MR-based FoV Extension of Human Attenuation Correction in Whole-Body MR/PET Hybrid Imaging

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Introduction. In whole-body MR/PET hybrid imaging, the human tissue attenuation correction (AC) of simultaneously acquired PET data can be based on the MR data. However, the MR field of view (FoV) is limited due to B_0 inhomogeneities and gradient nonlinearities at the edges of large FoVs. Therefore, the human AC map may be truncated or geometrically distorted towards the edges of large FoVs and thus the PET reconstruction may be biased [1]. The bias can be corrected using a maximum-likelihood a-posteriori algorithm (MLAA) for estimating the truncated parts from the PET emission data [2]. The aim of this work is to explore extending the MR-based AC map using a purely MR-based FoV extension. Recently, we proposed a method to extend the FoV by determining an optimal readout gradient field which locally compensates B_0 inhomogeneities and gradient nonlinearities [3]. In this work, we applied this method to whole-body MR/PET examinations on patients and evaluated the impact on the PET reconstruction. The reported bias was reduced and the PET reconstruction was in good agreement with a PET/CT reference measurement performed in the same patient.

Materials and Methods. All scanning was performed on an integrated MR/PET hybrid whole-body imaging system (Biograph mMR, Siemens Healthcare Sector, Erlangen, Germany). The system-specific B_0 inhomogeneities of the main magnetic field and the nonlinearities of the gradient field were systematically measured once using an MR probe array.

Geometrical distortions of the patient's arms due to B_0 inhomogeneities and gradient nonlinearities at off-center positions were locally compensated using an optimized space-dependent readout gradient as described in [3]. A multi-slice spin-echo-based sequence was implemented to calculate and adapt an optimized readout gradient individually for each slice and arm position [4]. The FoV was set to 700*210 mm^2 with 2.19*2.19 mm^2 in-plane resolution, transversal, 5 mm slice thickness, 20 mm spacing, and 4 bed positions.

For validation of the impact on the PET reconstruction, a patient (male, 36y) who underwent an ^{18}F-FDG PET/CT and subsequently a simultaneous MR/PET examination showing several metastases was measured using the described FoV extension. The additional MR data offering an extended FoV were used to complete voxel-wise the truncated AC map. The voxels filling the missing parts were assigned to soft tissue with an attenuation value of μ=0.10 cm^{-1}.

A linear interpolation in z-direction was used to allow for the stated spacing between transversal slices and thus reduce the acquisition time to 43 sec per arm position and bed position.

The original AC map and the modified AC map were used for retrospective iterative 3i21s OSEM PET reconstructions. The difference was compared to the PET/CT scan serving as intraindividual standard of reference.

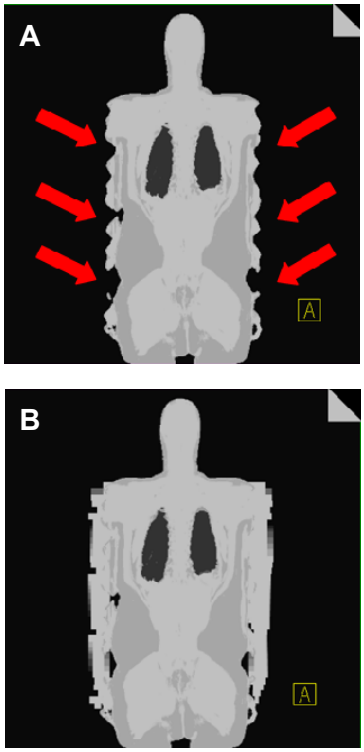

Figure 1: Truncation artifacts of patient's arms (arrows in A) can be significantly reduced using MR data acquired in an extended FoV (B).

Results. Figure 1A shows the original AC map containing truncation artifacts of the patient's arms. The missing parts were filled using MR data acquired in an extended FoV as displayed in Fig 1B. Quantitative comparisons of PET reconstructions using the limited AC map (Fig 2A) and the extended AC map (Fig 2B) results in a difference showing an underestimation of the PET signal for the limited FoV (Fig 2C). The PET reconstructions were quantified in standardized uptake values corrected by the body weight (SUVbw). The maximum bias value of SUVbw_max=3.00 was found in an osseous metastasis showing a SUVbw_max value of 9.18 for the limited FoV, 12.18 for the extended FoV and 12.00 for the PET/CT reference scan.

Discussion. The reported bias of the PET reconstruction due to FoV limitations was significantly reduced using an MR-based FoV extension. Quantitative comparisons of a region of interest containing an osseous metastasis and showing the largest bias was in good agreement with a PET/CT reference scan. Although similar results can be obtained by using the MLAA algorithm, the described method is purely MR-based and thus obviates the need for additional corrections based on the PET emission data. Therefore, the presented method might be interesting for special applications such as oncology and cardiology and might also be applicable to specialized PET tracers with little uptake in the arms.

Conclusion. Our method using an MR-based FoV extension showed an improvement of PET quantification in whole-body MR/PET hybrid imaging.

References. (1) Delso G et al., Med Phys 2010, 37:2804-12. (2) Nuyts J et al., 2010, IEEE Nucl Sci Symp Conf Record. (3) Blumhagen J O et al., 2011, In Proc. 19th Annual Meeting ISMRM (#2693). (4) Blumhagen J O et al., 2011, In Proc. 28th Annual Meeting ESMRMB (#604).

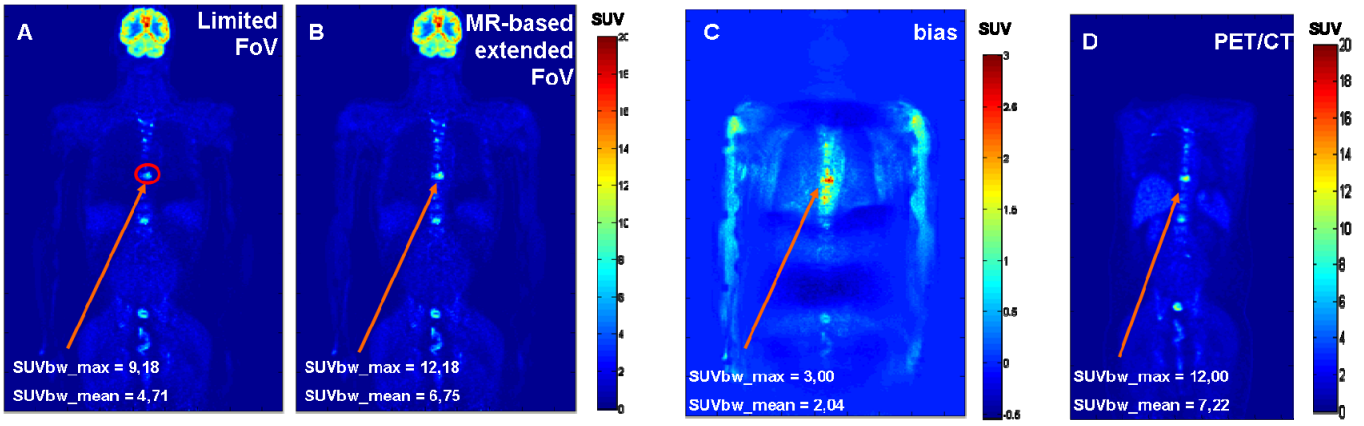

Figure 2: (A) PET reconstruction using an MR-based soft tissue AC map limited by typical truncation artifacts at the edges of the FoV. (B) PET reconstruction using an MR-based FoV extension. (C) Difference map. (D) PET/CT scan in the same patient serving as standard of reference.