TECHNICAL NOTE

Introducing the GammaPen: All-in-One Gamma Probe for Sentinel Lymph Node Biopsy

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Abstract

Purpose: Using an itra-operative gamma probe after injection of radiotracer during surgery helps the surgeon to identify the sentinel lymph node of regional metastasis through the detection of radiation. This work reports the design and specification of an integrated gamma probe (GammaPen), developed by our company.

Materials and Methods: GammaPen is a compact and fully integrated gamma probe. The detector module consists of a thallium-activated Cesium Iodide (CsI (Tl)) scintillator, and a Silicon Photo Multiplier (SiPM), shielded using Tungsten housing. Probe sensitivity, spatial resolution and angular resolution in air and water, and side and back shielding effectiveness were measured to evaluate the performance of the probe based on NEMA NU3 standard.

Results: The sensitivity of the probe in the air/water at distances of 10, 30, and 50 mm is 18784/176800, 3500/3050, and 1575/1104 cps/MBq. The spatial and angular resolutions in the air/scattering medium are 40/47 mm and 77/87 degrees at a 30 mm distance from the probe. The detector shielding effectiveness and leakage sensitivity are 99.91% and 0.09%, respectively.

Conclusion: The results and surgeon experience in the operating room showed that GammaPen can be effectively used for sentinel lymph node localization.

Keywords: Gamma Probe; Sentinel Lymph Node; Performance Evaluation.

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1. Introduction

Detection of tumors metastases is an important step in staging, prognosis, and development of a treatment plan [1-3], because of this importance there are various methods for detection of Sentinel Lymph Nodes (SLN) [4, 5]. A gamma probe is one of the most effective devices used for the detection and localization of SLN [6,7]. The Performance of a gamma probe depends on the chosen detector material, detector size and collimation [8-11], specifications which affect a gamma probe performance for accurate identification of sentinel lymph node described by its sensitivity, side and back shielding, angular resolution and spatial resolution [12]. However, there are various methods for gamma probes evaluation [9, 13] while the most common standard is NEMA NU3 [14]. In this technical note, the innovations in the electronics of GammaPen, which causes high accuracy detection beside small dimension of the electronic boards, is presented, and then, the performance parameters of GammaPen based on NEMA NU3-2004 standard is reported.

2. Materials and Methods

2.1. GammaPen Design

Designed GammaPen is a pocket gamma probe dedicated for Sentinel Lymph Node Biopsy (SLNB) (Figure 1). This all-in-one probe consists of detection parts and electronics encapsulated in an ergonomic housing.

Figure 1. The GammaPen system

The detection parts comprise a CsI (Tl) scintillation crystal coupled to a photodiode. Crystal dimension is designed for optimized use with 140 keV gamma rays (the dominant gamma energy of Tc-99m). Detector parts are shielded in the 2.8 mm thick tungsten for side and back shielding and placed in a housing. The head tip diameter is about 14.5 mm.

GammaPen body consists of head housing made of stainless steel and electronic parts housing which is made of aluminum. The overall weight of the body is about 170 g with tungsten, battery, and electronic parts. Dedicated electronics is designed for signal processing and data acquisition.

First of all, the pre-amplification of signal is performed on the electronic board (Figure 2). Then, signal amplitude compares with two voltage levels, which are controlled by micro controller variable current Digital to Analog Converter (DAC) output. With changing current DAC output, we can scan counts in different energies to find energy the peak of Tc-99m.

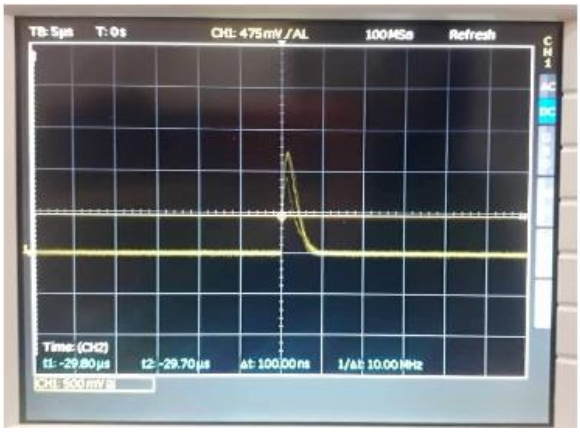

Figure 2. Simplified circuit schematic of signal pre-amplification and the signal measured with HAMEG oscilloscope (A Rohde & Schwarz Company)

Count rates shown in dot-matrix LCD and audio output helps the user to easily find high rate lymph nodes. The control unit is equipped with a membran keypad for using settings and options.

2.2. Performance Evaluation

Sensitivity, spatial and angular resolution in air and scatter medium, and shielding of GammaPen measured using NEMA NU3 standard [14]. The radiation source used for this purpose was 1 mm diameter point like the source of Tc-99m solution with 0.362 MBq. For tests in

air, the source-to-probe centerline was at least 50 mm far from any scattering material while, for tests in scattering medium measurements were in a 25 cm long, 25 cm wide, 20 cm deep container filled with water where the source was placed in the depth of water and the probe was positioned such that its tip touches the water surface.

3. Results

Sensitivity is one of the most important parameters for lymph node detection to find low-uptake or deep-seated nodes. Since sentinel nodes are mostly located in about 30 mm depth of the body surface [15-19], the sensitivity of GammaPen in air at 10, 30, and 50 mm distances is 18784, 3500, and 1575 cps/MBq, respectively. Sensitivity in scattering medium was also measured at 10, 30, and 50 mm distances as 17680, 3050, and 1104 cps/MBq (Figure 3). As expected, sensitivity in scattering medium is less than sensitivity in air. Our results also confirm that the sensitivity is inversely proportional to the square of the distance from the probe [20, 21].

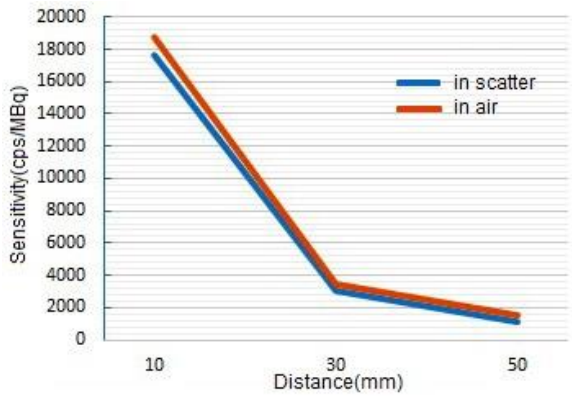

Figure 3. Sensitivity in air and scattering medium at 10, 30, and 50 mm

The high spatial resolution of the gamma probe helps accurately identify lymph nodes near each other and also the nodes close to the injection site [22]. Spatial resolution and sensitivity are dependent on the characteristics of the collimator and the crystal [23]. Improving one of them results in worsening the other, so the sensitivity and spatial resolution should be optimized [22]. The spatial resolution and angular resolution in scatter medium are 47 mm and 87 degrees at a 30 mm distance from the probe in scatter medium, while they are 40 mm and 77 degrees in air. This difference is because of the scatter medium effect. It is important for gamma probes to have low shielding leakage, as weak shielding may cause detecting unwanted photons originated from out of the Field Of View (FOV), which leads to surgeon mistakes [22, 24-25]. The detector shielding effectiveness and leakage sensitivity are 99.91% and 0.09% for GammaPen.

4. Discussion

The NEMA-NU3 standard provides a platform for comparing various gamma probes regarding their performance parameters. In comparison with different commercially available systems, the GammaPen with collimator have high sensitivity and comparable spatial resolution and angular resolution with other probes that do not utilize an external collimator. It should be noted that side and back shielding of the GammaPen is better than other commercially available systems [8, 13, 14].

5. Conclusion

In this report, we described the design and performance evaluation of the GammaPen. The innovative electronic design of signal processing and peak detection resulted in a lightweight compact structure with a small dimension beside high accuracy. Measured performance characteristics of GammaPen showed that it can potentially be used for sentinel lymph node identification during radiosurgery. The probe was successfully used in several operations by an expert surgeon [26].

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