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Surgical treatment for epilepsy involving language cortices: A combined process of electrical cortical stimulation mapping and intra-operative continuous language assessment

Xi Zhang, Guojun Zhang, Tao Yu, Duanyu Ni, Lixin Cai, Liang Qiao, Wei Du, Yongjie Li *

Beijing Institute of Functional Neurosurgery, Department of Functional Neurosurgery, Xuanwu Hospital, Capital Medical University, China

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ABSTRACT

Objective: The purpose of this study was to improve the surgical treatment of epilepsy by maximising seizure control while protecting language function.
Methods: A combined process of extra-operative electrical cortical stimulation (ECS) mapping, direct ECS and intra-operative continuous language assessment was performed during complicated operative cases. Of the 24 epilepsy patients, nine had a complex relationship between the seizure onset zone and the language cortices. The combined process was used in these nine patients. In the other 15 patients, surgical resection was completed based on extra-operative ECS results alone. Evaluations were performed before and after surgery to assess language function and seizure control.
Results: The intra-operative continuous language assessment provided important information at the time of the resection. Seven extra-operative ECS positive language sites were resected without obvious language deficits in two patients. Resection was interrupted by language disturbances in an area where no extra-operative ECS positive site was identified in one patient. In three other patients, functional boundary was undefined in extra-operative ECS result, epileptogenic cortices were maximally resected during the continuous language assessment. In terms of seizure control, 18 of 24 (75%) patients reached Engel's class I, including all nine patients who underwent intra-operative continuous language assessment. One patient had minor surgery-related language deficits three months after resection.
Conclusions: Intra-operative continuous language assessment proved to be complementary to extra-operative ECS mappings. The combination of ECS mappings and intra-operative continuous language assessment can maximise the resection of epileptogenic cortices and preserve language function in difficult cases involving the language cortex.

1. Introduction

The protection of patients' language function is critical during brain surgery involving the language cortices. When surgery involves the dominant hemisphere, the risk of language impairment is increased. Despite the progress made in the localisation of language areas,[1,2] it remains difficult to perform resections involving the language cortex in some complex cases.

Electrical cortical stimulation (ECS) is the gold standard of language mapping in epilepsy surgery.[3] Cortical mapping with ECS is widely used and can effectively protect language function in the context of epilepsy surgery. Typically, either extra- or intra-operative ECS mapping is used separately to identify the language cortex.[3,4] However, in some intricate cases, such as those with undefined ECS results, the risk of functional impairment is increased, rendering surgery more difficult. Discrepancies have been found between extra- and intra-operative ECS language mapping results, as well as between ECS mapping results and post-operative language evaluation outcomes.[5,6] Besides, cerebral language organisation in humans is complex, and individual variability exists in the distribution of the language area. This means that it is best to locate language function with multiple methods.[7] Thus, further methodological optimisation is needed, particularly in patients with ambiguous ECS results.

This study focuses on the surgical treatment for patients with a complex relationship between seizure onset zone and language cortex, as identified by extra-operative ECS. In these patients, surgery may damage language function or the epileptogenic cortices may not be resected completely if we use extra-operative

* Corresponding author at: Beijing Institute of Functional Neurosurgery, Department of Functional Neurosurgery, Xuanwu Hospital, Capital Medical University, 45 Changchun Avenue, Beijing 100053, China.
Tel.: +86 10 8319 8882; fax: +86 10 8316 3174.
E-mail address: lyj8828@vip.sina.com (Y. Li).

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ECS alone. We combined the extra-operative ECS with direct ECS and intra-operative continuous language assessment to maximise seizure onset zone resection while protecting language function. In addition, we analysed the discrepancies between the different assessment stages and designed language tasks in order to design surgical strategies for the complicated cases. No previous reports have systematically described the methods and results of this combined process.

2. Methods

Twenty-four patients with epilepsy underwent subdural electrode implantation and extra-operative ECS language mapping. Complex relationships between the language cortices and the seizure onset zones were found in nine patients. These nine patients underwent continuous language assessment during surgical resection. In order to verify language function and seizure control, all 24 patients were evaluated before and after resection.

2.1. Patients

Sixteen males and eight females between 15 and 43 years of age were included in the study. Three were left-handed, one was ambidextrous and the rest were right-handed. All patients had refractory symptomatic partial epilepsy and underwent surgical treatment between September 2009 and June 2011 at the Beijing Comprehensive Epilepsy Centre. All patients met the following criteria: (1) underwent subdural cortical electrode video-electroencephalographic (video-EEG) monitoring and extra-operative ECS language mapping; (2) had a seizure onset zone located close to or overlapping with the classical distribution of the language cortices; and (3) signed an informed consent to participate in this study.

2.2. Non-invasive evaluation

2.2.1. Neuroimaging techniques

Neuroimaging data of all patients were obtained by using standard magnetic resonance imaging (MRI) on a 3.0 T unit with conventional sequences. Thirteen patients had structural abnormalities. The clinical data are summarised in Table 1. Magnetoencephalography (MEG) was used in seven patients to guide the implantation of subdural electrodes.[8]

2.2.2. Video-EEG monitoring

Interictal/ictal scalp electroencephalography (EEG) was recorded using a video-EEG monitoring system (DaVinci; Embla, Broomfield, CO, U.S.A.), according to the international 10–20 system. At least three routine seizures were captured for each patient.

2.2.3. Baseline language testing and follow-up

To investigate the impact of surgery on language function, all patients were evaluated using a validated Chinese version of the Western Aphasia Battery (C-WAB), which is derived from the Western Aphasia Battery (WAB) with modifications based on Chinese linguistic features and culture. The C-WAB is composed of six language-related aspects: fluency, comprehension, repetition, naming, reading and writing. Language function is measured using an index termed an aphasia quotient score (AQs) in the C-WAB; a normal AQs is at least 93.8.The testing was performed before surgery (baseline testing) and then one week and three months after surgery. The serial results for each patient were compared to identify any changes in language function.

2.3. Invasive monitoring

All patients underwent implantation of intracranial electrodes. On the basis of multiple pre-surgical evaluations, including semiology, multiple neuroimaging tests, interictal/ictal scalp EEGs and intra-operative electrocorticography (ECoG), intracranial electrodes were implanted over the patients' cortical areas that were preliminarily identified as the seizure onset zone. The grid electrode is composed of stainless contacts with a 5-mm diameter and a regular centre-to-centre interval of 10 mm; the number of electrode contacts in each patient ranged from 32 to 128. After the subdural electrodes were implanted and fixed, a photograph was taken to identify the topological relationship between the cortical surface and the contacts. The photo was also used to confirm that the same location was stimulated in both the extra- and intra-operative ECS.

2.4. ECS for language mapping

2.4.1. Extra-operative ECS protocol

Extra-operative ECS was performed using a GRASS S-12 Biphasic Stimulator (Grass-Telefactor/Astro-Med, Inc., West Warwick, RI, USA). The current threshold for afterdischarge (AD) was tested at each site before functional testing. Language mapping was performed with the following parameters: frequency of 50 Hz, pulse duration of 0.2 ms and primary intensity of 1 mA. The current intensity was increased by increments of 1 mA until either language disturbance occurred or the intensity reached AD threshold. The maximum intensity was 10 mA if no response occurred.

2.4.2. Extra-operative ECS language tasks and judgement of results

To evaluate the various language functions, a single task was deemed insufficient for extra-operative ECS.[9] In our research, six language tasks were extracted from the C-WAB battery, including basic tasks (spontaneous speech, comprehension and visual naming) and additional tasks (repetition, reading and writing). Spontaneous speech was used as a screening task to test each electrode site. The remaining basic tasks were performed in all sites located in the classical language areas and in all potential resection regions. Additional tasks were selected based on reports of locations where language impairments were evoked during ECS (e.g., writing impairment in the frontal lobe and reading impairment in the temporal and occipitotemporal areas). The testing order was basic tasks first followed by additional tasks. If a definite language impairment (e.g., speech arrest, anomia or wrong naming,) was repeatedly evoked by the stimulation without ADs, this site was designated a complete positive site. There were also some partial impairment signs elicited in the process, such as decreased fluency, semantic paraphasia and tone changes. These partial impairment sites were re-evaluated during surgery.

Tone is of great importance in oral Chinese. Mandarin, the most widely used Chinese language, is a tonal language that uses relatively small pitch variations to alter the meanings of words. A mistake in the tone elicited by ECS means that the meaning of the word was changed. Therefore, tone errors should be identified during ECS.

Language disturbance caused by muscle spasms of the tongue or throat may further complicate the evaluation. In such situations, we asked patients to open their mouths in order to check tongue mobility. Patients were also encouraged to speak despite the language disturbance. If patients had normal tongue mobility but dysarthria, the corresponding cortical site was considered to be either the throat muscle motor cortex or the language cortex.