THE UNIVERSITY OF UTAH
DEPARTMENT OF BIOMEDICAL ENGINEERING

Validating Cortical Surface Electrode Localization Uncertainty with Simulation and Clinical Stimulation

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INTRODUCTION

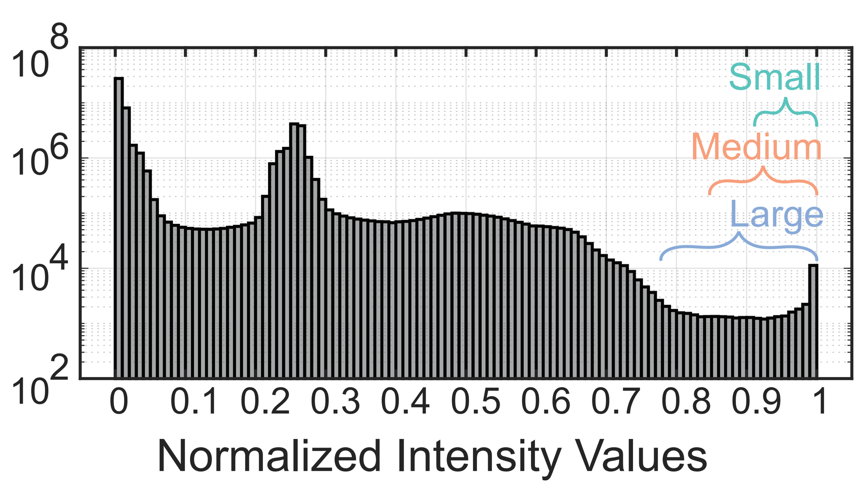
- Electrocorticography (ECoG) is an invasive technique commonly used to monitor patients with intractable epilepsy to aid in seizure onset localization and eloquent cortex mapping
- Modeling accurate electrode locations is necessary to make predictions about stimulation or seizure focus localization
- Brain shift occurs after surgical implantation of the ECoG array
    - When the post-operative CT is co-registered to the pre-operative MRI the electrodes appear to be inside the brain instead of on the cortical surface
- The electrode localization and projection to the cortical surface are based off of thresholding the CT
    - CT acquisition between patients and centers differs, therefore we want to use a threshold that is insensitive to these differences

AIM: Determine if the CT threshold range affects electrode localization and the resulting simulation of clinical ECoG measurements during stimulation.

METHODS

1. *Preprocessing:* Co-registered the pre-operative MRI (A) and the post-operative CT (B) of an epilepsy patient. The brain shift is outlined in red.

2. *Electrode Localization:* Segmented the electrodes from the CT using three different reasonable intensity threshold ranges.



3. *Projection:* Calculated the centroid and orientation of each electrode segmentation (C - pink and blue) and projected each electrode along its normal vector to the cerebral spinal fluid (csf) surface (C - green)[1]. Then incorporated each node of a 2.3 mm diameter electrode into the csf surface mesh (D).

4. *Meshing:* Built a finite element volumetric mesh with csf, white matter, gray matter, and ventricular surfaces (E).

5. *Simulation:* Solved the bioelectric field problem for bipolar stimulation between two ECoG electrodes. Finite element method voltage solutions to the Poisson equation were compared to clinical bipolar stimulation recordings.

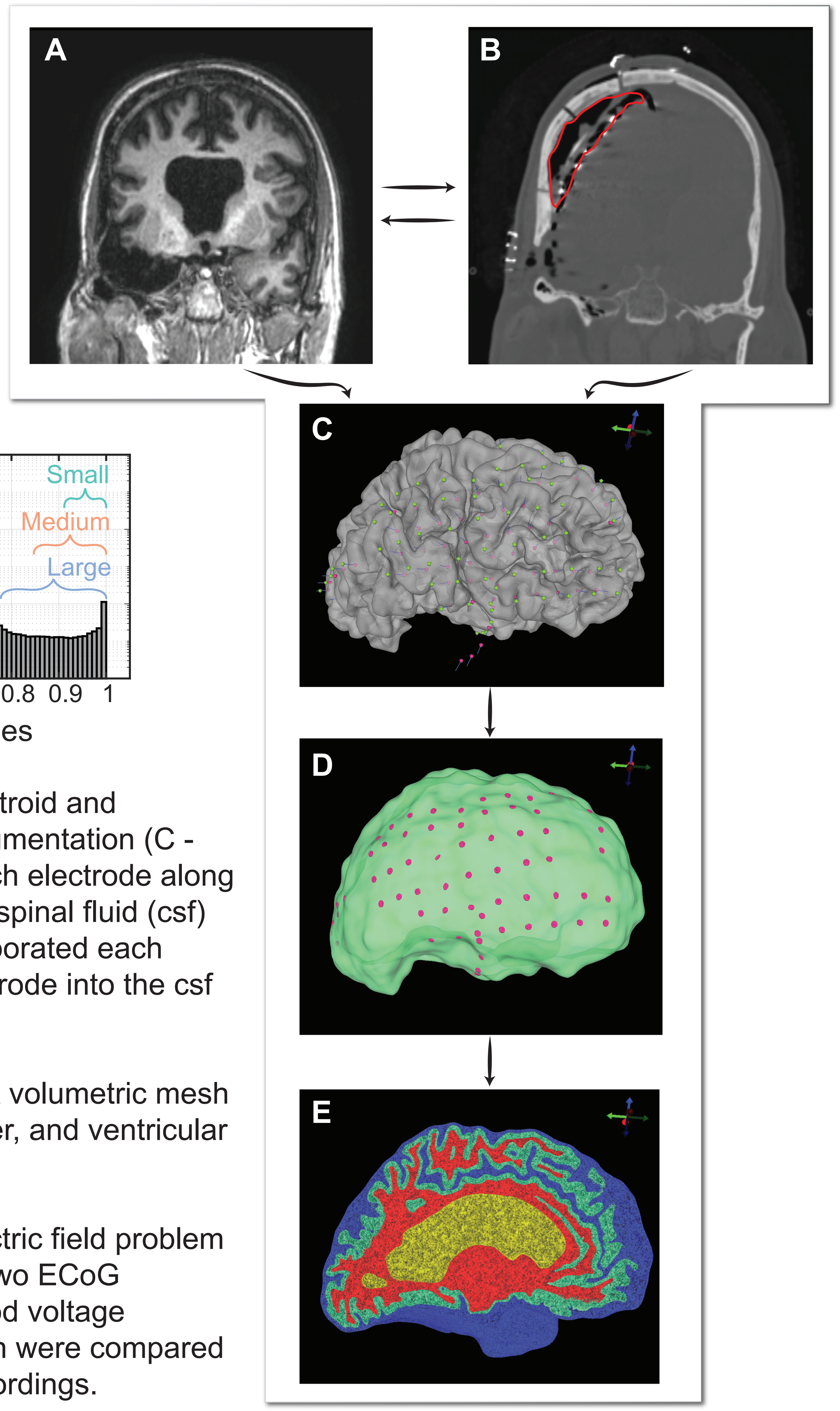


Figure 1. Methods flowchart.

RESULTS

We created three finite element meshes with the three different electrode localizations based on their threshold range and solved the bioelectric field problem for bipolar stimulation between electrodes 18 (0.5 mA source) and 23 (-0.5 mA sink), shown in *Figure 2.*

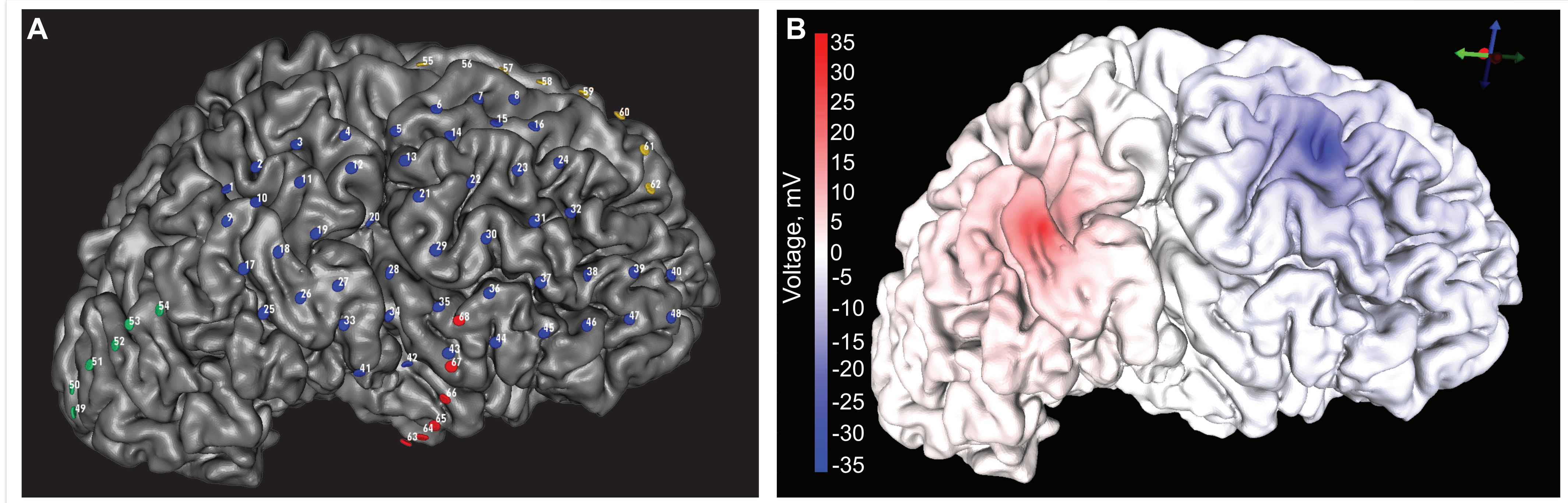


Figure 2. A) Numbered electrode localizations, colors correspond to separate grids or strips of electrodes. B) Exemplary voltage solution for bipolar stimulation between electrodes 18 and 23, respective source (0.5 mA) and sink (-0.5 mA).

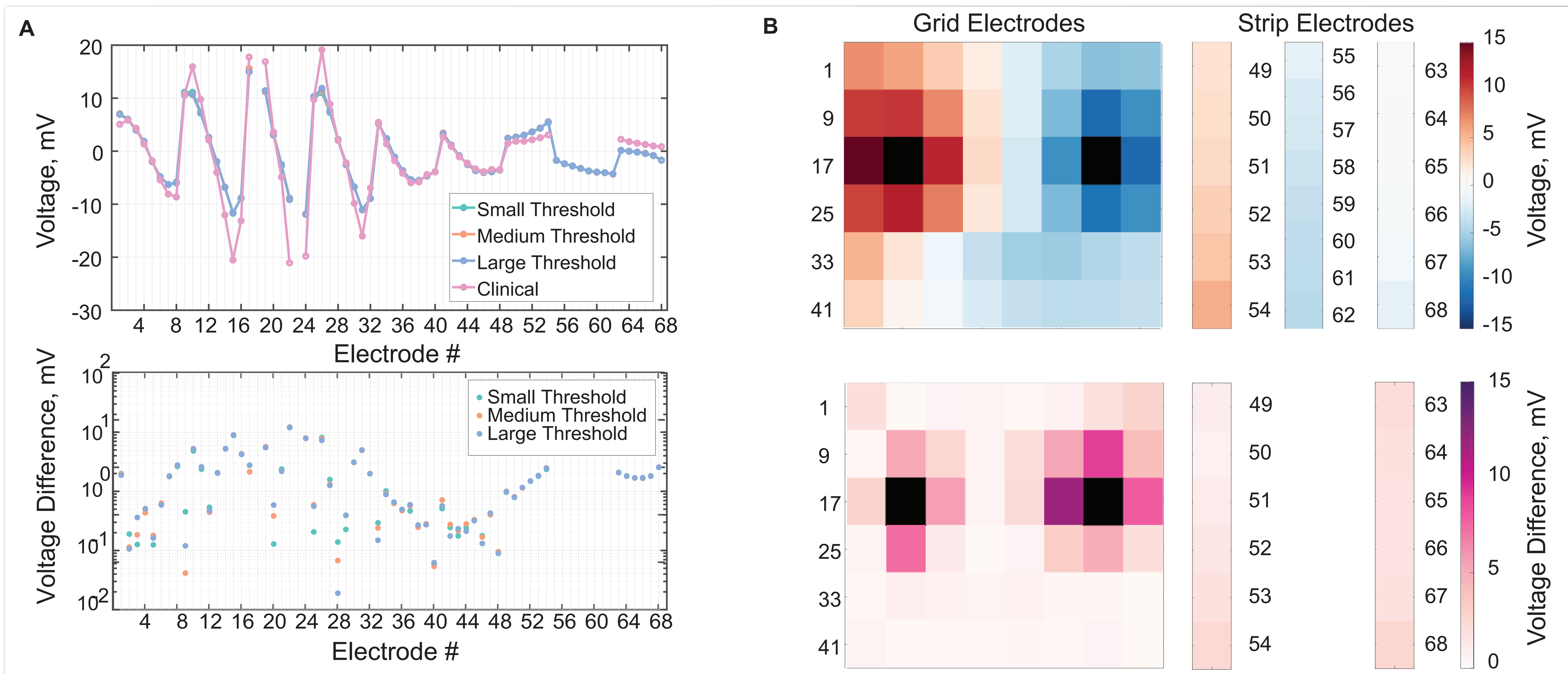


Figure 3. A) Voltage solutions for each electrode-location model and the clinically recorded voltages (no clinical voltages for electrodes 55-62) and the absolute voltage difference between each model and the clinical values. B) Spatial voltage solutions and voltage differences for the large threshold model for the grid and strip electrodes, source and sink electrodes are black.

CONCLUSIONS

We compared simulations for three different electrode-localizations based on a small, medium, and large CT threshold range to clinical recordings.

- The three threshold models did not have large voltage differences when simulating clinical stimulation.
- The electrodes with the greatest absolute difference to the clinical recordings were around the source and sink electrodes. This is to be expected because the voltage is the greatest in those regions.
- Moving forward, we can use any of the threshold ranges because they did not greatly differ in their simulation solutions. This insensitivity to the threshold range gives us more confidence in the electrode locations of our models.

FUTURE DIRECTIONS

- Evaluate how other modeling parameters, like csf thickness, introduce uncertainty into our computational models. Determining where this uncertainty originates from could potentially improve our error around the source and sink electrodes.
- Create a tool to visualize the uncertainty of our FEM solutions, to better account for uncertainty when making clinical decisions based on models.

REFERENCES

1. Brang, D., Dai, Z., Zheng, W. & Towle, V. L. Registering imaged ECoG electrodes to human cortex: A geometry-based technique. *J. Neurosci. Methods* **273**, 64–73 (2016).

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