INTERNATIONAL JOINT CONFERENCE RADIO 2017
GOIÂNIA 30 YEARS LATER
25 - 29 SEPTEMBER 2017
CONVENTION CENTER
GOIÂNIA, BRAZIL
Sharing Experiences
SBPR
Sociedade Brasileira de Proteção Radiológica

Relationship Between Infill Patterns in 3D Printing and Hounsfield Unit

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ABSTRACT

Introduction: One of the requirements for a phantom to correctly simulate the human body is that the radiation attenuation of the material used is compatible with the values of its corresponding tissues. The aim of this study is to evaluate the values of Hounsfield Unit (HU) in a 3D printed material in order to verify its compatibility, on tomography, with human tissues, so that it can be used as feedstock for simulators constructed in 3D printers. Methods: Cubes with 2cm of edge were printed using ABS filament with 8 different forms of internal filling. The samples were irradiated by a CT scanner, the measured HUs and their results compared to the literature. Results: Modification of the filling form as well as its percentage influenced the HU values that ranged from -133 to -451. Conclusion: The specific variations of internal fill patterns directly influence the interaction of the material used with the radiation, thus altering the HU values. Despite the variation found, the HU values were sufficient to simulate few tissues in the human body, which requires future studies with new materials that further attenuate the radiation and the range of tissues to be expanded.

Keywords: 3D Printing, Radiologic Phantom, Radiation Protection, X-Ray Computed Tomography.

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1. INTRODUCTION

The analysis of the tomographic images is performed by means of mathematical calculations, where the attenuation suffered by the object is transformed into a scale called the Hounsfield Scale that determines the nature of the tissue [1]. Therefore, the attenuation is graded in a way that can be related to the specific density of each organ or tissue of the human body. The denser, the greater the attenuation and, consequently, the greater the Hounsfield Number. The densities are directly linked to the radiation attenuation [2]. One of the requirements for a phantom to correctly simulate the human body is that the radiation attenuation of the material used is compatible with the values of its corresponding tissues. The aim of this study was to evaluate the values of Hounsfield Unit (HU) in a 3D printed material in order to verify its compatibility, on tomography, with human tissues, so that it can be used as raw material for simulators constructed in 3D printers.

2. MATERIALS AND METODS

The raw material used in the study was Acrylonitrile Butadiene Styrene (ABS), filament chosen for its low cost, easy acquisition, good dimensional stability and resistance after printing [3]. Because the material itself has its characteristic specific density and to achieve densities close to those of the human body, different internal fill patterns were used during the impressions. By means of the printing software (Simplify 3D) 6 different forms of filling were created (rectilinear, triangular, grid, wiggle, fast honeycomb, full honeycomb) and all with 80% filling of material. In the rectilinear form, cubes with 60% and 100% internal fill were also made, totaling 8 ABS cubes with 2cm of edge. For the attenuation analysis the mean HU was used in a mean area of $100mm^2$ in a Phillips Brilliance CT scanner with 80kV and 235 mAs current.

3. RESULTS AND DISCUSSION

The modification of the form of filling as well as its percentage influenced the values of HU that varied between -133.4 and -451.4 (TBLE 1). These differences in impression generated discrepancies in the magnitudes within the Hounsfield Scale, which were approximated to the values of HU for lung tissues and human fat [4].

Table 1: Hounsfield (HU) values for the sample cubes.

	Cubes							
	Cube 1	**Cube 2**	**Cube 3**	**Cube 4**	**Cube 5**	**Cube 6**	**Cube 7**	**Cube 8**
Percentage	60%	100%	80%	80%	80%	80%	80%	80%
Infill	Rect	Rect	Rect	Triangular	Grid	Wiggle	Fast HC	Full HC
HU	-451.4	-133.4	-278.8	-306.7	363.5	-242.5	-360.6	-209.8

*Rect: Rectlinear.

4. CONCLUSION

The specific variations of internal fill patterns directly influence the interaction of the material used with the radiation, thus altering the HU values. Despite the variation found, HU values were sufficient to simulate few tissues in the human body, which requires further studies with new materials that further attenuate the radiation and the range of human tissues to be expanded.

5. ACKNOWLEDGMENT

The authors would like to thank PROPPI/IFSC for their support through the 2016 Universal Research Calls and the 2016 Research Groups Calls.

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