The Safe Area in the Parieto-Occipital Lobe in the Human Brain: Diffusion Tensor Tractography

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OBJECTIVE: **A recent study reported on the relatively safe area in the frontal lobe for performance of neurological interventions; however, no study on the posterior safe area has been reported. In this study, using diffusion tensor tractography, we attempted to identify the safe area in the parieto-occipital lobe in healthy subjects.**

METHODS: **A total of 47 healthy subjects were recruited for this study. Eleven neural tracts were reconstructed in and around the parieto-occipital area of the brain using diffusion tensor tractography. The safe area, which is free from any trajectory of 10 neural tracts, was measured anteriorly and medially from the line of the most posterior and lateral margin of the brain at 5 axial levels (from the cerebral cortex to the corona radiata).**

RESULTS: **The anterior boundaries of the safe area in the upper cerebral cortex, lower cerebral cortex, centrum semiovale, upper corona radiata, and lower corona radiata levels were located at 31.0, 32.6, 32.7, 35.1, and 35.2 mm anteriorly from the line of the most posterior margin of the brain, respectively, and the medial boundaries were located at an average of 34.7, 38.1, 39.2, 36.1, and 33.6 mm medially from the line of the most lateral margin of the brain, respectively.**

CONCLUSIONS: **According to our findings, the safe area was located in the posterolateral portion of the parieto-occipital lobe in the shape of a triangle. However, we found no safe area in the deep white matter around the lateral ventricle.**

INTRODUCTION

Invasive neurological interventions could often result in neural injury of the brain (4, 8, 14, 21, 25). These interventions comprise the operation, procedures of the shunt operation, radiotherapy, or radiosurgery (4, 8, 14, 21, 25). These interventions have been performed based on known neuroanatomy or experience (5). Anatomic identification of the safe area for performance of invasive neurological interventions could provide useful information for clinicians in the neuroscience field. However, due to limitations of previous neuroimaging techniques, such as conventional brain computerized tomography or magnetic resonance imaging, in identification and evaluation of neural tracts in the live human brain, research on this topic has been neglected.

In contrast, diffusion tensor tractography (DTT), which is derived from diffusion tensor imaging (DTI), enables identification and localization of neural tracts in 3 dimensions in the live human brain (18). A recent study (11) reported on the relatively safe area in the frontal lobe for performance of invasive neurological interventions. However, few DTT studies on the posterior safe area have been reported (2, 17). We hypothesized that the safe area in the parieto-occipital lobe could be identified using the reconstructed neural tracts for the cingulum, superior

Key words
- Diffusion tensor tractography
- Neural tract
- Parieto-occipital lobe
- Safe area

Abbreviations and Acronyms
AF: Arcuate fasciculus
CR: Corona radiata
CRP: Corticoreticular pathway
CS: Centrum semiovale
CST: Corticospinal tract
DTI: Diffusion tensor imaging
DTT: Diffusion tensor tractography
IFOF: Inferior fronto-occipital fasciculus
ILF: Inferior longitudinal fasciculus
MLF: Middle longitudinal fasciculus
OR: Optic radiation
ROI: Region of interest
SLF: Superior longitudinal fasciculus
SST: Somatosensory tract

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longitudinal fasciculus (SLF), middle longitudinal fasciculus (MLF), inferior longitudinal fasciculus (ILF), inferior fronto-occipital fasciculus (IFOF), arcuate fasciculus (AF), and optic radiation (OR) (1, 3, 6, 7, 9, 10, 15, 16, 19, 24).

In the present study, using DTT, we attempted to identify the safe area in the parieto-occipital lobe in healthy subjects.

METHODS

Subjects

We recruited 47 healthy subjects (men, 27; women, 20; mean age, 34.3 ± 11 years; range, 20–54 years) with no previous history of neurological, physical, or psychiatric illness. All subjects understood the purpose of the study and provided written, informed consent before participation. The study protocol was approved by the Institutional Review Board of a university hospital.

Diffusion Tensor Tractography

DTI data were acquired using a 6-channel head coil on a 1.5-T Philips Gyroscan Intera (Philips, Ltd., Best, the Netherlands) with single-shot echo-planar imaging. For each of the 32 noncollinear diffusion sensitizing gradients, we acquired 60 contiguous slices parallel to the anterior commissure-posterior commissure line. Imaging parameters were as follows: acquisition matrix = 96 × 96; reconstructed to matrix = 128 × 128 matrix; field of view = 221 × 221 mm^2; TR = 10,726 ms; TE = 76 ms; parallel imaging reduction factor (SENSE factor) = 2; EPI factor = 59; b = 1000 s/mm^2; NEX = 1; and a slice thickness of 2.3 mm (acquired voxel size 1.73 × 1.73 × 2.3 mm^3). Eddy current-induced image distortions were removed using affine multiscale 2-dimensional registration at the Oxford Centre for Functional Magnetic Resonance Imaging of Brain Software Library (FSL; www.fmrib.ox.ac.uk/fsl) (20). We reconstructed 11 neural tracts (corticospinal tract [CST], somatosensory tract [SST], corticoreticular pathway [CRP], fornix, cingulum, SLF, MLF, ILF, IFOF, AF, and OR) using DTI-Studio software (CMRM, Johns Hopkins Medical Institute, Baltimore, Maryland, USA) (12). Fiber tracking was based on the fiber assignment continuous tracking algorithm and a multiple regions of interest (ROIs) approach. Two ROIs were placed on the known anatomic CST area: ROI 1, anterior portion of the upper pons on the axial image (blue color) and ROI 2, anterior portion of the lower pons on the axial image (blue color) (**Figure 1**) (9, 15); for the STT area: ROI 1, posterior portion of the upper pons on the axial image (blue color) and ROI 2, posterior portion of the lower pons on the axial image (blue color) (10); for the CRP area: ROI 1, reticular formation of the medulla on the axial image and ROI 2, tegmentum of the midbrain on the axial image (24); for the fornix area, ROI 1, junction between column and body on the axial image and ROI 2, junction between body and crus on the coronal image (3); for the cingulum area, ROI 1, anterior portion of the cingulum on the coronal image (green color) and ROI 2, middle portion of the cingulum on the coronal image (green color) (3); for the SLF area, ROI 1, a triangular shape just lateral to the CST near the anterior horn of the lateral ventricle on the coronal image and ROI 2, a triangular shape near the posterior horn of the lateral ventricle where the tracts ran from posterior to anterior on the coronal image (7); for the MLF area, ROI 1, the white matter of the superior temporal gyrus (anterior portion) on the coronal slice and ROI 2, the white matter of the superior temporal gyrus (posterior to the ROI 1) on the coronal slice (16); for the ILF area, ROI 1, surrounded the white matter of the anterior temporal lobe on the axial slice and ROI 2, around the white matter of the occipital lobe (1); for the IFOF area, ROI 1, the external capsule of the coronal section near the anterior horn of the lateral ventricle and ROI 2, around the white matter of the occipital lobe (1); for the AF area, ROI 1, the deep white matter of the posterior parietal portion of the SLF on the axial image (green color) and ROI 2, the posterior temporal lobe on the axial image (blue color) (19); and for the OR area, ROI 1, the lateral geniculate nucleus on the axial image and ROI 2, the bundle of OR at the middle portion between the lateral geniculate nucleus and occipital pole (6). Fiber tracking was started at any seed voxel with a fractional anisotropy of >0.2 and ended at a voxel with a fractional anisotropy of <0.2 and a tract turning angle of <60 degrees (13).

Measurement of the Safe Area in 5 Axial Levels

The safe area was measured in the 5 axial levels from the upper cortex to the lower corona radiata (CR) level; the upper cortex level, 46.4 ± 3.3 mm above the bicommissure level (the first axial image that can be seen on both AC and PC); the lower cortex level, 39.3 ± 3.2 mm above the bicommissure level; the centrum semiovale (CS) level, 31.1 ± 2.6 mm above the bicommissure level; the upper CR level, 23.7 ± 2.2 mm above the bicommissure level; and the lower CR level, 18.7 ± 1.9 mm above the bicommissure level.

The safe area, which is free from any trajectory of 11 neural tracts (CST, SST, CRP, fornix, cingulum, SLF, MLF, ILF, IFOF, AF, and OR), was defined as shown in **Figure 1**. We set the line of the most posterior margin of the brain and the line of the most lateral margin of the brain. The anterior boundary of the safe area was then defined using the standard of the most posterior point free from any trajectory of 10 neural tracts and was measured anteriorly from the line of the most posterior margin of the brain in the anteroposterior direction. The medial boundary of the safe area was defined using the standard of the most lateral point free from any trajectory of 10 neural tracts and was measured medially from the line of the most lateral margin of the brain in the mediolateral direction. The anterior boundary of the common safe area was defined using the standard of the most posterior point of the safe area for all 5 axial levels and the medial boundary of the common safe area was defined using the standard of the most lateral point of the safe area for all 5 axial levels. The anterior and medial boundaries of the safe area were calculated as an individual pixel unit and converted to millimeters. In addition, the anterior and medial boundaries of the safe area were represented as percentage divided by the entire distance between the line of the most anterior margin of the brain and the line of the most posterior margin of the brain in the anteroposterior direction, and the distance between the midline and the line of the most lateral margin of the brain in the mediolateral direction.

Statistical Analysis

The SPSS program (version15.0; SPSS, Chicago, Illinois, USA) was used for statistical analysis. The safe area point was used for determination of variances between the right and left hemispheres, between men and women. The significant level of the P value was set at 0.05.