Clinical Neurophysiology 124 (2013) 1737–1744

Contents lists available at SciVerse ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Gamma activity modulated by picture and auditory naming tasks: Intracranial recording in patients with focal epilepsy

Katsuaki Kojima [a], Erik C. Brown [e,f], Naoyuki Matsuzaki [a], Robert Rothermel [d], Darren Fuerst [b], Aashit Shah [b], Sandeep Mittal [c], Sandeep Sood [c], Eishi Asano [a,b,*]

[a] Department of Pediatrics, Wayne State University, Detroit Medical Center, Detroit, MI 48201, USA
[b] Department of Neurology, Wayne State University, Detroit Medical Center, Detroit, MI 48201, USA
[c] Department of Neurosurgery, Wayne State University, Detroit Medical Center, Detroit, MI 48201, USA
[d] Department of Psychology, Wayne State University, Detroit Medical Center, Detroit, MI 48201, USA
[e] Psychiatry and Behavioral Neurosciences, Wayne State University, School of Medicine, Detroit, MI 48201, USA
[f] Wayne State University, School of Medicine, Detroit, MI 48201, USA

See Editorial, pages 1710–1711

ARTICLE INFO

Article history:
Available online 18 May 2013

Keywords:
Epilepsy surgery
Intracranial ECoG recording
Ripples
High-frequency oscillations (HFOs)
Language
Speech
Outcome

HIGHLIGHTS

- Picture- and auditory-naming tasks differentially augmented gamma activity.
- Older patients showed more extensive gamma-augmentation in the left dorsolateral-premotor area.
- Both picture- and auditory-naming-related gamma-augmentation predicted language outcome.

ABSTRACT

Objective: We measured the spatial, temporal and developmental patterns of gamma activity augmented by picture- and auditory-naming tasks and determined the clinical significance of naming-related gamma-augmentation.
Methods: We studied 56 epileptic patients (age: 4–56 years) who underwent extraoperative electrocorticography. The picture-naming task consisted of naming of a visually-presented object; the auditory-naming task consisted of answering an auditorily-presented sentence question.
Results: Naming-related gamma-augmentation at 50–120 Hz involved the modality-specific sensory cortices during stimulus presentation and inferior-Rolandic regions during responses. Gamma-augmentation in the bilateral occipital and inferior/medial-temporal regions was more intense in the picture-naming than auditory-naming task, whereas that in the bilateral superior-temporal, left middle-temporal, left inferior-parietal, and left frontal regions was more intense in the auditory-naming task. Patients above 10 years old, compared to those younger, showed more extensive gamma-augmentation in the left dorsolateral-premotor region. Resection of sites showing naming-related gamma-augmentation in the left hemisphere assumed to contain essential language function was associated with increased risk of post-operative language deficits requiring speech therapy ($p < 0.05$).
Conclusions: Measurement of gamma-augmentation elicited by either naming task was useful to predict postoperative language deficits.
Significance: A smaller degree of frontal engagement in the picture-naming task can be explained by no requirement of syntactic processing or less working memory load. More extensive gamma-augmentation in the left dorsolateral-premotor region in older individuals may suggest more proficient processing by the mature brain.

* Corresponding author. Address: Division of Pediatric Neurology, Children's Hospital of Michigan, Wayne State University, 3901 Beaubien St., Detroit, MI 48201, USA. Tel.: +1 313 745 5547; fax: +1 313 745 0955.
E-mail address: eishi@pet.wayne.edu (E. Asano).

1388-2457/$36.00 © 2013 International Federation of Clinical Neurophysiology. Published by Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.clinph.2013.01.030

1. Introduction

Important cognitive functions in humans include overt naming to visually- and auditorily-presented stimuli. Regardless of the modalities of stimuli initially perceived by sensory cortices, naming behaviors commonly consist of understanding of the meaning of stimuli, followed by formation and articulation of a relevant answer. To localize the brain regions responsible for overt naming, investigators have measured naming-related augmentation of gamma activity at 50–120 Hz recorded on intracranial electrocorticography (ECoG) (Sinai et al., 2005; Tanji et al., 2005; Towle et al., 2008; Wu et al., 2010; Miller et al., 2011; Kojima et al., 2012a,2013). Thereby, cortical sites showing naming-related gamma-augmentation were co-localized within language-related sites defined by electrical stimulation with statistically-significant accuracy. Our previous ECoG study of 13 epileptic patients with left-hemispheric language dominance on Wada test demonstrated that resection of the left superior-temporal, inferior-frontal, dorsolateral-premotor, and inferior-Rolandic sites showing auditory-naming-related gamma-augmentation predicted postoperative language deficits requiring speech therapy (Kojima et al., 2012a). Thus, we defined the summation of these four regions of interest as the '*canonical language region*'. Our recent ECoG study of 77 epileptic patients demonstrated that the risk of postoperative language deficits requiring speech therapy was predicted by resection of the sites showing auditory-naming-related gamma-augmentation in the canonical language region of the left hemisphere assumed to contain essential language function (Kojima et al., 2013); thereby, left-handed patients with left-sided seizure foci and early-onset left-sided neocortical lesions were assumed to have right-hemispheric language dominance, while the remaining patients were assumed to have essential language function still existing in the left hemisphere (Rasmussen and Milner, 1977; Akanuma et al., 2003; Möddel et al., 2009). Importantly, the prediction performance of gamma-augmentation measures remained significant, even after controlling for the effects of electrical stimulation or the extent of resection involving the canonical language region (Kojima et al., 2013). Thus, measurement of auditory-naming-related gamma-augmentation is warranted in presurgical evaluation of epilepsy.

As it has been previously suggested that auditory and visual naming tasks engage different cortices, a visual naming task may also improve the presurgical prediction of essential language sites. In this study, we addressed the following issues: (i) We determined the spatial–temporal patterns of picture- and auditory-naming-related gamma-augmentation on ECoG, and determined the common and differential gamma-augmentation elicited by two different naming tasks. It remains uncertain how extensively regions outside the modality-specific sensory cortices will show common or differential gamma-augmentation. If differential gamma-augmentation is observed extensively outside the sensory cortices, assignment of two naming tasks will be encouraged in presurgical evaluation to increase the sensitivity for localizing the cortical regions involved in naming. (ii) We determined whether patients above 10 years, compared to those younger, showed more extensive engagement in the left dorsolateral-premotor and right inferior-frontal regions during the picture-naming task, as demonstrated in our previous study of auditory-naming-related gamma-augmentation (Kojima et al., 2013) as well as studies using functional MRI (fMRI) (Adleman et al., 2002; Gaillard et al., 2003; Brown et al., 2005; Szaflarski et al., 2006). The replication of such developmental ECoG changes in a naming task involving a separate sensory modality would further support the concept of age-dependent utilization of the aforementioned sites. (iii) We finally determined whether a post-operative language deficit requiring speech therapy would be predicted by a logistic regression model incorporating picture-naming-related gamma-augmentation measures.

2. Methods

2.1. Patients

This study has been approved by the Institutional Review Board at Wayne State University. The inclusion criteria consisted of: (i) patients with focal epilepsy who underwent extraoperative subdural ECoG recording as a part of presurgical evaluation in Children's Hospital of Michigan or Harper University Hospital in Detroit between January 2007 and May 2012; (ii) language mapping using measurement of gamma-augmentation elicited by the picture-naming task (Wu et al., 2011) and that elicited by the auditory-naming task (Brown et al., 2012; Kojima et al., 2012a); and (iii) written informed consent obtained by patients or their guardians.

2.2. Definition of anatomical regions of interest

The anatomical regions of interest included: the superior-temporal region (BA 22/41/42), inferior-frontal region (inferior frontal gyrus involving BA 44/45), dorsolateral-premotor region (dorsolateral portion of BA 6), and inferior-Rolandic region (BA 4/3/1/2 not more than 4 cm superior from the sylvian fissure; Haseeb et al., 2007; Fukuda et al., 2008) (Fig. 1). The summation of these four regions was referred to here as the '*canonical language region*' (Kojima et al., 2013).

In addition, the present study described: the middle-temporal region (middle temporal gyrus involving BA 21/37), inferior-temporal region (inferior temporal gyrus involving BA 20/37), medial-temporal region (BA 27/28/34/35/36), medial-occipital region (medial portion of BA 17/18), polar-occipital region (polar portion of BA 17/18), inferior-occipital region (inferior portion of BA 19/37), lateral-occipital region (lateral portion of BA 19/37), inferior-parietal region (BA 39/40), middle/superior-frontal region (lateral portion of BA 46/9/8) and medial-frontal region (medial portion of BA 6/8 and posterior portion of BA 24/32/33), bilaterally (Brodmann, 1909; Mitelman et al., 2003; Matsuzaki et al., 2012; Kojima et al., 2013; Fig. 1).

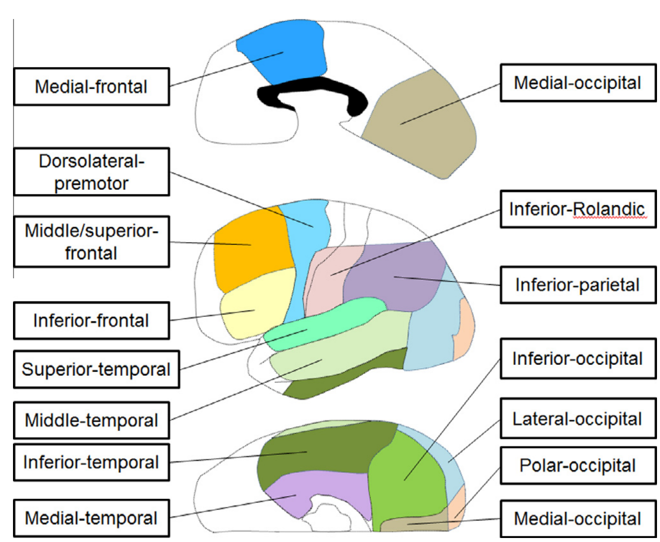

Fig. 1. Definition of anatomical regions of interest. Regions outside of the aforementioned 14 regions were collectively defined as 'other', in each hemisphere.