In Vivo 3D Imaging of Human Lateral Geniculate Nucleus using Optimized Inversion Recovery Sequence at 3T and 7T

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[Introduction] Lateral geniculate nucleus (LGN) functions as a thalamic relay station in the projection of visual pathway from retinal ganglion cells to the primary visual cortex. A recent MR imaging study of human LGN in vivo demonstrated that the height of LGN is smaller in glaucoma patients than normal (those without glaucoma) subjects [1]. This study implies that morphometry of LGN is an important potential biomarker for the neurodegenerative glaucoma disease. However, precise delineation of LGN anatomy in 3D using MR image is technically challenging because of the LGN’s location deep in the brain, small size (diameter 4 – 6 mm), and tissue signal similar to the surrounding white matters, such as optic radiation (OR). In this study, we demonstrated a significant improvement in the tissue contrast of LGN by a using magnetization-preparation-rapid-acquisition-gradient-echo (MPRAGE) sequence with optimized inversion time (TI) at 3T and 7T.

[Methods and materials] All scans were performed on a 3T and 7T scanner (Siemens Medical Solutions, Erlangen, Germany) with single-loop surface coils for imaging ex vivo brain specimen, and 32-/9-channel RF head coils for imaging LGN in vivo. MR imaging of the brain specimen was performed at 3T to assess the degree of LGN tissue contrast improvement with inversion-recovery (IR) vs. proton-density (PD) imaging in 2D, which is known to produce the best LGN tissue contrast among conventional MR sequences. The specimen was also scanned at 7T to image the LGN using 3D MPRAGE. MR imaging of LGN in vivo was performed at 3T and 7T with two normal, healthy volunteers (28, 40 yrs). A series of IR gradient-echo (GRE) images were obtained by varying T1’s. Tissue signal intensity and contrast was measured by placing ROIs over the OR, LGN, thalamus, and internal capsule and was then plotted against TI. The image intensity (y) vs. inversion time (t) was fitted using $y = a\cdot(1 - e^{-bt})$. We determined the TI that maximized the relative contrast of LGN (L) to other tissues (C) which was defined by $|C-L|/|C+L|$. Then, the relative contrast of LGN was compared between PD turbo-spin-echo (TSE) and IR-GRE image with the optimal TI at 3T. In addition, the proposed LGN imaging method was compared with conventional GRE and MPRAGE imaging with CSF suppression at 7T. Finally, LGN was segmented from the proposed MPRAGE images and the volume of LGN was measured.

[Results and conclusions] Substantial changes in tissue signal intensity with varying TI’s were detected on IR-GRE images of ex vivo specimen (Fig. 1A and B). The relative contrast of LGN was maximized at TI = ~120 ms at 3T because the greatest suppression of signal intensity in OR was at this value. The relative contrast of LGN was higher on the IR-GRE images than PD-TSE image: 64.5% vs. 30.5%, and 50.0% vs. 22.3% at two different slices (Figs. 1C – F). The IR imaging of LGN in vivo vs. PD-TSE imaging revealed the same trend (data not shown). High-resolution images of the ex vivo mid-brain obtained using 3D MPRAGE sequence with TI = ~200 ms at 7T are shown in Fig. 2. The relative contrast of LGN (L) to other tissues (C) which was defined by $|C-L|/|C+L|$. Then, the relative contrast of LGN was compared between PD turbo-spin-echo (TSE) and IR-GRE image with the optimal TI at 3T. In addition, the proposed LGN imaging method was compared with conventional GRE and MPRAGE imaging with CSF suppression at 7T. Finally, LGN was segmented from the proposed MPRAGE images and the volume of LGN was measured.

In conclusion, excellent tissue contrast of LGN and suppression of the surrounding OR tissue signal were achieved using a 3D MPRAGE sequence with appropriate TI. This sequence was superior to other sequences commonly used for LGN imaging including PD, GRE, and typical MPRAGE. MR imaging of LGN at 7T was superior to 3T with doubling of SNR at 7T. An imaging method that allows accurate and reliable volume measurement of LGN is crucial for the investigation of the association between LGN atrophy and neurodegenerative glaucoma.