SIMULTANEOUS PET/MR HYBRID IMAGING: MR BASED CONTINUOUS VALUED ATTENUATION MAP GENERATION AND ITS EFFECT ON QUANTITATIVE PET IMAGING

Krishnan Bharath Navalpakkam[1], Harald Braun[2], Susanne Zeigler[2], Harald H.Quick[2], Joachim Hornegger[1], and Torsten Kuwert[3]
[1]Pattern Recognition Lab, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany, [2]Institute of Medical Physics, Erlangen, Germany, [3]Clinic of Nuclear Medicine, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Introduction: Recent advances in multimodality imaging have shown that a PET/MR integration is indeed feasible [1]. This fusion capability makes it now possible to image metabolism (PET) in conjunction with excellent soft tissue contrast and high spatial resolution (MRI). PET/MR hybrid imaging shows potential to substitute conventional PET/CT hybrid imaging in cases where excellent soft tissue contrast and/or less ionizing radiation is beneficial. However, MR-based attenuation correction (AC) for PET images still remains a problem at large. In PET/CT systems, a simple energy scaling from CT energies (40-140 keV) to PET energies (511 keV) is sufficient to generate attenuation maps. But such a relationship is not straightforward to achieve in PET/MR systems as MRI and PET inherently measure two different physical phenomena. Often, a segmentation based approach is used for attenuation correction. It has been shown that with the availability of a multitude of MRI sequences, the generation of a CT-substitute can be realized [2]. The objective of this contribution is therefore two fold 1) Generate a continuous valued CT like attenuation map (μ-map) from dedicated MRI sequences; 2) Compare its PET quantification accuracy with respect to a CT based μ-map as the gold standard.

Material and Methods: 12 patients underwent a PET/CT scan on a Siemens Biograph 64, (Siemens AG, Healthcare Sector, Erlangen, Germany) followed by a PET/MR examination on a Siemens Biograph mMR (Siemens AG, Healthcare Sector, Erlangen, Germany), 80 minutes after the PET/CT examination. All the patients were administered ^{18}F-FDG as radiotracer. Two dedicated MRI sequences were acquired for each of the patients. First, an Ultrashort Echo Time sequence (UTE) with dual echoes of TE1=0.07 ms and TE2=2.46 ms with a flip angle of 10° was acquired. The images were then reconstructed to a matrix size of 192x192x192 voxels with an isotropic voxel size of 1.562 mm^3. Second, a two-point DIXON VIBE sequence was acquired with voxel dimensions of 192x126x128 and a voxel size of 2.6x2.6x2.58 mm^3. The total scan time for UTE and DIXON VIBE data acquisition was 2.67 min. We used ε-insensitive Support Vector Regression (ε-SVR) for the purpose of model generation [3]. In all 5 features in the form of mean, median, minimum, maximum and variance across a neighborhood radii of 3x3x3 voxels were extracted from UTE-TE1, UTE-TE2, DIXON-Fat and DIXON-Water images. The model was trained using one set of images. Three μ-maps were generated 1) Patient CT (μ-map$_{CT}$) 2) ε-SVR predicted CT (μ-map$_{MR}$) 3) Segmented CT (μ-map$_{CTSeg}$). The first two were converted to PET energy (511 keV) by hybrid scaling [4] and the third μ-map was threshold into air (HU<-200), fat (-200<HU<0), soft tissue (0<HU<300) and bone (HU>300) and Linear Attenuation Coefficients (LAC's) of 0 cm^{-1}, 0.0854 cm^{-1}, 0.1 cm^{-1} and 0.151 cm^{-1} were assigned respectively.

Results: Fig.1 shows relative difference (%) images from attenuation corrected PET volumes using μ-map$_{CTSeg}$ (Fig. 1b) and ε-SVR predicted μ-map$_{MR}$ (Fig. 1c) with respect to μ-map$_{CT}$ (Fig. 1a) as "Gold Standard". 20 Regions of Interest (ROI) were drawn randomly for 2 patients on the relative difference images generated by μ-map$_{CTSeg}$ and μ-map$_{MR}$. Minimum underestimation and maximum overestimation errors were extracted from each ROI. μ-map$_{MR}$ results in better maximum overestimation errors for most regions (< 25%) in comparison to μ-map$_{CTSeg}$ (< 45%) (Fig. 2).

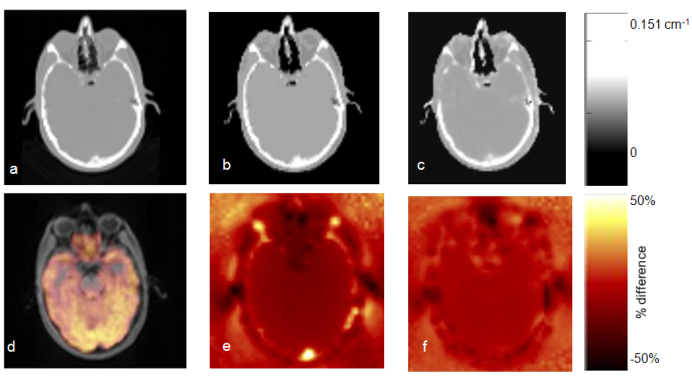

***Figure 1**: Top: μ-maps derived from a) Patient CT (μ-map$_{CT}$) b) Segmented CT (μ-map$_{CTSeg}$) c) Predicted CT (μ-map$_{MR}$). Bottom: d) Fused MR and PET. Relative difference (%) of attenuation corrected PET using e) μ-map$_{CTSeg}$ and f) μ-map$_{MR}$. Note: Bone overestimation errors ("hot spots") using μ-map$_{CTSeg}$ have been reduced due to better bone density estimation by μ-map$_{MR}$.*

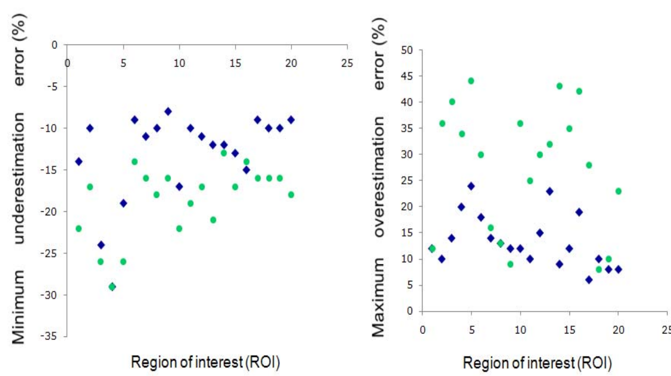

***Figure 2**: Severe underestimation errors > 25% were observed in both μ-map$_{MR}$ (blue) and μ-map$_{CTSeg}$ (green) at the soft tissue-air and soft tissue-bone interfaces. In most ROI's, μ-map$_{MR}$ yielded more accurate results than μ-map$_{CTSeg}$.*

Conclusion: A continuous valued μ-map using ε-SVR based on UTE and DIXON VIBE sequences was generated and the corresponding attenuation corrected PET using μ-map$_{MR}$ was found to be more accurate than μ-map$_{CTSeg}$.

[1] "Simultaneous PET-MRI: a new approach for functional and morphological imaging", Pichler et. al, Nature Medicine 14, 459 - 465 (2008). [2] "CT Substitute Derived from MRI sequences with Ultrashort Echo Time", Adam Johannson et. al. Med. Phys. 38, 2708 (2011). [3] "Support Vector Regression Machines", Vapnik et. al, NIPS 1996: 155-161. [4] "X-ray-based attenuation correction for positron emission tomography/computed tomography scanners", Kinahan et. al, Semin Nucl. Med, 2003 Jul; 33(3):166-79.