Performance evaluation of a digital PET/CT based on NEMA NU 2-2018 protocol and Jaszczak phantom analysis: comparison between ^{68}Ga and ^{18}F

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INTRODUCTION

The recent digital PET detectors technology may improve diagnostic capabilities and patient care by providing higher image quality. An accurate estimation of PET/CT performances will provide a better understanding of the relation between injected activity and the desired image quality.

AIM

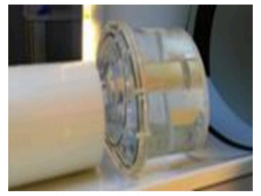
This work aims to evaluate performance of Philips VEREOS digital PET/CT in terms of image quality, spatial resolution in air and sensitivity according to NEMA NU 2-2018 protocol and with a Jaszczak phantom analysis. We assessed these performances for gallium-68 and fluorine-18 sources using an in-house software in order to handle the analysis with a more flexible tool.

METHOD

Image Quality (IQ)

NEMA IQ measurement method

- NEMA body phantom, scatter phantom and fillable spheres were filled with activity concentrations as recommended by NEMA NU 2-2018 procedures.
- A specific manufacturer protocol was used for this acquisition.
- Recovery contrast, variability and residual error in corrections were calculated according to NEMA protocol implanted into an in-house software developed with MATLAB, as shown in the following figures.



NEMA phantom set-up

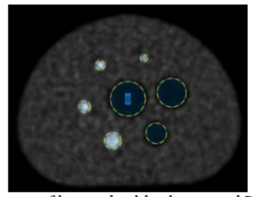
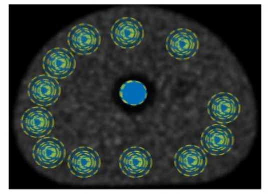


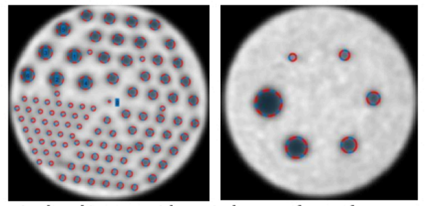
Image of hot and cold spheres and ROIs.



Background and centered ROIs for variability evaluation

Jaszczak IQ measurement method

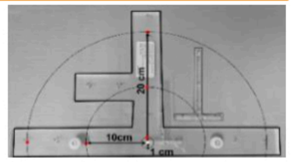
- Deluxe Jaszczak phantom was filled with an activity concentration of 21.5 and 18.5 kBq/mL, at acquisition time, for gallium-68 and fuorine-18 respectively.
- A clinical standard protocol was used (OSEM:3u5ss, PSF: 1u6ss, Gaussian Filter: 2mm and acquisition duration: 5min with two steps).
- We evaluated percentage contrast (C) [4] and mean visibility index (VI) [1] for each group of rods.
- Other image quality metrics were also analyzed : standard deviation to mean ratio (SMR) [4], mean contrast to noise ratio (CNR) for six spheres and signal to noise ratio (SNR) in homogenous section.



Analyzed images with our in-house software for visibility index and percentage contrast for Jaszczak phantom.

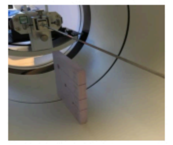
Spatial resolution

Axial and transversal spatial resolutions were measured according to NEMA NU 2-2018 procedures, using point sources of gallium-68 and fuorine-18 (1-2 MBq within a 1mm diameter glass capillary tube). The sources were mounted on an acrylic bracket as shown in the right figure.



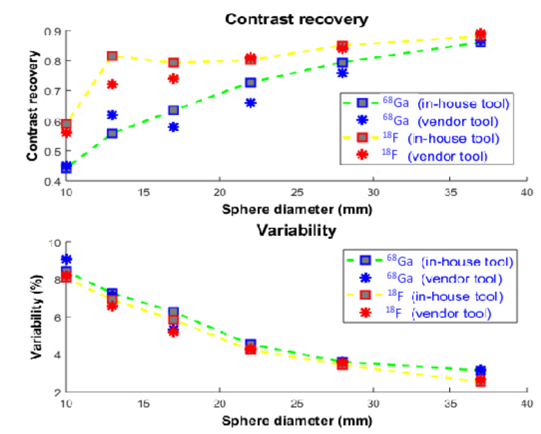
Sensitivity

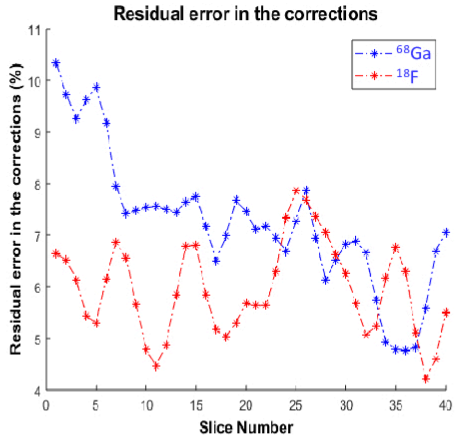
Based on NEMA NU 2-2018 protocol, the sensitivity were measured using a 70 cm line source (3-5 MBq) for both gallium-68 and fluorine-18. Inserted into metal sleeves the source was mounted on a specific support and fixed at the center of transaxial field of view (FOV) and 10 cm offset. All the analysis were performed using the manufacturer software.



RESULTS

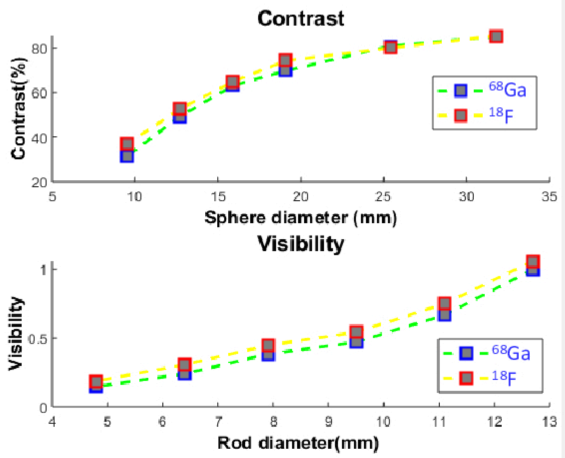
Image quality based on NEMA NU 2-2018 analysis

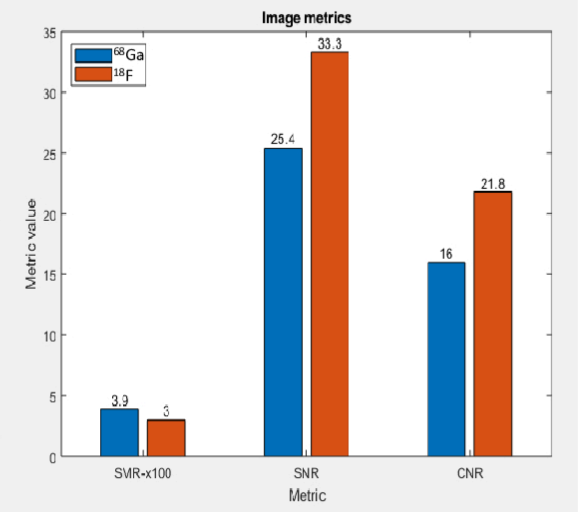




- Contrast recovery ranges were from 0.43 and 0.58 (smallest hot sphere) to 0.86 and 0.88 (largest cold sphere) for gallium-68 and fluorine-18 respectively.
- Variability in the back ground decreases from 8.4% and 8% (smallest hot sphere) to 3.1% and 2.5% (largest cold sphere) for gallium-68 and fluorine-18 respectively.
- Residual error in corrections inside the lung insert were 7.03% (7.88% vendor tool) and 5.80% (6.02% vendor tool) for gallium-68 and fluorine-18 respectively.

Image quality based on Jaszczak phantom analysis





- Contrast values (%) increased from 31.3 and 36.8 (smallest sphere) to 85.1 and 85.4 % (largest sphere) for gallium-68 and fluorine-18 respectively.
- Mean visibility index values in each group of rods increased with the rod diameter, from 0.15 and 0.19 (smallest rod) to 1 and 1.1 (largest rod) for gallium-68 and fluorine-18 respectively.
- SMR values, calculated from homogenous section, were 3.9% (^{68}Ga) and 3.0% (^{18}F).
- SNR values were 25.4 for gallium-68 and 33.3 for fluorine-18.
- Mean CNR calculated from all spheres were 16.0 for gallium-68 and 21.8 for fluorine-18.

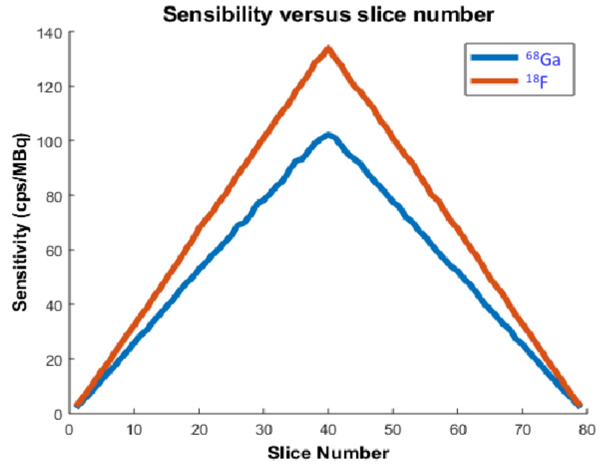
Spatial resolution

- Mean spatial resolutions at the center of FOV were 4.88 mm (^{68}Ga) and 4.03mm (^{18}F) in axial direction, and 3.97 mm for both gallium-68 and fluorine-18 in transversal direction.
- Mean spatial resolution decreases when distance from the center of FOV increases, in axial direction, they are 5.09 mm (^{68}Ga) and 4.35 mm (^{18}F) at 10 cm, and 5.9 mm (^{68}Ga) and 4.68 mm (^{18}F) at 20 cm.
- In transversal direction, at 10 cm, the values became 4.47 mm for both gallium-68 and fluorine-18, and 5.38mm (^{68}Ga) and 5.34mm (^{18}F) at 20 cm.

Position in FOV	Spatial Resolution (FMWH in mm)			
	Axial		Transversal	
	^{68}Ga	^{18}F	^{68}Ga	^{18}F
1 cm	4.88	4.03	3.97	3.70
10 cm	5.09	4.35	4.47	4.47
20 cm	5.90	4.68	5.38	5.34

Sensitivity

- Sensitivities measured at center of transaxial FOV were 4.1 cps/kBq (^{68}Ga) and 5.3 cps/kBq (^{18}F). These values were slightly lower at center of FOV than at 10 cm offset which were 4.3 (^{68}Ga) and 5.5 (^{18}F) .
- The sensitivity per slice increased linearly from distal slice toward central slice.



Position in FOV	Sensitivity (cps/kBq)	
	^{68}Ga	^{18}F
@ 0 cm	4.1	5.3
@ 10 cm (offset)	4.3	5.5
Mean	4.2	5.4

CONCLUSIONS

- Our results for gallium-68 and fluorine-18 are comparable to other reported studies [5]
- Recovery contrast decreases when volume of sphere decreases , this is more remarkable in gallium-68 than fluorine-18.
- Variability increases when spherical volume decreases in similar way for both gallium-68 and fuorine-18, although this quantity is higher for gallium-68 than fuorine-18 whatever the volume of sphere.
- Relative error in corrections is lower for fuorine-18 than gallium-68.
- Generally, NEMA NU-2 phantom analysis shows that fuorine-18 offer a better image quality than gallium-68.
- Similarly, Jaszczak phantom analysis show a better image quality obtained with fuorine-18 than gallium-68, the contrast, the visibility index and all other image metrics (SNR, SMR and CNR) are better for fluorine-18 than gallium-68 for all spheres volumes.
- The spatial resolution in air is slightly higher for fluorine-18 than gallium-68 and it is better at center of FOV than peripheral positions.
- The sensitivity is higher for fuorine-18 than gallium-68.
- Our in-house software provides very similar results comparing to that obtained by vendor software analysis. However, differences observed for the smallest spheres are due to a more accurate positioning of regions of interests in our software.
- In the near future, reconstruction parameters for gallium-68 imaging will be optimized using our analysis software.

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