MRI-based Attenuation Correction for PET Reconstruction

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Introduction

The concept of combining Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) into a single scanner has been around for many years [1]. While hybrids like PET/CT are used frequently in clinical applications, MRI/PET has many advantages such as higher soft tissue contrast and lower radiation dose to the patient. Figure 1 shows examples of hybrid fusions for a neck tumor. The PET/CT fusion (Fig. 1a) shows no apparent contrast between the tumor and the surrounding normal tissues, while the tumor in MRI/PET (Fig. 1b) can be identified with a clear boundary. MRI/PET has high clinical implications, but there is still no solution to the problem of attenuation in PET. The attenuation effect is a process in which photons passing through the body are absorbed before reaching the photon detectors causing the calculated position of the photons to be incorrect [2]. The resulting images have poor contrast, poor resolution, and artifacts, such as high signal in the lungs and on the skin. The attenuation can be determined using a transmission scan, which uses a rotating radioactive source to measure attenuation, or Computed Tomography (CT) images in the case of PET/CT hybrids. Both of these scans directly measure the attenuation of the tissue, but CT is not available in MRI/PET, and transmission scans increase both the duration of the scan and the dose to the patient. It would be ideal to use MRI for attenuation correction, but it is difficult to do since MRI does not measure the attenuation of the tissues directly. Some groups [3,4] have made progress, but there is still no established method for creating attenuation maps with MRI. The goal of this study was to test methods for determining the attenuation correction map from MRI.

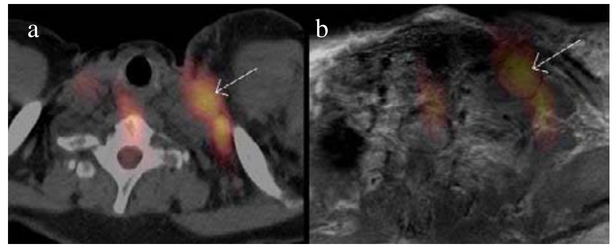

Figure 1: (a) PET/CT fusion; (b) PET/MRI fusion

Material and Methods

PET, CT and MR examinations were performed for the same patient on a Siemens Biograph 16 HI-REZ PET/CT scanner as well as a Philips Achieva 3-Tesla MRI system. The PET data was reconstructed without attenuation correction (Fig. 2a) and with CT based attenuation (Fig. 2b) using Software for Tomographic Image Reconstruction (STIR). The T1-weighted MR images were co-registered with the uncorrected PET data using Medical Image Processing, Analysis and Visualization (MIPAV). The registered MR images are then segmented into regions of air and other tissues in MIPAV, where a value of zero is assigned for air, and 0.096 cm^{-1}, the attenuation value of water, is assigned elsewhere. The PET data is then reconstructed using these MR based attenuation maps (Fig. 2c).

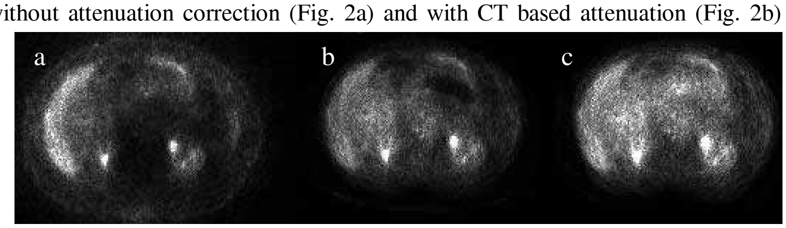

Figure 2: Examples of PET images (a) Non-Attenuation Corrected; (b) Attenuation Corrected from CT; (c) Attenuation Corrected from MRI

Results and Discussion

The most difficult step to reconstructing PET images in MRI/PET is obtaining an accurate attenuation map from MRI. Traditional methods to approach this problem use image segmentation, a method where materials are differentiated and then assigned to different groups. The most important features to segment are air, bone, and soft tissue. This is the method used by Zaidi et al. [3] for reconstruction of the brain, but segmentation of the torso is more difficult due to the many types of tissue and the difficulty in identifying the bone. Another method for MRI-based attenuation correction is to acquire different sequences of MR images to reveal certain anatomical structures [4]. Then, the tissues can be segmented by taking the information from each sequence, such as identification of bone by using a sequence that enhances bone structure. In this study we propose another method of attenuation correction by first segmenting air and soft tissues, but not bone, from the MRI. The distortions in the MRI attenuated images can then be used to provide a more accurate segmentation of the tissues. The new segmentation provides an updated attenuation map that can be used in the reconstruction, so one can continue to update the map and reconstruct the images until satisfactory images are obtained. This method has the advantage of using approximate PET images to help improve the segmentation rather than relying on segmentation of the MRI alone. In the abdominal slice in Figure 2, this method of segmenting air and tissue (Fig. 2c) is reasonable compared to the CT based attenuation correction (Fig. 2b). Inaccuracies appear only in the spinal and intestinal regions and can be corrected with further segmentation.

Conclusion

MRI-based attenuation correction is very important in the development of MRI/PET hybrid scanners. Without these corrections, one must rely on transmission scans, which will increase the dose of radiation to the patient, increase the length of the scan, and may cause misalignment errors due to patient motion. The method outlined in this paper is a first step toward improved MRI-based attenuation correction, which is necessary for the development of fast and efficient MRI/PET scanners.

References

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