An Easily Implemented, Open Access Semi-Automatic Pipeline for Intracranial Electrode Localization

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INTRODUCTION

Depth EEG has been used increasingly for localization of seizure foci in refractory epilepsy.

Placement of depth electrodes provide unparalleled opportunities for collecting neuro-electrophysiology data.

Intracranial electrodes need to be accurately localized to draw meaningful conclusions from electrophysiological data and demand for more efficient methods to localize implanted electrodes has grown as the volume of these procedures continues to increase.

We developed a semi-automated pipelne that integrates pre-operative MRI and post -operative CT data to determine electrode locations.

METHODS

The semi-automated pipeline (Fig. 1) was tested with a sample of patients (n=6) who underwent implantation of sEEG electrodes.

We co-registered the pre-op MRI with the post-op CT (3D Slicer, Boston, MA) to align electrodes in patient-specific anatomy and extracted a volumetric brain image (FSL, Oxford, UK) to create a mask that represented the dataspace of interest (MATLAB, Natick, MA). The image was processed using intensity thresholding automatically determined on an image-by-image basis using descriptive statistics. Fused contacts in the image were automatically identified and bisected based on relevant shape properties.

Accuracy was evaluated by total contact count and by direct visualization of the output centroid coordinates plotted on the original post-op CT images.

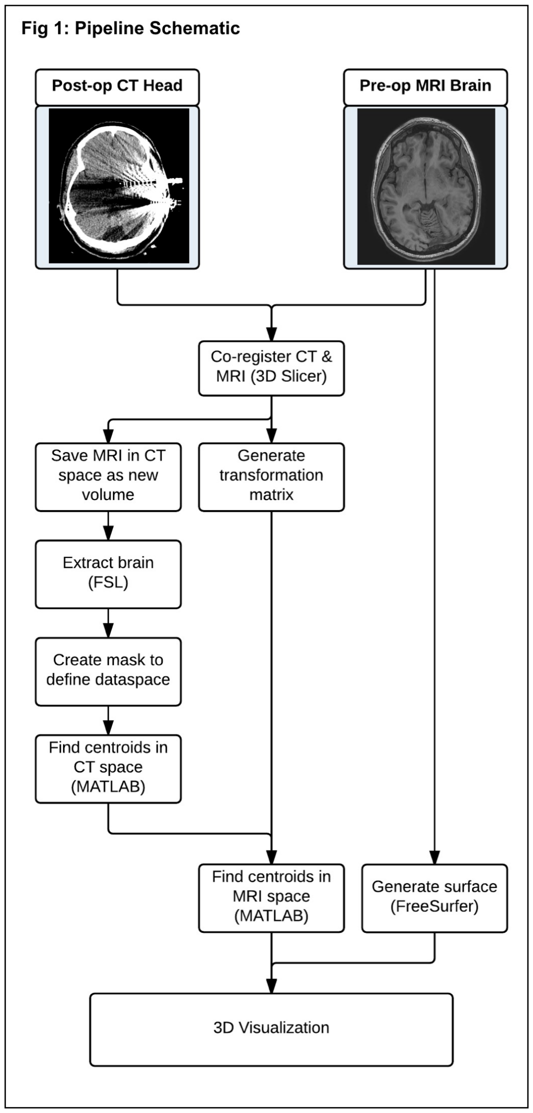

Figure 1. A schematic representation of the pipeline that uses pre-operative MRI and post-operative CT imaging, FSL, 3D Slicer, FreeSurfer, and our own in-house MATLAB code to generate accurate 3D visualizations of electrode contacts in patient specific anatomy or standard space.

RESULTS

The pipeline was used to localize 785 intra -cranial electrode contacts. Visualization of the centroid locations on post-operative CT verified that centroids marked contact locations (Figs. 2A & 2B). Sensitivity for contacts was 99.4% and specificity for contacts was 99.6%. The pipeline successfully excluded extra-cranial contacts in all cases (Fig. 2C). All false positives were the result of detecting electrode anchors that were within the cranial vault. Three-dimensional visualization following transformation into MRI space provided further evidence that centroid coordinates reflected true contact locations (Fig. 3).

Table 1: Total Contact Count ($n = 6$)

ID	No. of intracranial contacts	No. of detected contacts	Difference
49	180	179	-1
44	134	133	-1
46	117	117	0
50	106	109	+3
51	106	103	-3
52	142	142	0

Table 1. The total number of electrodes and the number of electrodes detected by the pipeline.

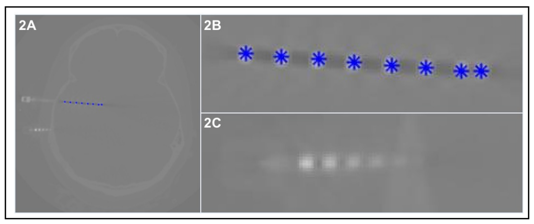

Figure 2. Centroid coordinates generated by the pipeline are marked on the patient's CT image to validate accuracy. Extracranial contacts are exluded by the pipeline.

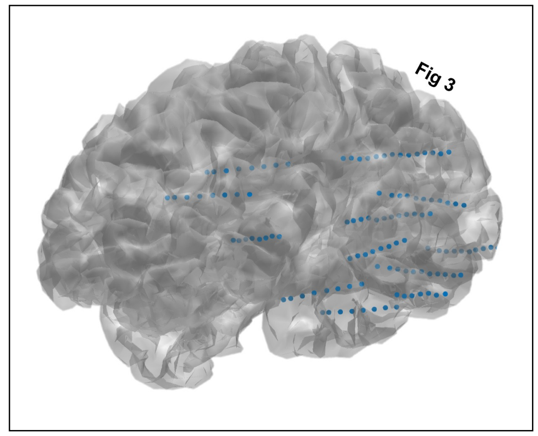

Figure 3. The 3D visualization for a single patient with intracranial electrodes shown as blue dots.

CONCLUSIONS

The method described is an accurate and easily-implemented method for intracranial electrode localization using MATLAB and open access software. Compared to similar open access methods, our pipeline requires minimal user input, which significantly reduces person-hours required for task completion. From a clinical perspective, this pipeline allows for seamless retrospective analysis of electrode locations and thus has the potential for widespread use in clinical and electrophysiological research. Future directions include continued refinement of sensitivity and specificity, and desiging a graphic user interface to improve ease of use.

REFERENCES

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