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Review
of the Ph.D. thesis of Mr. Meysam Dadgar entilted
Feasibility study of lesion detection by means of Total-Body Jagiellonian Positron Emission Tomography scanner
Supervisor: Prof. dr hab. Paweł Moskal

General description and content-related evaluation of the thesis

The dissertation consists of eight chapters: Introduction, Basics of the cancer and its classification, Basics of Positron Emission Tomography, The J-PET detector, Methodology, Results, Summary and Discussion and Conclusion. They are preceded by the Abstract and a List of Tables and in the end there is a List of Figures, References and Appendix. The thesis was written on 88 pages altogether. The structure of thesis conforms to principles and requests to the structure of a scientific thesis.

The main goal of the dissertation was to determine the smallest detectable lesion in liver by Total-Body J-PET scanner based on plastic scintillators. Author focused on physical parameters like spatial resolution and sensitivity first, then on patient related parameters like body mass index and their influence on the possible size of the diagnosed lesion.

The topic of this thesis is current and relevant in the context of up-to-date research and development of new diagnostic tools used in medicine also in economical context as the proposed Total-Body J-PET scanner might lead towards a much more economical diagnosis than currently existing devices.

Along the performed investigations, the Author had the opportunity to work in a large research group contributing to its success represented in the form of 8 publications in prestigious journals during 2020-2021 as one of coauthors, in the next 6 publications and conference materials as first author (two papers in submission process).

The dissertation is divided into two main parts: related to theoretical background and description of the own results.

The first chapter is dedicated to a short introduction to the subject. The Author presents the state-of-the-art in the field of technological progress regarding Total-Body PET in a concise and factual manner, explains what tools have been used and briefly describes the research process. Information is supported by relevant citations when necessary.

The theoretical part consists of three following chapters containing the basics, necessary to understand the investigations provided by the Author. Given the J-PET scanner is dedicated for diagnostic purposes, the next chapter starts from basic pathophysiological information related to cancer and its classification, then anatomy and tumors of the liver are described. Finally, diagnostic tools, their advantages and pitfalls are discussed. As Positron Emission Tomography is the valuable diagnosis apparatus in the molecular diagnostic context, giving more information than other devices like Computed Tomography or Magnetic Resonance Imaging, the following chapter is dedicated to the description of PET basics. The Author fluently shifts from discussing one issue to another, after explaining the basics of PET, discusses the limitations of the method related to the size of the diagnosed object and then discourses physical parameters relevance such as sensitivity and spatial resolution. Then "tumor to background ratio" and "body mass index" are outlined as important parameters, useful in estimating the diagnostic value of Total Body J-PET scanner. Finally, principles for operation of the J-PET scanner and Total Body J-PET scanner are presented, underlying J-PET technology advantages in comparison with conventional tomographs. The theoretical part of the thesis ends with the aim of the research.

Chapter 5 is dedicated to simulation toolkits, digital XCAT anthropomorphic phantom, QETIR image reconstruction software and AMIDE software. The acceptance angle was described in more detail as an important parameter influencing the quality of Total Body J-PET imaging. In the presented study commonly available tools and the J-Collaboration own ideas like GATE Output J-PET Analyzer (GOJA) were flexibly combined.

Chapter 6 is devoted to results presentation. At the beginning of this chapter the outcomes of simulations performed to determine the optimum acceptance angle in the Total-Body J-PET scanner are presented. The dependence of the different types of coincidences on the diverse value of the acceptance angle was also investigated. In the next step, obtained results allowed to apply dedicated acceptance angle criteria to remove the contribution of the most oblique coincidences in the image reconstruction and finally provided the possibility of detecting smaller lesions in a higher number of image reconstructions. Simulations were performed with point sources and cylindrical phantoms for the determination of optimum characteristics of Total-Body J-PET. The second group of the simulations were performed by application of human-grade XCAT anthropomorphic phantoms. Then results of the simulations were analyzed by a dedicated GOJA tool. Application of GOJA is important given that conventional image reconstruction software could not be compatible due to the unique configuration of the J-PET-based scanners and their special detection principle. In the case of the image reconstruction, Quantitative Emission Tomography Iterative Reconstruction (QETIR) developed by the MEDISIP research group from Ghent University in Belgium has been used. The results showed that the Total-Body J-PET tomograph can detect centimeter-grade lesions for various ranges of the XCAT phantoms depending on the body mass index of the patient and physical parameters of the device.

Summary and Discussion are presented in Chapter 7, Conclusions of the proposed simulation-based study and methods to enhance lesion detectability of the Total-Body J-PET are presented in Chapter 8. The Author demonstrated that the objectives of the work were achieved.

Since the presented construction of Total-Body J-PET is unique, the discussion was limited to the interpretation of the own results.

The bibliography contains 93 references mainly published during last few years. Unfortunately, the bibliographic description is not uniform, lowercase letters are often incorrectly used instead of capital letters.

Although the thesis is well-structured and generally well written and the methodology along with simulations results are mostly clearly described, the Author did not avoid a few minor errors and ambiguities in the thesis. Comments and questions that arose during the Ph. D. thesis review are listed below:

- Lack of abbreviation list, which would facilitate the thesis reading.
- Some numbers provided in the Introduction are not consistent with the rest of the thesis (11 different analysis conditions, 24 as number of the reconstructions, 126 reconstructed images). It should be explained that they are related to the number of independent modules or XCAT phantoms.
- The discussion of the chapters content presented in Introduction is inconsistent with the final version of the thesis and the table of contents.
- Figures are not always linked to literature references in the descriptions (e.g. Figure 11 or 13), even in the case of auto citations (e.g. Figure 27).
- Wrong notation of keV (e.g. page 18).
- Information regarding when the first Total-Body PET was constructed would highlight one's own achievements.
- The lesions presented in Figure 21 should be described more in details.
- It is not clear if the body mass index was related to age and gender.
- Detailed explanations should be provided when the information is presented first time (application of the value 183 cm for the length of the phantom was clarified only in the Results chapter).
- Author mentioned three basic files as input data (page 41), but described only two. It is a pity that particular steps of the simulations were not described in more details or presented in a table.
- Several simulations means how many? (page 45).
- What was the quantitative limit of activity for cold phantom?
- The results presented in chapter 6.1 and 6.4 should be summarized at the end of subsection.
- Not all iterations were described in the chapter 6.3.
- The single-slice rebinning algorithm (SSRB) and true Mont Carlo methods were not described. Why were they chosen?
- Why such 11 XCAT phantoms were chosen (randomly perhaps)? Why are not all the results presented in the thesis?

- How can diverse influence on the obtained results for different number of iterations be explained? Why such a high uncertainty was observed for the 30 cm lesion (Figure 56)? How to avoid in the future the possible errors related to iteration numbers?
- How were the numbers presented in Table 3 calculated as relative values?
- Why the 8:1 amounts of activity in comparison to the background tissue was investigated?
- Occasional linguistic, grammatical (correct tense) and punctuation errors and typos.

Final conclusion

Despite some criticism stated above, the dissertation of Ph.D. student Meysam Dadgar describes very interesting and valuable research work towards cheaper and more precise Total-Body J-PET. In my opinion, the doctoral dissertation contains original results which should help in further multi-stage development of the device. The previously listed shortcomings do not significantly affect its scientific level and my final positive assessment.

I conclude that the thesis reaches standards of quality required for doctoral thesis and meets the requirements of the Act form of academic degrees and academic titles and degrees and title in art and I make proposal to assume it and admit it to public defense. Therefore I recommend for admission of Mr. Meysam Dadgar to further stages of the procedure towards the degree awarding of Ph.D. in physics.