3D Visualization and Quantification of Subdural Electrode Shift due to Craniotomy Opening

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INTRODUCTION

Intracranial electroencephalography (iEEG or ECoG) electrodes are placed in cases of medically refractory epilepsy as a means to locate cortical epileptogenic zones (regions of seizure onset) amenable to surgical resection. Without aid of medical imaging derived brain/electrode models for surgical planning, surgeons have relied on electrode positions to have remained stationary throughout patient monitoring, and during the reopening of the craniotomy. Cortex beneath electrodes exhibiting seizure activity is removed with the expected result of seizure control. This study seeks to quantify electrode shift due to decompression of the brain during the reopening of the craniotomy, and builds a case for adoption of electrode/brain model reliance for electrode position determination instead of traditional visual assessment at the reopening of the craniotomy.

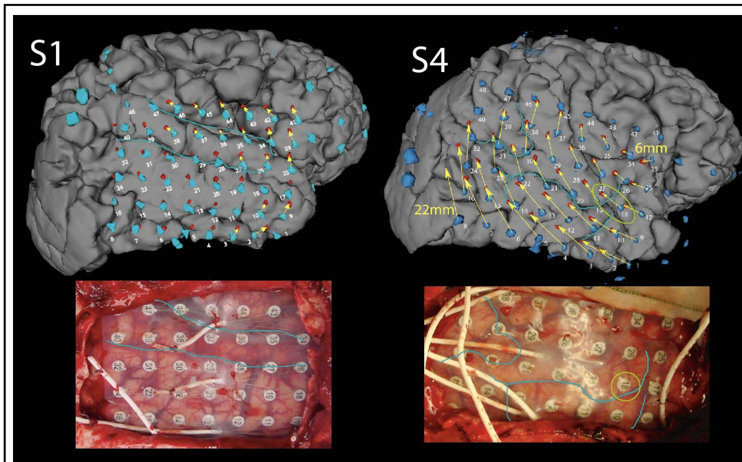

Figure 1. Illustration of grid shift during reopening of craniotomy. Blue electrodes are measured with CT imaging, while red electrodes are based on surgical navigational coordinates measured in the operating room. Two subjects are shown here, S1 shows relatively low shift, while S4 depicts a major shift, verified with intraoperative photography. Electrode 18 is circled as an example, where in the model (blue above) it appears anterior to the superior temporal sulcus, while intraoperatively it appears posterior.

METHODS

Eight patients (S1-S8) with medically intractable epilepsy undergoing surgical implantation of subdural electrodes for epileptic zone localization were enrolled in this study. *MRI processing* MRI data obtained post-electrode implantation was processed using Freesurfer (www.surfer.nmr.mgh.harvard.edu) to produce patient-specific 3D cortical surface models (1-3). *CT Image Processing* Post-implantation, gantry angle-corrected CT data was co-registered to post-implant MRI data (4, 7) using FLIRT (FMRIB software library http://www.fmrib.ox.ac.uk/fsl). The CT data was then thresholded and binarized to limit the image information to the electrodes only (5), which are shown in blue in Figure 1. *Intra-Operative Stealth Electrode Localization* During surgical resection the Stealth navigation system was operated using the same high resolution MRI described above. Upon re-exposure of the electrode grid, our neurosurgeon (WM) placed the Stealth navigational probe in the center of each electrode and coordinates were recorded from the navigation monitor. Stealth coordinates were then transformed into the same coordinate space as the Freesurfer rendered cortical surfaces for visualization (Figure 1, top). *Measurement of Electrode Shift* The center of mass was found for each of the CT measured electrodes determined before opening and compared to the coordinate measured after opening as described above.

RESULTS

7 patients exhibited comparable shift of electrode position with an average of 4.3mm stdev: 1.18mm. The electrodes in one patient (S4) shifted dramatically on average 13.5mm, maximum: 22mm, and minimum 6mm (Figure 1, S4).

DISCUSSION

The degree to which electrodes shift due to craniotomy reopening has never been quantified. Here we show in a dataset of 8 patients the average shift likely due to brain swelling is on the order of 4.3mm, while in extreme cases can be much larger due to sliding, and not swelling. We conclude that it is essential to verify intraoperatively electrode shift, knowing in the best case that they have shifted subtly from the position in which they resided during epileptic monitoring.

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REFERENCES

1. Dale AM, et al: Neuroimage 9:179-194, 1999.
2. Fischl B, et al. Neuron 33:341-355, 2002.
3. Fischl B, et al. Neuroimage 9:195-207, 1999.
4. Grzeszczuk R, et al. J Comput Assist Tomogr 16:764-773, 1992.
5. Morris K, et al. AJNR Am J Neuroradiol 25:77-83, 2004.
6. Silberbusch MA, et al. Am J Neuroradiol 19:1089-1093, 1998.
7. Tao JX, et al. Clin Neurophysiol 120:748-753, 2009.

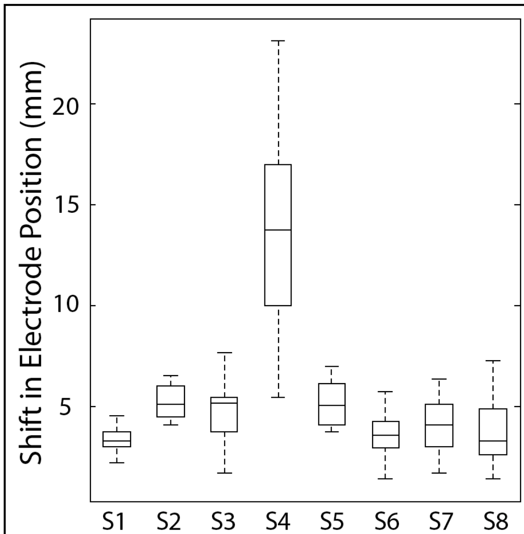

Figure 2. Resulting measurements of electrode shift in each of the 8 subjects (S1-S8). Subject 4 showed an extreme case of grid shift during the reopening of the craniotomy at the time of follow-up resection.