Interleaved PET data sorting for improved image quality in combined PET/MR

Richard Laforest[1], Ju-Chieh Cheng[1], Agus Priatna[2], Man Chun Jeffrey Lau[1], Shivak Sharma[1], and Pamela K Woodard[1]
[1]*Radiology, Washington University Medical School, St.Louis, MO, United States,* [2]*Siemens, St.Louis, MO, United States*

Background: Combined PET/MR is a novel imaging technology that allows for simultaneous acquisition of PET and MR images. PET and MR Data acquisition, although simultaneous, is however performed independently. For ECG gating acquisition, this leads to a temporal mismatch between the individual PET phases relative to the MR phases. Typically, PET data are sorted in 8 cardiac phases with the trigger start time corresponding to the ECG pulse while cine MR can be acquired with 20 or more phases. Increasing the number of PET phases to match the MR would increase the temporal sampling but would results in decreased statistics in the individual phase images and poorer image quality. This abstract presents a novel sorting algorithm of the PET list mode data that allows for an exact temporal match of the PET cardiac phases to the MR cardiac phases, and at the same time, allows improvement in counting statistics in the PET images.

Method: 4 patients with no known cardiac history underwent cardiac ^{18}F-FDG PET-MRI imaging approximately 2hrs post injection on a Biograph mMR (Siemens, Erlangen, Germany). The attenuation correction (AC) μ-map was acquired with a dual echo VIBE Dixon sequence (TE1/TE2 = 1.23 msec/2.46 msec, TR = 3.6 msec). Simultaneous with the MR-AC sequence, list mode PET data were acquired with ECG pulse monitoring for 15 minutes. During the PET acquisition, an ECG triggered real-time True FISP cardiac MR cine was acquired free-breathing (TE=1.24 ms/TR=118 ms, thickness = 5 mm, FOV 360 mm, FA=54°, base resolution = 128, bandwidth = 1260 Hz/pixel, shot per slice = 1, segments = 43, 20 phases, acquisition window of 956 ms, iPAT acceleration factor = 2). Three reconstructions were performed. First, the PET list mode data was sorted into 8 phases of equal duration (~136 ms), with trigger times coinciding with the ECG pulse (standard methodology R1). Second, the PET list mode data was sorted into 20 phases of 54.6 ms with 50 ms temporal sampling similar to the MR cine (R2) but not using the MR phase trigger times. Finally, the PET list mode data was sorted into 20 phases with trigger times matching the trigger times of the MR cine phases (R3) using a phase duration of 136ms, interleaving the PET data. All PET images were reconstructed with 3D-OSEM (Ordered Subset Estimation Maximization) with 3 iterations, 21 subsets and Gaussian filter of 4 mm (with STIR software [1]). Myocardial FDG uptake and image noise were measured from the reconstructed PET images. Image noise was evaluated by the activity concentration coefficient of variance (CV) found in a large uniform area of uptake (Liver).

Results: Fig. 1 shows myocardium FDG concentration for the three reconstructions with higher tracer concentrations observed at systole. All three reconstructions led to similar activity concentration measurements. Fig. 2 shows liver FDG concentration for all cardiac phases. Larger fluctuations across phases are observed in the R2 images (blue diamonds). R1 led to an average value of 2924 Bq/mL with an average CV of 27%. The corresponding CV for R2 and R3 were 37.6% and 27%. R1 showed the poorest temporal sampling but an average temporal mismatch to the MR phases of 14.9 ms. R2 showed a temporal match of 21.2 ms to the MR phases and depicted the poorest noise. R3 showed excellent temporal match (since it used the MR trigger times for each phase) and the noise level equivalent to images of R1.

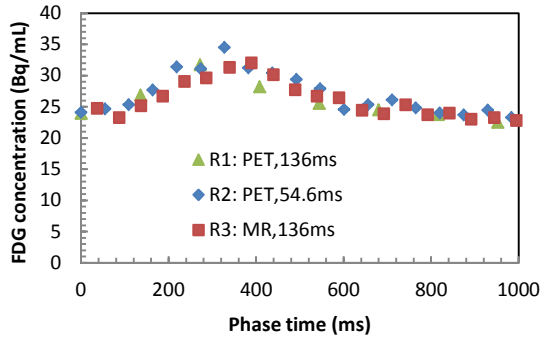

Figure 1. Myocardial tracer concentration in cardiac gated images for the three reconstructions.

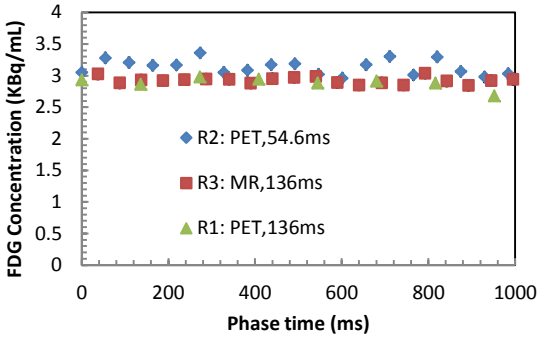

Figure 2. Liver tracer concentration in cardiac gated images for the three reconstructions.

Discussion: The proposed method offers the same statistical accuracy as in standard 8-gate binning but with the improved temporal sampling offered by MR. The accuracy of the approach is dependent upon the regularity of the cardiac rhythm since MR CINE slices are acquired over 20 seconds while the PET data are acquired for 15 minutes. The technique is however general in concept in which that arbitrary trigger times and phase duration, with tradeoff between statistical accuracy and motion blurring, can be used in the sorting of the PET data in order to achieve ideal temporal synchronicity of the PET to MR physiologic gating data, which could be either respiratory or cardiac gated.

Conclusion: The proposed PET-gating algorithm showed both excellent temporal resolution and temporal match with the cine -MR and also, showed the high statistical accuracy that matches the noise level observed in conventional PET cardiac gating.

References:

[1] Kris Thielemans *et al*, STIR: software for tomographic image reconstruction release 2, *Phys. Med. Biol.* 57 (2012) 867-883