

# Impact of Electrocorticographic High Gamma Activity Mapping on Language Outcome in Epilepsy Surgery

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## Introduction

Epilepsy surgery represents a critical treatment modality for patients with pharmacoresistant focal epilepsy. While the primary goal of such interventions is the resection of epileptogenic zones to achieve seizure freedom, preserving vital cognitive functions—particularly language—is equally imperative. In cases where the seizure focus resides near or within eloquent cortex, especially in the dominant hemisphere, the surgical challenge becomes twofold: optimizing resection while minimizing the risk of permanent language deficits. To navigate this balance, presurgical functional mapping plays a crucial role in delineating cortical areas responsible for language processing. Traditionally, Electrical Stimulation Mapping (ESM) has been the gold standard for identifying language-eloquent cortex during neurosurgical procedures. However, ESM is time-consuming, can induce after-discharges or seizures and relies on a relatively coarse sampling of cortical activity. In recent years, electrocorticography (ECoG) with high gamma activity (HGA; 70–150 Hz) mapping has emerged as a promising alternative or adjunct to ESM. HGA mapping enables real-time monitoring of cortical activity with high temporal and spatial resolution, providing a robust indicator of task-related neuronal engagement [1].

## Description

Electrocorticography involves the placement of electrode grids or strips directly on the cortical surface to record local field potentials. When a patient engages in a cognitive or sensorimotor task, neuronal populations in specific regions exhibit task-related modulations in the high gamma frequency range. These modulations reflect increased local cortical processing and are closely aligned with the hemodynamic responses measured in fMRI and the spiking activity of single neurons. Gamma activity is typically extracted using spectral decomposition techniques such as wavelet transforms or Hilbert transforms. Task-related HGA increases are then compared to baseline periods to identify statistically significant activation. Importantly, HGA mapping can be conducted during naturalistic tasks such as picture naming, reading, or listening to sentences, enabling the delineation of functionally relevant language areas [2].

To implement HGA mapping in clinical settings, several methodological steps are involved. Subdural grids and strips are implanted over regions of interest, typically guided by seizure localization and structural MRI. Language tasks are selected based on the cortical regions under investigation. Data Acquisition and Processing: ECoG signals are recorded during task performance. Signal preprocessing includes filtering, artifact rejection and spectral decomposition. HGA responses are statistically analyzed to identify significant task-related increases. These are overlaid on cortical surface reconstructions for visualization. HGA maps are combined with imaging data and seizure

localization to inform resection boundaries. Several clinical studies have evaluated the efficacy of HGA mapping for preserving language in epilepsy surgery [3].

A study involving pediatric epilepsy patients demonstrated that HGA mapping identified more extensive language-related cortex than ESM. Patients whose resections spared HGA-positive sites exhibited better post-surgical language outcomes. Found that HGA reliably localized Broca's and Wernicke's areas during speech tasks. Postoperative language deficits were minimized when these regions were preserved. Reported that HGA mapping provided faster and more precise language localization than ESM, especially in cases with time constraints or patient non-cooperation. A meta-analysis of studies using HGA mapping showed a strong correlation between high gamma activation and language cortex defined by ESM and fMRI, supporting its validity as a functional mapping tool. Introduced real-time HGA mapping during awake craniotomy, enabling intraoperative adjustments to preserve language areas. Patients showed stable or improved language function postoperatively. Surgeons can define safe resection boundaries by integrating HGA maps with structural and seizure data. Language-positive electrodes are preserved to minimize postoperative deficits [4].

While superior to ESM in some respects, HGA mapping still relies on electrode coverage, which may miss critical regions. Language organization varies widely across individuals, especially in cases of cortical reorganization due to early-onset epilepsy. Requires advanced signal processing skills and interdisciplinary collaboration. Different centers use varying task paradigms and statistical thresholds, complicating comparison and replication. Widespread clinical adoption is limited by equipment costs and the need for specialized personnel. Development of consensus guidelines for task design, signal processing and statistical interpretation. Machine learning approaches to streamline analysis and reduce operator dependency. Combining HGA with fMRI, Diffusion Tensor Imaging (DTI) and Magnetoencephalography (MEG) for comprehensive functional mapping. Emerging technologies may allow for extended monitoring and task flexibility. Incorporating patient-specific models of cortical reorganization to guide mapping in complex cases [5].

## Conclusion

Electrocorticographic high gamma activity mapping represents a transformative advance in the field of functional brain mapping. Its application in epilepsy surgery has significantly improved the precision with which language-eloquent cortex can be identified, enabling safer and more effective resections. Empirical evidence supports its utility in preserving language function, reducing mapping time and accommodating a broader range of patients. While challenges remain, including technical complexity and variability in protocols, ongoing innovations in signal processing, machine learning and multimodal integration promise to enhance its clinical adoption. As the field moves toward more personalized and neuroprotective surgical strategies, HGA mapping stands at the forefront of efforts to reconcile seizure freedom with cognitive preservation. Ultimately, the impact of high gamma activity mapping extends beyond surgical outcomes—it reflects a commitment to preserving the human capacity for language, expression and connection, even in the face of debilitating neurological disease.

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## Conflict of Interest

None.

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