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Electrocorticographic language mapping in children by high-gamma synchronization during spontaneous conversation: Comparison with conventional electrical cortical stimulation

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Summary
Introduction: This study describes development of a novel language mapping approach using high-γ modulation in electrocorticograph (ECoG) during spontaneous conversation, and its comparison with electrical cortical stimulation (ECS) in childhood-onset drug-resistant epilepsy.
Methods: Patients undergoing invasive pre-surgical monitoring and able to converse with the investigator were eligible. ECoG signals and synchronized audio were acquired during quiet baseline and during natural conversation between investigator and the patient. Using

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High-γ synchronization; Electrical cortical stimulation

Signal Modeling for Real-time Identification and Event Detection (SIGFRIED) procedure, a statistical model for baseline high-γ (70—116 Hz) power, and a single score for each channel representing the probability that the power features in the experimental signal window belonged to the baseline model, were calculated. Electrodes with significant high-γ responses (HGS) were plotted on the 3D cortical model. Sensitivity, specificity, positive and negative predictive values (PPV, NPV), and classification accuracy were calculated compared to ECS.

Results: Seven patients were included (4 males, mean age 10.28 ± 4.07 years). Significant high-γ responses were observed in classic language areas in the left hemisphere plus in some homologous right hemispheric areas. Compared with clinical standard ECS mapping, the sensitivity and specificity of HGS mapping was 88.89% and 63.64%, respectively, and PPV and NPV were 35.29% and 96.25%, with an overall accuracy of 68.24%. HGS mapping was able to correctly determine all ECS+ sites in 6 of 7 patients and all false—sites (ECS+, HGS− for visual naming, $n = 3$) were attributable to only 1 patient.

Conclusions: This study supports the feasibility of language mapping with ECoG HGS during spontaneous conversation, and its accuracy compared to traditional ECS. Given long-standing concerns about ecological validity of ECS mapping of cued language tasks, and difficulties encountered with its use in children, ECoG mapping of spontaneous language may provide a valid alternative for clinical use.

Introduction

The invasive pre-surgical evaluation of certain people with drug-resistant epilepsy (DRE) has two core objectives: localization of the seizure-onset zone and defining its anatomic relationship to the functionally essential cortex. The conventional standard-of-care for language mapping is based on electrical cortical stimulation (ECS) and use of cued response-inhibition paradigms. In addition to being time intensive, ECS is critically dependent on patient cooperation in a setting with several potential barriers to optimal patient participation. Additionally, ECS incurs risks of pain from inadvertent stimulation of dura mater and triggering after-discharges and even seizure(s), particularly in children where the threshold for clinical response-inhibition exceeds that for triggering after-discharges (Jayakar and Lesser, 2008). The choice of visual naming tasks for language mapping is based on a heuristic that nominal difficulties are encountered in virtually every type of aphasia, and preservation of naming sites would protect against post-surgical language deficits. However, it is recognized that dysnomia is often seen in the context of auditory conceptually based discourse, rather than as difficulty naming environmental objects (Hamberger, 2007). There is a lack of uniformity in language testing protocols used across the centers; and a majority of tasks lack sufficient external validity (Hamberger, 2007). More fundamentally, electrical interruption of cued cortical responses probably fails to capture the structure and function of human language networks under natural conditions and their reorganization in children with DRE.

In cognizance of these shortcomings, alternative approaches based on spectral changes associated with language processing have been investigated. Electrocorticograph (ECoG) high-γ modulation related to covert and overt word production has been shown to correspond with conventional neuroanatomical localization of language cortex (Pei et al., 2011). In a study including 13 patients, event-related synchronization in the high-γ frequency band (80—100 Hz) was observed to have 43% sensitivity and 84% specificity compared with ECS for language mapping with a visually cued naming task (Sinai et al., 2005). Whereas this method circumvents the procedure-related risks of ECS, it does not address the issue of dependence on patient cooperation and the validity of picture naming tasks. In pediatric patients, a particular concern regarding the use of trial-based experimental designs is the dependence on continuous patient cooperation and attention. Although trials presented in blocks facilitate reproducibility and convenient reference times for analyses, they require sustained attention, and may not represent a realistic model of natural behavior.

Recently, attempts have been made to study high-γ changes associated with spontaneous conversation with increased high-γ power over perisylvian frontal lobe and posterior superior temporal gyrus (STG) being reported in 2 patients (Towle et al., 2008). More recently, high- γ mapping of retrospectively identified non-experimental speech production was found to have 96.7% specificity, but only 18.9% sensitivity compared with either oral motor or language function detected by ECS in 3 adults. The authors concluded that their procedure was not usable for clinical language mapping (Ruescher et al., 2013). The present prospective study compares language mapping using high-γ modulation associated with spontaneous interpersonal conversation with conventional ECS using visual naming tasks in patients with childhood-onset DRE. We believe this approach is likely to allow functional mapping of language networks under almost natural, experimentally unconstrained, conditions.

Methods

Participants and experimental protocol

All patients with DRE admitted for invasive pre-surgical evaluation after April 2012 were eligible for inclusion. However,