Contribution ID: **43** Type: **Oral**

3D printing of an anthropomorphic head phantom for PET/MRI

Sunday, 29 May 2022 17:55 (15 minutes)

Introduction: Quality assurance tests of functional nuclear medicine imaging with positron emission tomography (PET) in combination with MRI requires standardized phantoms visible in both modalities. The required measurements are usually performed using homogeneously filled PMMA phantoms. However, anthropomorphic, heterogeneous phantoms are needed to replicate patient examinations in the best possible way and consider attenuation correction correctly. For this purpose, a realistic human skull was reproducibly manufactured by 3D printing using alabaster casting techniques.

Methods: Based on the anatomical bone structures from MIDA model [1] a sagittal bisected negative mold was calculated and transform into a printable file. 3D printing was performed using water-soluble polyvinyl alcohol (PVA). Following some casting preparation, both printed molds were cast with alabaster-mixture. This material imitates bone and provides properties comparable to human cortical bone. After the curing process, the halves were put in water so that PVA dissolved and the gypsum enriched with water. This step is decisive for the phantom to give a signal in MRI. Finally the gypsum halves were composed and filled up with superabsorbent for brain imitation, in which a PVC flask was placed for activity filling as already shown by Harries et al. [2].

Results: The created phantom was used for cross-calibration and measured using UTE and DIXON sequence in PET/MRI. Both sequences obtained a realistic attenuation map segmentation. Based on this segmentation, the attenuation coefficients could be assigned correctly and the reconstructed and attenuation corrected images represent the expected activity concentration and linear attenuation coefficients. Compared to an activity standard (filled spherical phantom) the accuracy of the PET measured activity concentration was 0.96 for DIXON- and 0.90 for UTE- based attenuation correction.

Conclusion: It was shown that structures of the human skull can be realistically and reproducibly imitated by 3D printing a segmented negative mold and subsequent alabaster casting. Furthermore, the created phantom could be segmented correctly by means of MRI.

References
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Session Classification: Special session on PET/MR and TB-PET phantoms

Track Classification: PET/MR and TB-PET phantoms