Reproducibility of MRI-DUTE-based attenuation correction maps in brain tumor patients

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Introduction

Development and validation of an accurate MRI-based attenuation correction (AC) method is necessary for quantification of PET data in integrated MR-PET scanners. Implementing an MR-based AC method is very challenging because the MR signal is not directly related to tissue linear attenuation coefficients (LACs) and bone/air segmentation is extremely difficult using conventional sequences. The AC method we proposed [1] uses a dual-echo ultra-short echo time (DUTE) sequence that can detect bone [2, 3]. We have previously presented proof-of-principle studies suggesting this method agrees reasonably well with the segmented CT method which we suggested as the "silver standard" for any segmented MR-based AC method. Our method has the potential of providing more accurate results than an atlas-based method in patients who have structural abnormalities due to surgery or tumors. In this work we investigated the reproducibility of the DUTE-based AC method in brain tumor patients.

Materials and Methods

Simultaneous MR-PET data were acquired using the MR-compatible BrainPET scanner that operates while inserted into the bore of the Siemens 3T Tim Trio MR scanner [4].

Data acquired in 10 brain tumor patients at 4 time points during the course of their treatment were analyzed for this study. Treatment planning CTs obtained at the beginning of the study were also available for each patient and were used to generate the CT-derived attenuation maps (μ-maps). No surgical procedures that would alter the skull/brain morphology were performed between the CT and MR-PET scans.

The DUTE sequence was implemented to collect signals at two echo times during the same acquisition (TE 0.07/2.24 ms, TR 200 ms, FA 10°, radial projections 32,000, bandwidth 1532 Hz/Px, FOV 320 mm, base resolution 192, acquisition time 3:20 min:sec). To generate the μ-map, a head mask was first obtained from the $DUTE_2$ data and then the air and bone voxels were identified using the combined $DUTE_1$ and $DUTE_2$ information. Finally, known LACs were assigned to bone, tissue, and air cavities (0.151, 0.096 and 0 cm^{-1}, respectively).

The DUTE-derived μ-maps for each visit were compared against the segmented CT-derived μ-map for the patient to determine misclassified voxels. The following six categories of misclassifications were considered: water as bone, bone as water, bone as air, air as bone, water as air and air as water. The DUTE-derived μ-maps for each patient were also compared across time points to test for reproducibility.

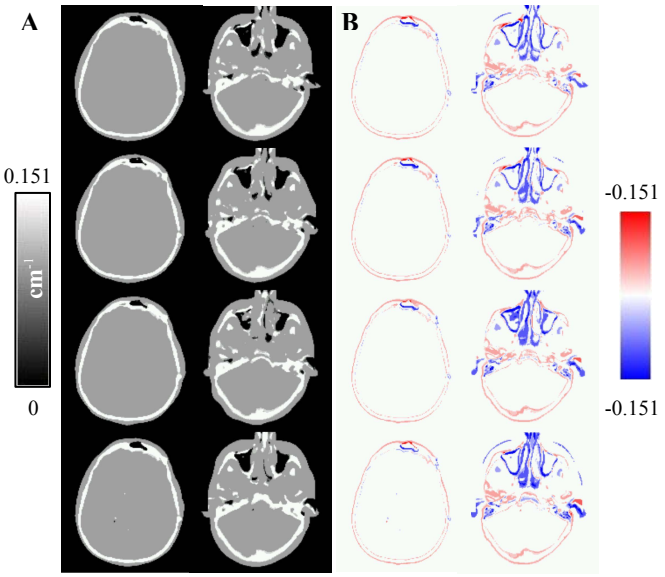

Figure 1. (A) Representative DUTE-based attenuation maps across four visits in a patient; (B) Corresponding map of misclassified voxels in DUTE-based attenuation map with respect to CT-based attenuation map.

Results and Discussion

DUTE-based μ-maps obtained from the data collected at four visits for a representative patient are shown in Fig. 1A (slices at two different locations are shown in each case). Bone, soft tissue, and air are represented by white, gray, and black, respectively. The corresponding maps of misclassified voxels in the DUTE-based μ-map with respect to the CT-based μ-map (Fig. 1B) showed the challenges of segmenting the full thickness of the skull (red) and distinguishing air from tissue in difficult sinus regions (blue). The chart in Fig. 2 shows the percentage of misclassified voxels for each category of misclassification in brain tumor patients across four time points.

In general, the images and chart demonstrate good overall agreement between the DUTE-based μ-map and the "silver standard" segmented CT-based μ-map (mean=85.30%). The highest intrapatient variability (SD=2.46%) was observed in the subject with the lowest agreement to the CT method (mean=81.62%). A visual inspection of the UTE data obtained in this patient revealed motion artifacts. Based on observation, much of the discrepancies across time points are due to poor quality of DUTE data obtained when patients move a significant amount, especially in the jaw area, where segmentation is already challenging. Further development of MR-based attenuation correction algorithm and DUTE sequence is under way to improve agreement to the segmented CT-based μ-maps.

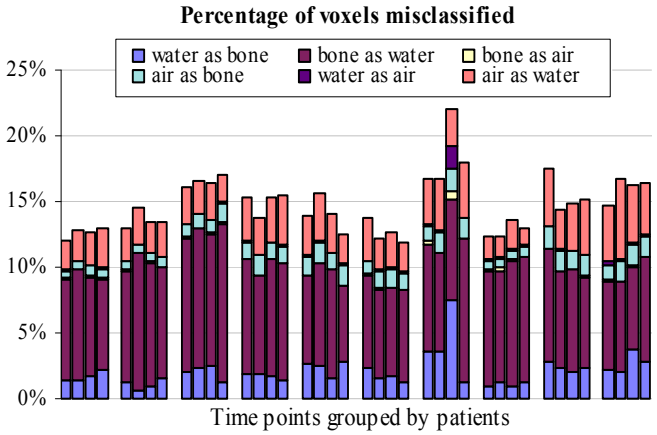

Figure 2. Percentage of misclassified voxels for each category of misclassification across four time points for each patient (n=10). Average percentage of misclassification across all patients was 14.70%. Percentage relative SD ranged from 2.17% to 13.40%.

References: [1] Catana C et al., J Nucl Med 2010; 51:1431-1438; [2] Reichert ILH et al., MRI, 2005; 23(5): 611-618; [3] Robson MD et al, NMR in Biomed, 2006; 19(7):765-780; [4] Schlemmer HP et al, Radiology, 2008; 248(3):1028-35