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Radioisotope guided surgery with imaging probe, a hand-held high-resolution gamma camera

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Abstract

Since 1997, our group of Physics together with Nuclear Physicians studies imaging probes (IP), hand-held, high-resolution gamma cameras for radio-guided surgery (RGS). Present work is aimed to verify the usefulness of two updated IP in different surgical operations. Forty patients scheduled for breast cancer sentinel node (SN) biopsy, five patients with nodal recurrence of thyroid cancer, seven patients with parathyroid adenomas, five patients with neuroendocrine tumours (NET), were operated under the guide of IP. We used two different IP with field of view of 1 and 4 in.^{2}, respectively and intrinsic spatial resolution of about 2 mm. Radioisotopes were ^{99m}Tc, ^{123}I and ^{111}In.

The 1 in.^{2} IP detected SN in all the 40 patients and more than one node in 24, whereas anger camera (AC) failed locating SN in four patients and detected true positive second nodes in only nine patients. The 4 in.^{2} IP was used for RGS of thyroid, parathyroid and NETs. It detected eight latero-cervical nodes. In the same patients, AC detected five invaded nodes. Parathyroid adenomas detected by IP were 10 in 7 patients, NET five in five patients. One and 4 in.^{2} IPs showed usefulness in all operations. Initial studies on SN biopsy were carried out on small series of patients to validate IP and to demonstrate the effectiveness and usefulness of IP alone or against conventional probes. We propose the use of the IP as control method for legal documentation and surgeon strategy guide before and after lesion(s) removal.

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Keywords: Gamma ray imager; Scintillation detector; Position-sensitive photomultiplier tube; Portable gamma camera

1. Introduction

Radio-guided surgery (RGS) uses gamma probes (GP) providing acoustic signals [1,2]. GP are useful in several instances after pre-positioning lesions with anger camera (AC) images [2]. However, searching with the sole aid of an acoustic signal is sometimes difficult and can generate pitfalls [3].

Some researchers assess that direct intra-operative imaging in the operating theatre is likely to help surgeons. Several groups built and studied high-resolution (HR) portable cameras either based on scintillation crystals, or on semiconductors [4–9].

Sentinel node (SN) is a surgical diffuse technique and effective method for breast cancer staging [1,2]. Though leading institutions report higher than 90% success rate in detecting SNs, techniques adopted are not fully

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standardized. Some surgeons suggest both vital blue dye and/or radioactive colloids [10,11] using only intra-operative detection of radioactivity with GP, whereas several teams prefer lympho-scintigraphy (LS) with AC, followed by intra-operative GP detection [1,2,12,13,14]; others suggest the use of LS plus a dye if LS misses the node [15]. LS is generally performed on planar views; some studies [16,17] suggest more complex LS methods including SPECT and triangulations.

There is probably a rationale for such a rich variety of techniques. Radio-guided SN Biopsy is a rather easy and fast procedure, allowing well-trained teams to remove the SN in about 10 min. Sometimes, however, the detection and exertion of SN may be troublesome [3,18]. In addition, SNs detection with both AC and GP may occasionally be unsuccessful or can miss the second or third node.

Other radio-guided techniques utilized new scintigraphic devices to localize the pathologies as RGS of thyroid, parathyroid and neuroendocrine tumours (NET).

Our group started constructing and using imaging probes (IP) since 1997 [19]. The IP is a miniature, portable gamma camera; it can be hand held as a GP thus giving high-resolution images in the operating theatre. Field of view (FOV) of hand-held cameras is necessarily small, 1–4 in.^{2} [20] whereas intrinsic spatial resolution generally ranges from 1 to 3 mm [6,21], much better than resolution of AC. Since first prototype, RGS and continuous feedback between Physic and Nuclear Medicine were the methods to update our IP.

Aim of present work is to verify if two updated prototypes of IP are of real help for surgeons during different operations.

2. Equipment and method

2.1. Imaging probes

Two prototypes showing 1 and 4 in.^{2} FOV, providing 2.4 mm intrinsic spatial resolution with a weight of 1 and 2 kg, respectively, were prepared by our group. Basic elements of these devices are: a full tungsten (W) square hole collimator with CsI(Tl) crystals integrated into holes, a position-sensitive photomultiplier tube (PSPMT), and home-made readout electronics and data acquisition system. Data can be transferred to a processor integrated with a 10 in. screen. Image visualization in operating theatre can occur on the 10 in. screen.

The collimator is a structure of 200-μm-thick W septa, forming $2.2 \times 2.2\,mm^2$ square holes in which the crystals are inserted [22]. Collimators are 30 mm long, with the basal 5 mm of each hole occupied by a CsI(Tl) crystal. Thus, the length of collimator from its free surface to the outer crystal edge was 25 mm. PSPMTs were the Hamamatsu R8520-00-C12 and Hamamatsu R8500 [23], respectively for the 1 in.^{2} and the 4 in.^{2} FOV devices. Collimators and other parts of IP are US and EU patented [24].

Fig. 1 shows how we assembly the 1 in.^{2} device with collimator–scintillator array and the PSPMT R8520-00-C12.

Readout of PSPMT occurs with home-made, low-power consuming, miniaturized resistive chain and a compact dedicated four channel ADC, 12 bit, 20 Msample/s each.

Data acquisition system card is connected via USB bus to a dedicated system based on embedded PC. The USB ADC-card has a sampling period of 50 ns and an acquisition time, for each event, of 10 μs using as trigger the 10th dynode signal. The software was developed under C++ on Linux Operative System environment. It performs on-line the corrections and calculations needed to reconstruct the scintigraphic image. Data are transferred to buffer memory in order to display images on real time, when operators move the IP on patient's skin to search the hot spot of radioactivity.

The collimator–scintillator arrays are respectively 10×10 and 18×18 elements for the 1 in.^{2} and the 4 in.^{2} IPs. Fig. 2 (top) shows a flood field irradiation image of the 1 in.^{2} detector, whereas Fig. 2 (bottom) shows a cross-section of a row of the image above.

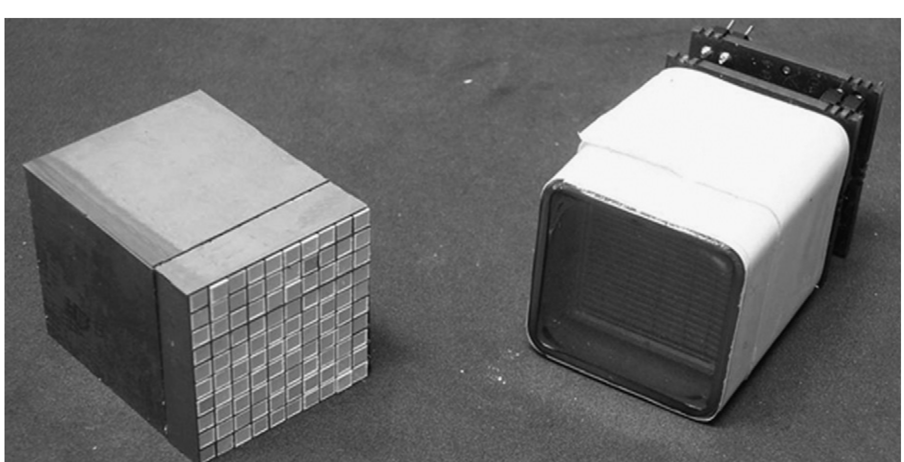

Fig. 1. PSPMT R8520-00-C12 and collimator–crystal array.