Design, Development and Implementation of µSPC Phantom for Quality Control in Micro-SPECT / CT and Micro-PET / CT Systems
Qualitative Study

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Keywords: µSPC Phantom, Quality Control, Micro-SPECT/CT.

Abstract: The µSPC phantom is designed for the quality control of micro-SPECT/CT and micro-PET/CT systems. However, it is an assembly of six patterns stored in a cylindrical box and enabling to control both micro-SPECT unit in terms of uniformity, linearity and spatial resolution than micro-CT unit in terms of uniformity , linearity, spatial resolution, diffusion rate, low contrast detectability, linearity of Hounsfield coefficients and slice thickness. The construction material is plexiglass. As for the implementation, it was made on a micro-SPECT/CT machine of the type "speCZT eXplore CT 120".

1 INTRODUCTION

Preclinical imaging has recently evolved considerably, but it has only been concerned with small animals (mice, rats...). The results obtained in preclinical tests are extremely useful in the fields of clinical imaging (Glover, 2010; Dillenseger, 2013; Lina, 2009; Peremans, 2011) and pharmacology ((Matthews, 2013; Slavine, 2008). However, given the size of these animals, the instruments used have better imaging performance than those used for humans.

The expected results of the images obtained are so important that we must be quite demanding in considering their qualities. The continuous production of better qualities of these images is ensured by the development of adequate quality control protocols (Glover, 2010; Moran, 2011; Jan, 2006). These protocols are developed with reference to quality control protocols already adopted in clinical imaging.

The preclinical imaging techniques targeted by this work are micro-SPECT / CT and micro-PET / CT.

2 METHODS AND MATERIALS

For the design of our phantom we chose to work with solid works software (Fig.1) because it's easy to use and to adapt.

When designing the µSPC phantom (Fig. 1), we have tried to make sure that it allows checking the majority of quality parameters acquisition micro-SPECT / CT and micro-PET / CT systems while respecting the dimensions of acquisition areas offered by each machine. For this, we have referred to the NEMA accreditation for micro-SPECT and micro-PET (Seret, 2011) and ACR accreditation for micro-CT (Panetta, 2012) and we have fixed seven quality control parameters that are uniformity (micro-SPECT, micro-PET, micro-CT), linearity (micro-SPECT, micro-PET, micro-CT), spatial resolution (micro-SPECT, micro-PET, micro-CT), diffusion profile (micro-CT), linearity coefficients Hunsfield (micro-CT), low contrast detectability (micro-CT) and thicknesses of slices (micro-CT). As for the uniformity that can be measured following an acquisition done on the homogeneous solution, for each of the selected parameters we designed a pattern enabling to evaluate it (Tab.1). The patterns will be stored in a cylinder (part 1) with sealing cover (parts 8, 9, 10, 11 and 12), which are the body of the phantom (Fig. 1).

For the implementation of the µSPC phantom, we made acquisitions on micro-SPECT/CT machine of the type "speCZT eXplore CT 120" (GE Healthcare) of the in vivo preclinical imaging

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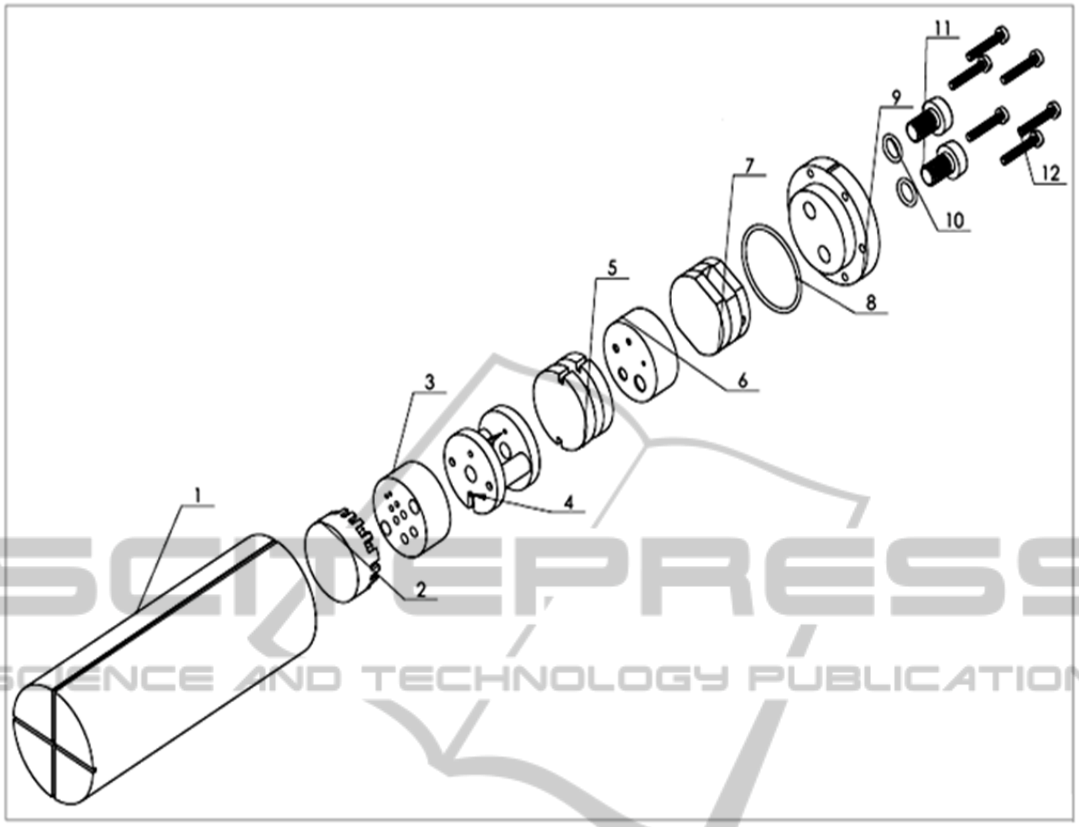


Figure 1: Conception of the µSPC phantom with SOLIDWORKS.

service in the Hospital Hautepierre of Strasbourg. This camera is constituted by a micro-SPECT unit and micro-CT unit. The detection head of the micro-SPECT unit "eXplore speCZT" consists of ten sensors plan CZT semiconductor having a surface of 64 cm2 and 5 mm thick. The detectors are stationary and located in form of decagon around a rotating and interchangeable cylindrical collimator (Fig. 4) ((Glover, 2010; Dillenseger, 2013; Hohui, 2010). As for the CT unit "Explore CT 120", it is constituted by an X-ray high efficiency tube of 5 kW whose voltage can vary between 70 and 120 kV and is attached to a planar array of CCD detectors 3500x2300. The X-ray beam used for the micro-CT unit is conical (Dillenseger, 2013).

For the realization of the phantom we used essentially the Plexiglas which is cheaper than and as efficient as plastic acrylate. When for machining the various parts, we carefully performed on conventional lathe and milling despite their small size.

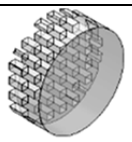
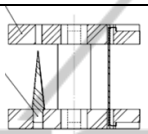
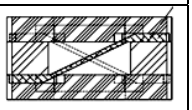
3 RESULTS

3.1 Realization of the µSPC Phantom

Figure 2: µSPC phantom.

According to the design, we realized the body of the phantom that is a cylindrical enclosure with sealed cover and with two holes for the introduction

Table 1: Conception of patterns contained in the µSPC phantom with SOLIDWORKS.

Parameter	N° (fig.1)	Pattern
Linearity (µPET, µSPECT, µCT)	2	
Spatial resolution (µPET, µSPECT)	3	
Spatial resolution and diffusion profil (µCT)	4	
Linearity of Hounsfield coefficients (µCT).	5	
Low contrast detectability (µCT)	6	
Slice thickness (µCT)	7	

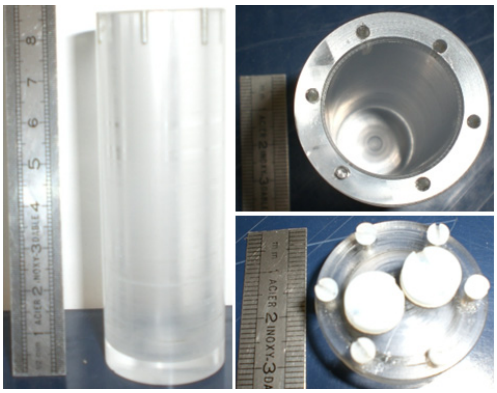
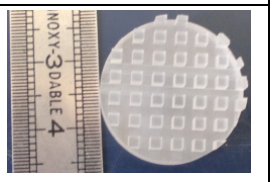
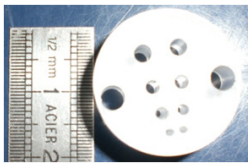
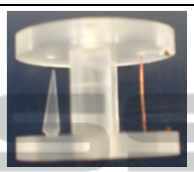
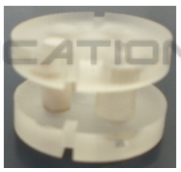


Figure 3: µSPC phantom body.

of solutions with contrast agents (Fig.3) and all the patterns for control of various performances like linearity, spatial resolution, diffusion profile, Hounsfield coefficients linearity, low contrast detectability and slice thickness measurements (Fig.2, Tab.2).

Table 2: Patterns contained in the µSPC phantom.

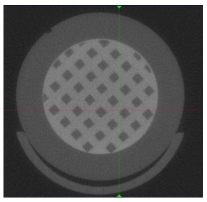
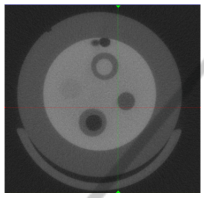
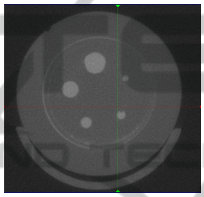
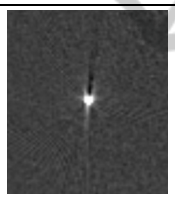
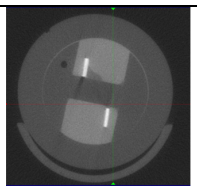
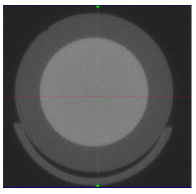
Quality parameter	Pattern
Linearity (µPET, µSPECT, µCT)	
Spatial resolution (µPET, µSPECT)	
Spatial resolution and diffusion profil (µCT)	
Linearity of Hounsfield coefficients (µCT).	
Low contrast detectability (µCT)	
Slice thickness (µCT)	

3.2 Acquisitions

For the realization of the acquisitions on µSPC phantom, we first filled it with a radioactive solution (V = 11.5 cm^3) made of demineralized and degasified water (for 48 hours) + 1 drop of aqueous eosin 2% + 0.1 ml of pertechnetate-99m solution (activity = 4.10 mCi) + 1 drop of Iomeron 400. After filling the phantom, we placed it in the tunnel of the machine.

The micro-CT acquisitions concerned the linearity, the diffusion profile, the linearity of Hounsfield coefficients, the slice thickness, the low contrast detectability and the uniformity (Tab.3).

Table 3: Micro-CT Acquisitions.

Quality parameter	Acquisition
Linearity	
Linearity of Hounsfield coefficients	
Low contraste detectability	
Diffusion profile	
Slice thickness	
Uniformity	

The micro-SPECT and micro-SPECT/CT acquisitions concerned linearity, uniformity and spatial resolution (Tab.4).

Micro-SPECT/CT acquisitions are made following the micro-CT acquisitions. Indeed, it comes to be positioned on the micro-CT acquisitions for achieving the micro-SPECT acquisitions, and then we proceed with image fusions. Thus, we were able to test micro-SPECT/CT images for uniformity, linearity and spatial resolution (Tab.5).

Table 4: Micro-SPECT Acquisitions.

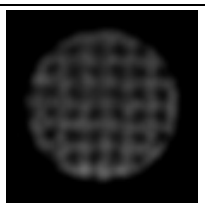
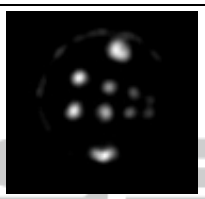
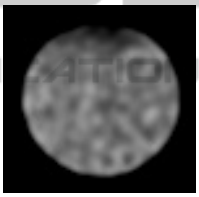
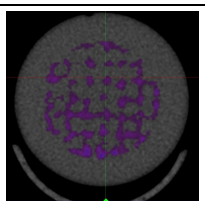
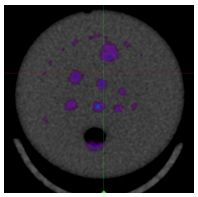
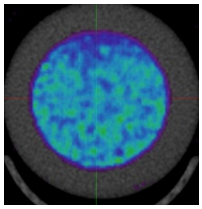
Quality parameter	Acquisition
Linearity	
Spatial resolution	
Uniformity	

Table 5: Micro-SPECT/CT Acquisitions.

Quality parameter	Acquisition
Linearity	
Spatial resolution	
Uniformity	

4 DISCUSSION

Knowing that we have worked on a new machine, we found that it presents qualitatively very good quality in terms of acquisition micro-SPECT.

Our µSPC phantom allowed, simultaneously, the quality control of the micro-SPECT unit and the micro-CT unit and consequently the whole of micro-SPECT/CT system. Indeed, for the micro-SPECT unit, we found that the spatial resolution is close to 1mm as we distinguished a boundary separation between the images of the two holes of 1mm diameter and separated by a distance also 1mm (Tab.4). In addition we have seen qualitatively the presence of geometric distortions (Tab.4). As for uniformity, we observed an artifact caused by the presence of air bubbles (Tab.4).

At the micro-CT acquisitions, we have tested the linearity of this unit (Tab.3), where the diffusion profile, it is very easy to measure on the image of Table 3 and in terms of the uniformity it is still easy to calculate on the image of the same table. While the study of the linearity coefficients of Hounsfield (Tab.3) is clearly measurable for air, Teflon and polyethylene, it is not the same for water because of the presence of contrast agent (Iomeron 400). The same thing for the low contrast detectability (Tab.3), the Iomeron 400 increased shift of X-ray attenuation rate between the Plexiglas and the solution what makes the condition of low water-Plexiglas contrast (Fig.4) is no longer there where it is convenient to work without contrast agent. On the other hand, to measure the slice thickness, low contrast with water gives results with more uncertainty (Fig.4) so that the results of this side are better with the contrast agents (Tab.3).

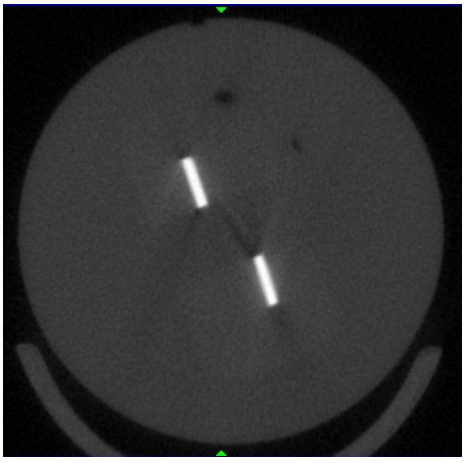


Figure 4: Image test for slice thickness in micro CT without Iomeron 400.

For micro-SPECT/CT acquisitions, we have noticed that uniformity parameter is rather imposed by micro-SPECT unit (Tab.4) which present morphologically weaker qualities compared to micro-CT. The same applies to geometric distortions, they are more pronounced in the figure in Table 5. Regarding the spatial resolution of the whole system, it is better than 1mm because the fusion with micro-CT can improve this quality.

If you do not see the test results of the spatial resolution micro-CT, it is because the needle of the test was broken when filling the phantom at Hautepierre hospital.

5 CONCLUSIONS

This work has allowed us to offer to the practitioner a new tool to better validate their results. Indeed, µSPC the phantom we realized present very interesting qualities because it allows to measure the fundamental parameters of quality whatever for micro-SPECT / CT or micro-PET / CT as the spatial resolution and linearity.

The dimensions of the field of view that differ from one device to another may or may not allow us to add a test pattern contrast especially for devices with a micro-PET unit. Moreover, we can achieve as an accessory that can mount or dismount depending on types of machines.

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