EDITORIAL

Pediatric stereoelectroencephalography: review of a cohort**Jeffrey P. Blount, MD**

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THE article titled “Robot-assisted stereoelectroencephalography in children” by McGovern and colleagues summarizes the Cleveland Clinic (CC) experience with stereoelectroencephalography (SEEG) in children.² For some time, the CC group has led the effort and experience in North America in SEEG, and this report is an important contribution to this legacy. They have reported a smaller, earlier component of this cohort previously.¹ In that paper, 30 patients younger than 20 years of age underwent implantation with a total of 402 electrodes (mean 13 electrodes/case). The epileptogenic zone (EZ) was successfully localized in 86% of cases and 61% went to a resection that resulted in seizure freedom of 56% at a mean follow-up of 26 months. In the intervening 4 years the authors’ experience has nearly doubled and represents the largest single-institution robotic SEEG series in children yet reported. As such, the paper provides an excellent summary of the state of the art of SEEG in children.

In this paper the study design remains a retrospective, single-institution, observational cohort.

The cohort of 57 pediatric patients undergoing robotic SEEG is sizeable but remains a small enough sample to preclude powerful statistical conclusions. The statistical methods used are appropriate and demonstrate that only a short hospital stay for SEEG and older patient age are significantly correlated with seizure-free outcomes. The numbers and rates presented are valuable to other centers: 12 electrodes on average per case, 10 minutes per electrode implant, 10 days of postimplant evaluation. The SEEG investigation yielded the EZ in 89% of the investigations and 74% of patients underwent resective surgery. A 50% seizure freedom rate was observed. This is a refreshingly honest value and reflects careful evaluation and prolonged follow-up. Ultimately, the value of SEEG lies in its capacity to inform and direct a resective strategy that confers seizure freedom without inducing neurological deficit. The steep pitch of the early phase of the Kaplan-Meier

curve shows that there still is room for these techniques to be refined and improve the degree of seizure freedom.

Complications are also presented in a more comprehensive manner than in prior publications related to pediatric SEEG. Up to this point, complications have been dismissed as vanishingly rare, but this cohort shows a 9.4% incidence of overall hemorrhages (asymptomatic and symptomatic) and a 1.5% incidence of acutely threatening bleeds (symptomatic—requiring evacuation).

The *Discussion* section also addresses multiple issues of interest and importance to programs developing SEEG protocols. Perhaps the most challenging issue is that the central component of successful SEEG is the existence of multiple well-planned hypotheses. This paper shares little of the strategies, paradigms, or insights used by the CC group to attain this critical component of successful SEEG planning. The capacity to visualize neural networks of seizure propagation in 3 dimensions remains the most conceptually challenging component of the planning process.

Other valuable observations include the following: 1) semiology in children is less contributory to seizures, so functional imaging is more important in trajectory planning; 2) the observed seizure freedom rate of only 50% is probably due to residual epileptogenic cortex adjacent to the resection margin or a distant EZ or hemispheric network; and 3) the electrophysiological fingerprint of SEEG electrodes at the EZ is characterized sequentially by preictal spiking, multiband fast activity, and concurrent suppression of lower frequencies. These comments are valuable and reflect careful consideration of these issues. The positive correlation of short sample time with good seizure outcomes may also suggest that there is a subtle overall binary quality for a given SEEG implantation strategy in children. The implant strategy appears broadly either to be successful and to result in rapid localization of the EZ, or to be unsuccessful where prolonged monitoring reveals a less clear delineation of the EZ.

There are other unique challenges to SEEG in pediatric patients that the authors have not addressed. These include strategies to deal with anchor bolt placement within the thin temporal bone of pediatric patients. The squamous temporal bone in young patients is often only 2–3 mm thick, which precludes secure placement of anchor bolts to sample temporal tissue in an orthogonal plane. Deep frontal lobe targets can also be difficult. Purely orthogonal electrodes would require forehead entry, which cannot be done, and the thin bone impairs good anchor bolt purchase and facilitates tangential deflection of the electrodes at the dura mater. Given the thoughtful nature and considerable experience of the CC group, these would be valuable additions for others pursuing SEEG in children.

References

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Response

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We thank Dr. Blount for his thoughtful and detailed response to our article. We agree that one of the most challenging issues for institutions developing SEEG programs is the generation of preoperative anatomic-electro-clinical hypotheses. There are 2 facets to this process. First, the generation of preimplantation hypotheses relies on all of the team members agreeing on this particular philosophy: that SEEG is a methodology designed to interrogate epileptic networks that are manifesting in a specific semiological and electrical fashion. If the team members instead view SEEG as a series of depth electrode implantations or a 3D grid, our view is that seizure freedom outcomes are likely to be worse because the information obtained from SEEG is not designed to be used in that fashion.

Second, the actual preimplantation hypotheses need to be formed by interpreting the semiology, video EEG, and anatomical radiological data. This is the process in which the team discusses the potential EZ location and the epileptic networks involved. This can be complicated and is

an evolving process, but trends emerge over time that tend to be consistent. For example, we may see a patient with nonlesional epilepsy who nevertheless has a semiological and EEG pattern consistent with a network that typically involves the orbitofrontal–mesial temporal–insular cortex. Our implantation strategy would then primarily revolve around interrogating those regions, with secondary electrodes planned in either connected regions or other cortical areas that team members think may be involved in seizure generation based on the available data. There are many possibilities, depending on the individual patient. In fact, this process remains a challenge in even the most experienced SEEG program because it can become easy to fall into a routine of placing electrodes in typical and standardized locations. One way in which we have tried to overcome this is by reviewing specific, individual electrodes at the end of each patient's case conference and asking for which hypothesis that electrode is giving us information. This process forces the group to re-examine the hypotheses as well as that individual's specific implantation strategy.

We also agree that the data tend to show a binary quality in that patients who stay longer in the epilepsy monitoring unit have a seizure-onset zone that is less easily defined. This can be true for a number of reasons: incorrect preimplantation hypotheses leading to poor sampling, a wider region of epileptogenic tissue than expected, or many others. It is also not surprising that, regardless of what those reasons are, these patients have worse seizure freedom outcomes. This reinforces the importance of developing multiple, well-reasoned hypotheses beforehand to obtain the most relevant information for that patient.

Finally, we regret that we could not include all of the technical details in the paper and thank Dr. Blount for pointing out some of the issues unique to children undergoing SEEG. We place the vast majority of our electrodes orthogonally and thus encounter many of the same issues, particularly with regard to thin squamous temporal bone. This typically occurs when placing electrodes in the mesial temporal region, specifically the temporal pole, amygdala, entorhinal cortex, and the head of the hippocampus. For orthogonal electrodes, this region tends to have a thick temporalis muscle and thin bone underneath. We have found that the most important factor in placing these electrodes is a short, smooth, and even drilling trajectory through the bone, in order to give the bolt the best opportunity to gain purchase in the bone. This is why the robotic platform is helpful; it provides a very stable platform for drilling. Occasionally, however, particularly with temporal pole electrodes, we are unable to obtain a stable enough purchase for orthogonal placement, and so we will abandon that electrode if necessary. But in general, electrodes can still be placed with reinforcement of the support dressing around the insertion site. As for deep frontal lobe targets, we typically maintain an orthogonal trajectory because these entry points are usually very close to the hairline and the small incisions heal very nicely, similar to the scars left by a standard Mayfield head-holder system, which is used so frequently in neurosurgical procedures. We believe that the benefits and safety of orthogonal implantations in this location (and using the described technique) overcome the potential drawbacks of small scars in

the front. Nevertheless, some groups will take an oblique frontal trajectory to the orbitofrontal region to avoid any incision off the hairline, but these trajectories tend to be very long, can be difficult to interpret electrically, and are typically slightly less accurate due to their length and obliquity.

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