Short Thesis for the Degree of Doctor of Philosophy (PhD)

Examination of imaging capability and optimization of small animal PET scanners

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The Examination takes place at the library of the Department of Physiology, Faculty of Medicine, University of Debrecen at 11:00 am, 16th January, 2015

Head of the Defense Committee: László Csernoch, DSc

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Andrea Dóczy-Bodnár, PhD

Members of the Defense Committee: János Mester, PhD
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The PhD Defense takes place at the Lecture Hall of Bldg. A, Department of Internal Medicine, Faculty of Medicine, University of Debrecen at 13:00, 16th January, 2015

2 Introduction

Positron Emission Tomography (PET) is one of the latest established medical imaging technique have been using in the clinical routine for three decades, and has proved to be successful in many areas of medicine. Applying this method an appropriate biologically relevant molecule labeled with a positron decaying isotope (radiopharmaceutical, tracer) is injected intravenously into the living body. The tracer molecules participate in certain biochemical and/or transport processes resulting in a characteristic distribution of the radiopharmaceutical depending on kind of the labeled molecules and the functional state of the investigated organism. The determination of the three-dimensional distribution is performed using gamma sensitive detectors arranged in a ring-like structure and coincidence detection technique. The acquired coincidence events provide the input data to the image reconstruction procedure. Comparing the resulting 3D tomographic image with that of another functional state of the same system (e.g. pathological versus physiological state) reflects functional difference(s). Due to the excellent sensitivity of the PET this non-invasive procedure enables detailed studies of tissue biochemistry providing information on neurological, psychological, cardiologic lesions and cancerous diseases. The significance of in-vivo models in biological research has increased, implying the demand for the in-vivo examination of small animals using imaging techniques. These animal models can successfully decrease the time and the cost of the drug development.

Small animal models have been frequently used in testing of developed new PET radiopharmaceuticals. Unfortunately, the small dimensions of the models require spatial resolution of around 1 mm is surpassing that of the human PET-cameras (~4-5 mm). To overcome this problem, specific programs have started to develop small animal PET scanners of high resolution and sensitivity. As a result, several research groups have reported on their developed devices and commercially available small animal PET cameras were also released. These instruments have smaller size crystals and ring diameter compared to the clinically used human PET cameras. To support comparison and eventual choice between these scanners recommended measurements and data evaluation protocols have been assembled in the NEMA NU 4 2008 standard allowing standardized determination of spatial resolution, field of view, sensitivity, image quality, etc. Nowadays this standard is used almost solely to determine the parameters of small animal PET cameras. In addition, procedures defined in NEMA NU-4 proved to be suitable to apply also in the optimization of a number of operating parameters such as reconstruction algorithms, coincidence time window and energy discrimination.

Tracer accumulations observed in real images appear, as a rule, on a non-zero tissue background. Due to the finite resolution, the images are distorted in the vicinity of the edge of the accumulations. To characterize this “partial volume effect” (PVE) induced distortion two parameters, the recovery coefficient (RC) and the contrast recovery coefficient (CRC) are used. The former parameter provides information

only on the accuracy of the measured accumulation within the lesion; however, the CRC values depend on the actual background accumulation thus it has a more direct relationship to the detectability of the lesions. The CRC parameter is determined typically using a special image quality phantom containing fillable spheres inserted into a volume serving as background. The ratio of the activity concentration in the spheres to that in the background volume (object contrast) is known from the input data and it can be also determined using the PET image. The ratio of the object contrast to the contrast determined from the image data results in the CRC. However, currently there is no available method to determine the CRC parameter of small animal PET devices, because in case of small dimensions the effect of the walls of the spheres („cold wall" effect) can distort the conditions of the imaging.

Knowledge of the exact geometrical parameters is fundamentally important in the image reconstruction procedure. The physical diameter of the detector ring of the scanner is well known, however, the gamma-photons are absorbed randomly in the volume of the crystals thus the exact lengths of the lines of response are not clear. Consequently, it is useful to introduce an effective radius parameter resulting in more realistic data during the image reconstruction. Unfortunately, currently there is no widely accepted method for its measurement definition.

The first Hungarian PET-program started in Debrecen in the early 90s. Within the frame of this program and in collaboration with experts of the MTA ATOMKI and the Mediso Ltd. the development of

a high resolution small animal PET camera (MiniPET-1) was started in 2001. The MiniPET-1 did not have full detector ring therefore the projections for the reconstruction were obtained by rotating the 4 detector modules arranged in 90 degree geometry. The performance of this device was fine for demonstration purposes but it did not meet the requirements of the biological and physiological research projects. Experiences obtained with the MiniPET-1 allowed starting a full detector-ring MiniPET-2 development in 2006. The detector system of this scanner consists of 12 detector blocks of ring shape geometry. A number of the applied technical solutions can still be regarded as pioneering in the field of PET. From the middle of the last decade developments of MRI (Magnetic Resonance Imaging) compatible PET systems have been started worldwide aiming the construction of PET-MRI dual modality tomographs. In cooperation of the ATOMKI, the Debrecen University and several European institutions an MRI compatible new MiniPET system development was started supported by a European Union grant resulting in the MiniPET-3 scanner.

The MiniPET-2 and 3 are appropriate serving biological and physiological research projects based on PET investigation of small animal models. These scanners and the related simulation and software developments have made possible the examination of the basic principles and procedures of PET imaging.

3 Aims

The MiniPET-2 small animal camera with the related biological research laboratories represents high research potential in Debrecen. In research projects applying the complex and expensive PET methodology optimized high performance imaging is a real requirement. Consequently protocol optimizations and methodological developments contributing to higher level PET imaging are extremely important also from the point of view of biological measurements.

It is known that the voxel data of a PET image are distorted by the limited spatial resolution and the related PVE effect. The quantitative accuracy and the detectability are especially concerned when the size of the lesion is relatively small. The CRC parameter have direct relationship to both the quantitative accuracy and detectability of lesions, however, currently there is no generally accepted method to determine its value for small animal PET scanners.

Taking the above discussed problems into account the mayor aims of present study were set as follows:

1. Optimization of the imaging capability of the MiniPET-2 scanner using the methods of NEMA NU-4 and own developed procedures.
2. Development of a new cold wall effect eliminating method to determine the contrast recovery coefficient for small animal PET scanners using the NEMA NU-4 image quality phantom.

3. Validation of our new CRC determination method by performing measurements using different small animal PET scanners installed in different preclinical research laboratories.
4. Investigation of combined tumor treatment applying several different radiopharmaceuticals (18FDG, 11C-metionin, 18F-FLT and 18FAZA) and using the MiniPET-2.

4 Materials and methods

4.1 Performance evaluation of the MiniPET-2 scanner using the NEMA NU-4 standard

We examined the effect of changes in the coincidence time window (τ) and the lower threshold of the energy discrimination (E_{lt}) setting on the measured (and/or evaluated) parameters of the MiniPET-2. Measurements and data evaluations were performed according to the NEMA NU4 standard using three different numerical values for both τ (2, 3 and 4 ns) and E_{lt} (250 keV, 350 keV, and 450 keV) while the upper limit of the energy window was kept constant at 650 keV because the higher energy range of the energy spectrum does not contain useful information.

Normalization correction was applied in all cases when images were reconstructed but attenuation correction was not accomplished because neither CT nor transmission data were available to the MiniPET-2 measurements. Investigations of the imaging features of MiniPET-2 were performed using the NEMA NU-4 standard image quality phantom and the related measurement protocols. This phantom is of cylindrical shape with fillable rod like cavities of different diameters (mimicking artificial lesions) drilled in cold solid background. In addition, it comprises also a fillable homogeneous cylindrical part and two inactive compartments. These elements were all necessary for the determination of the uniformity, recovery coefficients (RC) and the spillover ratios (SOR). Measured data were processed using the software developed in the Institute of Nuclear Medicine.

4.2 Additional small animal PET scanners used

We elaborated a new method to determine the recovery coefficients (CRC) using small animal PET cameras. Applicability of the developed new procedure was tested performing CRC measurements on five small animal PET scanners (GE Explore Vista, Genisys4, MiniPET-2, nanoScan PC and Siemens Inveon). Measurements on the Siemens Inveon, Genisys4 and GE Explore Vista scanners were performed in the USA at the Department of Molecular and Medical Pharmacology (UCLA) and the Department of Radiology (UCSD) institutes while measurements on the nanoScan PC were performed in Budapest at the site of the Mediso Ltd. The nanoScan PC was the only one (out of the five instruments) equipped with CT consequently, therefore we have not completed any scatter and attenuation correction.

4.3 Monte-Carlo simulations

Computer simulations were required to ensure validation of the measurement. These calculations were performed using GATE (a Monte Carlo-based simulation). These simulations proved to be useful and effective to understand the underlying physical processes. The related calculations were carried out using the High Performance Computing Cluster installed at the University of Debrecen.

4.4 Animal model and study design

Cells of drug-sensitive (Pgp+) lines and their non-sensitive (Pgp-) counterparts were implanted into immunodeficient (pathogen-free CB-17 SCID) mice and the animals and were used in the in-vivo

measurements completed on twenty-four (10 to 12 week-old) female mice.

The SCID mice were injected subcutaneously with Pgp+ (A2780AD) and Pgp- (A2780) human ovarian carcinoma cells. Another group of SCID mice was injected with Pgp+ (KB-V-1) and Pgp- (KB-3-1) human epidermoid carcinoma cells. All of the animals received all the four types of tumor, by two injections into the shoulders and two into the thighs. Four days after the injection a group of mice was treated with doxorubicin (DOX) combined with UIC2 monoclonal antibody and Cyclosporine-A (CSA). Another group of animals (tumor-bearing but untreated control) was injected with phosphate buffered saline.

5 Results

5.1 Performance optimization of the MiniPET-2 scanner using NEMA NU-4 protocol

We found that the spatial resolution of the MiniPET-2 as determined by the NEMA protocol was close to 1.2 mm in the center of the field of view increasing to 1.4 mm at the radial edge. We also found that changes in τ and E_{lt} values induced very small alterations (if any) in the spatial resolution parameter. In addition, it was found that the absolute sensitivity depended on both of these parameters. Based on the measured data, we can claim that increase of the coincidence time window above 3 ns is worthless, because it does not improve the sensitivity, but it increases the number of unwanted random coincidence events. The highest sensitivity was measured at E_{lt}=250 keV. However, based on the results of the global coincidence events and dead time tests we can state that in the case of E_{lt}=250 keV the number of scattered coincidence events can be extremely increased, thus the E_{lt}=350 keV setting seems more preferable. The above statements are supported by the analysis of image quality parameters. Summing up, we conclude that the optimum operating parameters of the MiniPET-2 is 350 keV for the lower energy threshold and 3 ns for the coincidence time window.

5.2 Determination of effective system radius of MiniPET-2

The physical radius of the detector ring of MiniPET-2 comprising 12 modules is 105.5 mm. A polygon-shaped detector system and the relatively long (compared to the base edge) scintillator crystals require the determination of the effective radius. For this purpose we developed a new method. It was assumed that inaccurate effective radius results in distorted image and the optimal value of the radius leads to the expected minimal distortion. To find the optimal value we used a custom made "MicroDeluxe" phantom having a number of rod like cavities with diameters 1.7, 1.8, 1.9, 2.0, 2.1 and 2.2 mm, respectively.

A digital mask was created matching the real image of the phantom. It was supposed that the optimal value of the assumed effective radius assures the most perfect overlap between the reconstructed image and the digital mask. The image reconstruction of the measured data was repeated using different effective radius parameters (from 103 mm to 120 mm with 0.5 mm steps) allowing to examine the dependence of the distortion on the effective radius. In order to characterize the distortion numerically intensity value of all pixels of the reconstructed image was set to zero if the pixels really belonged (according to the digital mask) to the rod like cavities of the phantom. Summed values of the masked image pixel intensities (C_{sum}) were generated in each case obtained with the different effective system radii. Optimal effective system radius was defined as the radius determining the minimal C_{sum}.

Based on the reconstructed images from the completed measurements we can say that our hypothesis (the image distortion is related to the effective radius used during the reconstruction) proved to be correct. The distortion was most significant with 103 mm and 115 mm effective radius setting, thus the optimal setting is somewhere between these two values of the effective radius. This way we demonstrated that the distortion can be quantified using our developed method. The C_{sum} values (calculated from the reconstructed images) versus effective radius plot had a minimum located at 109 mm arguing for a 109 mm optimal setting for the MiniPET-2 camera effective radius.

5.3 New method to determine contrast recovery coefficient

We developed a new method for the determination of CRC using the NEMA NU-4 image quality phantom (NU4IQ) scanned under special conditions. According to our protocol the active rod shaped compartments and the homogeneous region of the phantom are imaged although separately and not in the same alignment. An easily acceptable assumption was also made about the additivity of the detected activities in the field of view of the PET scanner.

According to our protocol a 60 min list-mode acquisition has to be made using the NU4IQ phantom filled with radioactivity with two successive alignments. In the first position (‘position 1’) the geometrical centre of the uniform cylindrical region of NU4IQ was placed in the centre of the field of view and scanned for 5 min (t_0 = 5 min). After this, the bed was shifted by 15 mm resulting in a partial overlap of the rods in

this ‘position 2’ and the cylindrical region in ‘position 1’. The acquisition is not stopped during re-positioning and the scan continued for additional 55 min. Having completed the 60 min acquisition, a series of images were reconstructed using the list-mode data file and setting the frame time window to [0, t_{rec_stop}] (where 60 min≥ t_{rec_stop} > t_0). This way the images from the uniform and rod sections of the phantom are artificially merged together. The list-mode data file and the reconstructions with different frame time windows allow creation of images with different object contrasts (OC). The merged image can be regarded as the image of an artificial image quality phantom (artNU4IQ) and the OC of which can be changed easily by different setting of t_{rec_stop}. The OC can be expressed with t_0 and t_{rec_stop} taking the decay of the isotope into account:

$$OC = \frac{N_0 + N_r}{N_0} = \frac{1 - e^{-\lambda t_{rec\_stop}}}{1 - e^{-\lambda t_0}}, \qquad (1)$$

where λ stands for the decay constant of the radioactive isotope, and N_r and N_0 refer to the detected coincidence events from the rods and the uniform background, respectively. Contrast recovery coefficients for each rod size were calculated using the reconstructed merged images according to the following equation:

$$CRC_{rod\_i} = \frac{\frac{C_{rod\_i}}{C_{background}} - 1}{OC - 1}, \qquad (2)$$

The C_{rod_i} (i=1, 2, 3, 4, 5) and $C_{background}$ refer to the evaluated mean activity concentration inside the rods and that of the background region applying appropriate VOIs.

We determined the CRC parameters for the MiniPET-2 and four other small animal PET scanners. We found that the mean pixel intensity of the background region of the reconstructed images increased with the OC. This is surprising, as relocating the phantom to the 'position 2' the background VOI does not contain activity any more. This phenomenon can be explained by the relatively large effect of image reconstruction distortions and scattered events on the intensity of reconstructed voxels far from the active rods. This effect was different for the investigated small animal PET scanners and can be considered as a camera specific feature. The smaller this effect the better is the imaging of the appropriate scanner.

CRC values were successfully determined using our method for the five small animal PET scanners tested as a function of the rod size and the OC. The calculated CRC values allows ranking of the cameras. Best performing cameras were the Siemens Inveon and the nanoScan PC, the MiniPET-2 was the third in the order preceding the GE Explore Vista and the Genisys4 cameras.

5.4 Examination of the effect of tumor therapy using MiniPET-2

Performed PET investigations demonstrated that the MiniPET-2 scanner and the appropriate radiopharmaceutical can be successfully used to detect Pgp positive and Pgp negative tumors and for the in-vivo follow up of Pgp the chemotherapy. The results confirmed that the MiniPET-2 with optimized camera settings is a very effective device which can be advantageously used in small animal research projects.

6 Summary

Positron emission tomography is an advanced and sophisticated imaging method frequently used in biomedical imaging. The MiniPET-2 a full ring PET system used in small animal research projects was installed in 2009 at the University of Debrecen, Department of Nuclear Medicine. Performance parameters of this scanner were determined according to the NEMA-NU4 standard. Dependence of some calculated system characteristics on the coincidence time window (τ) and the low threshold settings of the energy window (E_{lt}) were also investigated.

Altering τ and E_{lt} resulted in substantial changes in the nose equivalent count rate peak and the sensitivity while the image quality was effected only slightly. We found that from the point of view of image quality the optimal coincidence time window and low threshold energy window are 3 ns and 350 keV, respectively. The spatial resolution proved to be independent on the τ and E_{lt}, as expected. A set of specific measurements helped the determination of the optimal value of the effective system radius (109 mm) resulting in the best image quality.

Accurate determination of the contrast recovery coefficients (CRC) of small animal PET cameras cannot be performed according to the NEMA NU-4 protocol using the suggested image quality phantom. In order to circumvent this problem we developed a new method for this purpose using the same conventional image quality phantom available at each small animal PET lab, however, applying a different protocol. Our new procedure allows grading small animal PET scanners from the

point of view of good CRC value. Evaluated CRC values of five small animal PET cameras (GE Explore Vista, Genisys4, MiniPET-2, nanoScan PC and Siemens Inveon) showed good correlation with the visual observation/perception of the PET images.

We demonstrated that the MiniPET-2 camera with optimized setting can be applied effectively in biomedical studies. A set of our MiniPET-2 measurements with Pgp positive and negative human gynecologic tumor cell xenografts showed that this scanner is useful tool for in-vivo follow up of the chemotherapy.

7 List of publications

UNIVERSITY OF DEBRECEN
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PUBLICATIONS

Register number: DEENKÉTK/296/2014.
Item number:
Subject: Ph.D. List of Publications

Candidate: Imre Lajtos
Neptun ID: YWNF19
Doctoral School: Doctoral School of Molecular Medicine
Mtmt ID: 10037395

List of publications related to the dissertation

1. **Lajtos, I.**, Czernin, J., Dahlbom, M., Daver, F., Emri, M., Farshchi-Heydari, S., Forgács, A., Hoh, C.K., Jószai, I., Krizsán, Á.K., Lantos, J., Major, P., Molnár, J., Opposits, G., Trón, L., Vera, D.R., Balkay, L.: Cold wall effect eliminating method to determine the contrast recovery coefficient for small animal PET scanners using the NEMA NU-4 image quality phantom. *Phys. Med. Biol. 59* (11), 2727-2746, 2014.
   DOI: http://dx.doi.org/10.1088/0031-9155/59/11/2727
   IF:2.922 (2013)

2. **Lajtos, I.**, Emri, M., Kis, S.A., Opposits, G., Pótári, N., Király, B., Nagy, F., Trón, L., Balkay, L.: Performance evaluation and optimization of the MiniPET-II scanner. *Nucl. Instrum. Methods Phys. Res. Sect. A-Accel. Spectrom. Dect. Assoc. Equip. 707*, 26-34, 2013.
   DOI: http://dx.doi.org/10.1016/j.nima.2012.12.079
   IF:1.316

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List of other publications

3. Szalóki, G., Krasznai, Z.T., Tóth, Á., Vízkeleti, L., Szöllősi, A.G., Trencsényi, G., **Lajtos, I.**, Juhász, I., Krasznai, Z., Márián, T., Balázs, M., Szabó, G., Goda, K.: The strong in vivo anti-tumor effect of the UIC2 monoclonal antibody is the combined result of Pgp inhibition and antibody dependent cell-mediated cytotoxicity.
   PloS ONE. "accepted by publisher" (2014)
   IF:3.534 (2013)

4. Trencsényi, G., Márián, T., **Lajtos, I.**, Krasznai, Z.T., Balkay, L., Emri, M., Mikecz, P., Goda, K., Szalóki, G., Juhász, I., Németh, E., Miklovicz, T., Szabó, G.: 18FDG, [18F]FLT, [18F]FAZA and 11C-methionine are suitable tracers for the diagnosis and in vivo follow up the efficacy of chemotherapy by miniPET both in multidrug resistant and sensitive human gynecologic tumor xenografts.
   Biomed Res. Int. "accepted by publisher" (2014)
   IF:2.706 (2013)

5. **Lajtos I.**, Emri M., Trón L., Kis S.A., Opposits G., Márián T., Trencsényi G., Mikecz P., Spisák T., Krizsán Á.K.: A debreceni kisállat PET program eredményei: A MiniPET-1, MiniPET-2 és a MiniPET-3 kamerák leképezési tulajdonságai.
   IME. 12 (különszám), 33-38, 2013.

Total IF of journals (all publications): 10,478
Total IF of journals (publications related to the dissertation): 4,238

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of Web of Science, Scopus and Journal Citation Report (Impact Factor) databases.

30 September, 2014

8 Presentations and Posters List

8.1 Citable abstracts

1. Trencsenyi G., Mikecz P., Balkay L., **Lajtos I.**, Emri M., Miklovicz T., Nemeth E., Goda K., Juhasz I., Krasznai Z., Márián T., Krasznai Z.T. Measurement of the Effect of Combined Treatment of Multidrug Resistant Gynaecological Tumors in Mouse Tumor Xenograft Using MiniPET-II.(P0905). Eur J Nucl Med Mol I, 2012. 39:S556-S556

2. Balkay L., **Lajtos I.**, Opposits G. Examination of visual perception variability in detecting low contrast areas. Nucl Med Rev Cent E Eur, 2011. 14:A16-A16

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5. Kis S.A., Opposits G., **Lajtos I.**, Spisák T., Balkay L., Kovács G., Trón L., Emri M. Comparative analysis of image processing algorithms on quadratic and hexagonal grids (P062). Eur J Nucl Med Mol I, 2011. 38:S275-S275

6. Koselák M., Spisák T., Kis S.A., **Lajtos I.**, Opposits G., Galuska L., Hascsi Z., Szabó P., Emri M. Development of a multiparametric surface model for

interventions supported by virtual bronchoscopy (P082). Eur J Nucl Med Mol I, 2011. 38:S280-S280

7. **Lajtos I.,** Kis S.A., Emri M., Opposits G., Szikra D., Hegyesi G., Balkay L. Performance test of the Minipet_II scanner for several coincidence time and energy window using the Nema NU-4 standard. Nucl Med Rev Cent E Eur, 2011. 14:A13-A13

8. **Lajtos I.,** Kis S.A., Opposits G., Balkay L., Imrek J., Trón L., Emri M. Automated monitoring of the MiniPET-II Small Animal PET scanner operation parameters. Nucl Med Rev Cent E Eur, 2011. 14:A17-A17

9. **Lajtos I.,** Emri M., Kis S.A., Opposits G., Balkay L. Analysis of the Minimum Detectable Activity of a Small Animal Scanner. Proceedings of the IEEE Nuclear Science Symposium Conference Record (NSS/MIC), 2011.: 3839-3841

10. Márián T., Trencsényi G., Goda K., Szalóky G., Juhász I., Vízkeleti I., Szöllősi A., **Lajtos I.**, Mikecz P., Krasznai Z., Szabó G., Krasznai Z.T. The effect of combined treatment blocking p-glycoprotein function measured using MiniPET in xenograft tumor model. Nucl Med Rev Cent E Eur, 2011. 14:A23-A23

11. Opposits G., Spisák T., **Lajtos I.**, Pohubi L., Galuska L., Jakab A., Berényi E., Emri M. Automated region analysis of brain PET examinations (P307). Eur J Nucl Med Mol I, 2011. 38:S333-S333

12. Spisák T., Koselák M., Opposits G., Kis S.A., **Lajtos I.**, Trón L., Jakab A., Berényi E., Emri M. Digital brain atlas assisted localization software for

individual and population analysis of SPECT and PET data (PW118). Eur J Nucl Med Mol I, 2011. 38:S258-S258

13. Szabó-Péli J., Trencsényi G., Nagy T., Mikecz P., Németh E., Miklovicz T., **Lajtos I.**, Krasznai Z.T., Emri M., Galuska L., Márián T. Investigation of PGP pump functions with PET radiotracer 11C-verapamil. Nucl Med Rev Cent E Eur, 2011. 14:A23-A23

14. Trencsényi G., **Lajtos I**., Bakó F., Jószai I., Balkay L., Emri M., Kertai P., Mikecz P., Galuska L., Márián T. Investigation of syngenic rodent tumor models using MiniPET-II scanner. Nucl Med Rev Cent E Eur, 2011. 14:A21-A21

15. Balkay L., **Lajtos I.**, Garai I., Emri M. Physical model of the signal-to-background ratio based PET-guided tumor volume delineation algorithm. Eur J Nucl Med Mol I, 2010. 37:S261-S261

16. **Lajtos I**., Emri M., Kis S.A., Opposits G., Molnár J., Balkay L. Analysis of the Minimum Detectable Activity of a Small Animal Scanner. Proceedings of the IEEE Nuclear Science Symposium Conference Record (NSS/MIC), 2010.: 2224-2227

17. Trensenyi G., **Lajtos I**., Molnár J., Krasznai Z.T., Balkay L., Emri M., Kertai P., Galuska L., Márián T. Detection of Primary Tumor and Metastasis In a New Animal Model Using MiniPET-II. Eur J Nucl Med Mol I, 2010. 37:S406-S406

18. Kis S.A., Emri M., **Lajtos I.**, Trón L., Imrek J., Valastyán I., Kalinka G., Novák D., Molnár J., Hegyesi G., Balkay L. Determining performance parameters of the small animalPET scanner miniPEt-ii according to nema NU-4 standard (P20). Nucl Med Rev Cent E Eur, 2009. 12:47-47

19. Kis S.A., **Lajtos I.**, Emri M., Trón L., Opposits G., Bukki T., Hegyesi G., Imrek J., Valastyan I., Molnár J., Novák D., Balkay L. Performance Test of the MiniPET-II Small Animal Scanner According to the NEMA NU-4 Standard. Proceedings of the IEEE Nuclear Science Symposium Conference Record (NSS/MIC), 2009.: 3185-3189

8.2 Other abstracts

1. **Lajtos I.**, Kis S.A., Emri M., Opposits G., Nagy F., Pótári N., Balkay L. Analysis of the imaging performance of a small animal PET scanner at low contrast. IEEE Nuclear Science Symposium and Medical Imaging Conference. 2012

2. Péliné Szabó J., Trencsényi G., Nagy T., Mikecz P., Németh E., **Lajtos I.**, Emri M., Galuska L., Márián T. A multidrog rezisztencia kimutatása 11C-verapamil PET tracerrel. MKE Őszi Radiokémiai Napok 2010. Keszthely. 2010

3. Trencsényi G., **Lajtos I.**, Péliné Szabó J., Miklovicz T., Balkay L., Emri M., Kertai P., Mikecz P., Galuska L., Márián T. Tumoros kisállat modellek in vivo vizsgálata MiniPET-II kamerával. MKE Őszi Radiokémiai Napok 2010. Keszthely. 2010

4. Kis S.A., Emri M., **Lajtos I.**, Trón L., Imrek J., Valastyán I., Kalinka G., Novák D., Molnár J., Hegyesi G., Balkay L. MiniPET-II kisállat PET kamera működési paramétereinek meghatározása a nema NU-4 szabványnak

megfelelően. Debrecen 2009 július, Hevesy György MONT XVI. Kongresszusa. 2009

5. Kovács G., Kis S.A., **Lajtos I**., Opposits G., Balkay L., Trón L., Emri M. Sinogram correction methods in MIniPET-II. Eliopoulos, Görögország 2009 szeptember ITBS. 2009

6. Balkay L., Bojtos P., Martos J., Kollár J., Garai I., **Lajtos I**. Comparison of Performance Parameters of Tree 64-Slice CT Scanner. IEEE Nuclear Science Symposium. Valencia, Spainand Medical Imaging Conference. 2011

7. **Lajtos I**., Kis S.A., Emri M., Opposits G., Balkay L. Investigation of the Low Count Detectability in Nuclear Medicine Images Using Human and Model Observer. IEEE Nuclear Science Symposium. Valencia, Spain. 2011