Distribution and Network of Basal Temporal Language Areas: A Study of the Combination of Electric Cortical Stimulation and Diffusion Tensor Imaging

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■ OBJECTIVE: **The basal temporal language area (BTLA) is considered to have several functions in language processing; however, its brain network is still unknown. This study investigated the distribution and networks of the BTLA using a combination of electric cortical stimulation and diffusion tensor imaging (DTI).**

■ METHOD: **10 patients with intractable focal epilepsy who underwent presurgical evaluation with subdural electrodes were enrolled in this study (language dominant side: 6 patients, language nondominant side: 4 patients). Electric stimulation at 50 Hz was applied to the electrodes during Japanese sentence reading, morphograms (kanji) reading, and syllabograms (kana) reading tasks to identify the BTLA. DTI was used to identify the subcortical fibers originating from the BTLA found by electric stimulation.**

■ RESULTS: **The BTLA was found in 6 patients who underwent implantation of the subdural electrodes in the dominant hemisphere. The BTLA was located anywhere between 20 mm and 56 mm posterior to the temporal tips. In 3 patients, electric stimulation of some or all areas within the BTLA induced disturbance in reading of kanji words only. DTI detected the inferior longitudinal fasciculus (ILF) in all patients and the uncinate fasciculus (UF) in 1 patient, originating from the BTLA. ILF was detected from both kanji-specific areas and kanji-nonspecific areas.**

■ CONCLUSION: **This study indicates that the network of the BTLA is a part of a ventral stream and is mainly composed of the ILF, which acts as a critical structure for lexical retrieval. ILF is also associated with the specific processing of kanji words.**

INTRODUCTION

The basal temporal language area (BTLA) was first described in patients with temporal lobe epilepsy (TLE) who underwent implantation of subdural electrodes.[1] The application of electric stimuli to the fusiform gyrus 3 cm to 7 cm from the temporal tip at a high intensity caused global receptive and expressive aphasia without disturbance of visual memory or constructional apraxia. Electric stimulation at a lower intensity induced only anomia.[1,2] These areas were considered to have several functions in language processing and are known as BTLAs. These studies reported that surgical resection of these areas produced no lasting language deficit. By contrast, several other reports showed that alexia or agraphia of kanji (morphograms), 1 of the Japanese writing systems, was caused by a lesion in the left fusiform gyrus or in the posterior inferior temporal region, which indicates that the BTLA plays an important role especially in Japanese language processing.[3,4] The other report emphasizes the importance of preserving BTLAs in the subtemporal hippocampectomy to improve verbal memory outcomes.[5] The Japanese language has a unique feature that its written sentences consist of both morphograms (kanji) and syllabograms (kana). Kanji characters, which originated in China, are visual figures strongly associated with semantics, and thus their pronunciations

Key words
- Basal temporal language area
- Diffusion tensor imaging
- Electric cortical stimulation
- Language processing

Abbreviations and Acronyms
BTLA: Basal temporal language area
CT: Computed tomography
DTI: Diffusion tensor imaging
IFOF: Inferior fronto-occipital fasciculus
ILF: Inferior longitudinal fasciculus
MLF: Middle longitudinal fasciculus
MRI: Magnetic resonance imaging
ROI: Region of interest
SLF: Superior longitudinal fasciculus
TLE: Temporal lobe epilepsy
UF: Uncinate fasciculus
VLA: visual language area

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Citation: World Neurosurg. (2017) 106:1-8.
http://dx.doi.org/10.1016/j.wneu.2017.06.116

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

depend on the context in which they appear. Kana letters are phonologic entities somewhat comparable with the alphabet in European languages. Although recent advancements in neuroscience have elucidated complex and dynamic mechanisms of language processing, the networks associated with the BTLA are still unknown. Furthermore, only a few studies have described the processing of kanji words.[6,7]

This study investigated, by using a combination of electric cortical stimulation and diffusion tensor imaging (DTI), the networks associated with the BTLA, including the areas that process kanji words specifically.

METHOD

Patient Population

Ten patients (6 men, 1 left-handed and the rest right-handed, median age 30 years (range, 14–47 years) with intractable focal epilepsy who underwent presurgical evaluation with subdural electrodes between May 2015 and October 2016 were enrolled in this study. Table 1 shows the clinical characteristics of the patients. No patient had gross language deficits, and this was confirmed by extensive neuropsychologic evaluation in all the patients. The results of their presurgical neurologic examinations were unremarkable. The language dominant hemispheres were judged to be on the left in 9 patients and on the right in 1 patient by the Wada test or functional magnetic resonance imaging (MRI). These patients underwent craniotomies to implant subdural electrodes to locate the epileptogenic zone and functional areas for presurgical evaluation. Consequently, the subdural electrodes were implanted in the language dominant sides in 6 patients (Patients 1–6) and in the language nondominant sides in 4 patients (Patients 7–10). This study was approved by the Ethical Committee of Sapporo Medical University Graduate School of Medicine (No. 23-161), and written informed consent was obtained from all the patients.

Image Acquisition and Processing

All patients underwent preoperative neuroimaging with a 3-T MR scanner (Signa HDxt 3.0T version16, GE Health Care, Fairfield, Connecticut) equipped with an 8-channel head coil. Diffusion-weighted images were collected using the 18-direction diffusion-encoding scheme with a 220-mm field of view and a 128 × 128 matrix (1.72 × 1.72-mm pixels), a 2.4-mm slice thickness, and a maximum b-value of 1000 seconds/mm^2. The anatomic MR image for each patient was used to construct skull-stripped 3-dimensional anatomic MR images, and individual diffusion-weighted image volumes were realigned to the subject's skull-stripped anatomical MR image with iPLAN Cranial 3.0 (Brainlab, Feldkirchen, Germany).

Implantation of Electrodes

Subdural electrodes were implanted in the lateral and basal aspects of the temporal lobes in all patients. The grids consisted of 2 or 4 rows, each row containing 5 to 8 platinum electrodes, with a 10-mm center-to-center interelectrode distance. Disc-shaped electrodes 4.0 mm in diameter were embedded in Silastic sheets with an exposed surface 2.3 mm in diameter. The strip consisted of a single row of 6 electrodes of the same configuration as used for grids. The locations of the implanted electrodes were determined using a presurgical 3-dimensionally reconstructed MRI image coordinated with postoperative high-resolution volumetric computed tomography (CT) (1-mm slice thickness) to provide a visual correlation between each electrode position and the corresponding cortical area or deep structure (Figure 1).

Evaluation of Language Functions in the BTLA

Cortical electric stimulation was performed for functional mapping as part of the routine presurgical evaluation in a monopolar fashion. Repetitive square wave electric currents of alternating polarity with a pulse width of 0.3 millisecond were delivered at a frequency of 50 Hz for 5 seconds. The electric current was

Table 1. Patient Profile

Pt	Age/sex	Handedness	Language Dominant Side (assessment)	Side of Implantation	Diagnosis	Presurgical WAIS-R		
						PIQ	VIQ	FIQ
1	45F	Lt	Rt (Wada)	Rt	Rt TLE	59	55	53
2	35M	Rt	Lt (fMRI)	Lt	Lt TLE	110	101	106
3	22F	Rt	Lt (Wada)	Lt	Lt TLE	58	59	55
4	22M	Rt	Lt (Wada)	Lt	Lt TLE	99	101	100
5	28M	Rt	Lt (Wada)	Lt	Lt TLE	80	77	76
6	39F	Rt	Lt (Wada)	Lt	Lt TLE	99	94	106
7	14M	Rt	Lt (Wada)	Rt	Rt FLE	-	-	-
8	47M	Rt	Lt (Wada)	Rt	Rt TLE	75	84	78
9	31M	Rt	Lt (fMRI)	Rt	Rt PLE	84	76	78
10	17F	Rt	Lt (fMRI)	Rt	Rt TLE	87	75	78

Pt, patient; WAIS-R, Wechsler Adult Intelligence Scale-Revised; PIQ, performance IQ; VIQ, verbal IQ; FIQ, Full-scale IQ; F, female; Lt, left; Rt, right; M, male; Wada, Wada test; TLE, temporal lobe epilepsy; M, male; fMRI, functional MRI; FLE, frontal lobe epilepsy; PLE, parietal lobe epilepsy.