min.

Discussion

Since the implementation of the sentinel lymph node technique in breast cancer several technological advances have facilitated the performance of this procedure. Among these advances those which have improved the presurgical localization of the sentinel lymph nodes are of note such as the use of the hybrid SPECT-CT equipment. This equipment has improved the sensitivity and the specificity of presurgical lymphscintigraphy as well as providing better localization and preparation of the presurgical approaches.

In the present study we particularly centered on what intraoperative image acquisition could contribute to sentinel lymph node surgery in breast cancer apart from aiding in the localization of lymph nodes in complicated localization (previously observed with presurgical images). One possible bias or limitation of our study is the impossibility to evaluate the utility in this field since we used periareolar injection of the radiotracer which limits the detection of extraaxillary lymph nodes.

It is not possible to compare the sensitivity or specificity of the portable gamma camera in the detection of the sentinel lymph node with those of the conventional gamma camera or with SPECT-CT. Among other aspects, the field of vision, the time of image acquisition, and the number of photomultiplier tubes are inferior to those of the conventional gamma camera and SPECT-CT. Nonetheless, the portable gamma camera has demonstrated greater resolution
and quality in the images obtained in less than 1 min than the conventional gamma cameras. Moreover, the portable gamma camera has the advantage of being able to make images once each lymph node has been removed in the operating room. Sometimes the number of lymph nodes observed prior to surgery does not agree with the number of nodes extirpated and, on occasions, this is because the activity of some lymph nodes may mask the presence of others. It is in these cases that the portable gamma camera demonstrates a clear advantage over the other two gamma cameras. It should also be taken into account that the position of the patient in the operating room may differ from the position of the presurgical images which may displace the preoperative marks of the lymph nodes observed and not correctly orient the surgeon for a correct principal incision in the axilla. This may be solved with intraoperative images.

Another principal contribution which we have observed is that of visually checking the removal of all the lymph nodes. Following extirpation of the lymph nodes a scan is normally made with the gamma probe in search of residual activity in the surgical bed. This scan should be thorough and exhaustive to ensure correct confirmation of the removal of all of the lymph nodes but, sometimes, the lack of experience of the operator or the proximity of the lymph nodes to the points of injection may greatly complicate this process. In our experience, in two of the 46 cases, activity continued to be seen in the axillary region after a negative scan with the gamma probe, and after a more exhaustive search with the probe (directed by the image provide by the gamma camera) more sentinel lymph nodes were localized. The axillary staging did not change in either of these cases since these lymph nodes were negative for malignancy similar to those previously extirpated.

The intraoperative images have the advantage that with only one image a scanning of all the axilla may be made and guide the exhaustive search of the probe in cases with suspicious deposits of radiotrace. Moreover, the lymph node observed in the image can be confirmed to be the node which has been removed. The availability of a graphic document showing the absence of more deposits and suggesting the presence of more lymph nodes is also useful. Another advantage of intraoperative imaging is that the masking produced by the points of injection (which complicate the search even by very experienced surgeons) and eliminating them from the intraoperative image (with lead deposits in the points or attempting to avoid their appearance in the field of vision) may, in part, be avoided. In our study the intraoperative images were a great complement to the gamma probe in the localization of the sentinel lymph nodes and in confirming their extirpation. It is true that in two cases the lymph nodes were not observed in vivo but were seen ex vivo. It is very probable that if the time of acquisition in these two cases had been greater than 1 min they would have been observed in vivo. In addition, this will be solved with the development of new software allowing elimination of the injection points from the images and will even reduce the time of image acquisition.

With regard to the increase in the time of surgery with the use of the gamma camera, in our experience this increase was of a mean of 10 min. Nonetheless, the advantages provided and the fact that the intraoperative images often avoid an exhaustive search with the probe in zones in which it is not necessary, this time could be modified and even justified by the benefits obtained.

Conclusions

The use of intraoperative images is a great complement to the gamma probe in the localization of the sentinel lymph nodes in breast cancer, especially since they ensure extirpation of all the sentinel lymph nodes and graphic documentation confirming this. These images are also useful to guide the surgeon in localizing and removing lymph nodes with low activity not detected in the first scan with a probe.

Conflict of interest

The authors declare no conflict of interest.

References