Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 571 (2007) 48–51
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Performance evaluation of a mouse-sized camera for dynamic studies in small animals

George Loudos[a,*], Stan Majewski[b], Randy Wojcik[b], Andrew Weisenberger[b], Nicolas Sakellios[a], Konstantina Nikita[a], Nikolaos Uzunoglu[c], Penelope Bouziotis[d], Alexandra Varvarigou[d]

[a]NIMgroup, Biomedical Simulations and Imaging Applications Laboratory, School of Electrical and Computer Engineering, National Technical University of Athens, Iroon Polytecneiou 9, 15780 Zografos, Greece
[b]Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA
[c]School of Electrical and Computer Engineering, National Technical University of Athens, Iroon Polytecneiou 9, 15780 Zografos, Greece
[d]Institute of Radioisotopes-Radiodiagnostic Products, National Center for Scientific Research "Demokritos", 153 10 Athens, Greece

Available online 7 November 2006

Abstract

A mouse sized camera has been built in terms of collaboration between the presenting institutions. The system is used for the performance of dynamic studies in small animals, in order to evaluate novel radiopharmaceuticals. The active area of the detector is approximately 48×96 mm allowing depiction of the entire mouse in a single view. The system is based on two flat-panel Hamamatsu H8500 position sensitive photomultiplier tubes (PSPMT), a pixellated NaI(Tl) scintillator and a copper–beryllium (CuBe) parallel-hole collimator. In this work, the evaluation results of the system are presented, using phantoms and small animals injected with conventional radiophrmaceuticals. Average resolution was ~1.6 mm on the collimator surface and increased to ~4.1 mm in 12 cm distance from the detector. The average energy resolution was measured and found to be ~15.6% for Tc^{99m}. Results from imaging thin capillaries demonstrated system's high resolution and sensitivity in activity variations was shown. Initial dynamic studies have been carried out in small animals injected with Tc^{99m}-DTPA and Tc^{99m}-MDP. The results show system's ability to perform kinetic imaging in small animals.

Keywords: Small animal imaging; Dynamic studies; Mouse-sized camera; PSPMTs; Radiopharmaceuticals evaluation

1. Introduction

The evaluation of novel SPECT radiopharmaceuticals is performed either by biodistribution measurements in large number of small animals, in order to estimate optimal imaging time or by performing dynamic studies. It is obvious that the second method is highly preferable since radiopharaceuticals behavior is studied in the same animal over a time period. In this case, it is important to use a detector that can produce an image of the entire animal at sufficiently high resolution and sensitivity. A number of dedicated imagers have been presented over the past years using a variety of approaches [1–3].

Many of these systems are based on Position Sensitive Photomultiplier Tubes (PSPMTs), since they meet these requirements and they can be purchased at a relatively low cost [4–6]. The commercial availability of a new generation of square PSPMTs [7] and mainly Hamamatsu H8500 [8] allowed the construction of larger FOV cameras based on the combination of two ore more PSPMTs, while methods for recovering signals in the dead area between the PSPMTs were developed [9–11].

In this work, a mouse sized camera based on 2 H8500 PSPMTs has been constructed. In Section 2, the system is described while in Section 3, results from evaluation studies using phantoms and performance in applications with

*Corresponding author. Tel.: +00 30 2107722149; fax: 00 30 2107723556.
E-mail address: gloudos@central.ntua.gr (G. Loudos).

0168-9002/$ - see front matter © 2006 Published by Elsevier B.V.
doi:10.1016/j.nima.2006.10.026

small animals are presented. The results and future goals are discussed in Section 4.

2. Materials and methods

2.1. System components

The developed system is based on a pair of two square H8500 flat-panel PSPMT with external dimensions of 52 × 52 and 34 mm thick. The two H8500 PSPMTs are gently attached to each other with flexible cement along one edge and then taped against the glass face of the NaI(Tl) scintillator. Optimal HV for system operation was found to be 795 V.

The two PMTs are coupled to a NaI(Tl) crystal array (Bicron-St. Gobain [12]) with an active area of ~98 × 48 mm. The pixel dimensions are 1 × 1 × 5 mm with a pitch of 1.2 mm. The array is viewed through a 3 mm glass window and encapsulation is completed by an aluminum cover 50 μm thick. An optical grease [13] has been used for optical coupling of the PSPMTs to the scintillation array window. The parallel-hole collimator is made of lead and has hexagonal holes 1.2 mm in diameter and 0.2 mm thick septum walls (Tecomet Inc. [14]). It is 25 mm thick, and has an active area 52 × 105 mm.

The system is enclosed in an 8 mm tungsten (W) housing box 140 × 82 × 107 mm deep. The front face entrance window is of 0.5 mm thick, graphite-based composite material, manufactured principally for use in medical imaging tables [14].

2.2. Anode readout

Each of the H8500 PSPMTs has 64 anode pads in an 8 × 8 array. The 16 signals on each PMT are then connected to a subtractive resistive readout, which reduces the number of signals to just four per PMT plus one sum signal used for triggering. The sum is sent to a fast constant fraction discriminator and the eight signals are collected using two National Instruments PCI6110 ADCs which have four channels each [15]. The Kmax-based [16] data acquisition algorithm calculates the digitized signals from both PSPMTs to permit a single continuous active detector surface in one of the detection coordinates.

3. Results

3.1. Systems evaluation using phantoms

In order to calibrate the system, a point-like Tc^{99m} source was used, placed at a 50 cm distance from the detector with the collimator removed. Crystal pixels have been identified and the system's look up table (LUT) was determined as well as camera's flood image. In addition, a matrix mapping energy response was calculated and used for energy corrections. Finally, a flood source covering the entire field of view was used in order to correct for the collimator's response. Profiles drawn in X and Y direction have shown a good uniform response.

3.1.1. Spatial resolution

Spatial resolution was measured using a thin capillary (1.1 mm inner diameter and 8 cm long) filled with a Tc^{99m} solution. The capillary was placed with a slight rotation (~3 crystal pixels wide) and three profiles were averaged in order to avoid the effects of capillary positioning over one or two rows of crystal pixels. Thirteen measurements were taken at 0–12 cm distance from the detector surface. Average resolution was ~1.6 mm on the collimator surface and increased to ~4.1 in 12 cm distance from the detector. Spatial resolution curve is shown in Fig. 1.

3.1.2. Energy resolution

The energy resolution can be measured separately in the two PSPMTs and the area between them. Variations in the photopeak energy channel are observed. However, when normalization was performed using the energy response matrix the total energy resolution was found ~15.6% for Tc^{99m}.

3.1.3. Sensitivity

Sensitivity was measured with a flood source containing 100 ml of a 0.5 mCi Tc^{99m} placed in 0, 5 and 10 cm distance from the detector surface and only a small decrease was observed when distance was increased. Sensitivity was ~130 counts/min/μCi. A good linear response between activity and number of counts has been observed for activity values of 1–10 mCi. In Fig. 2, system's response measured in counts/min/cm^2 is presented.

3.1.4. Capillary imaging

Three capillaries were placed side-to-side, right on the detector surface. The middle one was empty, while the

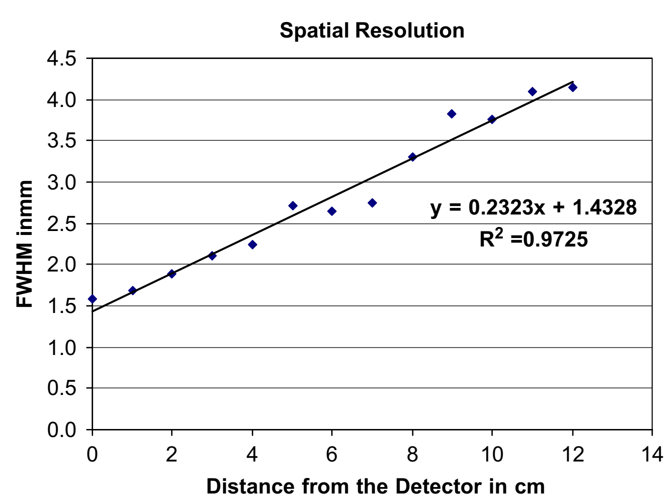

Fig. 1. Spatial resolution as a function of source to detector distance, using a 1.1 mm inner diameter and 8 cm long capillary filled with a Tc^{99m} solution.