Validation of a PET-derived Respiratory Signal by Comparison with an MRI Pencil-Beam Navigator Signal in Simultaneous PET/MR

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INTRODUCTION: Respiratory motion during PET and MRI acquisitions can cause image artefacts. A respiratory signal is needed to bin data and should ideally be derived directly from moving internal tissue rather than external devices. It has been shown that a signal can be extracted from PET list-mode data with Principal Component Analysis (PCA) [1] with no extra hardware or scanning time required. An absolute measure of diaphragm displacement can be obtained from an MRI pencil-beam navigator placed on the diaphragm. The advent of simultaneous PET/MRI scanners allows us to compare our PET-derived signal with an MR-derived signal. On 9 patients, we compare signals using correlation and gating. Further, we assess image sharpness following motion-compensation based on gating using the PET-derived signal. The motivation for this work was to enable motion correction of PET or MRI throughout a whole PET/MRI scan without need for MRI sequence modification or external devices.

METHODS: Materials: In-vivo data were acquired using an integrated 3T PET/MRI system (Biograph mMR, Siemens Healthcare, Erlangen, Germany) on 9 patients (mean age 60 ± 15 years) with a range of diseases (related to lung, cardiac, liver, pancreas, spleen, kidney) using two tracers (6 ^{18}F-FDG and 3 ^{68}Ga-DOTATATE). PET list-mode data were collected simultaneously with MRI pencil beam navigators (continuously acquired, TR = 150ms), with a mean overlap time of PET and MRI acquisition of 144 ± 22 s. Signal Extraction: Edge detection was performed on the MRI navigator images to extract a respiratory signal. A signal was extracted from the PET data according to [1] by unlisting into short (~0.4s) sinogram stack frames, spatially smoothing the sinograms, performing PCA, and finally temporally smoothing. The PCA 1st component weights reflect changes in detected counts due to respiratory motion and form the respiratory signal. Analysis: Correlation between the PET and MR derived signals was assessed with a 1D Pearson correlation coefficient. The PET data were grouped into 5 respiratory bins based separately on the PET and MR derived signal amplitudes. PET images for each bin were reconstructed (OSEM, 3 subsets, 10 iterations, no attenuation or randoms correction). Volumes of interest (VOIs) were registered (rigid, translation only) to a reference bin and the maximum displacement recorded. Motion corrected VOIs were then formed by warping each VOI according to the registration parameters and uncorrected/corrected volumes were compared with the Tenengrad Variance sharpness (TVS) metric [2], which is defined as the variance of the gradient of the volume found with the Sobel operator. All processing was performed with Matlab (Mathworks, Inc., Natick, MA) and PET unlisting and reconstruction was performed using STIR [3].

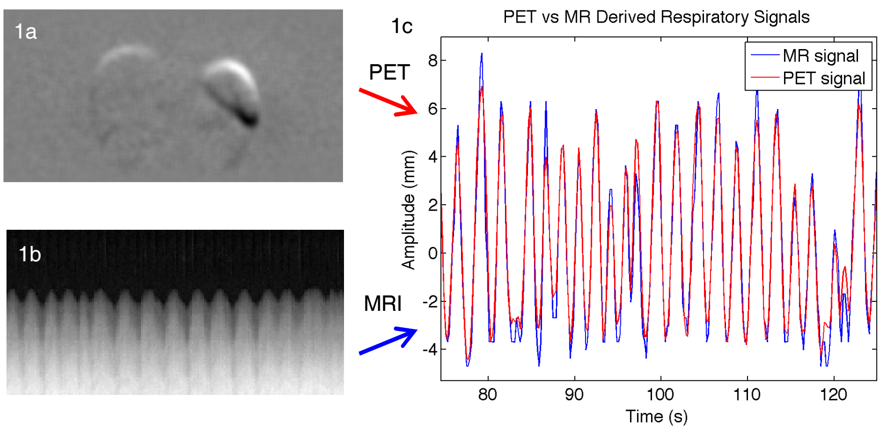

Figure 1: 1st principal component (1a) with corresponding weight values to form the signal (1c). MRI navigator image (1b) with corresponding signal from edge detection (1c).

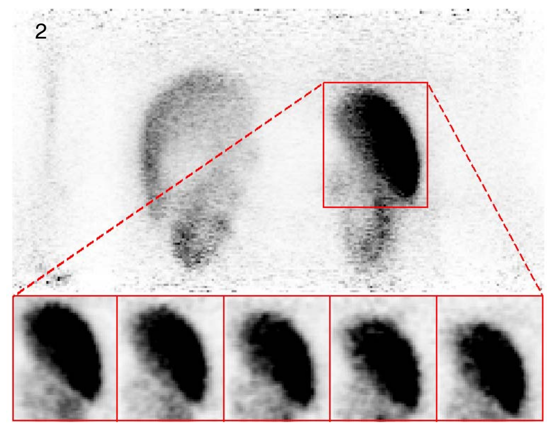

Figure 2: Uncorrected PET reconstruction with VOI extracted from 5 gates.

RESULTS: Over all patients the mean correlation between MRI and PET derived signals was 0.89 ± 0.09. Figure 1 shows the 1st PC, MRI navigator profiles and 50s section of the derived respiratory signals for a patient with high spleen tracer uptake. The PET-derived signal is scaled to match the MRI-derived absolute (mm) signal for visual analysis. Figure 2 shows the ungated PET reconstruction and the same VOI extracted from each gated reconstruction for the amplitude gating regime based on the PET-derived signal. Gating by amplitude gave comparable results for inter-gate displacements by registration between PET and MRI signal based gating schemes (Figure 3). After registration and combination, TVS demonstrated a mean sharpness increase between uncorrected and corrected volumes of 35% (range 0-117%).

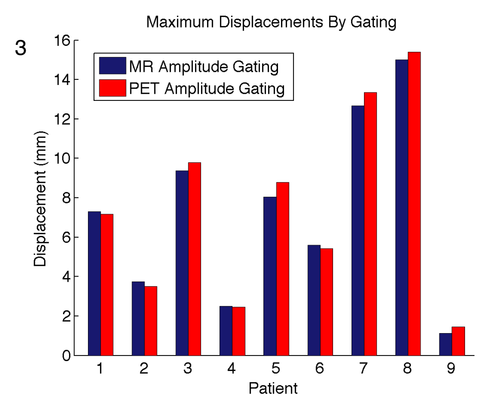

Figure 3: Maximum inter-gate displacements found by amplitude gating per patient with MR and PET derived signals

CONCLUSION AND DISCUSSION: We have provided evidence to show the validity of a PET-derived signal by comparison with a 'gold standard' MRI navigator both in signal correlation and in respiratory gating results, and have further shown that the improvements in image sharpness by gating. As the PCA technique requires no additional scan time, hardware or MRI sequence modification, motion correction can be performed without affecting a clinical PET/MRI protocol. Potential applications include using the PET-derived signal as an alternative to MRI navigators in order to monitor motion during a whole scan and guide respiratory correction of raw PET or MRI data.

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