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Bidirectional neural connectivity between basal temporal and posterior language areas in humans

Kunihiko Araki [a], Kiyohito Terada [a,*], Keiko Usui [a], Naotaka Usui [b], Yasukiyo Araki [a], Koichi Baba [b], Kazumi Matsuda [b], Takayasu Tottori [b], Yushi Inoue [c]

[a] Department of Neurology, National Epilepsy Center, Shizuoka Institute of Epilepsy and Neurological Disorders, Japan
[b] Department of Neurosurgery, National Epilepsy Center, Shizuoka Institute of Epilepsy and Neurological Disorders, Japan
[c] Department of Psychiatry, National Epilepsy Center, Shizuoka Institute of Epilepsy and Neurological Disorders, Japan

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HIGHLIGHTS

- Basal temporal language area (BTL) plays an important role to convert visual semantic information into phonological representation.
- Neural connectivity between BTL and other language areas is not well known, because no study of direct BTL stimulation has been reported.
- We demonstrated the neural connectivity between BTL and Wernicke's language area by cortico-cortical evoked potential method.

ABSTRACT

Objective: The basal temporal language area (BTL) is known to be involved in the semantic processing of language. To investigate the neural connectivity between BTL and the posterior language area (PL), we used cortico-cortical evoked potential (CCEP) technique.
Methods: Four patients with intractable epilepsy who underwent presurgical evaluation with subdural electrodes were examined. All patients were right-handed and left language dominance by Wada test. We directly stimulated 20 pairs of electrodes placed on BTL in patient 1–3, putative BTL in patient 4, and PL in patient 1–4. In patient 4, all electrodes on the left temporal basal area were stimulated.
Results: We could record 132 CCEP responses including 40 responses by the left basal temporal stimulation in patient 4. The waveforms from PL to BTL were triphasic, while those from BTL to PL were biphasic. The mean latency of the first negative peak (N1) was shorter at BTL (31.8–41.0 ms; mean 35.1 ms) than at PL (39.6–73.2 ms; mean 52.3 ms).
Conclusions: We revealed the uneven bidirectional connection between BTL and PL.
Significance: We speculated that the two language areas are connected mainly through subcortical fibers from PL to BTL and through cortico-cortical fibers from BTL to PL, mediated by multisynaptic transmissions.

1. Introduction

Since the pioneering attempts of Penfield and Jasper (1954) to localize higher brain functions by electrical stimulation, many studies of functional localization have been conducted, in which language is one of the most sophisticated areas. Penfield described two cortical language areas; Broca's area and Wernicke's area (posterior language area: PL). Lüders et al. (1991) defined another language area in the fusiform (occipitotemporal) gyrus of the dominant temporal lobe, which they named basal temporal language area (BTL). The BTL has been studied using function magnetic resonance imaging (fMRI) (Binder et al., 1997; Cohen et al., 2000), positron emission tomography (Gross-Glenn et al., 1991; Cabeza and Nyberg, 2000), magnetoencephalography (Tarkiainen et al.,

Abbreviations: BTL, basal temporal language area; PL, posterior language area; CCEP, cortico-cortical evoked potential.

* Corresponding author. Address: Department of Neurology, National Epilepsy Center, Shizuoka Institute of Epilepsy and Neurological Disorders, 886 Urushiyama, Aoi-ku, Shizuoka 420-8688, Japan.
E-mail address: kyht-terada@umin.net (K. Terada).

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Table 1
Profiles of individual patients.

Patient	1	2	3	4
Age/sex	46/M	37/F	23/F	18/M
Handedness/language dominancy[a]	R/L	R/L	R/L	R/L
Side of the implanted electrodes	Bilateral	L	L	Bilateral
Diagnosis	TLE	R TLE	L TLE	L TLE
Surgery	No surgery	SAH	ATL	SAH
Etiology	–	HS	FCD	NS
Seizure outcome (Engel)	–	I-a	I-a	II-b

[a] Language dominance was determined by Wada test. R = right, L = left, TLE = temporal lobe epilepsy, SAH = selective amygdalohippocampectomy, ATL = anterior temporal lobectomy, HS = hippocampal sclerosis, FCD = focal cortical dysplasia, NS = nonspecific.

2002; Bowyer et al., 2005), and event-related potentials (Nobre et al., 1994). According to these studies, BTL presumably plays a role in converting visual semantic information into phonological representation (Usui et al., 2003, 2005). Resection of BTL produces transient language disruptions (Krauss et al., 1996). However, the neural connectivity between BTL and other language areas has not been demonstrated.

Matsumoto et al. (2004, 2007) introduced a new electrophysiological technique named "cortico-cortical evoked potential (CCEP)" for in vivo evaluation of neural fibers in humans. Using this technique, we have studied the neural connections of motor and basal temporal regions (Terada et al., 2008, 2012; Umeoka et al., 2009). In the present study, we attempted to clarify the neural connectivity between BTL and PL also using the CCEP method.

2. Methods

2.1. Patients

We studied four patients with medically intractable temporal lobe epilepsy who underwent chronic subdural electrode implantation because of inconclusive results from noninvasive presurgical evaluation (Table 1). The data from the same persons investigated in this study have already been published elsewhere (Terada et al., 2008, 2012; Umeoka et al., 2009). Language dominance was determined by the Wada test. All patients were right handed, with left hemisphere-dominance for language (Table 1). Neurological examinations were normal in all patients. MRI revealed right hippocampal atrophy in patient 2, focal cortical dysplasia of the left inferior temporal gyrus in patient 3, and was normal in patients 1 and 4. To delineate the epileptogenic area, video-EEG monitoring and single photon emission computed tomography were performed in all patients. Neuropsychological test was also performed in all patients before surgery (Table 1).

Intracranial electrodes made of platinum-iridium alloy and 2.3 mm in diameter were implanted bilaterally (patients 1 and 4) or in the left (patients 2 and 3) hemisphere (Table 1, Figs. 1–4). The center-to-center inter-electrode distance was 10 mm. Electrode placement in each patient is indicated in Figs. 1–4: patient 1; temporo-parietal anterior (TPA) and posterior grid (TPP, 2 × 6), left temporo-occipital superior (LTOS) and inferior grid (LTOI, 2 × 6), left anterior temporal strip (LAT, 1 × 6), left basal anterior strip (LBA, 1 × 6), left basal posterior strip (LBP, 1 × 6): patient 2; left temporo-occipital superior (LTOA) and inferior grid (LTOB,

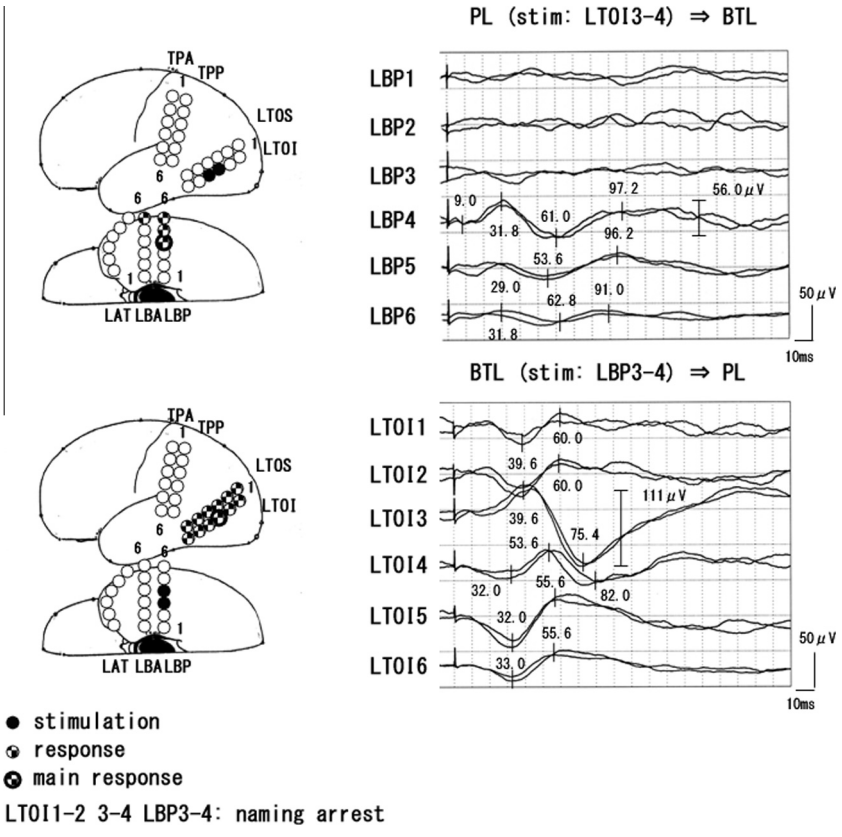

Fig. 1. Illustration of the cortico-cortical evoked potentials (CCEPs) in patient 1. The double filled circles denote the stimulation site. Checkered circle denotes the responding site. The circle with a bold edge (LBP4 and LTOI3) denotes the main response defined as the largest V1 among all responded electrodes. PL was localized at LTOI1–2 and 3–4, and BTL was localized at LBP3–4. TPA = temporo-parietal anterior, TPP = temporo-parietal posterior, LTOS = left temporo-occipital superior, LTOI = left temporo-occipital inferior, LAT = left anterior temporal, LBA = left basal anterior, LBP = left basal posterior, BTL = basal temporal language, PL = posterior language.