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Shift in electrocorticography electrode locations after surgical implantation in children

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Highlights

- The brain shifts after ECoG implantation surgery which can impact the interpretation of electrode locations.
- Average electrode shift immediately after implant in a pediatric population was 5.64 ± 3.27 mm, and shift was greater with larger estimated intracranial volume, in the parietal lobe, and on grids compared to strips.
- The shift in ECoG immediately after implantation could lead to a misinterpretation of electrode location particularly in patients with larger volume and for grid contacts over the parietal lobes.

Introduction

Recording electrical activity directly from the brain surface with subdural electrocorticography (ECoG) has great value in epilepsy, neuroscience, and developing neurotechnology, and there is a need for combining information across data types by localizing intracranial electrodes on imaging data. However, localizing post-implant electrode locations on pre-implant imaging data can be challenging due to brain shift, where operative placement of the electrodes leads to temporary deformation of the tissue. This deformation has been somewhat characterized in adults, but not yet in pediatric patients. This discrepancy in ECoG electrode location due to brain shift at the cortical surface can impact the interpretation of electrophysiological data and compromise clinical accuracy of neuronavigation systems.

In this study, we quantify the post-implant shift in ECoG contact location for pediatric patients. Our primary aims is to determine if shift is dependent on estimated total intracranial volume (eTIV), age, or cortical region directly underneath the electrode.

Results

SEX	n
Female	7 (39 %)
Male	11 (61 %)
PATHOLOGY	**n**
Cortical dysplasia	10 (56 %)
Normal parenchyma	4 (22 %)
Tumor(s)	2 (11 %)
Neurofibromatosis	1 (6 %)
Tuberous Sclerosis	1 (6 %)

Table 1: Demographics and Surgery Information.

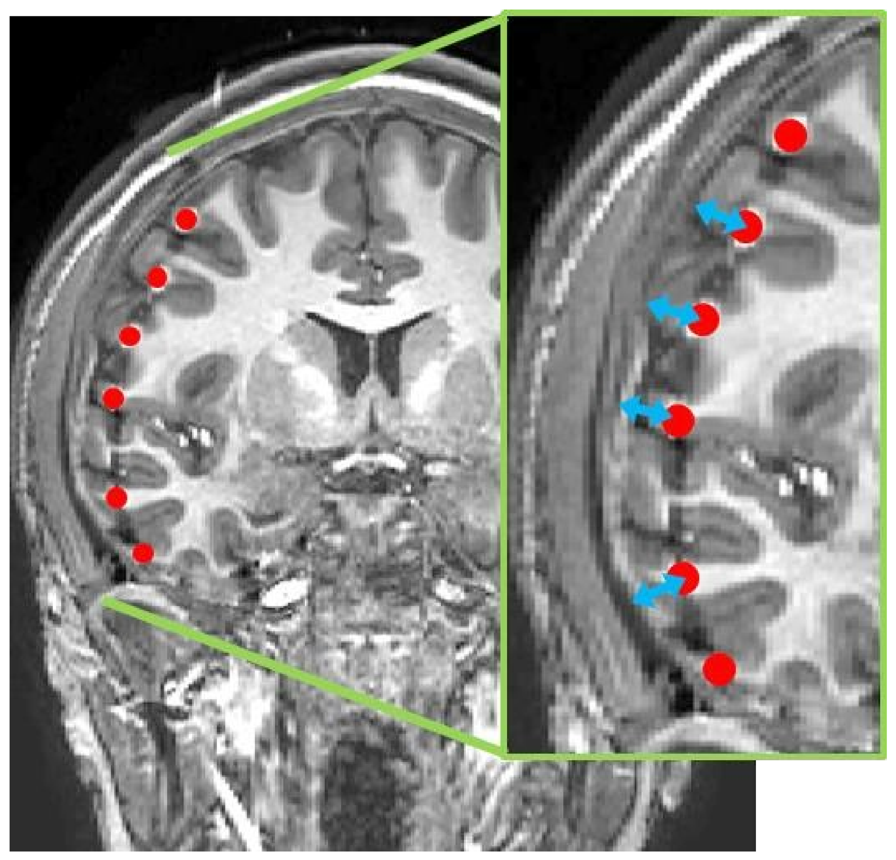


Figure 1: Example of brain shift colocalization from postoperative CT with electrodes overlayed on preoperative T1 MRI

A total of 1140 electrode contacts were assessed across 18 patients with a number of valid electrodes per patients from 24 to 83 (63.3 ± 16.7). Electrodes shift ranged from 0.01 to 17.0 mm with an average of 5.64 ± 3.27 mm shift from the original brain surface immediately after implant (Fig. 2).

Shift was significantly affected by eTIV (p = 0.038, mixed model), lobe (p < 0.001), and grid/strip (p < 0.001), but not age (p = 0.926). Age and volume were not significantly related (Fig 2). Fig. 3 shows this relationship between shift and volume (left) and age (right). Age and eTIV were not significantly related (linear regression analysis, R2 = 0.14, p = 0.132). The number of days between MRI and CT had no effect on shift.

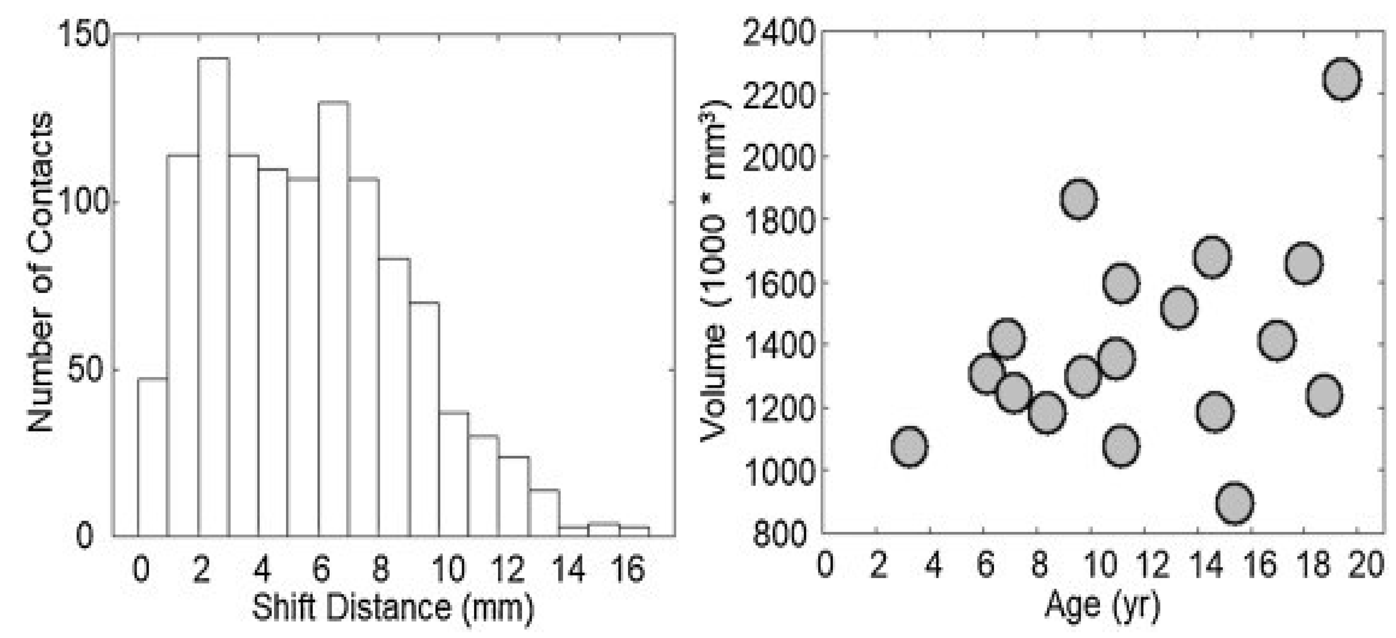


Figure 2:Distribution of ECoG location shift distances across contacts (Left) and relationship of age to eTIV (Right).

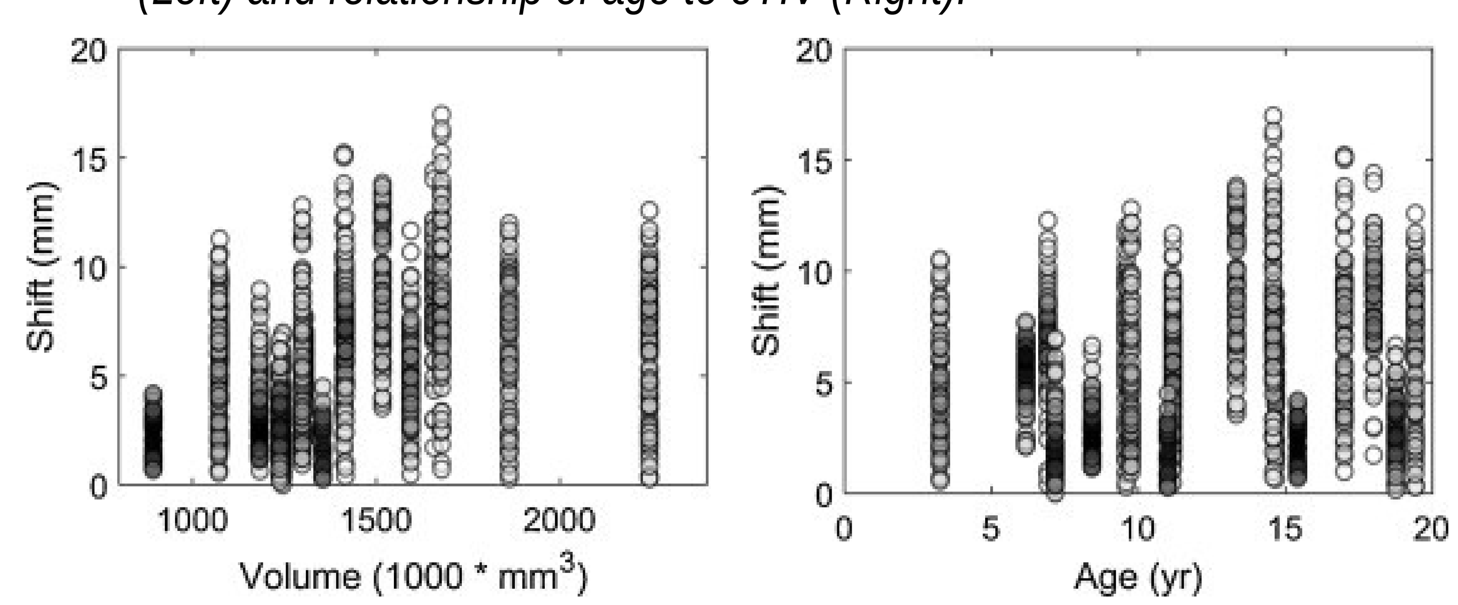
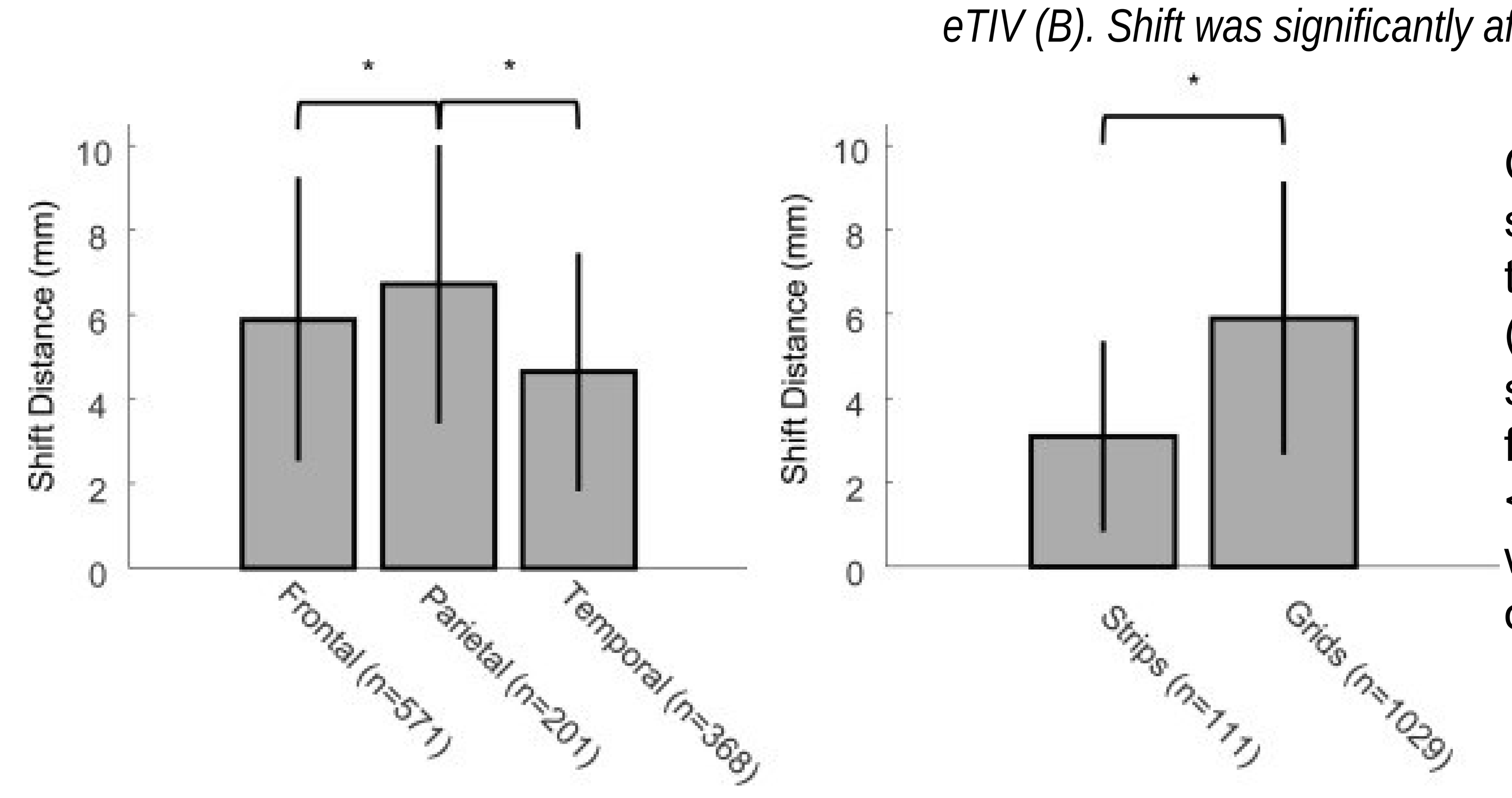


Figure 3:ECoG location shift at each contact compared to age (A) and eTIV (B). Shift was significantly affected by eTIV but not age.



Contacts in grids had significantly more shift than those of the strips (p < 0.001) (Fig. 4). Parietal contacts were significantly more shifted than frontal and temporal contacts (p < 0.001, Tukey) (Fig. 4). There were no contacts over the occipital lobe in this cohort.

Figure 4:Shift distance by lobe and strip/grid categorization. Bars represent the mean and error bars are standard deviation.

Methods

This was a retrospective analysis of patients with drug-resistant localized epilepsy who underwent craniotomy for placement of intra-cranial monitoring with surface ECoG in preparation for resective epilepsy surgery at Phoenix Children's Hospital (IRB: #17-052). All surgeries were performed at Phoenix Children's Hospital by the same surgeon (PDA) from 2014 to 2018, and all included patients had preoperative T1 MRI and CT taken within 24 hours postoperatively. Electrode shift was measured by comparing the brain surface on an MRI taken prior to electrode placement with the CT scan taken within 24 hours postoperatively. Shift was calculated using a validated iElectrodes toolbox. A mixed effects model was used to determine effect and significance of age, eTIV, lobe, and type of electrode on electrode shift. eTIV was calculated using FreeSurfer. Electrodes were manually categorized by lobe.

Conclusion

In this analysis, we successfully characterized post-implant electrode shift due to brain deformation in pediatric patients. This shift is over half the distance between electrodes and is consistent with previous studies but is relatively small considering typical resection sizes. However, surgeries are becoming less invasive leading to a need for submillimeter localization and interpretation of epileptic foci.

One limitation to this study is the time frame of post-implant CT. We used a single time point <24 hours post surgery, but further movement of electrodes is expected during recovery and again during resection surgery. Another limitation is that this study cannot speak to the cause of the electrode shift.

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