MR-BASED COMPENSATION OF RESPIRATORY MOTION ARTIFACTS OF IN-VIVO PET IMAGES ACQUIRED ON A SIMULTANEOUS WHOLE-BODY MR/PET SYSTEM

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Introduction

Positron emission tomography (PET) is a unique tool for the observation of metabolic activity using radioactively labeled pharmaceuticals such as ^{18}F-FDG. It is therefore a mandatory procedure in tumor staging and the detection of metastases. Though PET is highly sensitive to even picomolar concentrations of the radiotracer, its spatial and temporal resolution are limited. Acquisition time at one bed position is usually about 2 to 5 minutes. Since breath-hold techniques, as used in MRI, are not applicable at such an acquisition time, images are either severely blurred due to motion artifacts or have to be gated retrospectively, leading to a loss of detected radioactive decay events and thus to reduced SNR or to prolonged acquisition times. Combined whole-body MR/PET scanners offer the possibility to simultaneously acquire metabolic PET data as well as morphologic MR data [1]. By applying fast 3D- or 2D-multislice MR imaging sequences, the respiration-induced non-rigid deformations in the thorax and abdomen can be monitored under free breathing. In this work, we present a method which uses such deformation information to retrospectively correct multi-gated PET images for respiratory motion, thus achieving motion-corrected PET images while maintaining the full signal-to-nose ratio (SNR).

Materials and Methods

Three patients with different diagnostic indications underwent simultaneous PET/MR examination. PET data were acquired in listmode at one thoracic/abdominal bed position (FOV = 26 cm in z-direction) for 5 minutes. To monitor the elastic deformations during the respiratory cycle in this region, an MR scan was started simultaneously with the PET acquisition, serving two purposes at once: First, a navigator image showing the position of the diaphragm at the proximal end of the liver serves as a reference signal for the respiratory state. Second, a fast 2D-multislice spoiled gradient echo sequence is used to monitor the deformations in the body. To keep most of the motion in plane, sagittal slice orientation was chosen (imaging parameters: TR = 3.8 ms, TE = 1.7ms, 670 Hz/pixel, matrix size = 192 x 144 pixel, FOV = 300 x 225 mm, phase partial fourier = 6/8, measurement time per slice about 0.4 s). Each slice was measured repeatedly for about 5 s, yielding a total number of 12 images per slice at different time points. In this fashion the torso was imaged from right to left in 32 slices (slice thickness: 8 mm, spacing in between slices: 2 mm). The whole scanning time for this procedure is about 2.5 minutes.

The image post-processing and motion compensation procedure is schematically shown in Figure 1. According to the diaphragm positions (as obtained by the MR navigator) associated with each MR image, the slices were reordered to resemble consistent 3D volumes of the torso at different time points in the respiratory cycle (in this work we used 4 different positions). Then, a modified demon algorithm [1, 2] was used to perform a non-rigid 3D registration of the different respiratory states to the end-expiratory state. This way, for each time point in the respiratory cycle and each voxel in the 3D volume, a vector was calculated which directly relates the voxel position to its position in the end-expiratory state (Figure 2). PET images were reconstructed from listmode data using the MR-navigator as gating information. Gating thresholds where chosen in such a way, that each gate approximately consisted of an equal amount of counts (again, we used 4 gates in this work). Using the deformation information from the demon registration, the gated PET images were deformed to align with the end-expiratory state. In a final step, the aligned PET images were summed up on a pixel-by-pixel base to for the final motion-corrected image.

Results

Using the proposed method, respiration-induced abdominal and thoracic deformation could be monitored with a sufficient temporal and spatial resolution for subsequent motion estimation. Estimation by non-rigid registration of the different respiratory states in the MR images yielded reliable and accurate transformation fields for further processing. The presence of vessels (and thus edge information in the images) in lung and liver enabled an accurate estimation even in these rather homogeneous tissues (see Figure 2). Using this data, respiration-induced blur in PET images could be reduced in all three patients. The sharpness of the edges of the myocardium and lesions in the lung was comparable to the sharpness observed in gated PET studies, however, at significantly higher SNR.

Conclusion and Outlook

The proposed method is capable of reducing the respiration-induced motion blur in thorax and abdomen while maintaining a high SNR. This enables quantitative PET evaluation in these moving areas as well as reducing the applied radiotracer dose. Image quality might be improved even further by incorporating the MR-acquired tissue deformation information already during PET reconstruction.

References

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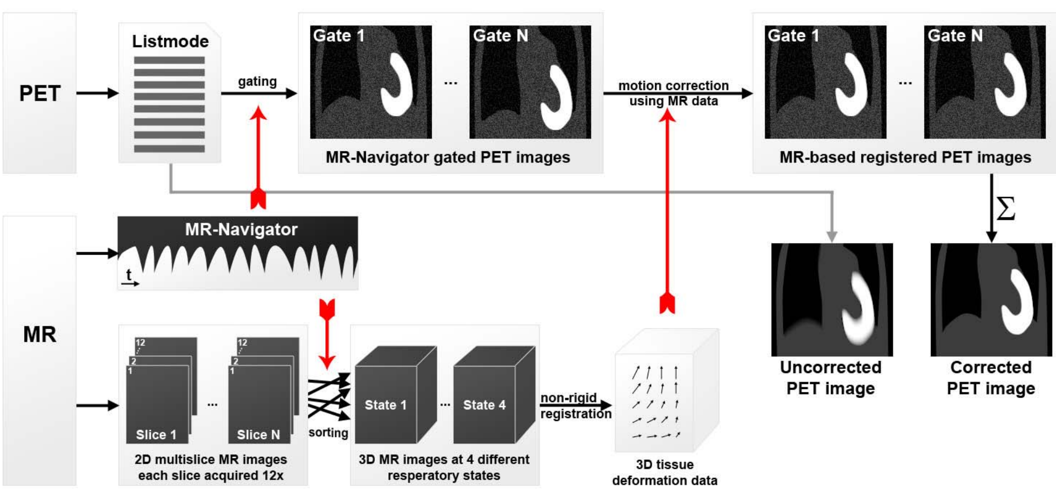

Figure 1: Flow diagram of the proposed method. The data from the MR navigator is used to both, PET gating and sorting the MR image slices into multiple consistent 3D blocks, each one showing a different respiratory state. Deformation data obtained from registering these states to the end-expiratory state are used in order to deform the gated PET images. Summing up these corrected images yields the desired motion-corrected PET images.

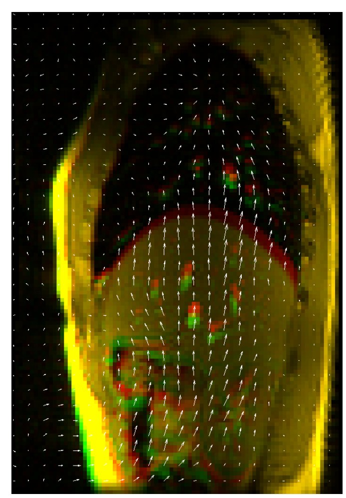

Figure 2: Example slice showing end-expiratory state (red channel), intermediate state (green channel) and the obtained deformation data.