X Congreso Regional Latinoamericano IRPA de Protección y Seguridad Radiológica
"Radioprotección: Nuevos Desafíos para un Mundo en Evolución"
Buenos Aires, 12 al 17 de abril, 2015
SOCIEDAD ARGENTINA DE RADIOPROTECCIÓN

METHODOLOGY FOR CONSTRUCTION OF HOLLOW SPHERES FOR USE IN PHYSICAL PHANTOMS

Oliveira, A. C. H.[1,2], Oliveira, F.[3] Vieira, J. W.[3,4] Lima, F. R. A.[1,2]

[1] Universidade Federal de Pernambuco (UFPE)
[2] Centro Regional de Ciências Nucleares do Nordeste (CRCN-NE)
[3] Instituto Federal de Educação, Ciência e Tecnologia de Pernambuco (IFPE)
[4] Universidade de Pernambuco (UPE)

ABSTRACT

In positron emission tomography (PET), quantitative evaluation of spatial resolution/object size, attenuation and scatter effects is often performed using phantoms with hollow spheres. Fillable, plastic-walled spheres are commercially available in several sizes. Radioactive solutions in any concentration can be injected into the spheres. Hollow spheres have several desirable traits, including repeatable, consistent use, and standardization across measurements at different institutions, since identical items are distributed by a single manufacturer. The objective of this work is to describe a methodology for construction of hollow spheres using rapid prototyping. It was used the software SolidWork (2014) to create five 3D models of the hollow spheres with inner diameters of 10 mm, 13 mm, 17 mm, 22 mm, and 28 mm. These models were based on hollow spheres of NEMA/IEC PET body phantom. It was used a Cubex Duo 3D printer (3D Systems) to build the hollow spheres. The material used was the ABS (acrylonitrile butadiene styrene) resin.

1. INTRODUCTION

Besides the use in oncology, positron emission tomography (PET) is of importance in neurology, for example in diagnosis of Alzheimer's disease and epilepsy, as well as in cardiology (BAZANEZ-BORGERT, 2008; SYDOFF et al., 2014). Quantitative PET is generally focused on determination of accurate values for local tracer concentration as a prerequisite for further quantification, either via standardized uptake value (SUV) or tracer kinetic modeling. Spatial resolution, attenuation and scatter effects, lesion detectability and lesion radioactivity quantitation are often evaluated using physical phantoms with a set of hollow spheres of various diameters (TURKINGTON et al., 2001; BAZANEZ-BORGERT, 2008; HOFHEINZ et al., 2010). For example, the National Electrical Manufacturers Association (NEMA) NU-2 standard for clinical PET scanners specifies the International Electrotechnical Commission (IEC) body phantom (Figure 1) with multiple hollow spheres (NEMA, 2007).

The hollow spheres are filled with a radionuclide solution having the desired contrast ratio with respect to the background radionuclide solution. Typically the sphere diameters and activity concentrations are chosen to simulate the clinical or preclinical scan conditions for scanners designed for human or small-animal imaging, respectively (DiFILIPPO et al., 2010).

[1] Author's Email. oliveira_ach@yahoo.com

Hollow spheres have several desirable traits, including repeatable, consistent use, and standardization across measurements at different institutions, since identical items are distributed by a single manufacturer. However, there are some drawbacks to using hollow spheres. One is that only specific and limited sizes are available commercially (TURKINGTON et al., 2001).

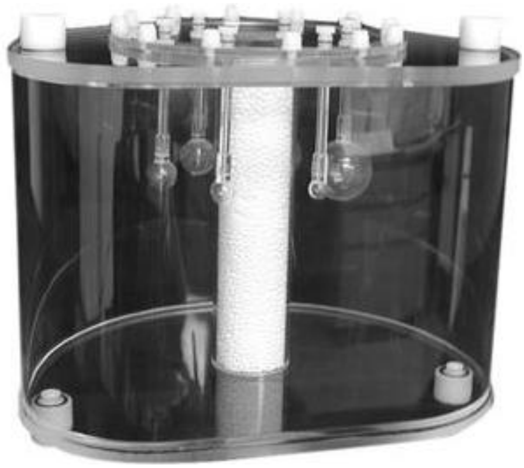


Figure 1. NEMA/IEC PET body phantom.

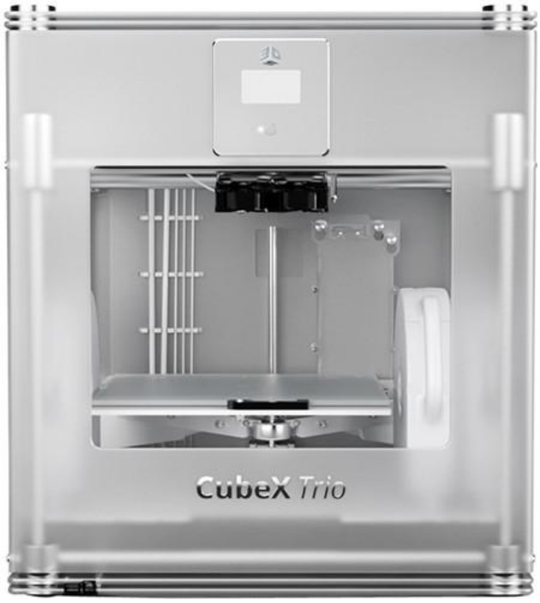
The objective of this work is to describe a methodology for construction of hollow spheres using rapid prototyping.

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional (3D) computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing. 3D printers usually work by depositing plastic resins layer upon layer onto a platform to build the desired 3D object. This technology is finding applications in various areas of medicine including surgical planning, component manufacturing for x-ray imaging systems, phantom production, and even printing real biological tissues (SOLOMON; SAMEI, 2014).

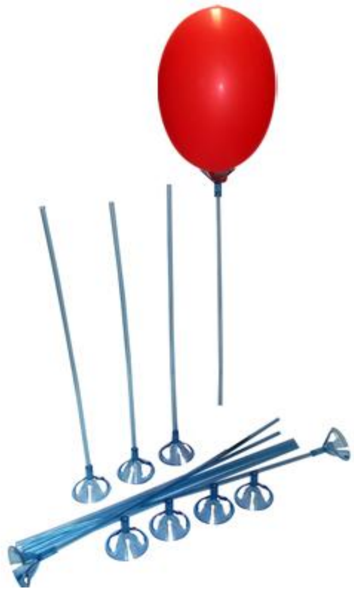
2. METHODOLOGY AND RESULTS

For construction of hollow spheres, it was used a Cubex Duo 3D printer (3D Systems) (Figure 2a). The CubeX 3D Printers create the models by pulling filament from the cartridge through the print jets via the delivery tubes. The material used was the ABS (acrylonitrile butadiene styrene) resin. ABS supplied by 3D Systems has density 1.05 g/cm^3, is not soluble in water and its softening point is 105 Cº.

To allow the filling of radionuclide solution from out of the phantom, balloon supports was used (Figure 2b). The balloon support used (BWB Embalagens) has two parts: a balloon support *per se* and a straw (outside diameter of 4.3 mm).



(a)



(b)

Figure 2. Cubex Duo 3D printer (3D Systems) (a) and balloon supports (BWB Embalagens) (b).

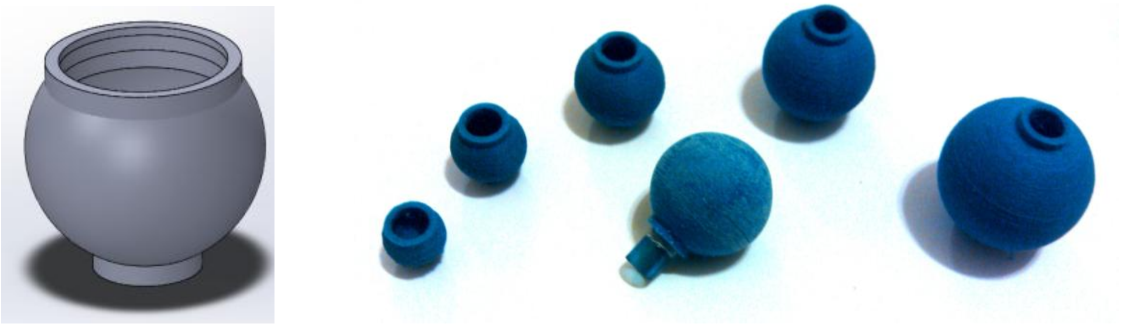
It was used the CAD (computer-aided design) software SolidWork (2014) to create the 3D models of the hollow spheres. Have been created five spheres with inner diameters of 10 mm, 13 mm, 17 mm, 22 mm, and 28 mm, based on hollow spheres of NEMA/IEC PET body phantom. Table 1 shows the dimensions used.

Table 1. Dimensions used to create 3D models of the hollow spheres.

Sphere's Inner Diameter	**10 mm**	**13 mm**	**17 mm**	**22 mm**	**28 mm**
Sphere's Outer Diameter	11 mm	14 mm	18 mm	23 mm	29 mm
Hole's Diameter	7.75 mm	7.75 mm	7.75 mm	7.75 mm	7.75 mm
Hole's Edge Thickness	2 mm	2 mm	2 mm	2 mm	2 mm
Hole's Edge Height	1.75 mm	1.75 mm	1.75 mm	1.75 mm	1.75 mm
Base's Cylinder Diameter	5 mm	5 mm	6 mm	10 mm	12 mm
Base's Cylinder Height	0.75 mm	0.75 mm	0.75 mm	0.75 mm	0.75 mm

After created 3D models, they should be saved in a format to be read by the CAM (Computer Aided Manufacturing) system. The format *.stl (Stereolitography) is standard for 3D printers. In this format, the surfaces of 3D models are divided into less complex parts, forming a triangulation mesh on the object surface. CAM systems help in planning for the printing process. These software provide tools and information on the object to be printed (SILVA, 2006; RODRIGUES, 2014). The CAM system provided by 3D Systems is the Cubify Invent Software. In this software, *.stl files are converted to *.cubex, to be read by the 3D printer.

After printing, the terminal ends of the balloon supports were sawed and glued in the holes of the spheres. Finally, the spheres were manually sanded to remove the bases and imperfections. Figure 3 shows a 3D model of a sphere and the printed spheres.



(a) (b)

Figure 3. 3D model of a hollow sphere (a) and the built hollow spheres (b).

3. CONCLUSION

In this work, it was described a methodology for construction of hollow spheres using rapid prototyping. These spheres are used to evaluate spatial resolution, attenuation and scatter effects, lesion detectability and lesion radioactivity quantitation in PET.

So far it has not been possible to perform experiments to validate the built hollow spheres. For this, it intend to compare PET images of the NEMA/IEC PET body phantom with its original spheres and with the built spheres.

4. REFERENCES

BAZANEZ-BORGERT, M.; BUNDSCHUH, R. A.; HERZ, M.; MARTÍNEZ, M.-J.; SCHWAIGER, M.; ZIEGLER, S. I. Radioactive spheres without inactive wall for lesion simulation in PET. **Z Med Phys**, 18, 2008.
DiFILIPPO, F. P.; GALLO, S. L.; KLATTE, R. S.; PATEL, S. A Fillable Micro-Hollow Sphere Lesion Detection Phantom Using Superposition. **Phys Med Biol.**, 55(18), 2010.

HOFHEINZ, F.; DITTRICH, S.; POTZSCH, C.; VAN Den HOFF, J. Effects of cold sphere walls in PET phantom measurements on the volume reproducing threshold. **Phys. Med. Biol.**, 55, 2010.

NEMA - National Electrical Manufacturers Association. **NU 2-2007: Performance Measurements of Positron Emission Tomographs**. National Electrical Manufacturers Association, 2007.

RODRIGUES, L. **Metalização de Superfícies Não Condutoras: ABS.** Dissertação de Mestrado. Faculdade de Engenharia Universidade do Porto, Portugal, 2014.

SILVA, J. V. L. Planejamento de processo para prototipagem rápida. In: VOLPATO, Neri. **Prototipagem rápida:** Tecnologia e aplicações. São Paulo: Edgard Blücher Ltda, 2006.

SOLOMON, J.; SAMEI, E. Quantum noise properties of CT images with anatomical textured backgrounds across reconstruction algorithms: FBP and SAFIRE. **Med. Phys.**, 41 (9), 2014.

SYDOFF, M.; ANDERSSON, M.; MATTSSON, S.; LEIDE-SVEGBORN, S. Use of wall-less ^{18}F-doped gelatin phantoms for improved volume delineation and quantification in PET/CT. **Phys Med Biol**, 59, 2014.

TURKINGTON, T. G.; DEGRADO, T. R.; SAMPSON, W. H. Small Spheres for Lesion Detection Phantoms. **IEEE Nuclear Science Symposium Conference Record**, 4, 2001.