Clinical evaluation of ZTE skull segmentation

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Target audience: PET/MR, physicist.

Purpose

One of the main challenges of attenuation correction in hybrid PET/MR scanners is the correct identification of bone tissue. A recent development has been the publication of a new bone identification technique, based on 3D radial zero echo time (ZTE) imaging[1]. This sequence provides high-resolution, isotropic images, suitable for bone segmentation, without the need of preparation pulses or multiple echoes, making it a very time-efficient acquisition. The goal of the present study is to compare ZTE bone images of clinical patients with the corresponding CT datasets, obtained using a tri-modality scanner setup.

Methods

A new paradigm for MRI bone segmentation, based on proton density-weighted ZTE imaging, was disclosed earlier this year. In this study we reviewed the bone maps obtained with this method on fifteen clinical datasets acquired with a PET/CT-MR tri-modality setup (GE Discovery 750w MR and 690 PET/CT). The MR acquisition parameters were: FOV 26cm, ST 1.4mm, 188 slices, FA 1°, frequency 192, 4 NEX, BW 62.5kHz. The CT scans acquired for PET attenuation correction purposes were used as reference for the evaluation. Quantitative measurements based on the Jaccard distance were performed, as well as qualitative scoring of anatomical accuracy by an experienced radiologist and nuclear medicine physician.

Results

The average overlap distance between ZTE and CT bone masks evaluated over the entire head was 52±6% [range 38-63%]. When only the cranium was considered, the distance was 39±4% [range 32-49%]. These results surpass previously reported attempts with dual-echo UTE, for which the overlap distance was in the 47-79% range[2,3,4]. Anatomically, the calvaria is consistently well segmented, with frequent but isolated voxel misclassifications. Air cavity walls and bone/fluid interfaces with high anatomical detail, such as the inner ear, remain a challenge.

Discussion

Our results are in agreement with those reported in the methodological paper by Wiesinger et al. Relying on single-echo PD imaging is more time-efficient than the multiecho/multisequence $T2^*$ estimation approaches. This is restricted by the intrinsic signal-to-noise limitations of low flip-angle ZTE acquisition, leading to a tradeoff between the achievable resolution and the need for additional averaging. Overall, the anatomical detail of ZTE bone masks was insufficient for direct clinical inspection, but acceptable for attenuation correction purposes. The problem remains of false positive bone identification in certain interfaces affected by local field inhomogeneities and partial volume effects.

Conclusion

This is the first clinical evaluation of skull bone identification based on a zero echo time sequence. The results suggest that proton density-weighted ZTE imaging is an efficient means of obtaining high-resolution maps of bone tissue with sufficient anatomical accuracy for PET/MR attenuation correction.

References

1. Wiesinger et al, ISMRM 2014; 5819
2. Keereman et al, J Nucl Med. 2010; 51:812-818.
3. Catana et al, J Nucl Med. 2010; 51:1431-1438.
4. Delso et al., J Nucl Med. 2014; 55:1-6

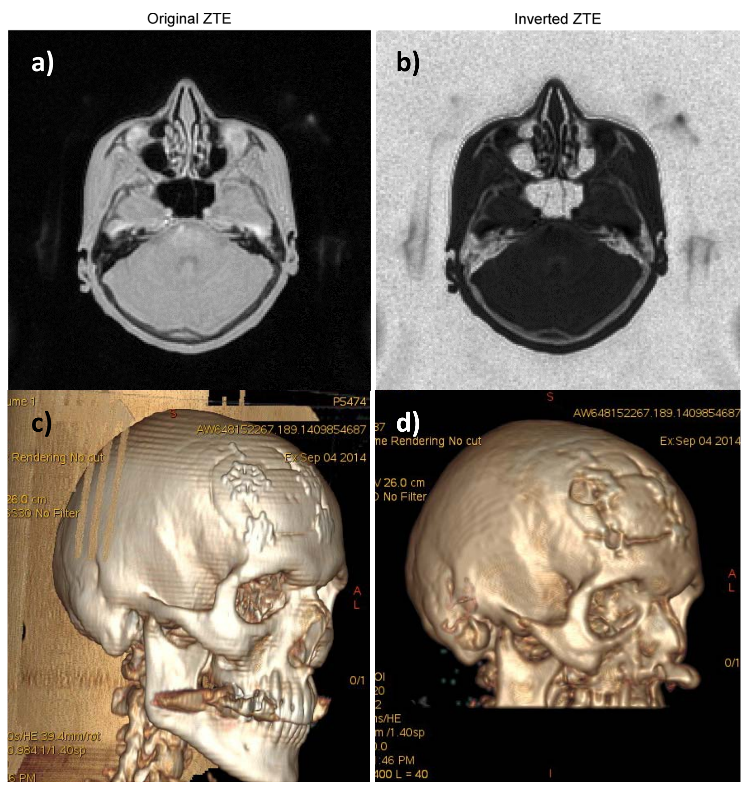

Fig.1: Axial views of a typical post-operative ZTE volume (a) before and (b) after intensity rescaling. Volume rendered views of the reference CT dataset (c) and ZTE-based bone mask (d).