Title

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INTRODUCTION

Stereo-electroencephalography (SEEG) is a commonly used method for intracranial monitoring in patients with medically intractable epilepsy. Depth electrodes are inserted to localize seizure onset zones and map epileptic and neural networks in order to plan further therapeutic surgeries such as resection or neuromodulation.

Due to the placement of SEEG electrodes in deep brain structures, accuracy is important to ensure the intended areas are sampled and to minimize complications. Various methods exist for placement, and can be broadly classified into frameless and frame-based methods. The former includes robotic-assisted insertion and frameless navigation guidance systems, and the latter most commonly includes Leksell and CRW frame-based insertion. Despite the widespread use of these techniques, a recent meta-analysis was unable to find superiority of one method over the others.

We aimed to compare the accuracy, precision, and safety of these methods. We hypothesized that frame-based insertion would be more accurate and precise as compared to frameless insertion, with equal safety profiles for the two techniques.

OBJECTIVES

- Compare frame-based insertion using a CRW frame (Integra) and frameless insertion using the StealthStation S7 (Medtronic) navigation system for commonly used temporal SEEG targets.
- Identify which insertion method is superior in terms of accuracy, precision, and safety.

MATERIALS AND METHODS

We retrospectively examined electrode targets in SEEG patients that were implanted with either frame-based or frameless methods at a level 4 epilepsy center. We focused on two commonly used targets: amygdala and hippocampal head. Stealth station software was used to merge preoperative MR with postoperative CT images for each patient, and coordinates for each electrode tip were calculated in relation to the midcommissural point. These were compared to ideal coordinates, defined as 2mm lateral to the most medial point of the uncus for the amygdala, and 2mm lateral to the most medial point of the hippocampus at the level of the choroidal point for the hippocampal head. The two methods were then compared in regard to error (absolute distance to target) and bias (directional distance to target) with respect to this ideal location.

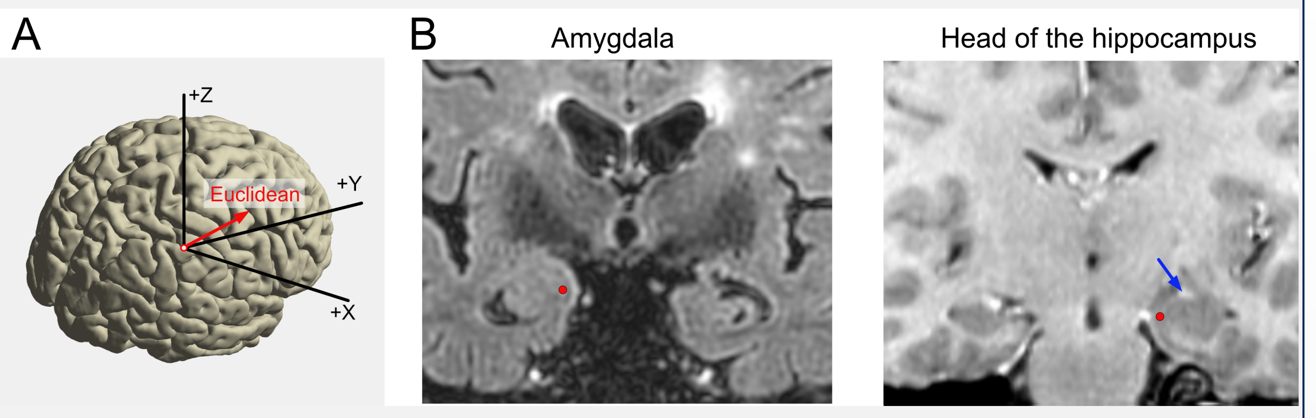

Figure 1. Anatomical reference and surgical target. The left panel depicts axes of reference: medial-lateral (X), anterior-posterior (Y) and ventral-dorsal (Z). Euclidean distance reflects an estimate of total distance from the midcommissural point across all three axes. The right panel depicts surgical targets that are defined a priori based on anatomical landmarks, and indicated here with red dots in coronal MR FLAIR image for amygdala and coronal MR with gadolinium image for hippocampal head. These ideal coordinates are defined as 2mm lateral to the most medial point of the uncus for the amygdala, and 2mm lateral to the most medial point of the hippocampus at the level of the choroidal point (blue arrow) for the hippocampal head.

RESULTS

A total of 81 SEEG electrodes were identified in 23 patients (40 amygdala and 41 hippocampal head). Eight of 45 electrodes (18%) placed with the frameless technique and 0 of 36 electrodes (0%) placed with the frame-based technique missed their target and were not clinically useful. Average Euclidian distance comparing actual to ideal electrode tip coordinates for frameless vs frame-based techniques were 11.0mm vs. 7.1mm ($p < 0.001$) for amygdala and 12.4mm vs. 8.5mm ($p < 0.001$) for hippocampal head, respectively. Standard deviations were 4.2mm vs. 2.2mm ($p = 0.009$) for amygdala and 4.1mm vs. 2.3mm ($p = 0.024$) for hippocampal head. There were no hemorrhages or clinical complications in either group.

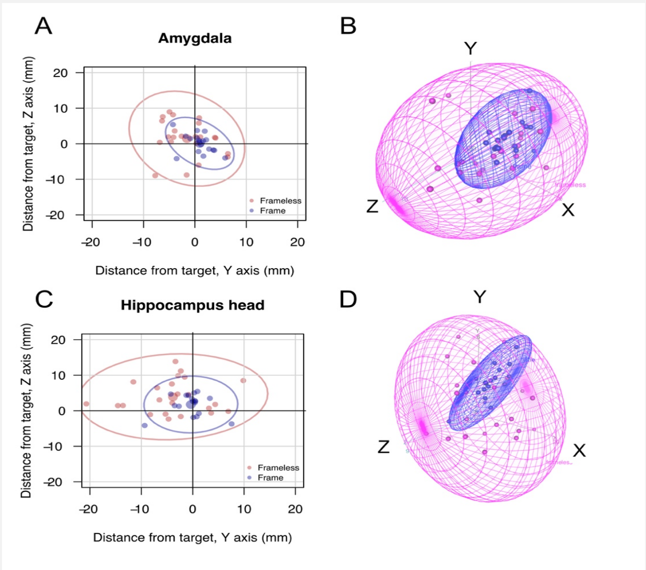

Figure 2. Localization of individual electrodes. referenced to the target location (axis origin) for amygdala (A-B) and hippocampus head (C-D) electrodes. (A) and (C) show the 2-dimensional projections on the Y-Z plane; (B) and (D) show electrode locations in 3-dimensional space. Electrodes are color coded according to the surgical procedure: frameless (red) or frame (blue). Ellipses (2D or 3D) indicate 95% confidence interval for electrode position. In (A) and (C), larger dots indicate mean coordinates for each insertion procedure.

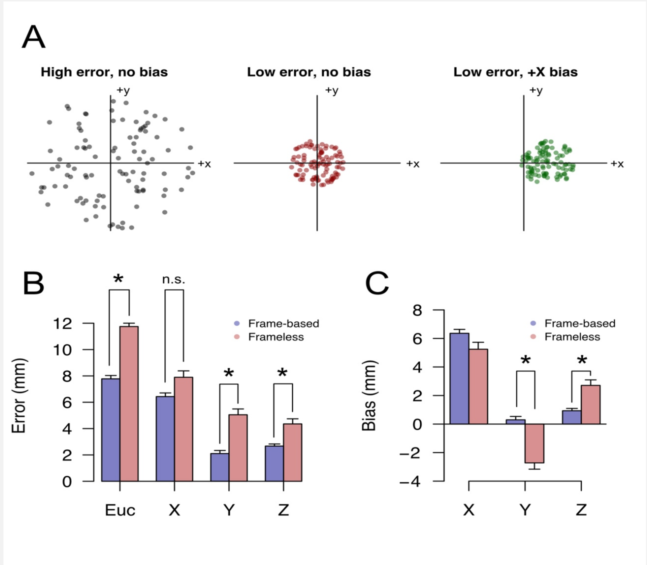

Figure 3. Error and bias in electrode localization. (A) For each electrode, we calculated two different metrics of deviation between ideal and real electrode location: error (absolute difference) and bias (signed difference). (B) Location error for all electrodes, pooled across targets (hippocampal head/amygdala), in all axes (X/Y/Z) and overall Euclidean distance (Euc). (C) Bias for all electrodes in X/Y/Z axes.

CONCLUSIONS

Frame-based SEEG insertion is significantly more accurate and precise, and results in more clinically useful electrode contacts, compared to frameless insertion. This has important implications for centers not currently using robotic insertion.

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