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# SURGICAL GAMMA PROBE FOR IDENTIFICATION OF SENTINEL LYMPH NODE

**Fábio E. da Costa [1], Paulo R. Rela [1], Margarida M. Hamada[1]**
**Andréia Bufoni Farah[2] and Renato Santos de Oliveira Filho[2]**

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
fecosta@ipen.br, prela@ipen.br and mmhamada@ipen.br

[2] Universidade Federal de São Paulo/ Escola Paulista de Medicina
Rua Botucatu 740
04023-900 São Paulo, SP
andreiafarah@bol.com.br and rsof@terra.com.br

## ABSTRACT

Surgical gamma probes have been widely used in oriented surgery, to locate the sentinel lymph nodes in breast cancer and malignant melanoma during the surgery. In this technique, the intra-operative localisation of the sentinel lymph node is carried out using a surgical gamma probe. A radiotracer, such as colloidal suspensions of $^{99m}$Tc in human albumin emitting γ-rays of 140 keV is administered (in the tumour site or close) in the patient, before operation, and the radiotracer travels from the tumour to the sentinel lymph node. Then the probe measures the labelled radioactivity, identifying and locating the sentinel lymph node once a visually occult disease, in order to remove it surgically. In this work, a pilot group of surgical gamma probes were developed at IPEN/CNEN-SP with high nationalisation indices, included the detector set. The probes final sizes were 14.0 mm diameter and 170 mm long and their characteristics were compared with imported probes and finally they were used in actual surgeries.

## 1. INTRODUCTION

The sentinel lymph node is the first lymph node from which the tumor is drained and becomes involved in metastasis from the tumor [1]. It is required to be located with relatively high spatial resolution ( few mm), either at the pre-operative or intra-operative surgery stage. For this purpose, the radioactive labeled surgery technique has been used.

In this technique, the intra-operative localization of the sentinel lymph node is carried out using a surgical gamma probe. A radiotracer, such as colloidal suspensions of $^{99m}$Tc in human albumin, emitting γ-rays of 140 keV, is administered (in the tumor site or close) in the patient, before operation, and the radiotracer travels from the tumor to the sentinel lymph node. Then, the probe finds the labeled radioactivity, identifying and locating the sentinel lymph node and the visually occult disease, in order to remove it surgically and to proceed to its hystological analysis [2]. Localization and evaluation of sentinel lymph node conveniently radiolabeled by specific tracer is improved by using intra-operative gamma probes with great sensitivity and accuracy.

In this work, a surgical gamma probe using a CsI(Tl) crystal scintillator (5x5x5 $mm^3$) coupled to a Hamamatsu S5106 photodiode, in vertical position to the gamma ray beam, was developed as showed in Fig. 1. Due to a low signal level from the photodiode, a special attention was paid to the preamplifier, built in two parts [3], to obtain a low noise and a reduced size probe.

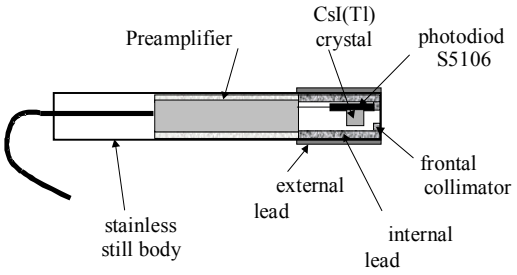


**Fig. 1. CsI(Tl) gamma probe internal schematic diagram.**

## 2. EXPERIMENTAL METHODS

The surgical gamma probe was built using a CsI(Tl) crystal scintillator coupled to a Hamamatsu S5106 photodiode and part of the developed preamplifier encapsulated in a stainless steel tube, containing an internal and an external lead collimator. The second part of the preamplifier and some other electronic components were assembled in a box with the counting unit and a audio track system, which was developed to constitute a device of intra–operative gamma detection for sentinel node biopsy.

Systematic measurements of spatial resolution, lateral counting leakage, angular resolution and maximum sensitivity were carried out. The results of these characteristics were evaluated, comparing them to the commercial probes using the reference protocol [4,5,6].

The spatial resolution, defined as the minimum distance required between two punctual radioactive sources to identify them as two distinct points, was obtained using two $^{99m}$Tc source points, separated by 25 mm distance from each other and covered with a 10 mm thickness acrylic sheet, in order to simulate a tissue equivalent absorption and scattering medium. The best characteristics for spatial resolution is the smallest distance between two radioactive sources that the probe can identify. To accurate the spatial resolution of the developed probe, it was built with a 2 mm thickness lead collimator with a 4 mm diameter center hole set up in front of the probe crystal.

The lateral counting is the count rate from lateral exposition of the probe to the radioactive source that reaches the detector. This leakage can induce a false orientation to the probe. The protocol evaluates the probe counting ratio from a radioactive source positioned in the lateral and over the tip of the probe. As a consequence, the lateral count rate must be as small as possible. The literature suggests lateral counting values smaller than 0.1% of maximum sensitivity as the ideal value. To reduce the lateral counting rate, the probes developed incorporated inside a 0.7 mm thickness lead shield involving the detector and a 1.3 mm thickness lead shield externally, as showed in Fig. 1.

The angular resolution is the probe angular sensitivity measured with a radioactive source positioned 3 cm and 30 cm from the tip probe. The better results for the angular resolution is the smallest value because it reduces the background count and helps the target localization. The shield sum improves the spatial resolution and reduces the lateral leakage and, consequently, obtaining better results for the angular resolution.

The maximum sensitivity of the probe is determined positioning a radioactive source directly on the probe tip. A $^{57}$Co radioactive source was used, due to its close energy to the $^{99m}$Tc. The ideal maximum sensitivity is a probe that can count all incident gamma photons that reach the detector. For a real situation, the literature suggests values higher than 5cps/kBq.

The commercial gamma probes require an audio track system that produces a proportional sound frequency to the count rate. This helps the surgeon to find the interest point without looking at the counter. This system was also included in the probe developed.

## 3. RESULTS AND DISCUSSION

Table 1 shows the spatial resolution of the developed and commercial probes and the minimum requirements suggested by the literature. The band values found in commercial probes and in the developed probes are due to different types of optional collimators. Sometimes, the best collimator is not good for using in a specific point in the human body, then the surgeon looks for an appropriate probe diameter besides the best collimator. As it was observed, all probes developed meet the minimum requirements for supraclavicular and axilla region.

**Table 1. Spatial resolutions**

| Developed Probes (5 samples) | Commercial Probes (12 samples) | Minimum requirements |
|---|---|---|
| 11 to 14 mm | 8 to 33 mm | ≤25 mm supraclavicular-region<br>≤15 mm extremities, axilla, groin. |

Table 2 shows the angular resolution of developed and commercial probes and the minimum requirements suggested by the literature. This is not a strict parameter, but the literature suggests values smaller than 40°. Practically all probes developed meet this requirement.

**Table 2. Angular resolutions**

| Developed Probes (5 samples) | Commercial Probes (12 samples) | Minimum requirements |
|---|---|---|
| 35 to 45° | 12 to 80° | ≤40° |

Table 3 shows the maximum sensitivity of developed and commercial probes and the minimum requirement suggested by the literature.

**Table 3. Maximum sensitivity**

| Developed Probes (5 samples) | Commercial Probes (12 samples) | Minimum requirements |
|---|---|---|
| 10 to 30 cps/kBq | 2 to 100 cps/kBq | ≥5 cps/kBq |

Table 4 shows the lateral counting percentage of the developed and commercial probes and the minimum requirement suggested by the literature.

**Table 4. Lateral counting**

| Developed Probes (5 samples) | Commercial Probes (12 samples) | Minimum requirements |
|---|---|---|
| 0.1 to 1% | 0.004 to 20% | ≤0.1% |

Fig. 2 shows the complete device developed by the IPEN. The probes were tested in real surgeries conditions in collaboration with the Escola Paulista de Medicina, UNIFESP, approved by its Ethical Committee. In all surgeries a commercial device (Neoprobe 1500) [7] was available for comparison.


**Fig. 2. Probe and counter developed at IPEN.**

In a pilot study with 10 patients with cutaneous melanoma performed, the IPEN probes demonstrated to be efficient to identify the sentinel node and a good relation between the radiation values detected in the sentinel node and the background. For all surgeries, the sentinel node was reached, not requiring the help from a commercial probe.

## 4. CONCLUSIONS

The developed probes met the minimum requirements suggested by literature, for the following characteristics: spatial resolution, angular resolution, maximum sensitivity and lateral counting. The developed probes show suitable to be used in identification the sentinel node.

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