A simulation based study to introduce small animal Total-Body PET by J-PET technology

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***Abstract*—Nowadays, there is a new trend in the Positron Emission Tomography PET concerning a novel generation of PET tomographs – Total-Body PETs. Growing interest in the human grade systems transferred also to the small animal studies. In this simulation work we want to evaluate the performance of the two unconventional, cost-effective Total Body PET systems designed for rodents and constructed with the technology researched by the Jagiellonian-PET Collaboration from Jagiellonian University in Cracow, Poland. For this purpose we choose the sensitivity as a standard metric for tomographs. Obtained sensitivity for mouse-like geometry amounted to 2.35% and for rat-like - 2.6%.**

***Index Terms:* Small animal Total-Body Imaging, J-PET, sensitivity.**

I. Introduction

The existing limitations in human studies such as drug development, novel treatment monitoring, investigating functionalities of new imaging modalities, etc. forced researchers to find different testing organisms. Seeing that there are many common diseases between humans and rodents like rats and mice, they proved to be ideal systems for such preclinical research. Thus obtained background became an essential step before any human-based trials [1].

Positron Emission Tomography (PET) scanner as one of the devices for molecular imaging is an ideal instrument for early oncological diagnosis and physiological imaging [2]. Since the detailed imaging of rodents is impossible with human-grade tomography due to their small anatomical dimensions, there is a need for the development of dedicated small animal PET systems with high sensitivity and excellent spatial resolution. Nowadays, with new trends in PET tomography and the development of first human-grade Total-Body PET systems, there is also a growing interest in extending of field of view of small animal PET scanners. The main advantage of the development of Total-Body tomographs is their higher sensitivity, the possibility of dynamic full-body imaging, etc. [3]. Development of the small animal Total-Body PET tomograph with currently utilized technology requires the use of many consecutive detection units, where each unit can act as a separate scanner. However, this approach entail high construction cost due to large number of photodetectors, scintillator crystals and readout electronics. Therefore, development of an alternative, cost-effective technology for construction of extended field of view tomographs can be the key to increase the accessibility of the Total-Body PET scanners.

A novel approach to PET systems was introduced by the Jagiellonian-PET (J-PET) Collaboration at the Jagiellonian University in Cracow, Poland. Since 2013 there is an ongoing research and the development of cost-effective Total-Body PET [4-6]. In oppose to the traditional tomographs, J-PET uses an axially arranged detection units, each consisting of a plastic scintillator strips readout with silicon photomultipliers on both ends. Such unique geometrical configuration allows for simple introduction of extended field of view with only a use of longer scintillator strips.

The main aim of this study is to compare sensitivity and imaging functionality of suggested tomograph based on J-PET technology with currently exist scanners.

II. Methods

The presented study was carried out using Geant4 Application for Tomographic Emission (GATE) software, which is a validated Monte-Carlo based simulation toolkit [7]. Two types of Total-Body J-PET scanners: for mouse and for rat based studies, have been simulated. They consists of 12 (16) axially arranged detection panels, respectively. Each panel is composed of 2 modules of plastic scintillators located next to each other in radial direction. The geometrical configuration of the simulated geometries is described in the Table 1.

TABLE I
GEOMETRICAL CONFIGURATIONS OF SMALL ANIMAL TOTAL-BODY J-PET

Scanner	Mouse TB J-PET	Rat TB J-PET
Scintillation dimension [mm]	1x1x250	1x1x300
Number of panel	12	16
Diameter [cm]	11	16
AFOV [cm]	25	30

Geometrical configuration of small animal Total-Body J-PET which utilizes EJ-230 plastic scintillators provided by Eljen Technology. Both of the presented scanners are composed of similar detection panels with the only difference in their length.

This work was supported by Foundation for Polish Science through TEAMPOIR.04.04. 00-00-4204/17, the National Science Centre, Poland (NCN) through grant No. 2019/35/B/ST2/03562 and grant PRELUDIUM 19, agreement No. UMO-2020/37/N/NZ7/04106.The publication also has been supported by a grant from the SciMat Priority Research Area under the Strategic Programme Excellence Initiative at the Jagiellonian University.

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In this study the sensitivity, as one of the main characteristics of PET tomographs, was investigated. For this purpose radioactive point sources were simulated in various positions as described in the Table 2.

TABLE 2
POSITIONS OF POINT SOURCES TO ESTIMATE SENSITIVITY OF THE SCANNERS

Scanner	Mouse TB J-PET	Rat TB J-PET
Radial offset [mm]	0, 5, 10, 15, 25 & 40	0, 5, 10, 15, 25, 50 & 60
Axial offset	0 to 80 mm By the steps of 10 mm	0 to 12 mm By the steps of 10 mm

Coordinates of the point source utilised to evaluated sensitivity of small animal Total-Body J-PET. The activity of each one of the point sources set to 370 KBq.

III. RESULTS

In order to estimate the sensitivity of Mouse and Rat Total-Body J-PET several point source with different axial and radial offsets from the centre were simulated. Fig1. shows the obtained sensitivity for mouse (Fig.1) and rat (Fig.2) tomograph versions. The sensitivity at the centre of the field of view achieved by the Mouse and Rat Total-Body J-PET was 2.35% and 2.6% respectively.

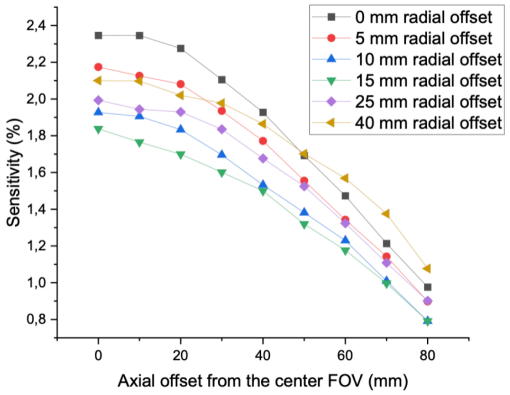

Fig. 1. Absolute sensitivity of mouse small animal Total-Body J-PET with 54 point sources with radial and axial offset. Due to symmetrical configuration of scanners, these 54 point sources are able to map sensitivity of all part of scanner.

IV. CONCLUSION

While the Total-Body PET imaging is becoming a trend in the nuclear imaging, both in pre-clinical and clinical research, their cost is one of the main parameters which slows down they widespread usage. Solution for this problem is researched by the Jagiellonian-PET Collaboration who introduces a novel, cost-effective approach to tomograph construction . The main aim of this simulation based study was to evaluate performance of the proposed small animal Total-Body PET

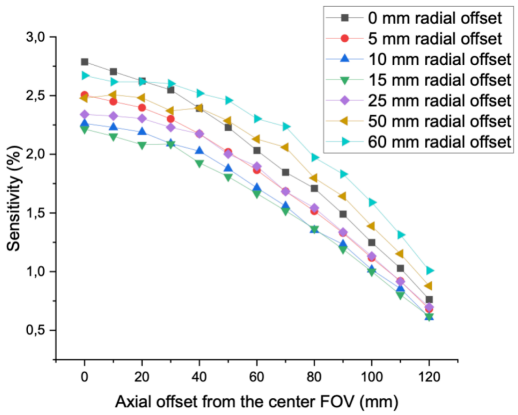

Fig. 2. The absolute sensitivity of the rat Total-Body J-PET by 65 point sources which has been distributed with both radial and axial offset. The absolute sensitivity of 2.6% has been achieved at the centre of rat Total-Body J-PET.

scanners constructed with the J-PET technology. Sensitivity as one of the most important characteristics of tomographs for example in lesion detectability, was selected in order to check the feasibility of the small animal J-PET. The achieved sensitivity of small animal Total-Body J-PET is comparable with the current scanner, while among tomographs, our introduced geometry has larger AFOV [8].

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