Incorporation of TOF information reduces artifacts in simultaneous TOF PET/MR scanning

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Target audience: Physicists, Radiologists / Nuclear medicine physicians

Purpose:

In simultaneous PET/MR scanning, MR data is employed for PET photon attenuation correction (MR-AC). Bone or metal implants could lead to inconsistencies in the MR-AC maps, thereby affecting the PET images[1]. Lesions close to bone or implants may be obscured and remain unnoticed or cannot be accurately assessed. A possible solution could be the inclusion of time-of-flight (TOF) information into the PET image reconstruction algorithm. This study aims to evaluate the influence of TOF information on artifact reduction and improvement in PET image quality in clinical simultaneous TOF PET/MR scanning.

Methods

Part A (clinical): A total of 35 patients with various malignant tumors were included and scheduled for a comparative scan in a new simultaneous TOF PET/MR scanner (GE SIGNA). TOF and non-TOF PET images were reconstructed, clinically examined and compared by a radiologist/nuclear medicine physician. Differences in the image quality, especially those related to (implant) artifacts, were assessed using a 5-point scale, ranging from zero (no artifact) to four (severe).

Part B (simulation): In seven patients the reconstructions were repeated after the introduction of artificial signal voids in the attenuation map to simulate three different sized clinically relevant metal artifacts in the maxilla, humeral head, chest, sternum, thoracic spine, lumbar spine and below the femoral head. The reconstructed images were then compared with reconstructed images that had no simulated artifacts for the TOF and non-TOF reconstructions.

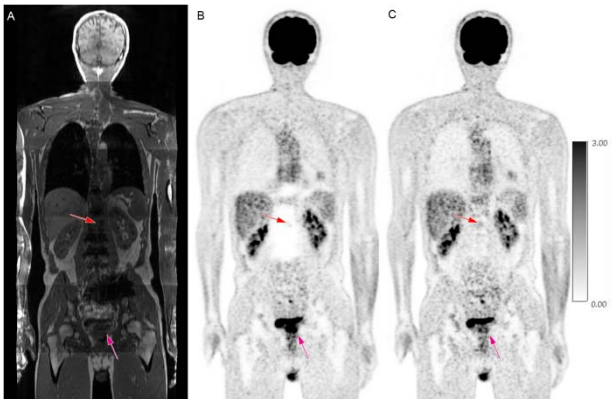

Fig.1: A patient with thoracolumbar spinal fusion: A) T1 weighted MRI, B) non-TOF PET, C) TOF PET. In the non-TOF PET image a spinal bone metastases is obscured (red arrow) due to the metal artifacts also shown in the MRI. (PET range 0-3 g/ml)

Results

Part A: A total 46 image artifacts were being evaluated. Two patients had large (fig. 1) and six patients had small implant-related artifacts, ten patients had dental implants/fillings and 19 patients had implant-unrelated artifacts. Overall, the average score was 1.3 ± 1.0 (mean ± std) for the non-TOF PET and 0.7 ± 0.8 for the TOF images (fig. 2) (P<0.01, Wilcoxon matched-pairs signed rank test).

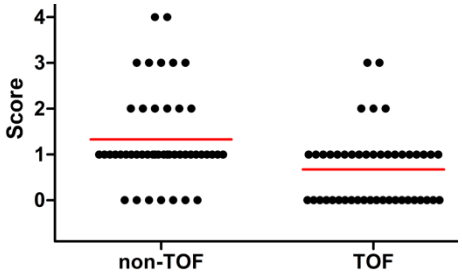

Fig.2: The scoring of the artifacts in the clinical cases. (0 = no artifact, 4 = severe artifact)

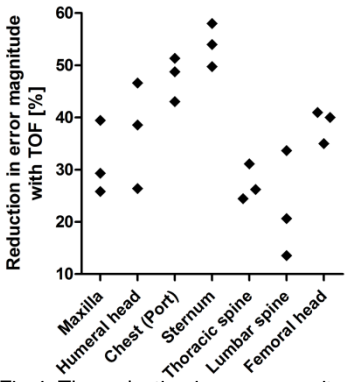

Fig.4: The reduction in error magnitude with TOF when simulating signal voids with three sizes in seven locations.

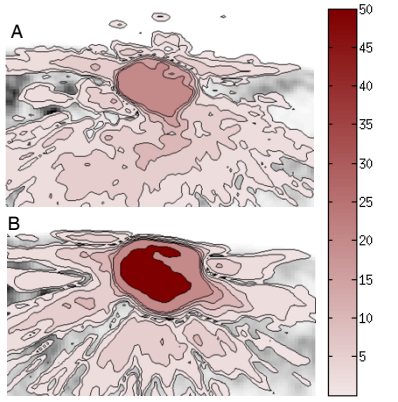

Fig.3: Axial image map showing the absolute percentage error in (A) TOF and (B) non-TOF, after inserting a signal void in the chest simulating a port implant. (Range 0-50%)

Part B: Fig. 3 shows an example of a simulated chest port implant. The error near the implant is lower with TOF. In all cases the magnitude and impact of the error was reduced when TOF information was included in the reconstruction (fig. 4). However, for all anatomical regions investigated except for the lumbar spine, the number of small magnitude (-5% to -30%) errors present in the TOF image was greater than in the non-TOF image.

Discussion:

From a clinical point of view the image quality and the reader confidence was improved significantly near artifacts with the inclusion of TOF. The simulations showed that TOF information reduced the impact of artifact related errors in all metal implant cases. TOF not only improves e.g. signal-to-noise ratio, accuracy, lesion detectability and the convergence rate of the iterative algorithm[2-6], its inclusion also makes the system become better-conditioned and therefore less sensitive to errors in the attenuation map. The use of TOF in conjunction with other (MR) techniques to correct for metal artifacts could possibly even further improve overall image quality and clinical reader confidence.

Conclusion:

These results suggest that PET imaging may significantly benefit from the integration of TOF information in simultaneous TOF PET/MR scanning.

References

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