Motion Averaged MR-Based Attenuation Correction for Coronary 18F-Fluoride Hybrid PET/MR

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Introduction and Objective

• Simultaneous hybrid PET/MR scanners offer the opportunity to obtain spatially and temporally co-registered images with the advantages of both modalities. In cardiac applications, PET imaging can reveal disease activity and metabolism, while cardiac MR reveals morphology, function and myocardial scarring on late gadolinium enhanced imaging.

• Recently, 18F-fluoride PET/CT has been shown to identify micro-calcification in atherosclerotic plaques associated with a recent myocardial infarction [1]. PET/MR offers the ability to investigate active coronary atherosclerosis while reducing the radiation dose compared to PET/CT allowing repeated and longitudinal studies.

• PET image reconstruction requires knowledge of the PET-photon attenuation of the object in order to produce accurate images of PET tracer activity. The current standard approach for MR-based attenuation correction (MRAC) is breath-held volumetric imaging to freeze motion of the chest and abdomen. However, for imaging the heart, alignment of anatomy during PET data collection and attenuation measurement is crucial.

In this work, we propose mapping attenuation using a free-breathing golden-angle radial gradient echo sequence and compare the PET images produced with this novel approach and the standard breath-held approach.

Methods

• Six patients with diagnosed cardiovascular disease or risk factors were imaged using a Siemens Biograph mMR.
• PET and MR data were acquired simultaneously between 40 and 90 minutes after injection of 10 mCi 18F-sodium fluoride [1].

MR Attenuation Correction

• The standard approach used end-expiration or end-inspiration, breath-hold (BH), 3D-DIXON-VIBE gradient echo (coronal orientation, FOV 500 x 400 x 260 mm^3, resolution 4.1 x 2.6 x 3.1 mm^3, TR/TE1/TE2 3.6/1.23/2.46 ms, FA 10^o, scan time 19 s).
• The motion-averaged approach used free-breathing (FB), golden-angle radial (GAR), stack-of-stars, 3D VIBE gradient echo [2] (coronal orientation, FOV 500 x 500 x 240 mm^3, resolution 3 x 3 x 3 mm^3, TR 4.5 ms, in-phase TE, FA 9^o, no fat suppression, 1600 radial acquisitions, scan time ~7 min).
• GAR-VIBE images (adaptive coil-combination) were segmented into soft tissue and background air.
• GAR-VIBE-MRAC data were also self-gated according to center-of-k-space intensity [3] (as in Siemens WIP 793) to reconstruct an end-expiration GAR-VIBE-MRAC volume.

MRAC Map Segmentation

Fig. 1. GAR-VIBE image pixel values were plotted as a histogram. A clear peak at zero was discernible in all images The first trough was used to automatically segment soft-tissue from background. This approach was chosen to be independent of user interaction to find the noise level. For comparison, in the DIXON-VIBE-MRAC maps, both soft tissue and fat were reassigned as soft tissue and lung was assigned as background air.

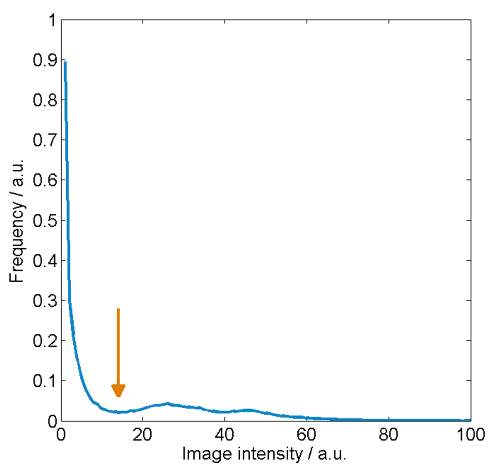


Image Analysis

Images were analyzed for image quality by an expert panel (blinded) to assess the presence of attenuation correction image artifacts (higher score = more artifact).

Results

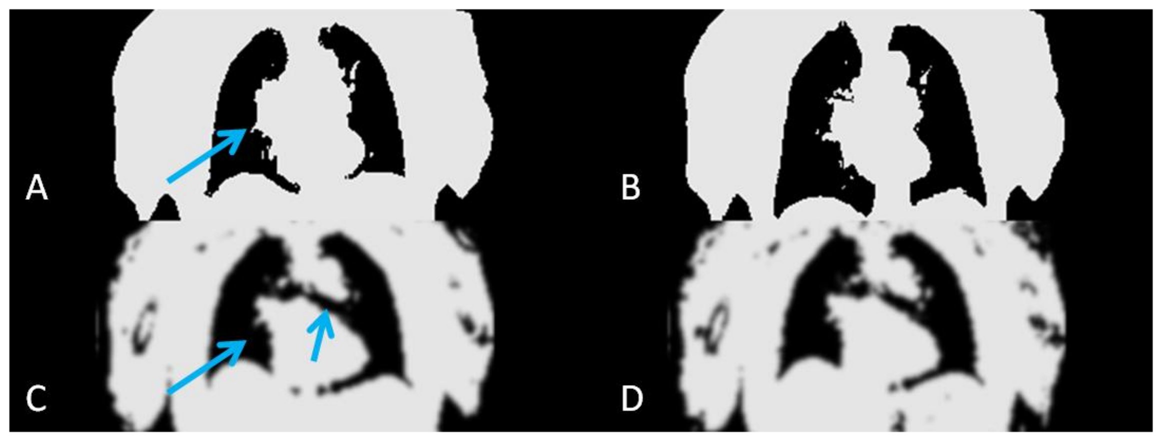


Fig. 2. MRAC attenuation correction maps for A) standard end-expiration breath-hold DIXON-VIBE, B) end-inspiration DIXON-VIBE, C) motion-averaged golden-angle radial VIBE, D) end-expiration GAR-VIBE. Artifacts in the MRAC of the DIXON method are seen on the heart/lung boundary and in the bronchi (arrows).

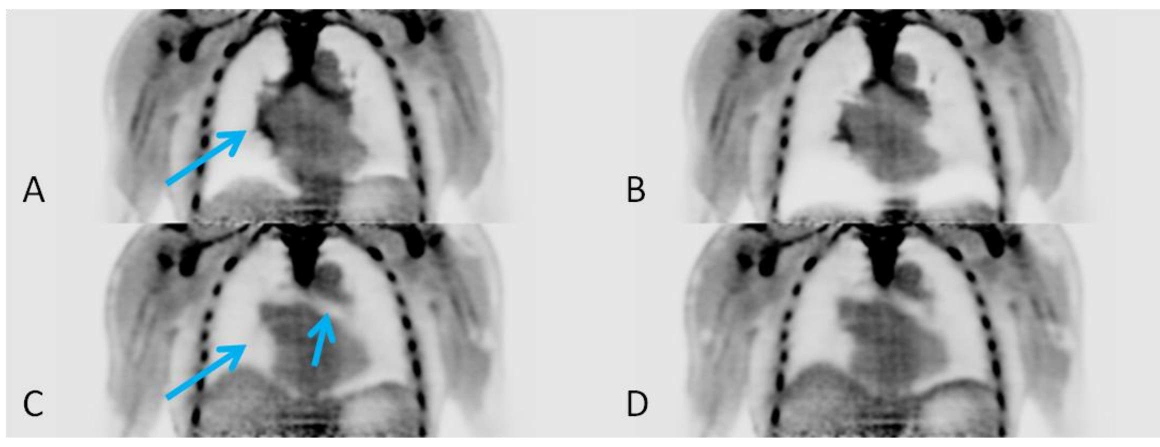
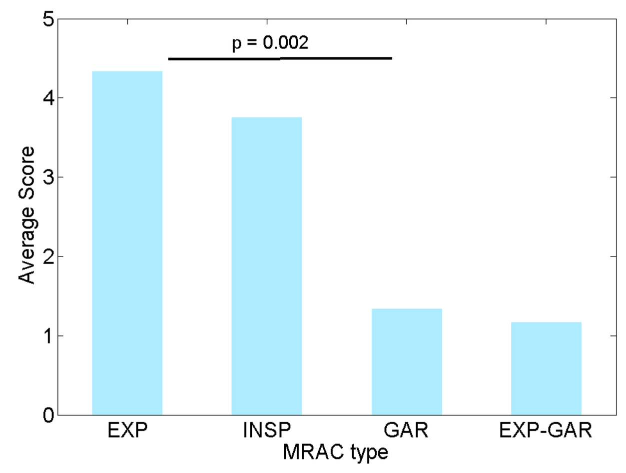


Fig. 3. Typical attenuation corrected PET images with same MRAC maps as in Fig. 2. Artifacts in the PET image at the heart/lung boundary and in the bronchi are eliminated using the motion-averaged free-breathing GAR-VIBE-MRAC approach.

Fig. 4. Average scores assigned to PET images by expert panel for each MRAC approach (high scores represent increased artifact). Poor scores are found for both end-expiration and end-inspiration breath-hold approaches. Motion-averaged free-breathing GAR-VIBE-MRAC shows significantly better scores than breath-hold DIXON-VIBE. No significant difference is seen between GAR-VIBE and end-expiration gated GAR-VIBE.



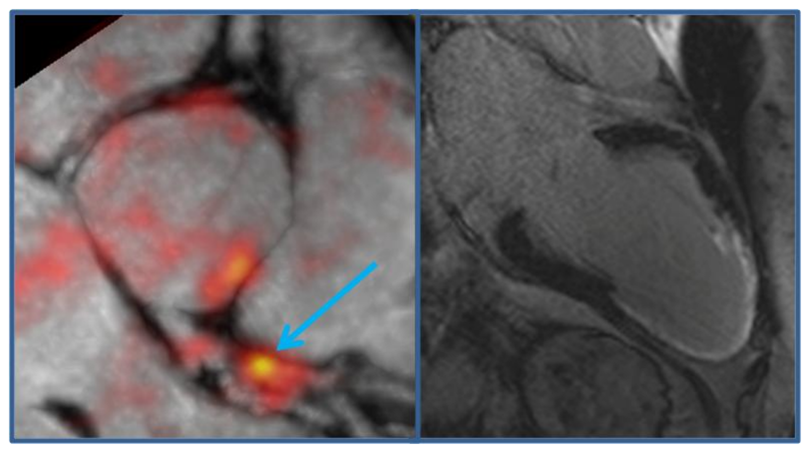


Fig. 5. PET image fused with gadolinium contrast-enhanced MRA (left) shows increased 18F-fluoride signal co-localized with a left anterior descending coronary artery plaque (arrow), corresponding to the infarct territory seen on delayed contrast enhanced MRI (right) in a patient with recent myocardial infarction.

Discussion and Conclusions

• Motion-averaged MRAC is necessary for artifact-free PET/MR images in the heart. Using the novel golden-angle radial MRAC approach is superior to the standard breath-hold DIXON-VIBE-MRAC approach.

• Using this approach, we were able to identify increased 18F-fluoride uptake in the coronary artery plaque of a patient who had recently had a myocardial infarction.

• PET/MR has the potential to allow repeated imaging at lower radiation dose compared to PET/CT in clinical and research studies.

References

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[3] Grimm R et al. Med Image Comput Comput Assist Interv 2013;16:17-24.

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