ORIGINAL ARTICLE

The Intraoperative Mini Gamma Camera in Primary Hyperparathyroidism Surgery

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Abstract

Introduction and objectives: The evolution of primary hyperparathyroidism surgical treatment has been improved after the arrival of new techniques that allow for better parathyroid gland tracking. A mini gamma camera has recently been developed that makes it possible to take intraoperative parathyroid gammagrams.

The objective of this study was to evaluate the utility of this technique.

Method: We prospectively studied 29 patients with primary hyperparathyroidism, comparing the diagnostic effectiveness of the MGP with the results obtained with preoperative techniques (ultrasound scan plus Tc99m-sestamibi gammagraphy).

Results: The sensitivity and specificity of the mini gamma camera were superior to those of the preoperative techniques, applied to the lateral neck as well as to the face of the neck (lateral: 89.6% sensitivity and 96.15% specificity compared to 79.31% and 92.59% respectively; and neck face: sensitivity and specificity 83.3% and 90.91% against 48.39% and 72.73%).

Conclusions: The portable mini gamma camera accurately tracks pathologic parathyroid glands. In that sense, it could be useful when considering a radio-guided surgery with minimal parathyroid invasion.

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KEYWORDS

Miniature gamma camera; Primary hyperparathyroidism; Parathyroid adenoma; Intraoperative procedures; Radio-guided surgery

PALABRAS CLAVE

La minigammacámara intraoperatoria en la cirugía del hiperparatiroidismo primario

Resumen

Introducción y objetivos: La evolución del tratamiento quirúrgico del hiperparatiroidismo primario se ha visto favorecido por la aparición de nuevas técnicas que permiten una mejor localización de las glándulas paratiroideas. Recientemente se ha desarrollado una minigammacámara portátil (MGP), que permite realizar gammografías paratiroides intraoperatorias. El objetivo del estudio ha sido valorar la utilidad de esta técnica.


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Procedimientos intraoperatorios; Cirugía radioguiada

Métodos: Estudiamos prospectivamente 29 pacientes con hiperparatiroidismo primario y evaluamos la validez diagnóstica de la MGP comparando los resultados obtenidos con las técnicas preoperatorias (ecografía + gammagrafía Tc99m-sestamibi).

Resultados: La sensibilidad y especificidad de la minigammacámara es superior a las técnicas preoperatorias, tanto por lado como por cuadrante del cuello (por lado: sensibilidad del 89,6% y especificidad del 96,15% frente a un 79,31 y 92,59%, respectivamente, y por cuadrante: sensibilidad y especificidad del 83,33 y 90,91% versus 48,39 y 72,73%).

Conclusiones: La MGP localiza de forma precisa las glándulas paratiroides patológicas, por lo que podría resultar útil al plantear una cirugía radioguiada mínimamente invasiva paratiroida.

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Introduction

The treatment of primary hyperparathyroidism (PHP) is mainly surgical. Historically, the surgical approach involved a bilateral neck exploration with the systematic identification of the 4 parathyroid glands. In the hands of an experienced surgeon, the success rate of this type of approach exceeded 95%. However, the appearance of imaging techniques allowing preoperative location of the glands and the determination of intraoperative parathyroid hormone or parathormone (iPTH) have represented a considerable progress towards applying less invasive surgical techniques.

At present, the combination of Tc99m-sestamibi (MIBI) scintigraphy scans and high resolution ultrasonography is the gold standard for preoperative, parathyroid gland location tests. However, the sensitivity varies between 69% and 96% depending on the works reviewed. Moreover, it drops drastically in cases of PHP by hyperplasia, when patients present associated thyroid disease or in those cases in which the glands have an ectopic location.

This variable sensitivity of preoperative location techniques explains the continued interest in developing new methods that allow a more accurate, intraoperative location of parathyroid glands. Their successful identification would decrease operative time and increase the success rate of the intervention.

In turn, the introduction of new surgical techniques for the treatment of PHP, such as minimally invasive surgery or radioguided surgery, has made intraoperative location of the parathyroid glands into a subject of great relevance.

In this regard, we propose a new imaging technique, intraoperative scintigraphy with a mini gamma camera (MGC), for the management of PHP. Due to its reduced size, especially when compared with traditional gamma cameras, the portable mini gamma camera (PMG) provides great mobility and ease of use, thus enabling scintigraphic imaging of the parathyroid glands during surgery.

Material and Methods

The study was conducted at our Otolaryngology Service, in coordination with the Nuclear Medicine Service and with the collaboration of the Endocrinology, Anatomical Pathology and Clinical Analysis Services.

We prospectively studied a total of 29 patients diagnosed with PHP by the Endocrinology Service who were referred to our department for surgical treatment.

The study period lasted for 20 months, from September 2006 to May 2008.

We used the following equipment for the preoperative location study: a GE Healthcare Ultrasound Logiq 5-Pro ultrasound device, a 12L probe of 7 MHz and a parathyroid scintigraphy device (E.CAM, Siemens) in 2 phases after intravenous injection of 740 MBq of Tc99m-sestamibi (Cardiolite®, Brystol-Myers Squibb, USA).

We used the portable MGC (Sentinella 102S®) (GEMImaging) to conduct the intraoperative study. This device has the following characteristics:

- Caesium iodide detector, 30×30 matrix, 30-120 s per image, 4 mm pinhole collimator.
- Flexible arm provided with a pinhole collimator at its distal end for capturing images.
- Computerised system with 2 screens, enabling the simultaneous display of scintigraphic images, for both the nuclear physician and the surgeon.

Regarding the selection criteria for patients in this study, we included all cases of PHP referred to our service, without excluding those with a negative preoperative study or cases with associated thyroid disease. We excluded cases of hyperplasia due to their reduced number.

Before surgery, all patients underwent an ultrasound study and a Tc99m-sestamibi scintigraphy, and both tests were evaluated by the same person.

We used the PMG during surgery in all cases.

In order to assess the usefulness of this technique we designed a validation study with no variations in our protocol in relation to this type of condition, only adding the use of the MGC to the usual procedure.

The methodology followed in the operating room was as follows: after anaesthesia the nuclear physician administered an intravenous dose of 111-183 MBq of Tc99m-sestamibi. After this, we began the surgery by lifting the flap and fixing the surgical field, thus the 15-20 min period required for isotope uptake by the parathyroid glands was allowed to elapse. Following this time period, we proceeded to the first acquisition of scintigraphic images, using the flexible arm of the MGC to place the collimator just above the surgical field. After taking images in the anterior and lateral
projections, when appropriate, we continued with the surgery (Figs. 1 and 2).

Once the pathological parathyroid gland was located and excised, we proceeded, in all cases, to take images of the excised material and the surgical field, thereby confirming that the excised material was truly responsible for the initial detection, as well as an absence of pathological detection in the surgical field.

All patients underwent intraoperative measurement of iPTH and extemporaneous study of the surgical specimen.

In order to carry out the statistical analysis, we used the statistical package SPSS® version 15.0, which enabled us to perform a descriptive analysis of our sample.

The interpretation of results from the imaging techniques was based on the surgical findings and the results of the anatomopathological study.

We assessed the capacity of the imaging techniques, both preoperative and intraoperative, to correctly locate the pathological parathyroid glands. "Correct location" refers to locating the glands not only by the left or right side of the neck, but also by upper or lower quadrant in relation to the thyroid isthmus. For those cases who had undergone a unilateral, cervical approach, we considered that they suffered no contralateral parathyroid involvement when, 6 months after surgery, patients were asymptomatic and presented calcemia and parathormone (PTH) values within normality.

Results

The study included a total of 31 patients, of which 29 suffered adenomas (single or multiple) and only 2 suffered hyperplasias. The latter were excluded from the study due to their reduced number.

No patient had a family history of PHP or any association with multiple endocrine neoplasia (MEN).

Table 1 summarises the epidemiological and clinical characteristics of patients included in the study.

Up to 44.8% of cases (13 patients) in the study presented associated thyroid disease and 3 patients had undergone previous neck surgery: 2 had undergone thyroid-type surgery and 1 had undergone parathyroid-type surgery.

Table 2 shows the preoperative, intraoperative, surgical and anatomopathological results of the patients in the study.

Regarding the surgery performed, 24 patients (82.7%) underwent a unilateral surgical approach and 5 had a bilateral cervical exploration, in 1 case due to the presence of a double adenoma and in the other 4 cases due to diagnostic errors of both the preoperative and intraoperative techniques. Of these 4 patients, in the first case the preoperative study was positive (right inferior adenoma), whereas the intraoperative result was negative. Surgical exploration was started by the right side of the neck, in

<table>
<thead>
<tr>
<th>Table 1</th>
<th>General Characteristics of Patients With Hyperparathyroidism (n=29).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>Age (mean±SD)</td>
<td>56.14±16.19</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>27.59 (13.71-45.74)</td>
</tr>
<tr>
<td>Presence of symptoms</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>7</td>
</tr>
<tr>
<td>Yes</td>
<td>21</td>
</tr>
<tr>
<td>Bone</td>
<td>17</td>
</tr>
<tr>
<td>Renal</td>
<td>12</td>
</tr>
<tr>
<td>Digestive</td>
<td>9</td>
</tr>
<tr>
<td>Neuropsychiatric</td>
<td>5</td>
</tr>
<tr>
<td>Hypercalccemic crisis</td>
<td>1</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>14</td>
</tr>
<tr>
<td>Others</td>
<td>8</td>
</tr>
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</table>
Table 2  Results of the Location Study (Preoperative and Intraoperative), Surgery and Definitive Anatomopathological Findings.

<table>
<thead>
<tr>
<th>Patient</th>
<th>MIBI-Scintigraphy Scan+Ultrasound Pathology</th>
<th>Thyroid Pathology</th>
<th>Surgery</th>
<th>Mini Gamma Camera</th>
<th>Anatomical Pathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>L inferior</td>
<td>L inf. adenoma</td>
</tr>
<tr>
<td>2</td>
<td>Right</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R superior</td>
<td>R sup. adenoma</td>
</tr>
<tr>
<td>3</td>
<td>R ectopic thymic</td>
<td>Yes</td>
<td>Adenomectomy</td>
<td>R ectopic thymic</td>
<td>R ectopic thymic adenoma</td>
</tr>
<tr>
<td>4</td>
<td>L inferior</td>
<td>No</td>
<td>Adenomectomy</td>
<td>L inferior</td>
<td>L inf. adenoma</td>
</tr>
<tr>
<td>5</td>
<td>R ectopic thymic</td>
<td>Yes</td>
<td>Adenomectomy</td>
<td>R ectopic thymic</td>
<td>R ectopic thymic adenoma</td>
</tr>
<tr>
<td>6</td>
<td>R superior/L inferior</td>
<td>Yes</td>
<td>TT+partial parathyroidectomy</td>
<td>R superior/L inferior</td>
<td>No pathological PT located</td>
</tr>
<tr>
<td>7</td>
<td>R inferior/L inferior</td>
<td>Yes</td>
<td>Total parathyroidectomy with autograft+LHT</td>
<td>L inferior</td>
<td>Double adenoma: L inf./R inf.</td>
</tr>
<tr>
<td>8</td>
<td>L inferior</td>
<td>Yes</td>
<td>Partial parathyroidectomy+LHT</td>
<td>L superior intrathyroid</td>
<td>L sup. intrathyroid adenoma</td>
</tr>
<tr>
<td>9</td>
<td>Right</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R inferior</td>
<td>R inf. adenoma</td>
</tr>
<tr>
<td>10</td>
<td>R inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R ectopic (retroesophageal)</td>
<td>R retroesophageal adenoma</td>
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<tr>
<td>11</td>
<td>Negative</td>
<td>Yes</td>
<td>Partial parathyroidectomy+RHT</td>
<td>R superior</td>
<td>R sup. adenoma</td>
</tr>
<tr>
<td>12</td>
<td>R inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R sup.</td>
<td>R sup. adenoma</td>
</tr>
<tr>
<td>13</td>
<td>R inferior</td>
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<td>R inferior</td>
<td>R inf. adenoma</td>
</tr>
<tr>
<td>14</td>
<td>R inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>Negative</td>
<td>L sup. adenoma</td>
</tr>
<tr>
<td>15</td>
<td>L inferior</td>
<td>Yes</td>
<td>Adenomectomy</td>
<td>L inferior</td>
<td>L inf. adenoma</td>
</tr>
<tr>
<td>16</td>
<td>L inferior</td>
<td>Yes</td>
<td>Partial parathyroidectomy</td>
<td>L inferior</td>
<td>L inf. adenoma</td>
</tr>
<tr>
<td>17</td>
<td>Left</td>
<td>Yes</td>
<td>Partial parathyroidectomy</td>
<td>L superior</td>
<td>L sup. adenoma</td>
</tr>
<tr>
<td>18</td>
<td>R inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R inferior</td>
<td>R inf. adenoma</td>
</tr>
<tr>
<td>19</td>
<td>Negative</td>
<td>Yes</td>
<td>Adenomectomy</td>
<td>R superior/L inferior</td>
<td>L inf. adenoma</td>
</tr>
<tr>
<td>20</td>
<td>R inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R inferior</td>
<td>R inf. adenoma</td>
</tr>
<tr>
<td>21</td>
<td>R inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R inferior</td>
<td>R inf. adenoma</td>
</tr>
<tr>
<td>22</td>
<td>L ectopic thymic</td>
<td>No</td>
<td>Adenomectomy</td>
<td>L ectopic thymic</td>
<td>L ectopic thymic adenoma</td>
</tr>
<tr>
<td>23</td>
<td>R inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>R inferior</td>
<td>R inf. adenoma</td>
</tr>
<tr>
<td>24</td>
<td>Left</td>
<td>Yes</td>
<td>Adenomectomy+RHT</td>
<td>R inferior</td>
<td>R inf. Adenoma</td>
</tr>
<tr>
<td>25</td>
<td>Negative</td>
<td>Yes</td>
<td>Partial parathyroidectomy+RHT</td>
<td>R inferior</td>
<td>R inf. adenoma</td>
</tr>
<tr>
<td>26</td>
<td>L inferior</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>L inferior</td>
<td>L inf. adenoma</td>
</tr>
<tr>
<td>27</td>
<td>Negative</td>
<td>No</td>
<td>Partial parathyroidectomy</td>
<td>Negative</td>
<td>L sup. adenoma</td>
</tr>
<tr>
<td>28</td>
<td>L inferior</td>
<td>No</td>
<td>Adenomectomy</td>
<td>L inferior</td>
<td>L inf. adenoma</td>
</tr>
<tr>
<td>29</td>
<td>L inferior</td>
<td>Yes</td>
<td>Partial parathyroidectomy</td>
<td>L inferior</td>
<td>L inf. adenoma</td>
</tr>
</tbody>
</table>

Inf, inferior; L, left; LHT, left hemithyroidectomy; R, right; RHT, right hemithyroidectomy; Sup, superior; TT, total thyroidectomy.
which a slightly enlarged right inferior parathyroid gland was observed. No evidence of a significant decline in iPTH values was observed after its excision, so we proceeded to explore the contralateral neck and found a left superior adenoma. In the second case, the preoperative study was negative, whereas the intraoperative study showed double uptake on the right and left sides. Surgery was started on the right side and found no pathological parathyroid glands, so we proceeded to explore the contralateral side of the neck, where we located a left inferior adenoma. In the third case we performed bilateral neck exploration due to a false positive result in both the preoperative and intraoperative tests. In both cases, uptakes were due to associated thyroid disease. In the last case we found no pathological parathyroid glands during surgical exploration or in the definitive anatomopathological study. Both the preoperative and intraoperative techniques showed double uptake on the right and left sides. We explored both sides of the neck without identifying pathological parathyroid glands and conducted total thyroidectomy without the definitive anatomopathological examination detecting parathyroid tissue. Inexplicably, the patient currently suffers hypoparathyroidism. This case was not included in the calculation of sensitivity, specificity and predictive values.

In 18 patients we performed excision of 1 adenoma plus 1 normal gland, in 1 case we performed excision of 2 adenomas and in 10 cases we only excised 1 adenoma. In 1 case we performed total parathyroidectomy with autograft due to a diagnosis of hyperplasia in the extemporaneous anatomopathological analysis, although the definitive report was of double adenoma.

We performed thyroidectomy (hemithyroidectomy or total thyroidectomy) in 8 patients (27.6%). Of these, in 7 cases it was programmed due to associated thyroid involvement and in 1 case it was due to a suspicion of intrathyroidal parathyroid which was not confirmed by the final anatomopathological examination.

All patients were monitored postoperatively 1 week, 1, 3, 6, and 12 months after surgery, with serial controls of the calcium, phosphorus, total protein and PTH levels. All remained normocalcemic 1 year after surgery. One patient suffered hypoparathyroidism and 2 presented high PTH levels. After further study of these 2 patients, we confirmed a contralateral adenoma in 1 of them, who is currently awaiting surgery, and vitamin D deficiency in the other, whose PTH levels were corrected after following medical treatment.

With respect to preoperative location techniques, the association between ultrasound and Tc⁹⁹m-sestamibi scintigraphy showed a sensitivity (Se) and specificity (Sp) of 79.31% and 92.59%, respectively, in locating the parathyroid glands on each side of the neck. However, when we analysed the capacity of these techniques to locate the glands by quadrants we noted that both parameters decreased significantly (Se: 48.39%; Sp: 72.73%).

The intraoperative MGC results were positive in 27 of the 29 patients studied. Of these, 3 presented a negative preoperative location study.

In 10 patients, the PMG refined the location of the parathyroid glands not only by side but also by quadrant. Furthermore, it presented 3 false positives and 3 false negative cases.

With all this, the intraoperative MGC showed sensitivity, specificity and predictive values by side of: Se: 89.66%; Sp: 96.15%; positive predictive value (PPV): 96.30%, and negative predictive value (NPV): 89.29%; and by quadrant: Se: 83.33%; Sp: 90.91%; PPV 92.59% and NPV 80%.

**Discussion**

The surgical treatment of PHP has evolved significantly in recent decades. For a long time, bilateral neck exploration with identification of all parathyroid glands has been considered as the treatment of choice for PHP, with the morphology of the glands indicating the need for their resection or not. In the hands of experienced surgeons, this approach offers a success rate of 90%–98%. However, given that in 80%–85% of patients PHP is due to uniglandular involvement, many authors consider bilateral exploration excessive and unnecessary in most cases. This fact, together with the development of new imaging techniques that allow a more accurate preoperative location of the parathyroid glands and the measurement of iPTH has led PHP treatment to evolve towards less invasive surgical techniques, such as unilateral neck exploration and, more recently, radio-guided surgery and minimally invasive surgery, with success rates similar to those of the traditional bilateral approach.

Among the wide range of existing preoperative location techniques, an association of Tc⁹⁹m-sestamibi scintigraphy (a technique in 2 stages with acquisition of early and late images) and high-resolution ultrasound is considered as the technique of choice for preoperative location of the parathyroid glands, as it combines the anatomical and physiological information provided by ultrasonography and scintigraphy, respectively.

We have used the association of ultrasonography and Tc⁹⁹m-sestamibi scintigraphy performed by the same examiner as a preoperative location study at our centre for many years. It has been widely documented that the combination of both techniques provides a number of advantages including: more accurate information regarding the location of pathological glands (location, depth), differentiation of a solitary adenoma from multiglandular involvement and evaluation of a possible associated thyroid condition. Lumachi et al. retrospectively analysed the sensitivity (Se) of ultrasound and of Tc⁹⁹m-sestamibi scintigraphy in patients with single adenomas and observed a sensitivity of 95% with the combination of both techniques versus 80% and 87% for ultrasonography and scintigraphy alone, respectively. Sipertine et al. prospectively observed a Se value of 79% for both techniques combined and 74% and 68% for ultrasonography and scintigraphy, respectively, when performed separately. Solorzano, who defended high-resolution ultrasound as a single technique for preoperative location, observed that ultrasonography and scintigraphy performed separately located 77% of adenomas correctly, whereas they located up to 90% of cases when used in combination.

However, these techniques have limitations, such as multiglandular pathology, double adenomas, ectopic locations and associated thyroid disease. In these cases, the sensitivity value decreases considerably.
In order to minimise location errors in patients with associated thyroid involvement, some authors perform a Tc\textsuperscript{99m}-sestamibi scintigraphy with a dual tracer (Tc\textsuperscript{99m}-sestamibi and Tc\textsuperscript{99m}-pertechnetate) instead of the usual, double phase technique.\textsuperscript{16,22} These authors argue that, from a technical point of view, the main limitation of Tc\textsuperscript{99m}-sestamibi scintigraphy performed with the double phase technique is related to the existence of thyroid nodules which, through their avidity for Tc\textsuperscript{99m}-sestamibi, may simulate pathological parathyroids and lead to false positives.\textsuperscript{21} In this regard, the use of Tc\textsuperscript{99m}-pertechnetate can partly overcome this limitation by allowing the removal of thyroid tissue during the scintigraphy.\textsuperscript{12} However, this technique has certain drawbacks which have limited its use: the acquisition times need to be extended and the patient is required to lie still. Other limitations would include patients with diminished or absent thyroid uptake and the possibility of eliminating low uptake parathyroid readings or those located immediately behind the thyroid.\textsuperscript{23}

Other authors recommend performing SPECT during parathyroid scintigraphy, as this improves the accuracy and sensitivity of the imaging technique.\textsuperscript{4,24-26} Due to its cost, the use of SPECT would only be indicated in cases of ectopic parathyroids, with inconsistent scan/ultrasound results, in associated thyroid condition and in persistent or recurrent PHP. Nevertheless, some authors do recommend it as a routine preoperative location technique.\textsuperscript{16,21,26}

In addition to the advances mentioned in relation to preoperative techniques, intraoperative surgical techniques aimed at facilitating the location of parathyroid glands during the surgical act have also been developed in recent years. These include gamma detection probes and serial measurement of IPTH. The use of gamma detection probes in PHP treatment helps to guide surgeons towards the location of pathological glands, and is especially useful in cases of ectopic adenomas or those in deep locations. It is also useful as a method for ensuring the excision of all pathological parathyroid tissue.\textsuperscript{12} This technique has favoured the emergence and development of minimally invasive, radioguided parathyroidectomy.\textsuperscript{4,9,12,16,20,27}

Measurement of IPTH provides surgeons with a quantitative confirmation of full excision of all hyperfunctional parathyroid tissue. A decrease of over 50% after 10 min of adenoma excision is the most commonly used healing criterion.\textsuperscript{5,28,29} Nevertheless, although its use is generally accepted, it is not free from controversy.\textsuperscript{28,30}

A further step in the development of these location techniques has led to the appearance of the intraoperative MGC. This MGC has a reduced size and weight which make it easy to handle, whilst providing high-quality scintigraphic imaging of parathyroid glands during surgery. This constitutes one of the main advantages of this new technology in relation to the gamma detection probe mentioned previously. These images can be taken not only during the course of surgery, thus facilitating the task of the surgeon, but also after its completion, providing confirmation of the absence of parathyroid uptake in the surgical field.\textsuperscript{31,32}

In this study we wanted to assess the usefulness of this new technique for the location of pathological parathyroid glands, not only by side, but also by neck quadrant, comparing the results obtained with those from preoperative location techniques (ultrasound-Tc\textsuperscript{99m}-sestamibi scintigraphy with a double phase technique).

In our study, the sensitivity and specificity values of preoperative location techniques were similar to those published in the literature.\textsuperscript{6,16-19}

When analysing the results obtained with the MGC we noted that this technique allowed a more precise location of pathological parathyroid glands. This was particularly striking in the location by quadrants (Table 3).

This was especially notable in cases with associated thyroid disease and in those with negative preoperative studies. In both situations, most authors recommend performing a bilateral cervical approach.\textsuperscript{31} In our sample, 44.8% of cases (13 patients) presented associated thyroid pathology. The MGC refined the location in 6 of these 13 patients. Moreover, 3 of them also had negative preoperative studies, which allowed us to perform a unilateral cervical approach instead of the traditional bilateral method reserved for such cases. Therefore, although our sample was not large enough to draw statistically significant conclusions, in the light of these results, we believe that the MGC could be beneficial in cases with negative preoperative studies, especially in those with associated thyroid disease.

Despite the good results obtained in our study, due to the limited number of patients studied and also to the fact that interpretation of the intraoperative scintigraphy was performed with prior knowledge of the results of the preoperative ultrasonography and scintigraphy in all cases, we cannot currently say that this technique may substitute preoperative studies as a method of locating the parathyroid glands.

What we can suggest, given the high sensitivity and, especially, the high specificity of the MGC for the location of the parathyroid glands by quadrant, is that in selected cases of single adenoma suspected through preoperative studies,

### Table 3  Comparison of Results from the Preoperative and Intraoperative Location Studies.

<table>
<thead>
<tr>
<th></th>
<th>Se</th>
<th>Sp</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>By side</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound+MIbI-scan</td>
<td>79.31</td>
<td>92.59</td>
<td>79.31</td>
<td>80.65</td>
</tr>
<tr>
<td>Intraoperative MGC</td>
<td>89.66</td>
<td>96.15</td>
<td>96.3</td>
<td>89.29</td>
</tr>
<tr>
<td><strong>By quadrant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound+MIbI-scan</td>
<td>48.39</td>
<td>72.73</td>
<td>71.43</td>
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<tr>
<td>Intraoperative MGC</td>
<td>83.33</td>
<td>90.91</td>
<td>92.59</td>
<td>80</td>
</tr>
</tbody>
</table>

NPV, negative predictive value; PPV, positive predictive value; Se, sensitivity; Sp, specificity.
this technique could serve as an ideal intraoperative location method when considering minimally invasive surgery. In fact, this course of action is currently being followed at our centre.

Finally, we wish to remark that, since the intraoperative MGC allows us to confirm the absence of residual pathological parathyroid involvement during the surgical act, it could eventually replace intraoperative PTH determination. Nevertheless, confirming this idea would require further studies to be conducted.

Conclusions

The intraoperative MGC represents an advance within PHP surgery. Following the completion of this study, we believe that this technique could be an ideal method for minimally invasive parathyroid surgery because of its high sensitivity and specificity values for the location of pathological parathyroid glands per neck quadrant.

Conflict of Interests

The authors have no conflict of interests to declare.

References

The Intraoperative Mini Gamma Camera a in Primary Hyperparathyroidism Surgery


