A Standardized Electrode Nomenclature For Stereoelectroencephalography Applications

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Introduction

Stereoelectroencephalography (SEEG) is widely performed on individuals with medically refractory epilepsy for whom invasive seizure localization is desired. Despite increasing adoption in many centers across the world, no standardized electrode naming convention exists, generating confusion amongst both clinical and research teams.

Prior EEG naming schemes have created intolerable confusion and there is currently no accepted and standardized nomenclature for SEEG electrodes. There is a need for an anatomically and spatially informative, trajectory specific, reproducible, and concise naming convention that will greatly facilitate sharing of information across both clinical and research settings within and between institutions.
Methods

We have developed a novel nomenclature, named the Standardized Electrode Nomenclature for SEEG Applications (SENSA) system.

The framework of this nomenclature requires each electrode name be comprised of a minimum of two characters, with more added as dictated by the individual trajectory and its relationship to other electrodes, and begins by assigning an uppercase letter and number to indicate the proximal entry point into the cerebral cortex.

Inter-rater reliability was evaluated by comparing original electrode names from 10 randomly sampled cases to those prospectively assigned by a seconded blinded rater.
Results

The first character is a single uppercase letter denoting the lobe of entry: F – Frontal, P – Parietal, T- Temporal, O – Occipital.

The second character is a digit representing the major gyrus/lobule through which the electrode enters. The most superior gyrus/lobule is indicated by “1” (for example, F1 indicates an entry point into the superior frontal gyrus), and progressively more inferior gyri/lobules are indicated by increasing numbers (for example, P2 indicates an entry point into the inferior parietal lobule).

*A preceding superscript $^\text{L}$ or $^\text{R}$ can denote side if bilateral electrode implantation is planned; patient specific features, such as lesions or vascular structures, can be depicted on brain diagrams*
Results cont.

A third character is a lowercase letter employed when multiple electrodes enter the same gyrus/lobule, in which case they are differentiated based on their relative location in the anterior-posterior (A-P) plane. For example: F1a is the most anterior electrode in the superior frontal gyrus, followed by F1b, and then F1c, etc.

Subsequent characters represent distal electrode targets as required, in the order of proximal to distal along the electrode trajectory, and followed by lowercase letters to identify their relative location in the A-P plane when there is more than one electrode present.
We have prospectively implemented this nomenclature in approximately 40 consecutive patients undergoing SEEG monitoring at our institution, constituting over 500 electrodes.

In a random sample of 10 prior cases with electrode names assigned by the lead neurosurgeon author and developer of the SENSA system (SS), there was 97.5% agreement with electrode names assigned by 4 additional blinded raters familiar with the naming system. Disagreements included errors in the order of naming distal targets along an electrode trajectory, and in assigning relative positions in the A-P plane for certain electrodes.
Left hemisphere gyral/region and target labelling in the SENS A scheme. Frontal and temporal lobes are divided into superior, middle, and inferior frontal/temporal gyri (F1/T1,F2/T2,F3/T3). The parietal lobe is divided horizontally along the extended axis of the intraparietal sulcus into P1 (superior) and P2 (inferior). The occipital lobe is divided along the extended axis of the lateral occipital sulcus into O1 (superior) and O2 (inferior). Distal target labels include A – Amygdala, C – Cingulate gyrus, H – Hippocampus, I – Insula, OF – Orbitofrontal cortex, OT – Occipitotemporal gyrus, PH – Parahippocampal gyrus.

SENSA system applied to 13 unilateral right electrodes, with lateral surface entry points (left image) and where applicable distal targets in the insula (inset box), orbitofrontal cortex (inset box), or mesial surfaces (right image) indicated by electrode-specific colored dots or broken lines.

Preoperative MR and post-implantation CT image overlays of implanted electrodes. A and B show in-plane trajectory views of electrode F3aOFa, which enters most anteriorly into the inferior frontal gyrus and terminates most anteriorly in the medial orbitofrontal cortex. C and D show in-plane trajectory views of electrode F3bIaOFb, which enters the inferior frontal gyrus more posteriorly, grazes the insular cortex most anteriorly, and terminates most posteriorly in the orbitofrontal cortex. E and F show in-plane trajectory views of electrode T2aA as it enters the middle temporal gyrus most anteriorly and terminates in the amygdala. Also visible in E is electrode T2bHa, which enters the middle temporal gyrus more posteriorly and terminates at the most anterior aspect of the hippocampus.
Discussion

While the complete name for each implanted electrode has the potential to include several characters, a maximum of 3 characters is all that is needed to provide a unique name for each electrode.

One limitation of this nomenclature is that it must be paired with high-resolution multi-planar anatomic imaging in order to truly appreciate detailed anatomic and inter-electrode relationships. However, rather than attempting to achieve those latter goals, the SENSA system strives to standardize SEEG trajectory naming in order to facilitate workflow while balancing competing interests including simplicity, anatomic specificity, and interrater reliability.
Summary Points

• This standardized naming convention, SENSA, provides a simple, concise, reproducible and informative method for specifying the target(s) and relative position of each SEEG electrode in each patient, allowing for successful sharing of information in both the clinical and research settings.

• General adoption of this nomenclature could pave the way for improved communication and collaboration between institutions.