

Evaluation of surgical gamma probes for sentinel node localisation in cervical and vulvar cancer

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Abstract

BACKGROUND: Sentinel node (SN) scintigraphy for cervical and vulvar cancer guides the gynaecological oncologist in finding the metastatic lymph nodes during lymphadenectomy. The role of the surgical gamma probe in the sentinel node concept in gynaecological oncology is to localise (SN) both intra-operatively and transcutaneously. Intra-operative hand-held collimated gamma probes are increasingly used for detection of the sentinel lymph node.

MATERIAL AND METHODS: A comparative evaluation of hand-held gamma probes: Neoprobe 1500, Europrobe, Gamma Finder®, Gamma Ray Prospector GRP1 and GPR2 was performed using different detection methods. Laboratory tests were performed in which sensitivity, spatial resolution and angular sensitivity were evaluated.

RESULTS: The results for each gamma probe were summarised and discussed.

CONCLUSION: Awareness of a gamma probe's capabilities and limitations should be considered in the appropriate selection of a device.

Key words: intra-operative probes, gamma probes, sentinel lymph node

Introduction

Sentinel nodes in cervical and vulvar cancer can be identified by using blue dye [1, 2] radioisotopes, or a combination of both [3–5]. The technique of using a hand-held probe for localization of dissected tissue was first described by Myers in 1960 [6] and at the same time the term “sentinel node” was first used by Ernest Gould et al [7]. In 1977, Ramon Cabanas was the first to combine the two elements of this approach: lymphatic mapping and SN identification [8]. Since then a wide range of hand-held gamma probes have been available with different detector materials, detector sizes and collimators. Gamma probes for surgical use consist of two main components: a hand-held sensor, which contains the gamma-sensitive crystal with amplifier, and a reading unit. The ratio between the number of gamma photons entering the probe and the number of detected photons expresses the efficacy of the detector in the probe. This depends on the crystal material, its dimensions and the gamma energy. The spatial resolution, sensitivity, count rate linearity and angular sensitivity describe the basic probe performance [9–13].

The purpose of the study was to compare available gamma probes and rank them in terms of their ability to localise lymph nodes.

Material and methods

Measurements were made in the nuclear medicine laboratory to compare the following hand-held probes:

- Neoprobe 1500 (Neoprobe Corporation, Dublin, Ohio, USA);
- Europrobe (Eurorad, Severs, France);
- Gamma Finder® (W.O.M., Ludwigsstadt, Germany);
- Gamma Ray Prospector GRP1 (Technical University of Gdańsk, Poland);
- Gamma Ray Prospector GRP2 (Technical University of Gdańsk, Poland).

A short description of these commercially available devices is given below showing details of probe construction and detection methods essential in maximizing detection rates:

1. Neoprobe 1500, 19 mm Detector Probe (Figure 1):
 - detector type: CdTe crystal;

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Figure 1. The Neoprobe Detector Probe — diameter: 19 mm with collimators.



Figure 2. The Europrobe's Detector Probes — diameter: 16 mm (right side of the picture), diameter; 14 mm (left side of the picture).

- energy range: 20 keV to 150 keV;
 - shielding: tungsten collimator, 9 mm aperture diameter;
 - length: 170 mm, diameter: 19 mm (25 mm — with external collimator).
2. Europrobe, Probe 1 (Figure 2):
 - detector type: CsI(Tl) with avalanche photodiode (APD);
 - energy range: 110 keV to 1MeV;
 - shielding: tungsten collimator, 6 mm aperture diameter;
 - length: 174 mm, diameter: 16 mm (19 mm — with external collimator).
 3. Europrobe, Probe 2 (Figure 2):
 - detector type: CdTe crystal;
 - energy range: 20 keV to 364 keV;
 - shielding: tungsten collimator, 4 mm aperture diameter;
 - length: 165 mm, diameter: 11 mm (14 mm — with external collimator).
 4. Gamma Finder® (Figure 3):
 - detector type: CdTe crystal;
 - energy range: 40 keV to 150 keV;
 - shielding: n/a, probe diameter 10 mm.
 5. Gamma Ray Prospector GRP1 and GRP2 (Figure 4):
 - detector type: NaI(Tl) with photomultiplier (PMT);
 - energy range: 20 keV to 1MeV;
 - shielding: lead collimator, 10 mm aperture diameter.

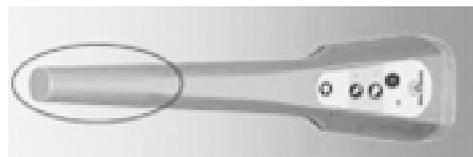


Figure 3. The wireless Gamma Finder®.



Figure 4. The Gamma Ray Prospector's Detector Probes, GRP1 combined with collimator (upper probe) and GPR2 with collimator (lower probe).

- GRP1 (early version) probe;
- length: 170 mm, diameter: 25 mm;
- GRP2 (latest version) probe;
- length: 150 mm, diameter: 19 mm (25 mm — with external collimator).

Measurement procedure

All measurements were performed using different activities of technetium-99m, within the range 0.185–18.5 MBq. Sensitivity, angular sensitivity and spatial resolution characteristics were tested. Table 1 shows a general summary of the basic characteristics of detector types used in gamma probes.

Equipment tests were performed using 0.185 MBq and 18.5 MBq of technetium-99m. Tests consisted of three groups of measurements:

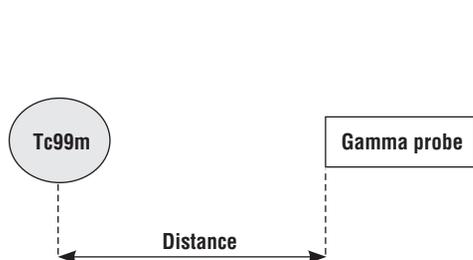
Sensitivity test — defined as the number of counts in relation to distance between the probe and the source. Measurements were taken at three distances: 30, 50 and 100 mm, in a collection time of 1 second with a source activity of 18.5 MBq. The distance of 30 mm seems to be most typical during surgical identification of SNs in cases of vulvar cancer, and the distance of 100 mm in instances of para-aortic SNs inspection.

Angular sensitivity test — defined as the number of counts in relation to the degree of deviation from probe axis at a constant distance from the source. Measurements were taken in a range of angles between -90° to $+90^\circ$, in a collection time of 1 second with a source activity of 18.5 MBq.

Spatial resolution test evaluated the ability of the probe to differentiate two radioactive sources situated close to each other. Measurements were taken using two tracer drops situated on a glass slide. The measurements were carried out at a distance of

Table 1. Basic parameters of detector types — a summary

Parameters	CdTe	Detector type CsI(Tl) + APD	Nal(Tl) + PMT
Energy range	15–150keV	110keV–1MeV	20KeV–1MeV
Low energy sensitivity & resolution	Excellent	Poor	Excellent
Medium/high energy sensitivity & resolution	Poor	Good	Good
Bias voltage	50–100V	200–500V	500–1000V
Dimensions	Small	Small/medium	Medium
Cost	Medium/high	High	Medium

**Figure 5.** The set-up geometry for measurements of the sensitivity.

15 mm, 20 mm and 25 mm from the radioactive source (0.185 MBq) with 1-second collection time.

Measurements were performed according to the scheme illustrated in Figures 5–7.

Results

Measurements were carried out according to the scheme illustrated in Figures 5–7. The results of ex vivo tests are presented in Table 2 and Figures 5–7. Table 2 shows a summary of comparison of sensitivity for tested probes.

The highest rates of sensitivity were obtained with GRP devices, medium sensitivity rates for Gamma Finder® and Europrobe and the lowest with the 19 mm Neoprobe system

Although GRPs had the highest count rate, the best angular resolution was demonstrated by Europrobe1 followed by GRP1. GRP2 and Europrobe2 demonstrated medium resolution, and the lowest resolution was shown by Gamma Finder® and Neoprobe 1500.

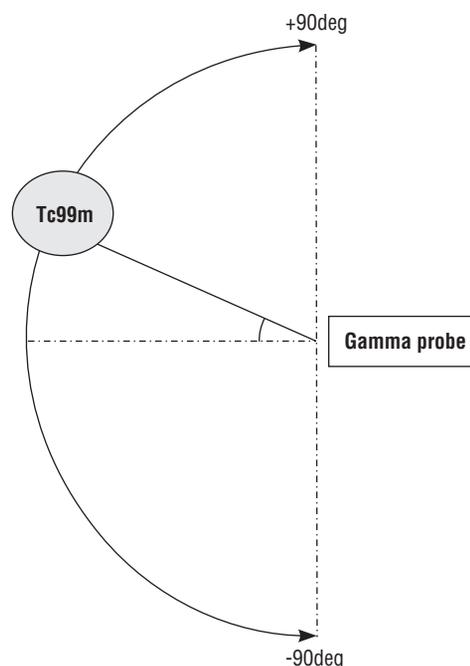
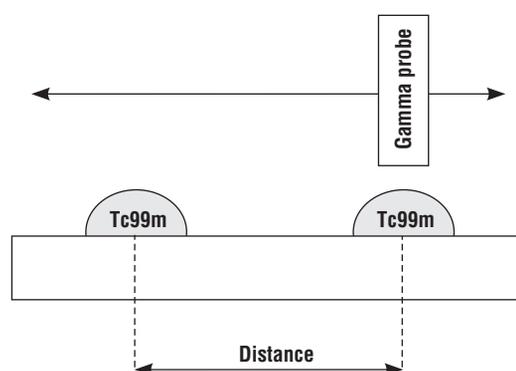
For an accurate measurable description of spatial resolution, we used a quality factor (top to nadir ratio) which is the ratio of counts under phantoms to counts between them (Figures 8–11). At a distance of 15 mm, Europrobe1 demonstrated the best results, followed by probes Europrobe2, Gamma Finder® and GPR2 (Figure 9).

For 20 mm similarly good results were demonstrated by Europrobe1 and GRP2 followed by Europrobe2 and Gamma Finder® (Figure 10).

For 25 mm, the best results were demonstrated by GRP2 followed by probes: Europrobe1, Europrobe2 and Gamma Finder® (Figure 11).

Discussion

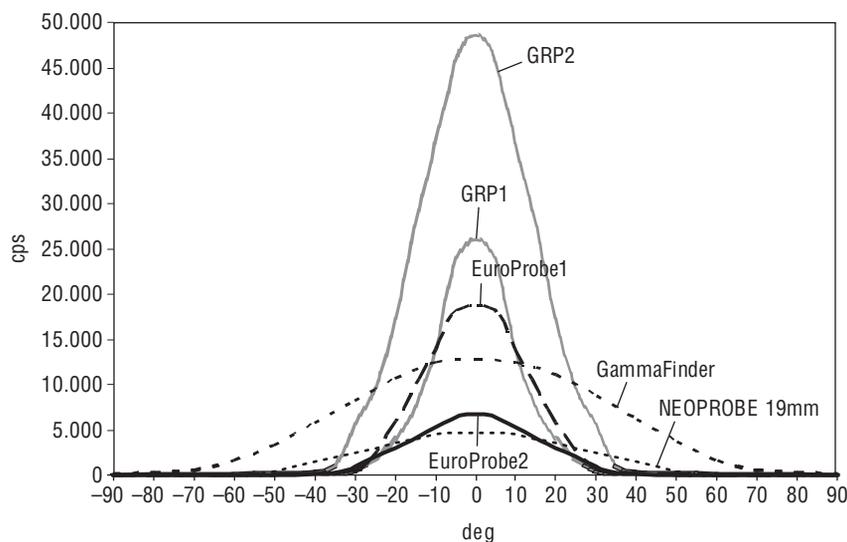
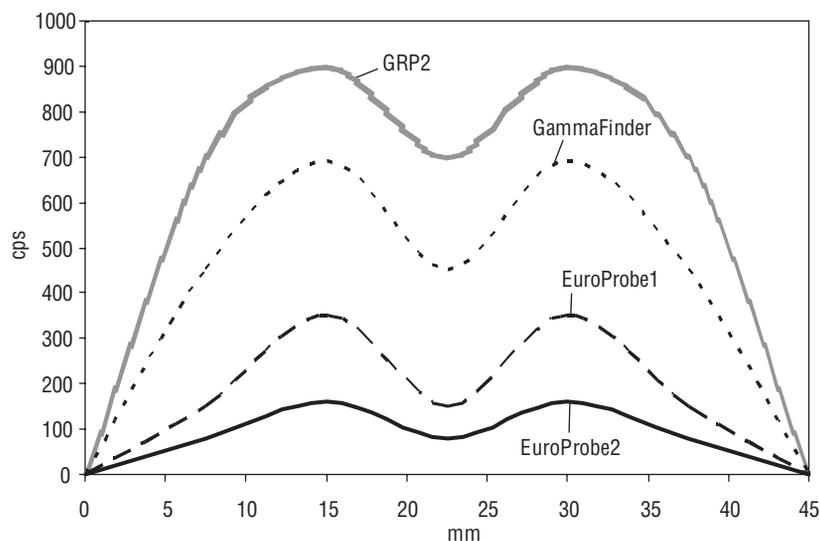
The intra-operative detection of SN relies not only on the visual inspection of the lymphatic basin to identify the blue dyed nodes,

**Figure 6.** The set-up geometry for measurements of the angular sensitivity.**Figure 7.** The set-up geometry for measurements of the spatial resolution.

but also on the assessment of the radioactive colloid in the SN with use of a gamma probe [10–12]. The gamma detector probe has become a standard for lymphatic mapping. The technique is presently being applied to breast cancer and melanoma. Several

Table 2. Comparison of sensitivity (counts vs. distance) for tested probes. Data collection time equals 1 second at source activity of 9.75 MBq

Distance [mm]	Type of probe					
	Neoprobe [count]	Gamma Finder® [count]	Europrobe1 [count]	Europrobe2 [count]	GRP1 [count]	GRP2 [count]
30	4.800	15.300	7.680	8.640	31.000	49.050
50	3.700	11.800	8.650	4.960	18.900	36.000
100	1.600	5.100	4.480	1.600	7.200	17.700

**Figure 8.** Angular resolution for tested probes.**Figure 9.** Spatial resolution with phantom hot nodes at a distance of 15 mm.

groups are also evaluating the technique in thyroid cancer and gynaecological and neuroendocrine tumours [1–5, 14–17]. It is a valuable tool in nuclear medicine and surgery with the identification, as defined, of any lymph node receiving direct lymphatic drainage from the lesion site [18–20].

According to Tiourina et al. [13], in choosing a surgical gamma probe, the surgeon and physicist should work together, and the necessary specific operational requirements should be matched with the properties of commercially available probes. Most tested probes presented satisfactory performance in labo-

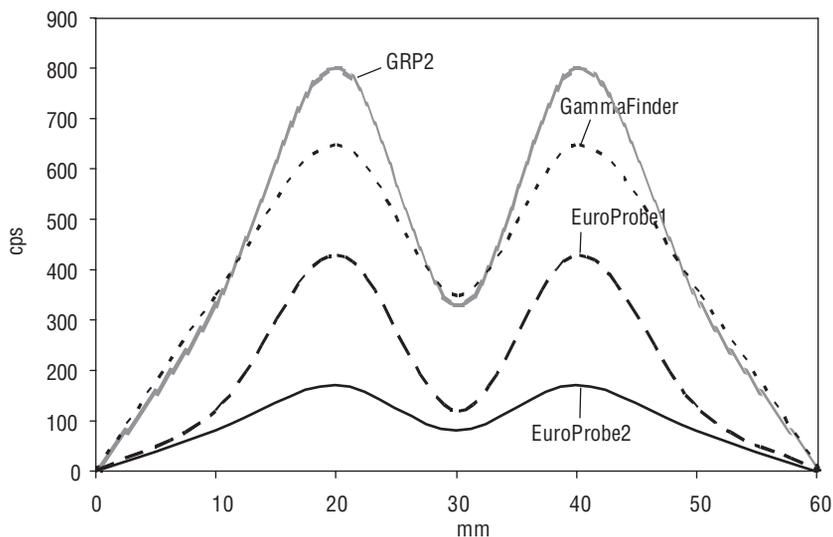


Figure 10. Spatial resolution with phantom hot nodes at a distance of 20 mm.

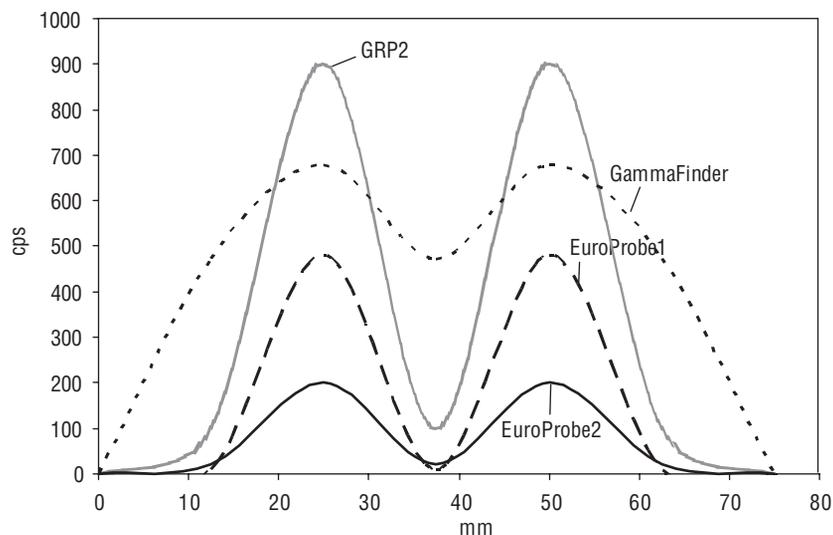


Figure 11. Spatial resolution with phantom hot nodes at a distance of 25 mm.

ratory testing. In our study, according to the surgeons scoring, the Europrobe had the leading ergonomic features. As far as sensitivity was concerned, GRP2 had the best results. Sensitivity is an important factor for the detection of lymph nodes with low uptake or in a deep location and for decreasing the injected radionuclide’s activity, causing less radiation absorbed doses to patients and staff involved in all aspects of the SN technique. Safety is crucial in the process of equipment selection.

The different results in sensitivity are due to the various types of detectors used in probes. The highest sensitivity rates were probes with scintillator NaI(Tl) with PMT, followed by those using CsI(Tl) with APD and CdTe crystal detectors (Table 2). Despite the good sensitivity of the detector, CsI(Tl) + APD Europrobe showed a slightly lower detection rate than Gamma Finder®. It is most probably due to the construction of the Europrobe collimator. The number of counts obtained in Neoprobe 1500 was the

lowest. This could be due to its early innovation, and in fact, it was the oldest model in the comparison.

The same investigators suggest that an angular resolution is required in order to achieve spatial resolution [13]. Although in our tests Gamma Finder® had good spatial resolution comparable with Europrobe2 (Figure 9), its angular resolution was the lowest (Figure 8). In spite of the lack of information about detailed detector construction, results recommend a small CdTe crystal situated close to the probe’s active surface with simple margin shielding.

This feature is particularly suitable to differentiate small radioactive sources (hot nodes) at close contact. This predisposes the Gamma Finder® to use in evaluation of SNs in thyroid, vulvar, breast cancer or melanoma. Its dimensions can create some difficulties inside the abdomen, particularly in the pelvis, during SN identification due to cervical or rectal cancer. Good angular resolution was obtained by technologically advanced tungsten collimators.

meters in the Europrobe1 combined with the use of a high sensitivity detector and good shielding. The lowest rate was recorded by a handheld Gamma Finder® with an unspecified collimator (probably of simple construction).

Probes with good shielding and an advanced collimator provided the best angular sensitivity. This is demanded for — deep SN localization, para-aortic SNs, or where SNs are close to the injection reservoir. The best spatial and angular resolution was demonstrated by Europrobe2 (probe 16mm) then GRP2 (Figures 7–11). Results of spatial resolution corresponded directly to the collimator construction in probes. At a distance of 15 mm, the advantages of the advanced collimator used in Europrobe1 can be seen; at distances over 20 mm, low-cost lead collimators are suitable. The weak score of GPR2 is because of the relatively large (10 mm) hole-diameter of the collimator. The use of a collimator with a hole-diameter of 5 mm resulted in parameters comparable to Europrobe. The disadvantage is lower sensitivity, although it is still higher than in Europrobe1.

A further important consideration maybe cost effectiveness when making a decision about an appropriate hand-held probe for SN detection in gynaecology. It has clearly been shown that GPR2 is an interesting solution when considering its good parameters together with its lower cost (ca 5000 EUR).

After laboratory testing, we can conclude that successful SN detection during surgery may depend on the performance of the hand-held gamma probe. Especially in the field of gynaecological oncology, it is important to have a probe with optimum operation characteristics, such as angular resolution, sensitivity and appropriate ergonomic features. Awareness of a gamma probe capabilities and intra-operative limitation should be understood prior to the selection of a probe.

References

1. Levenback C, Burke TW, Morris M, Malpica A, Lucas KR, Gershenson DM. Potential applications of intraoperative lymphatic mapping in vulvar cancer. *Gynecol Oncol* 1995; 59: 216–220.
2. Dargent D, Martin X, Mathevet P. Laparoscopic Assessment of the Sentinel Lymph Node in Early Stage Cervical Cancer. *Gynec Oncol* 2000; 79: 411–415.
3. de Hullu JA, Oonk MH, Ansink AC et al. Pitfalls in the sentinel lymph node procedure in vulvar cancer. *Gynecol Oncol* 2004; 94: 10–15.
4. Follen M, Levenback CF, Iyer RB et al. Imaging in cervical cancer. *Cancer* 2003; 98: 2028–2038.
5. Ramirez P, Levenback Ch. Sentinel nodes in gynaecological malignancies. *Current Opinion in Oncology* 2001; 13: 403–407.
6. Myers WG, Vanderleeden JC. Radioiodine-125. *J Nucl Med* 1960; 1: 149–164.
7. Gould EA, Winship T, Philbin PH, Hyland Kerr H. Observation on a 'sentinel node' in cancer of paratid. *Cancer* 1960; 13: 77–78.
8. Cabanas R. An approach for the treatment of penile carcinoma. *Cancer* 1977; 39: 456–466.
9. Adams S, Baum RP. Intraoperative use of gamma-detecting probes to localize neuroendocrine tumors. *Q J Nucl Med* 2000; 44: 59–67.
10. Britten AJ. A method to evaluate intra-operative gamma probes for sentinel lymph node localisation. *Eur J Nucl Med* 1999; 26: 76–83.
11. Hoffman EJ, Tornai MP, Janecek M, Patt BE, Iwanczyk JS. Intra-operative probes and imaging probes. *Eur J Nucl Med* 1999; 26: 913–935.
12. Schneebaum S, Even-Sapir E, Cohen M et al. Clinical applications of gamma-detection probes - radioguided surgery. *Eur J Nucl Med* 1999; 26: 26–35.
13. Tiourina T, Arends B, Huysmans D, Rutten H, Lemaire B, Muller S. Evaluation of surgical gamma probes for radioguided sentinel node localisation. *Eur J Nucl Med* 1998; 25: 1224–1231.
14. Noguchi M. Sentinel lymph node biopsy and breast cancer. *Br J Surg* 2002; 89: 21–34.
15. Chakera AH, Drzewiecki KT, Eigtved A, Juhl BR. Sentinel node biopsy for melanoma: a study of 241 patients. *Melanoma Res* 2004; 14: 521–526.
16. Stoeckli SJ, Pfaltz M, Steinert H, Schmid S. Sentinel lymph node biopsy in thyroid tumors: a pilot study. *Eur Arch Otorhinolaryngol* 2003; 260: 364–368.
17. Adams S, Baum RP. Intraoperative use gamma-detecting probes to localize neuroendocrine tumors. *Q J Nucl Med* 2000; 44: 59–67.
18. des Olmos RA, Hoefnagel CA, Nieweg OE et al. Lymphoscintigraphy in oncology: a rediscovered challenge. *Eur J Nucl Med* 1999; 26: 2–10.
19. Uren RF, Howman-Giles R, Chung D, Thompson JF. Nuclear medicine aspects of melanoma and breast lymphatic mapping. *Semin Oncol* 2004; 31: 338–348.
20. Mariani G, Erba P, Manca G, et al. Radioguided sentinel lymph node biopsy in patients with malignant cutaneous melanoma: the nuclear medicine contribution. *J Surg Oncol* 2004; 85: 141–151.