Stereoelectroencephalography (SEEG) in Pediatric Patients; A Proposed Decision Making Algorithm and One Institutions Results.

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Introduction

Although stereoelectroencephalography (SEEG) has been shown to be a valuable tool for preoperative decision-making in focal epilepsy, there are no prior reports of SEEG in the American pediatric population. In this study, we present the results of our experience using SEEG in pediatric patients and offer an algorithm for patient selection based upon seizure semiology, MRI findings, superficial EEG and ancillary testing.

Table 1.

Patient #	Age	Gender	MRI findings (abnormal vs normal)	EEG Finding	SEEG Implantation	SEEG Monitoring Period (days)	Resection	Resection Side	Seizure Outcome	Follow up (Months)	SEEG Selection Group
1	18	M	Abnormal	Multifocal	L	6	left temporal	L	II-B	0	II
2	18	F	Abnormal bilateral	Multifocal	L	13	Failed to localize	N	no resection	10	VI
3	13	M	Abnormal	Multifocal	B	9	family declined resection	N	no resection	0	II
4	16	M	Normal	Multifocal	L	8	left fronto-parietal	L	III-A	6	VIII
5	11	F	Abnormal bilateral	Multifocal	B	6	bilateral independent foci	N	no resection	0	II
6	16	M	Normal	Multifocal	R	10	Frontal	R	I-A	23	III
7	10	M	Abnormal	Multifocal	R	8	right frontal-temporal-insular	R	II-D	7	II
8	9	M	Abnormal	Multifocal	R	25	failed to localize	N	no resection	5	VI
9	18	F	Normal	Discrete	B	7	Right temporal	R	no f/u	0	IV
10	17	M	Abnormal	Multifocal	L	8	failed to localize	N	no resection	0	VIII
11	14	M	Normal	Multifocal	B	8	Right insular	R	III	21	III
12	11	M	Normal	Discrete	L	8	left frontal	L	no f/u	0	V
13	16	M	Abnormal	Multifocal	B	20	Left Temporal	L	II	22	I
14	6	M	Abnormal	Multifocal	B	7	(1) Front-temporal-parietal-in sula (2) hemispherectomy	R	I	23	II
15	14	M	Normal	Multifocal	R	6	R frontal-Sinsular	R	I-A	4	III
16	13	F	Normal	Multifocal	B	6	surgery being sche duled	N	no resection	0	III
17	17	M	Normal	Multifocal	R	14	Fronto-Temporal	R	no f/u	0	IV
18	15	F	Normal	Multifocal	L	13	Parietal	L	IV	4	III
19	5	M	Normal	Discrete	R	7	R frontal	R	I-A	0	III
20	11	F	Normal	Multifocal	L	20	Eloquent localization	N	no resection	0	VI
21	16	M	Abnormal	Multifocal	R	8	R Fronto-temporal	R	II-B	7	II
22	18	M	Normal	Multifocal	B	10	failed to localize	N	no resection	0	VII
23	14	M	Abnormal	Multifocal	B	6	bilateral inde-pendent foci	N	no resection	0	VI
24	13	F	Normal	Discrete	B	10	L frontal + temporal	L	I-A	5	II
25	18	F	Abnormal	Discrete	R	9	Fronto-temporal	R	III-A	13	II

Results of SEEG monitoring in pediatric patients in our single institution.

Methods

A retrospective analysis was performed on 25 consecutive pediatric patients (8 girls, 17 boys, mean age 14 ±3.9 years) with medically refractory epilepsy who were determined to be candidates for invasive EEG monitoring and underwent tailored SEEG insertion and monitoring. MRI findings, EZ localization, seizure-free outcomes, type of surgery performed, and complications were evaluated. A classification scheme for potential SEEG candidates based on non-invasive findings was developed and applied to the current series of patients.

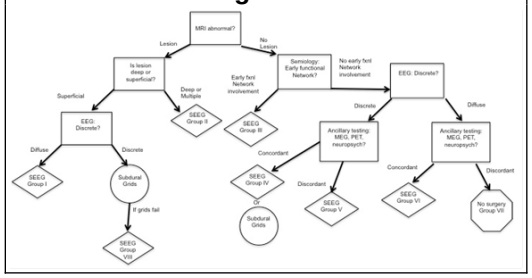
Results

Results: Sixteen patients (64%) underwent a resection after SEEG implantation. In patients who did not undergo resection (9 patients), reasons for resective surgeon contra-indication were:: (1) failure in localizing the EZ (four patients), (2) multifocal EZ (two patients), EZ located in eloquent cortex, preventing resection (one patient), and family declined resection (two patients). In patients who subsequently underwent resection, follow-up ranged from 4-23months. Seven patients (44%) experienced some seizure improvement (Engel II or III) and five (31%) were seizure-free (Engel Ia). In this case series, no complications were documented that are attributable to the SEEG procedure, 2 patients experienced complications from resective surgery; one CSF leak and the other required revision surgery

Discussion

The SEEG procedure was developed almost 60 years ago in France [13], and several European studies have shown it to be efficacious and safe for EZ localization in adults [8, 14-17]. This represents the first pediatric SEEG series from a single American epilepsy. Our results demonstrate that SEEG, once considered cumbersome and perhaps associated with excessive morbidity in this age group, maybe an effective and safe invasive method in selected patients with difficult to localize medically intractable focal epilepsies. Children pose special challenges with regard to epilepsy surgery. Children are likely to have developmental pathologies such as cortical dysplasia, which are known to have relative poor surgical results when compared to other etiologies. In this challenging group of patients, SEEG may represent an alternative method of invasive extra-operative monitoring by providing minimal morbidity and allowing extensive and bilateral implantations in pediatric patients with difficult to localize focal epilepsy. Only two studies have focused specifically on pediatric patients. In these two studies, Cossu and colleagues noted morbidity rates of 5.6% and 6.6% (one mortality) [16] and significant seizure improvement in 74% of children [8] and 80% of infants [16] following SEEG-guided resections, which is consistent with our finding of 72% with significant improvement.

Figure 1.



Given the paucity of data regarding SEEG in pediatric patients, we developed a decision-making tree (Figure 1) that will better indicate which patients are candidates for SEEG monitoring, with the hope that after enough data is collected, this tool will have some predictive value for the success of EZ localization and subsequent resection. This algorithm considers the patient's MRI findings, seizure semiology, superficial EEG, and ancillary testing as ictal SPECT, PET scan and MEG.

We included MRI findings as a major criterion for classifying patients because the presence of a lesion on MRI predicts a higher success rate for resective surgery [21, 22]. Seizure semiology is another important part of our decision-making process. There are numerous ictal findings that may have lateralizing or localizing properties [23]. Although semiology alone has limited ability to precisely localize the EZ, it can point to involvement of important functional networks. Such knowledge leads us to prefer SEEG over subdural electrodes because of its ability to delineate the anatomic relationship between the EZ and the functional network in a three dimensional aspect. The ability to sample deep structures is a primary advantage that SEEG

SEEG Selection Group	Subcategory	Description	Indicated Invasive Monitoring
I	Lesional 1	Superficial lesion on MRI and Diffuse/Multifocal EEG findings	SEEG
II	Lesional 2	Deep Lesion or Multiple lesions on MRI	SEEG
III	Normal MRI 1	Normal MRI with Early involvement of functional network on seizure semiology and diffuse/multifocal EEG	SEEG
IV	Normal MRI 2	Normal MRI with No evidence of early involvement of funtional network, however discrete EEG findings with Concordant Ancillary tests	SEEG or Subdural Grids
V	Normal MRI 3	Normal MRI with No evidence of early involvement of funtional network, however discrete EEG findings and Discordant ancillary tests	SEEG
VI	Normal MRI 4	Normal MRI with No evidence of early involvement of funtional network, with Diffuse/multifocal EEG and Concordant ancillary tests	SEEG
VII	Normal MRI 5	Normal MRI with No evidence of early involvement of funtional network, with Diffuse/multifocal EEG and Discordant ancillary tests	No surgery indicated
VIII	Failed Grids	Previously failed subdural grid monitoring	SEEG
I/a	Subdural Grids 1	Superficial lesion on MRI and Discrete EEG findings	Subdural Grids
II/a	Subdural Grids 2	Normal MRI, Early involvement of Functional Network, discrete EEG	Subdural Grids

SEEG selection groups and descriptions

holds over subdural electrodes, and therefore, the presence of a suspected deep lesion also influences us to use SEEG.

These basic principles allowed us to divide patients who are potential candidates for invasive monitoring into eight different. Patients in Groups II and III were the most common patients encountered. Of the 25 patients undergoing SEEG, 14 were in these two groups. The resections were proportionately represented, with 12 of 16 resections coming from Groups II or III. Interestingly, no patients from Group VI (normal MRI, diffuse EEG but with concordant ancillary testing) underwent resection following SEEG monitoring. Of the four patients in this group, two failed to localize, one had bilateral foci, and the last localized to an eloquent, unresectable focus.

We have found SEEG to be especially useful in patients without a lesion on MRI. Seizure freedom following resective surgeries in patients with normal pre-operative MRI has been significantly worse in the literature, with seizure-free rates as low as 17% [22, 24-26]. In our series 13 patients had non-lesional MRIs, of those 10 underwent surgical resection following SEEG monitoring. In the non lesional patients undergoing resection the seizure free rate was 40%. It is our hope that SEEG will increase the number of these patients who can have an EZ localized, and therefore undergo resection.

Similarly, seizure outcomes in patients with extra-temporal lobe epilepsy (and in particular frontal lobe epilepsy) are considerably worse in comparison to those with temporal lobe epilepsy, with reported seizure-free rates of 13-80% for frontal lobe epilepsy [27-30]. We hope that with longer follow-up and a larger sample size, our algorithm for SEEG selection will allow for earlier and more successful interventions for pediatric patients suffering from refractory epilepsy.

Conclusions

This study demonstrates that SEEG is a safe and effective method to localize the EZ in medically refractory pediatric epilepsy patients. Furthermore, we suggest an algorithm for standardizing appropriate SEEG candidates in the pediatric population. Nonetheless, long-term follow-up will be necessary to better evaluate and validate our results.