Potential role of a new hand-held miniature gamma camera in performing minimally invasive parathyroidectomy

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Abstract. *Purpose:* Sestamibi scans have increased the use of minimally invasive parathyroidectomy (MIP) to treat primary hyperparathyroidism (PHPT) when caused by a parathyroid single adenoma. The greatest concern for surgeons remains the proper identification of pathological glands in a limited surgical field. We have studied the usefulness of a new hand-held miniature gamma camera (MGC) when used intraoperatively to locate parathyroid adenomas. To our knowledge this is the first report published on this subject in the scientific literature.
Methods: Five patients with PHPT secondary to a single adenoma, positively diagnosed by preoperative sestamibi scans, underwent a MIP. A gamma probe for radioguided surgery and the new hand-held MGC were used consecutively to locate the pathological glands. This new MGC has a module composed of a high-resolution interchangeable collimator and a CsI(Na) scintillating crystal. It has dimensions of around 15 cm×8 cm×9 cm and weighs 1 kg. The intraoperative assay of PTH (ioPTH) was used to confirm the complete resection of pathological tissue.
Results: All cases were operated on successfully by a MIP. The ioPTH confirmed the excision of all pathological tissues. The MGC proved its usefulness in all patients, even in a difficult case in which the first attempt with the gamma probe failed. In all cases it offered real-time accurate intraoperative images.
Conclusion: The hand-held MGC is a useful instrument in MIP for PHPT. It may be used to complement the standard tools used to date, or may even replace them, at least in selected cases of single adenomas.

Keywords: Primary hyperparathyroidism – Parathyroid adenoma – Minimally invasive surgical procedures – Intraoperative procedures – Miniature gamma camera

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Introduction

The introduction of ^{99m}Tc-sestamibi scintigraphy to identify and locate preoperatively the parathyroid adenomas in primary hyperparathyroidism (PHPT) opened the possibility of performing single gland parathyroidectomies via minimal access, with outcome results similar to those achieved using bilateral neck exploration [1].

We have used the new hand-held miniature gamma camera (MGC) Sentinella 102 (GEM-Imaging SL, Spain) within the surgical field in order to verify its possible value in the detection of parathyroid adenomas when using minimally invasive access for parathyroidectomy. The use of portable hand-held gamma cameras has been reported in other medical fields, especially in surgery and pre-surgery sentinel node techniques [2–4] and thyroid scintigraphy [5]. To our knowledge, this is the first report on use of a hand-held MGC to intraoperatively locate pathological parathyroid glands.

Materials and methods

We included five patients with clinical and laboratory findings of PHPT, with positive ^{99m}Tc-sestamibi scintigraphy for a single adenoma. Calcium, phosphorus and parathyroid hormone (PTH) were registered pre-operatively and 3 months postoperatively. All the patients included in this study had previously given their informed consent, and the entire research project was authorised by the Committee for Ethical Research at the hospital.

A -planar conventional parathyroid scintigraphy (740 MBq, i.e. 20 mCi, ^{99m}Tc-sestamibi dual-phase scintigraphy protocol [6, 7]) had previously been implemented in all patients using two large field of view gamma cameras (GE Genie single-head and Elscint Helix dual-head gamma cameras), both equipped with parallel-hole, low-energy, high-resolution collimators. Images of the head and mediastinum were recorded in a 128×128 matrix, 20 min and 2 h post injection. In four patients a subtraction image was obtained 20 min after the injection of a standard dose of ^{99m}Tc-pertechnetate [185 MBq (5 mCi)] in order to clarify the origin (thyroid vs parathyroid) of abnormal ^{99m}Tc-sestamibi uptake. In order to improve the diagnosis, single-photon emission computed tomography (SPECT) images were acquired in one patient using the dual-head gamma camera and the following parameters: circular orbit, 120 steps over 360°, 25 s per step and a 64×64 matrix.

On the day of the surgery, 111–185 MBq (3–5 mCi) of ^{99m}Tc-sestamibi (Cardiolite, Bristol Myers Squibb Pharma Belgium Sprl) was injected in the operating room 10 min before surgery. Next, three to eight images, each of about 20–30 s, were acquired before and during the surgery with the Sentinella 102 equipped with a pin-hole 4-mm collimator and using a 300×300 matrix. Before the surgical incision, planar imaging was performed, placing the collimator at a distance of 15 cm. This permitted visualisation, at a low resolution, of the cervical and superior thoracic field, from the salivary glands to the heart.

The MIP was performed through a 2-cm cervical incision, made over the point of maximal isotope uptake as seen on preoperative imaging. Surgical telescopes 2.5× (Designs for Vision, USA) were used by the surgeon to improve the surgical field view.

Intraoperative location of the pathological gland was achieved by the use of both the gamma probe Navigator GPS (RMD Systems LLC, USA) and the hand-held MGC Sentinella 102. These devices were also used to verify the absence of positive radioactivity after resection of pathological gland. Complete removal of pathological tissue was confirmed by an intraoperative quick PTH assay (ioPTH) (PTH intact test, CV intra-assay 1.1%, CV inter-assay 2.8%, Cobas, Roche Diagnostics GmbH, Germany) before and 15 min after gland resection. Frozen sections of all resected glands were performed.

The new Sentinella 102 hand-held MGC (Fig. 1) has a head module composed of a high-resolution interchangeable lead collimator (pin-hole apertures of 1.0, 2.5 and 4.0 mm), a continuous CsI (Na) scintillating crystal and a flat panel position-sensitive photomultiplier tube. This gamma camera has dimensions of around 15 cm×8 cm×9 cm, weighs 1 kg and just requires a single 3-m wire connection to a laptop computer for proper operation. The real-time acquisition is controlled by a user software that runs under Windows XP. It is capable of showing high-quality planar gamma images of the body, which can be better obtained with the camera coupled to an articulated arm for good stability. This MGC is characterised by an intrinsic spatial resolution of 1.6 mm. Due to the use of a pin-hole collimator, it has a variable field of view (FOV) according to the aperture and to the distance from the body to the pin-hole, achieving a 20-cm FOV while maintaining reasonable resolution. The spatial resolution at a distance of 100 mm is 10 mm (pin-hole 2.5) and 18 mm (pin-hole 4). This small gamma camera offers a high sensitivity (200–2,000 cpm/μCi 10 mm away, 60–160 cpm/μCi 100 mm away), which allows quick imaging acquisition (less than 20 s). Its ability to localise small hot radiation regions is improved by means of accessory tools for reference position establishment between body and gamma image. We tested one of these tools, the so-called LASER Positioning System (LPS). It provides a LASER cross pointing at the FOV central point on the body, with a virtual cross mark at the same position in the gamma image.

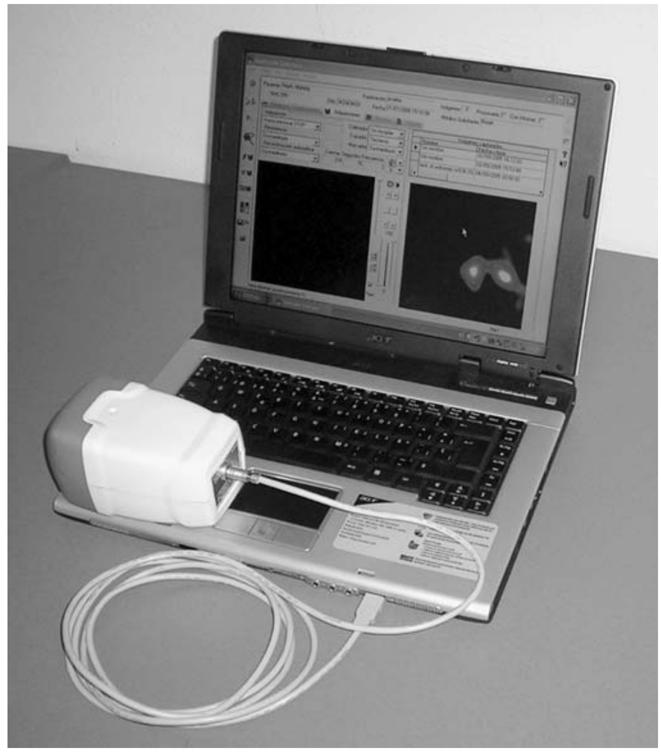

Fig. 1. Sentinella 102 gamma camera, with its connection to a laptop

Results

In all cases, all tests were positive. The five patients had PHPT owing to a single adenoma, and the proper location was correctly marked by preoperative sestamibi scans. We intraoperatively used the gamma camera to obtain a dynamic cervical scan every 10 min, and we could observe progressive wash-out of isotope from the thyroid and background, facilitating identification of the adenoma. In all cases, the MGC provided the same information as the preoperative imaging, and the initial images always showed a hot spot for the parathyroid adenomas. The gamma probe helped us to locate the glands and findings were always concordant with gamma camera scans.

The gamma camera was always able to locate surgically the adenomas at a good resolution, the head of the gamma camera being placed 5–10 cm from the thyroid (Fig. 2). After the excision, a scan of the gland ex vivo was performed (Fig. 3), and thereafter an image of the surgical field was taken in order to confirm absence of the previous hot spot. In one of the cases, with a preoperative diagnosis of adenoma in the right inferior parathyroid gland, a normal gland was found orthotopically although there was a hot spot and the gamma probe counts were still elevated. The resection of two small tumours did not alter this condition, with persistence of a hot spot on dynamic scintigraphy, and the frozen sections revealed two enlarged adenopathies. A lateral view of the surgical field with the gamma camera identified a posterior location of the hot spot (Fig. 2), and an adenoma was then found in the retro-oesophageal space, corresponding to a migrated superior parathyroid gland. In this case the intervention took slightly longer (100 min), but in the rest of cases, location was quick and easy (always less than 60 min), and all tools showed their usefulness. In all cases the results of ioPTH confirmed resection of the

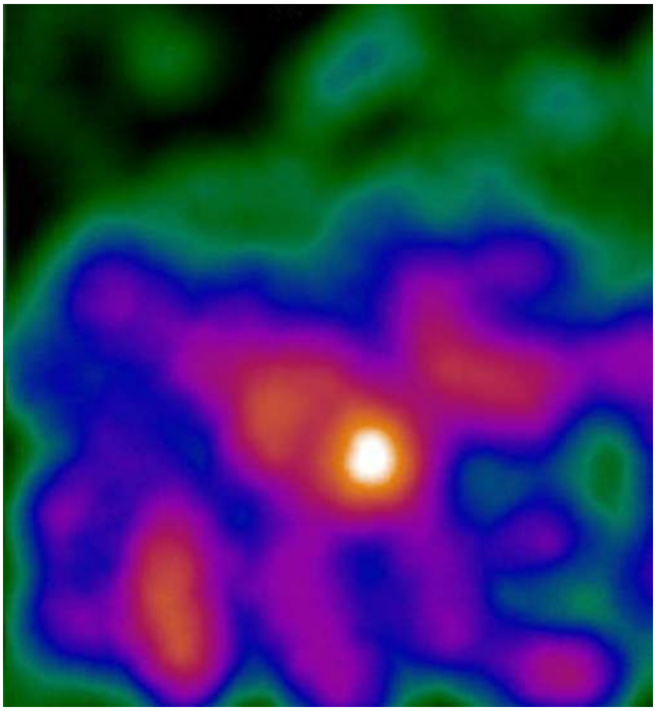

Fig. 2. ^{99m}Tc-sestamibi scintigraphy with the Sentinella 102. Lateral view of the cervical field shows anterior thyroid activity and a posterior parathyroid adenoma

pathological gland, with an average decrease of 76.9% in the hormone level.

The average size of the parathyroid adenomas was 2.3 cm×1.3 cm. The postoperative values of calcium, phosphorus and PTH were normalised in all cases.

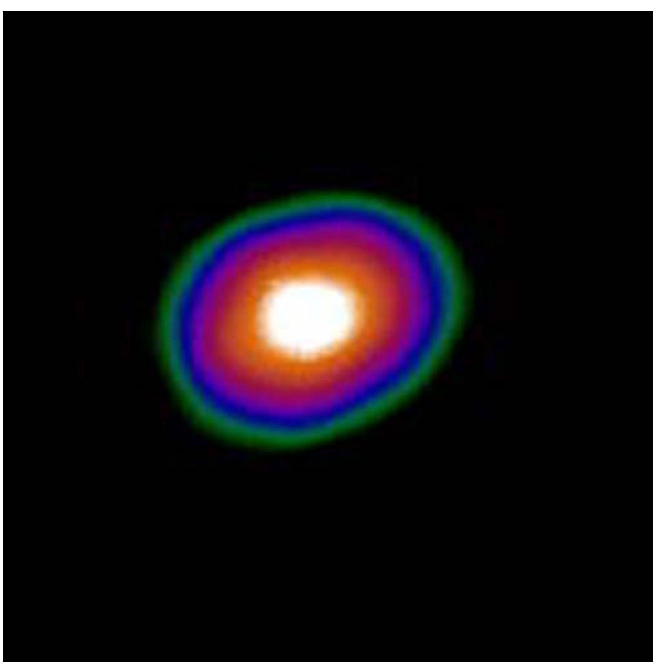

Fig. 3. ^{99m}Tc-sestamibi scintigraphy with the Sentinella 102. Parathyroid adenoma after its removal

Discussion

Most authors agree that ^{99m}Tc-sestamibi scintigraphy is the most powerful preoperative diagnostic tool in PHPT, and it has undoubtedly been responsible for the changes in therapeutic strategy. The addition of various techniques has increased the accuracy of ^{99m}Tc-sestamibi scintigraphy, the most frequently reported being the double-tracer subtraction technique with ^{99m}Tc-pertechnetate and SPECT [8–10].

Cases of PHPT with a single hot spot on ^{99m}Tc-sestamibi scintigraphy and without thyroid pathology are considered suitable for MIP. The success of radio-guided surgery and/or ioPTH in locating the glands and confirming the total excision of pathological tissue has been cited to justify MIP, and, when used together, these techniques achieve a high accuracy in selected cases [11]. Nevertheless, it is well established that sestamibi scans fail to provide information in inappropriate cases and that even ioPTH, the test reported to be the most accurate [12], sometimes fails or presents limitations [3, 13].

In our cases we used various diagnostic and therapeutic tools in an attempt to ascertain whether all the results were concordant with the findings of planar imaging using the new MGC. In all patients, the tests were positive for a single adenoma and these cases were scheduled for MIP.

Immediately prior to surgery, when the patient was in the operating room, a low dose of ^{99m}Tc-sestamibi, 111–185 MBq (3–5 mCi), was injected intravenously. We decided to perform the initial diagnostic scan and surgery on different days, similar to Rubello et al. [14], using low doses of isotope, in order to reduce the threat of radioactivity and to shorten the waiting time after injection. This allowed rapid wash-out of isotope from the thyroid and background, and provided better identification of a single spot of radioactivity. A gamma probe was used to locate the adenomas and its efficacy was compared with that of the MGC. In our opinion, use of the gamma probe can be avoided if an MGC is available: the morphological expression of anatomical structures on planar images and the possibility of obtaining lateral views provide more information than is acquired using a gamma probe, with its aspecific counts and sounds. Moreover, incomplete wash-out of the isotope from the thyroid may lead to misleading records from the gamma probe. In addition, we have confirmed the feasibility of using the MGC after giving low doses of isotope, as first indicated by Casara et al. [15, 16]. The concordance between the preoperative conventional sestamibi scans and the immediate presurgical MGC images leads us to think that, after more experience has been acquired, dynamic imaging could even replace the previous diagnostic scans, at least in order to decide upon the type of intervention. The initial low-resolution imaging, performed at a distance of 15 cm, permitted us to identify the adenomatous gland and to rule out the presence of ectopic tissue. Next, scans were performed at a shorter distance to increase resolution, permitting more accurate anatomical mapping. A quick ioPTH assay was performed in all patients before surgery and 10–15 min post adenoma resection. The aim of evaluating the completeness of removal of all hyperfunctioning parathyroid tissue was achieved in all cases using the MGC, which allowed us to see the complete disappearance of hot spots.

We have found just a single reference to the use of a gamma camera in the operating room for hyperparathyroidism, even though it was not hand-held and portable. This was a case report by Kitagawa et al. [17], who presented the use of a solid-state multi-crystal gamma camera for ^{99m}Tc-sestamibi scintigraphy preoperatively and intraoperatively, 1 h after injection of a large dose of 600 MBq (16.2 mCi) of isotope.

We have not found any mention in the scientific literature of the use of a portable hand-held MGC for intraoperative techniques related to the parathyroid. Although there are references on the use of portable hand-held gamma cameras for sentinel node detection [2– 4], it seems that surgeons are not completely sure about introducing small gamma cameras into the operating room. Imaging is perhaps not worthwhile if it sacrifices a lot of operating time and if quick and precise node localisation is not assured. These problems are significantly reduced by the high sensitivity of the Sentinella 102 and by using the LPS. The acquisition of valid images on the screen was very fast, and in some cases 20 s was enough to obtain a positive scan. Furthermore, we could verify a very good function with small amounts of isotope, confirming rapid wash-out of the isotope, as suggested by Rubello's group [9, 14–16] for radio-guided surgery. Moreover, radiation exposure of the surgeon and his team was much reduced.

In our opinion this new device is useful for localisation of pathological glands in cases of PHPT. It is easy to manage and allows different views to be taken, even lateral ones, permitting viewing of the entire surgical field or even of other parts of the body. It can substitute for gamma probes, whose determinations can be misleading in difficult cases, as occurred with one of our cases. On the other hand, it proved effective in identifying all the pathological tissue and in confirming its complete excision. Goldstein et al. [18] reported a very good cure rate of 98% in patients undergoing minimally invasive radioguided surgery without the intraoperative use of PTH measurement. This indicates that even without ioPTH, our method would be more accurate by virtue of the morphological information provided.

In conclusion, for the kind of case reported by us (PHPT due to a single adenoma, with positive uptake for sestamibi), our preliminary results indicate the proposed procedure to be very cost-effective. MIP was effective with the help of only the intraoperative MGC, after a very low dose of preoperative ^{99m}Tc-sestamibi, which permitted localisation and confirmation of complete removal of pathological tissue. In our opinion, the MGC could completely replace the intraoperative use of gamma probes. It would even be possible to replace the preoperative conventional sestamibi scans and the intraoperative determinations of PTH, although more experience is needed to confirm this exciting and cost-effective possibility.

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