On the Reproducibility of MR-based PET Attenuation Correction using a Probabilistic Atlas-based Method

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Introduction

Recently, there has been interest in MR-based PET attenuation correction (AC) due to the development of integrated MR-PET scanners that are not equipped with a transmission source. We have previously implemented an MR-based PET AC method using dual-echo ultrashort echo time (DUTE) and morphological MR images to segment the most relevant classes (i.e. bone, soft tissue, and air cavities). Voxel-wise attenuation maps ("mu-maps") were generated from these segmented images by assigning known linear attenuation coefficients (LAC) to each voxel class. These mu-maps were also demonstrated to agree well with the "sliver standard," the mu-maps generated by segmenting the corresponding CT images, and introduced minimal bias in the PET quantitative estimates when used for AC. [1] In this work, we investigated the reproducibility of the method by comparing the mu-maps produced from subject data acquired at different time points.

Materials and Methods

MR-PET scanner: Data were acquired using a Magnetom TIM 3-T MRI scanner (Siemens Healthcare, Erlangen) with the MR-compatible BrainPET prototype scanner inserted into the bore of the magnet for simultaneous MR-PET imaging. [2]

Data acquisition: Nine subjects with head CT data available were scanned on the MR-PET scanner at three time points. Between the scans, no medical procedures were performed that might have altered the morphology of the head.

Mu-map generation: The mu-maps were generated using the method described in [1], which uses a probabilistic atlas constructed from CT training data. We first produced a UTE-based mask to select the voxels corresponding to the subject's head [3] , then trained a classifier using MR data to compute the probability of each tissue class at every voxel in the head; the class with the largest probability was selected; finally, LACs of 0.151, 0.096, and 0 cm^{-1} were assigned to bone, soft tissue, and air voxels, respectively.

Data analysis: The structural MR images acquired at different visits of each subject were first co-registered; we then calculated the percentage of consistently identified voxels out of the total voxels in the mu-map; the three classes of voxels (air, soft tissue, and bone) were analyzed separately to test the reproducibility of inter-visit mu-map generation. Dice similarity coefficients (DSCs) [4] were calculated by dividing the number of consistently-identified voxels belonging to a particular class in each inter-visit comparison by the mean number of voxels that belong to the same class in their original mu-maps (a DSC of 1 means that the voxels for a particular class completely overlap, while a DSC of 0 indicates that there is no intersection for this class between the two mu-maps). In this study, DSCs were calculated for the comparisons between the first and second visits, the first and third visits, and the second and third visits. Maps of the differences between inter-visit mu-maps were also examined to determine the locations of the misclassified voxels.

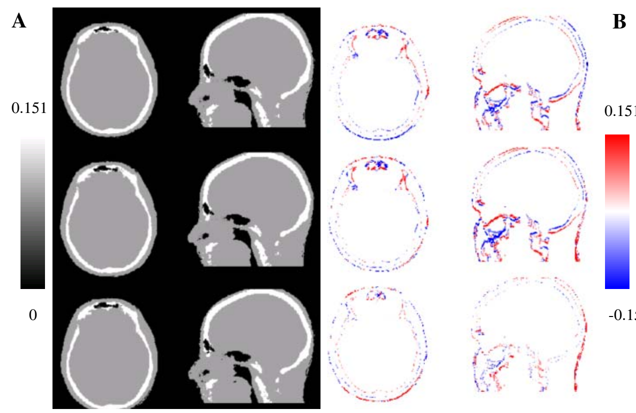

Figure 1. A: Mu-maps generated from the atlas-based method, with LACs (units in cm^{-1}) assigned to the three classes of voxels. The mu-maps are produced from the same patient across the three visits. B: Comparisons of misclassified voxels between the mu-maps produced for the same subject.

Results and Discussion

Representative images (in transverse and sagittal orientations) of the atlas-based mu-maps for one subject are shown in Figure 1A. The shades black, gray, and white indicate the three voxel classes: air, tissue, and bone, respectively. Mu-maps generated from each of the three visits are shown in chronological order.

Consistently identified voxels account for on average 95.76% of total voxels compared (SD = 2.60%). The difference between the mu-maps for one of the subjects is shown in Figure 1B, demonstrating the majority of head voxels were consistently identified. However, misclassified voxels still occurred in regions such as the frontal sinus and the base of the skull, where a mixture of tissue, bone, and air can be found.

The box plot in Figure 2 denotes the DSCs for each voxel class. Across all visits, the voxel classes are similar, as indicated by the DSC values near 1. Soft tissue voxels have higher DSCs than the other two classes as expected. Since DSCs are a measure of overlap and tissue voxels account for most of the volume in mu-maps, the same misclassified (i.e., non-overlapping) voxels would constitute a lesser proportion of total tissue voxels than other classes. Even though outliers exist in the comparison between the first and last visits (longest time interval between scans of all the comparisons), the DSCs are still close to 1, suggesting high similarity between the mu-maps.

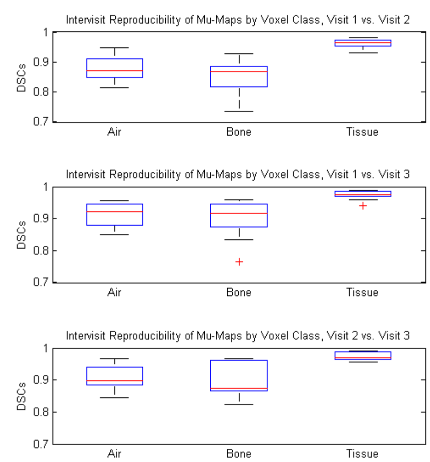

Figure 2. Dice Similarity Coefficients (DSCs) for all subjects (n=9). The box plots indicate that the voxel classes (air, bone, tissue) assigned in our atlas-based mu-map generation method agree for inter-visit mu-maps.

Conclusion

We demonstrate that the MR-based mu-map generation method we have recently proposed [1] produces reproducible mu-maps and could be a reliable solution for head AC in integrated MR-PET scanners.

Acknowledgements

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References

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