Dynamic Brain PET/MR using TOF Reconstruction

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Purpose: Integrated PET/MR scanners offer true simultaneous imaging, which is desirable for functional brain studies [1]. However, the temporal resolution of PET images is lower than that of MR images due to lower signal to noise ratio (SNR). Here, we show that by using the Time of Flight (TOF) properties of SiPM based detectors [2], the SNR of brain images is improved, enabling higher temporal resolution for SNR-equivalent PET images.

Methods: Five patients were consented according to the local IRB protocol to be scanned on an investigational whole body TOF PET/MR scanner (SIGNA PET/MR*, GE Healthcare, Waukesha, WI, USA) after the completion of a clinical PET/CT exam. The patients were injected with 410±80 MBq of FDG and after completing the PET/CT exam, were scanned 140±30 minutes post-injection with the TOF PET/MR machine for 40±9 minutes. The TOF PET/MR scanner has <400 ps timing resolution, 10.5% energy resolution, and 25cm axial field of view [3]. A Dixon based Lava-Flex sequence was used for MR attenuation correction, and an atlas-based algorithm was used for tissue segmentation in the head. PET images were reconstructed dynamically with 30 sec, 1 min, 2 min, 5 min and 10 min frames using two methods: a) non-TOF reconstruction with 28 subsets and 2 iterations and b) TOF reconstruction with 28 subsets and 2 iterations. A TOF reconstruction with 28 subsets and 5 iterations was used to reconstruct the whole acquisition, which was considered to be the gold standard under the assumption that the activity distribution did not change appreciably during the ~2 hours post injection, 40 minutes of acquisition. This image was subtracted from all dynamic images to get the noise image. Noise power was calculated from the temporal variations of each pixel in order to calculate the SNR. All reconstructions are performed with MR attenuation correction, crystal sensitivity correction, dead-time correction, random correction and scatter correction using OSEM algorithm.

Results: PET, MR and their fused images of both subjects are shown in Fig 1. Fig 2 (a-b) compares TOF and non-TOF reconstruction with 28 subsets and 2 iterations on a 30s frame duration of the first subject and shows the improved SNR obtained by TOF reconstruction. Fig 2 (b-f) compares TOF reconstruction with 28 subsets and 2 iterations using different frame durations (30s-10min). The 30s frame, with an average gray matter SNR > 8, is a good choice for functional brain studies using simultaneous PET/MR imaging. Fig 3 shows the SNR comparison between white matter and gray matter using TOF and non-TOF reconstructions on the 1st subject. As expected the SNR increases with the square root of acquisition time for all cases. It also shows ~45% SNR increase in white matter and 24% SNR increase in gray matter for TOF reconstruction compared to non-TOF reconstruction. TOF reconstruction also increased the SNR of both white matter and gray matter for all other subjects, by between 5% and 45% (25±15%).

Discussion: It is shown in five subjects that TOF reconstruction can increase the SNR of white matter and gray matter in PET images by 5%-45% compared to non-TOF reconstruction. With additional SNR gains using the TOF reconstruction method, dynamic images with shorter frame durations are possible while preserving reasonable image quality. This in turn effectively increases the temporal resolution of dynamic brain studies using simultaneous PET/MR imaging.

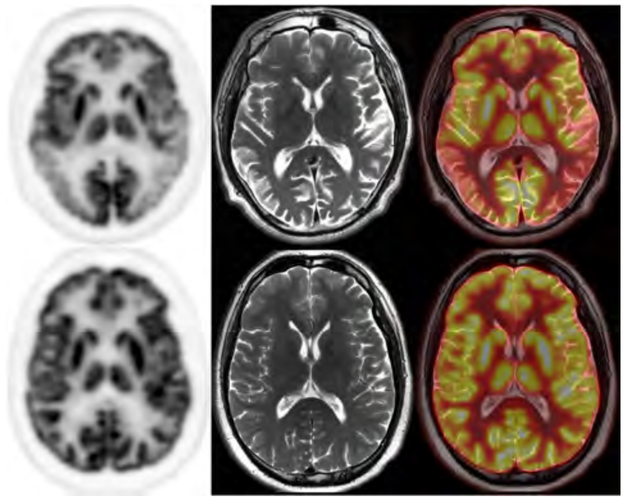

Fig 1: PET, FRFSE T2-weighted MR & fused PET/MR images of 2 subjects on a whole body TOF PET/MR scanner. PET images are reconstructed with TOF, 28 subset / 5 iterations.

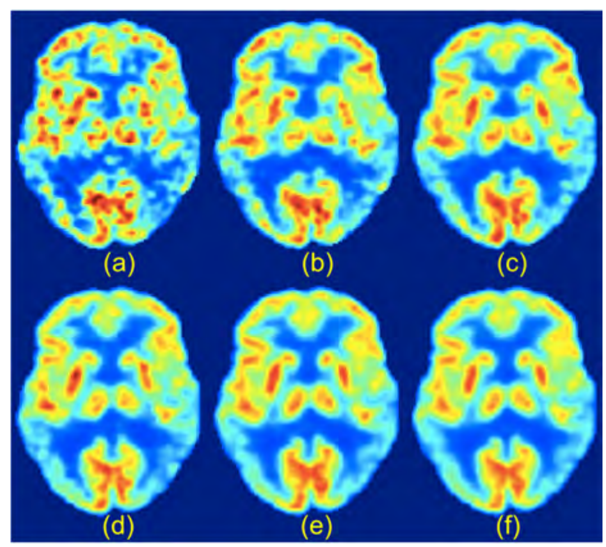

Fig 2: PET images: (a) 30s frame using non-TOF reconstruction with 28 subsets and 2 iterations and (b) 30s, (c) 1min, (d) 2min, (e) 5min & (f) 10min frame using TOF reconstruction with 28 subset and 2 iterations on a TOF PET/MR scanner.

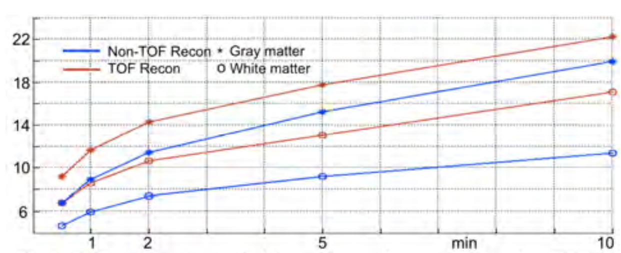

Fig 3: SNR comparison of white matter and gray matter using TOF and non-TOF reconstruction of the first subject. The acquisition time was varied from 30 sec to 10 min. TOF reconstruction SNR of white matter and gray matter is higher by 45% and 24% respectively.

References:

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