DEVELOPMENT AND CHARACTERIZATION OF A 3D-PRINTED ABDOMINAL PHANTOM

Mones E.[1,2,3], Beyene E.[1,2,3], Kaplanoglu T.[2,3], Moskal P.[2,3], Stępień E.[1,3]

[1]Department of Medical Physics, Faculty of Physics, Astronomy, and Applied Computer Science, Jagiellonian University, Kraków, Poland
[2]Department of Experimental Particle Physics and Applications, Faculty of Physics, Astronomy, and Applied Computer Science, Jagiellonian University, Kraków, Poland
[3]Center for Theranostics, Jagiellonian University, Kraków, Poland

Phantoms, physical or computational models mimicking human tissues and/or anatomy, are essential in medical imaging and therapy due to their role as testing and validation tool to ensure accuracy, consistency, and safety of medical equipment without the use of actual patients. Phantoms range from geometric (slabs, cylinders, etc) to anatomy-mimicking and human-like phantoms [1, 2]. Anatomy-mimicking phantoms offer a number of advantages over geometric phantoms such as providing a more realistic simulation of tissues, organs, or anatomical region of interest in the clinical setting, from performing quality assurance tests of the medical equipment to replication of imaging protocols in certain anatomical regions [1, 3]. In addition, utilizing phantoms in the clinical setting could verify the dosimetry and the image quality metrics of a radiation-emitting equipment.

However, anatomy-mimicking phantoms are generally costly which could hinder phantom use in the clinical setting. This encourages the fabrication of phantoms using additive manufacturing approach. 3D printing, a method under additive manufacturing process, has been utilized by a number of research and clinical institutions due to its cost-effectiveness, accommodation of simple and complicated anatomical geometries, high speed production process, and capability of producing patient-specific and data-driven or personalized anatomical-mimicking phantoms [2,3]. The research aims to develop a customized 3D-printed phantom of some of the organs in the abdomen region and to characterize the fabricated phantom by obtaining volumetric image acquisitions of the abdominal phantom without and with water filling using a diagnostic computed tomography (CT) scanner.

The phantom consists most of the organs in the upper quadrant of the abdomen: right and left kidneys, liver, spleen, and pancreas. Prior to the printing process, dimensions of the organs were modeled after the average dimensions of CT scan results of patients. Resin 3D printing process was employed to fabricate an anatomy-mimicking phantom that was also tissue-equivalent to water. The DICOM images of the phantom with and without water will be accomplished in a diagnostic facility using a CT scanner under different peak kilovoltages (kVp), window settings, and slice thicknesses. Parameters such as Hounsfield Unit (HU) and linear attenuation coefficient will be determined after CT scan images acquisition. HU and linear attenuation coefficient could inform about the conversion of the x-ray attenuation of the phantom's resin into its corresponding CT number, presence of artifacts, low-contrast performance, and CT number uniformity. Results of this research can be used in comparative studies of the dosimetry and imaging quality between two different CT scanners. Moreover, results from this study can be employed in the development of phantom for the dynamic and kinetic imaging with the total-body J-PET scanner [4].

Funding: *We acknowledge support from NCN (grants 2021/42/A/ST2/00423, 2021/43/B/ST2/02150, 2022/47/I/NZ7/03112, 2023/50/E/ST2/00574), MNiSW (IAL/SP/596235/2023 and SPUB/SP/627733/2025), SciMat and qLife Priority Research Areas, ERC Advanced Grant POSITRONIUM no. 101199807, PRISMAP (Project_1729020993_aniX3), and PLGrid infrastructure (PLG/2024/017688, PLG/2025/018762).*

References

[1] Wegner M, Gargioni E, Krause D. Classification of phantoms for medical imaging. Procedia CIRP., 2023; 119: 1140–5. https://www.sciencedirect.com/science/article/pii/S2212827123006340?ref=pdf_ download&fr=RR-2&rr=9abb88c57a7771ef.

[2] A K SN, Saxena K, Puzhakkal N, Mathew J, K DL. Development and validation of 3D printed anthropomorphic head phantom with eccentric holes for medical LINAC quality assurance testing in stereotactic radiosurgery. Med Eng Phys. 2024 Aug;130:104217. doi: 10.1016/j.medengphy.2024.104217.
[3] Katsikari K, Francis N, Maalej N, Pitsalidis C, Aamir R. 3D-Printed Anthropomorphic Phantom Framework for Spectral Photon-Counting CT: A Breast Phantom Application. IEEE Access 2024;13:6397–412. doi: 10.1109/ACCESS.2024.3521476.
[4] Moskal P, Stępień EŁ. Prospects and Clinical Perspectives of Total-Body PET Using Plastic Scintillators., PET Clinics. 2020;15:439–52.