Identifying appropriate contrast MR images to construct a digital head phantom for functional near infrared spectroscopy

Hiroshi Kawaguchi[1], Takayuki Obata[1,2], Kazuki Kurihara[3], Yosuke Takahashi[3], Eiji Okada[3], and Hiroshi Ito[1]

[1]*Molecular Imaging Center, National Institute of Radiological Sciences, Chiba, Japan,* [2]*Research Center for Charged Particle Therapy, National Institute of Radiological Sciences, Chiba, CHiba, Japan,* [3]*Department of Electronics and Electrical Engineering, Keio University, Yokohama, Japan*

Introduction The segmentation of head anatomy using magnetic resonance images (MRI) is an important and successful technique used in the attenuation correction of positron emission tomography combined with MRI (PET-MRI) [1]. Functional near-infrared spectroscopy (fNIRS) is another technique that requires a realistic three-dimensional digital head phantom based on anatomical head images to improve the accuracy of image reconstruction and visualization of image data [2]. The ultrashort TE sequence is suited to the job of attenuation correction in PET-MRI, but a similarly appropriate sequence for constructing an fNIRS digital head phantom is yet to be identified. In this study, we test several MRI sequences for their suitability to construct a digital head phantom for fNIRS.

Methods All MR experiments were performed with a 3.0-T clinical MR system (Signa HDx 3.0; GE Healthcare, Milwaukee, WI). A digital phantom for fNIRS usually consists of five tissue types: scalp, skull, CSF, gray and white matter. T1-weighted images (T1Ws) are often used in segmenting the brain because of the clear contrast between cerebral ventricles, gray and white matter. However, the boundary between skull and CSF in the subarachnoid space is ambiguous in T1Ws. Additional images are therefore necessary to successfully segment the CSF and skull. T2-weighted images (T2Ws) provide high contrast between the CSF-skull boundary, however high resolution T2Ws have low SNR and take a long time to acquire. As an alternative to T2Ws, we acquired both fat-saturated proton-density-weighted (FSPDW) and fast imaging employing steady-state acquisition (FIESTA) images. FSPDW is a modification of the 3D-SPGR T1W imaging sequence (the flip angle is decreased from 12 to 6 degrees) that provides high signal intensity throughout the head except for the skull. On the other hand, FIESTA quickly acquires images with high CSF signal but reduced intensity in other regions. The scalp, skull and CSF regions were segmented in both the T2W and FSPDW/FIESTA image sets by applying a region-growing algorithm with manual selection of the initial seed points. Morphological filtering was applied and the ordering of the superficial tissues was considered to minimize false segmentation by the region-growing algorithm. The images were also manually segmented under the supervision of a professional radiologist. The manually segmented images were used as the ground truth when evaluating the accuracy of the semi-automatic segmentation of the scalp, skull and CSF from the T2W images only and the FSPDW/FIESTA combination.

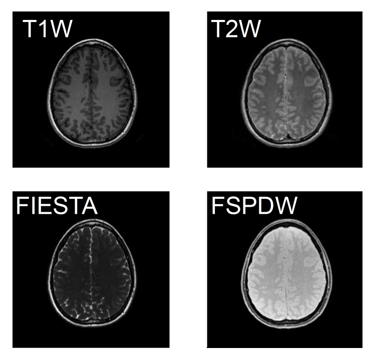

Fig.1 Contrast of MRI images

Results and Discussion The MRI contrast of T1W, T2W, FSPDW and FIESTA images are compared in Fig. 1. The segmentation results are shown in Fig. 2. The rows correspond to the scalp (top), skull (middle) and CSF (bottom), and the first three columns are the ground truth, segmentation with T2W and segmentation with FSPDW/FIESTA. The final two columns are subtractions of the second and third columns from the ground truth, from which it is clear that the errors in the T2W segmentation were greater than that of the FSPDW/FIESTA segmentation for all regions. The error rate (number of error pixels / number of true pixels * 100 [%]), of the scalp, skull and CSF were 8.9, 18.2 and 41.0 for FSPDW/FIESTA and 17.3, 25.4, 140.9 for T2W. Note that the error rate for the CSF region is much higher than that for the other two regions because of the lower number of true pixels and the complicated boundary of the CSF region in comparison to that of the scalp and skull. The acquisition time for a single slice with FSPDW, FIESTA and T2W were 1.35, 0.31 and 3.48 seconds, respectively. Even though two kinds of images are acquired, the combined FSPDW/FIESTA acquisition is faster than T2W acquisition.

Conclusion The combination of FIESTA and FSPDW produced more accurate results when segmenting the superficial tissues of the scalp, skull and CSF. Furthermore, the combined acquisition time of FIESTA and FSPDW is shorter than that of T2W. Therefore, FIESTA and FSPDW (in addition to T1W) imaging are necessary to construct a satisfactory digital head phantom for fNIRS.

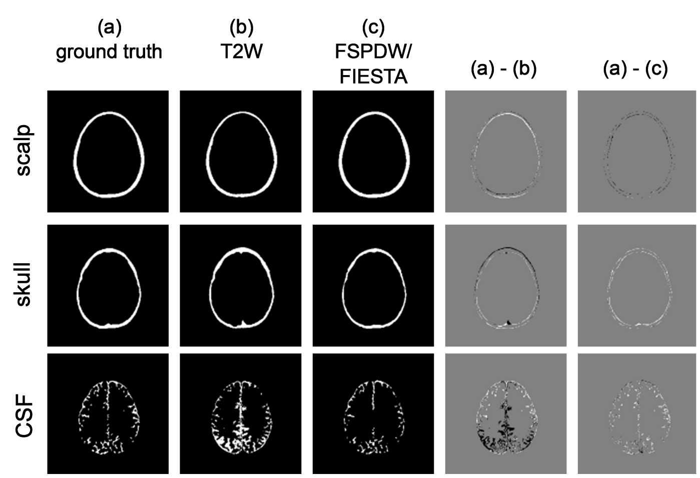

Fig.2 Segmentation results and error

References

[1] Keereman et al., J. Nucl. Med., 51, p. 812, 2010.

[2] Kawaguchi et al., Phys. Med. Biol., 49, p. 2753, 2004.