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# Analysis of surgical strategies for children with epileptic spasms

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**ABSTRACT**

***Objective.*** To investigate surgical prognostic factors in order to establish a surgical plan for children with drug-resistant epileptic spasms.

***Methods.*** We retrospectively analysed 64 children with drug-resistant spasms who were operated on in Beijing; the electroclinical features, surgical procedures, and surgical outcomes of these children were discussed in detail. We divided the seizure-free patients into several groups according to imaging, aetiology, and application of stereo-electroencephalography in order to investigate the extent of the various influencing factors.

***Results.*** Fifty-three (82.8%) patients had favourable outcome, and 11 (17.2%) had unfavourable outcome. Based on the univariate analysis, the factors associated with favourable seizure outcome were interictal high γ frequency ($\chi$ 2 = 4.161; $p$ = 0.041), concordance between MRI and interictal epileptic discharges (IEDs) ($\chi$ 2 = 6.148; $p$ = 0.013), and concordance between PET and IEDs ($\chi$ 2 = 4.281; $p$ = 0.039). Concordance between MRI and IEDs (OR = 0.083, 95% CI = 0.014–0.483; $p$ = 0.006) and continuous discharges on electrocorticography (OR = 0.109, 95% CI = 0.019–0.639; $p$ = 0.014) were important factors associated with a favourable surgical outcome.

***Significance.*** Resective surgery is an effective treatment for drug-resistant ES in children. A deeper understanding of the predictors of seizure outcome is beneficial for establishing a standard, one-stage resection procedure for spasms in order to benefit more patients who have not previously considered surgery. We propose a workflow for presurgical evaluation in children with epileptic spasms.

**Key words:** epileptic spasms, children, prognostic factors, surgical strategy

Epileptic spasms (ES) are a unique type of seizure [1] that classically occur in infants, as infantile spasms, with a certain age dependence. Symptoms may also develop after infancy or return later after an initial remission of infantile spasms. ES have been reported in many conditions, including malformation of cortical development (MCD), brain injury, perinatal asphyxia, and genetic abnormalities. Generally, patients with ES develop other epileptic symptoms, such as generalized tonic-clonic seizures or various types of focal seizures, by the age of three to five [2, 3]. Data on the surgical outcomes of children with ES, however, are scarce. ES are often considered to be a factor associated with poor prognosis after surgery; more importantly, the electroclinical characteristics of ES and their influence on postoperative efficacy are still unclear. The localization of the epileptogenic zone is difficult due to the symmetry of symptomatology and the extensiveness of the seizure onset, which makes epilepsy surgery for

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ES challenging. However, a recent paper indicated that not only is surgery a viable option for appropriately selected ES patients, but that postoperative efficacy is also comparable to that achieved for other types of focal epilepsy [4]. Considering that ES may be a potential type of focal epilepsy, focal resection is promising; besides, surgical treatment can improve neurocognition while curing epilepsy [5]. Advanced neuroimaging and invasive monitoring techniques have helped us to locate epileptogenic foci, so that patients of this type, who were not previously recommended for surgery, can become seizure-free upon resection of the foci. In an article from the United States, of 65 infants and children with drug-resistant ES who were treated with surgery, those patients with early surgical treatment or consistency between MRI lesions and EEG abnormalities tended to obtain better surgical outcomes [6]. Even if there is no specific lesion on MRI, a good surgical outcome can be achieved when there are focal metabolic abnormalities on PET. According to an Italian study, completeness of resection of the seizure onset zone and of the identifiable lesion is highly associated with a better surgical outcome [7-9]. Here, we retrospectively analysed 64 children with drug-resistant spasms, who we had operated on in Beijing, in order to discuss the aetiology, clinical features, operation procedures, and prognosis in detail. Our purpose was to explore the relationship between surgical efficacy and these factors, as well as to propose an appropriate preoperative scheme for drug-resistant ES.

## Methods

### Patients

Over 300 children with refractory ES were referred to the Epilepsy Center of Yuquan Hospital at Tsinghua University in Beijing between January 2013 and January 2019 for surgical consideration, with ES being a target for surgery. Medical records were collected to examine the clinical information, symptomatological characteristics, and examination data (including EEG data and imaging data) of the patients. The semiology of ES is defined as a sudden flexion or extension of the trunk or upper limbs lasting less than three seconds and most often occurring in clusters. Most of the patients were not good surgical candidates due to bilateral brain malformation, metabolic diseases, bilateral ictal EEG onset, and potentially inoperable types associated with genetic mutations. A total of 83 of these patients underwent surgical treatment with a suspicion of a localized origin. Of these, 19 were excluded for the following reasons:

- having undergone vagus nerve stimulation or deep brain stimulation;
- having had epileptic spasms previously and now presenting with a different type of seizure;
- or having had < one year of follow-up.

The remaining 64 patients with ES as the main type of seizure were selected for surgical treatment due to drug resistance and were followed for more than one year.

### Non-invasive workup and preoperative evaluation

The patients underwent a comprehensive presurgical examination, including MRI, scalp interictal and ictal video-electroencephalogram (VEEG), positron emission tomography (PET), and neuropsychological tests. For specific gene-related causes, such as tuberous sclerosis complex (TSC), the patient was scheduled for genetic testing, however, the genetic results and previous reports did not show any specific mutations associated with ES [10]. MRI scan sequences included three-dimensional (3D) T1-weighted 1.0-mm-thick slices, fluid-attenuated inversion recovery (FLAIR), and T2-weighted sequences. FDG-PET was superimposed on 3D brain MRI to identify potentially subtle changes in brain metabolism. Concordance between MRI, PET and interictal epileptic discharges (IEDs) was defined as localization of the visible lesion (MRI), hypometabolism (PET) and interictal discharges in the same brain region. VEEG and stereo-electroencephalography (SEEG) recordings were performed using a video EEG system (Nihon Kohden, Tokyo, Japan) with a high sampling rate. At least three habitual epileptic spasm seizures were captured. The IEDs, slow waves, and interictal high $\gamma$ band (around 60-90 Hz) were either observed visually or filled in automatically by the built-in software from Nihon Kohden. The IEDs were classified as focal, when only one lobe or one restricted region was involved, or bilateral or multiple, when both hemispheres were involved. Similarly, when a seizure was captured, the onset of ES was reviewed and assessed by two independent neurologists, who finally reached a consensus. Ictal VEEG patterns were also classified as focal or diffuse (including voltage decrement) according to the above standards. The asymmetry of the intensity of body jerking during ES can be detected by video monitoring. After completion of the detailed presurgical evaluation in a multidisciplinary epilepsy surgery conference, consensus regarding a surgical plan was reached. It should be emphasized that the choice of surgery depends on the concordance between the data for MRI, PET, and VEEG, however, the MRI data is most important, *e.g.* if the site of a lesion on MRI is concordant with interictal discharges, this would

be considered to be of significance in identifying the epileptogenic zone. None of the patients in our study were operated on based on PET imaging only, but this can be regarded as an important index to decide on a surgical procedure in combination with MRI and EEG. Subtle ictal EEG changes or ambiguous interictal discharges were considered to be more serious if supported by PET. Patients with structural lesions on MRI were also operated on with the aid of PET, even if the EEG was discordant. Stereo-electroencephalography (SEEG) was required if all of the non-invasive data was insufficient to determine the location or extent of surgical resection [11, 12].

### Seizure outcome

Surgical methods were selected according to the preoperative evaluation. Patients were followed for at least one year. Seizure outcomes were assessed by neurosurgeons according to the International League Against Epilepsy (ILAE) classification. As ES are common in infants and young children, aura are usually indescribable, and postoperative recurrences often occur in clusters; therefore, we defined favourable seizure outcome as ILAE Class 1 and 2 and unfavourable seizure outcome as ILAE Class 3-6.

### Statistical analysis

All of the analyses were performed using the Mann-Whitney *U* test and Pearson chi-square test. A multivariate logistic regression analysis was performed to determine independent factors correlated with surgery. A $p$ value of $\leq 0.05$ was considered to be statistically significant. Odds ratios and 95% confidence intervals (CIs) were also calculated for each of these parameters. SPSS software version 24.0 was used for the data analyses.

## Results

### Patient characteristics

All of the 64 patients had drug-resistant epileptic spasms. There were 38 males and 26 females, with a mean age at seizure onset of 0.95 ± 1.48 years. Out of the 64 patients, 45 (70.3%) had spasms in infancy, and 19 had late-onset spasms. There were 25 (39%) cases of MCD, including focal cortical dysplasia (FCD), hemimegalencephaly, schizencephaly, and polymicrogyria; 19 (30%) cases of tuberous sclerosis complex (TSC); 11 (17%) cases of perinatal hypoxia; and four (6%) cases of encephalomalacia (secondary to cerebral haemorrhage and encephalitis). Tumours were observed in two patients, and three cases were of unknown aetiology. The mean age at surgery was 3.33 ± 2.72 years, and the mean duration between seizure onset and surgery was 2.38 ± 2.12 years; 53 patients had multiple clusters of ES per day before surgery, and the remaining 11 had at least one cluster per week. Of the 64 cases, 41 presented with spasms only, and 23 had other types of spasms besides ES, including focal and generalized seizures. Spasms were mainly symmetric in 32 patients (50%) and mainly asymmetric in 32 (50%) (*table 1*).

### MRI and PET results

Fifty-three (83%) patients had an identifiable lesion on MRI. The MRI scans did not show abnormalities in 11 cases, and in this group, 10 had a favourable surgical outcome, while only one patient had an unfavourable surgical outcome. Of these 10 patients, eight had FCD confirmed after surgery, and nine had surgery confined to the frontotemporal lobe. PET scans were abnormal (showing focal, multiple, or diffuse abnormalities) in all of the patients, with localizing findings in 43 (67%) patients. In the focal hypometabolism group, 37 (86%) had a favourable surgical outcome, and in the bilateral hypometabolism group, 21 (33%) had a favourable surgical outcome. Fifty-four (90%) of the 64 patients were considered to have a lesion concordant with the main hypometabolism on PET, 45 of whom had a favourable result.

### Scalp EEG findings

Scalp VEEG was performed for all of the patients. Of the 64 patients, 38 (59%) had focal IEDs, and 26 (41%) had bilateral IEDs. Ictal patterns of ES were characterized by widespread slow waves with or without focal features including focal fast activities (>30 Hz) or a preceding spike. For ictal onset, 22 (34%) were focal and 42 (66%) were diffuse (including voltage decrement). Fifty of the 64 patients were considered to have a lesion concordant with the IEDs. Of these cases, 45 (90%) had a favourable surgical outcome. Concordance between PET and IEDs was found in 52 (81%) patients; among them, 46 (88%) cases had a favourable surgical outcome. Interictal high $\gamma$ frequency was detected in 43 (75%) patients, 39 of whom had a favourable surgical outcome. In the group with unfavourable surgical outcome, only four patients showed high $\gamma$ frequency (*table 1*).

▼ **Table 1.** Clinical characteristics according to seizure outcome (n = 64).

| Variable | Total (*n* = 64), % | Favourable outcome (*n* = 53) | Unfavourable outcome (*n* = 11) | *p* value |
|---|---|---|---|---|
| Sex (male) | 38 (59.4%) | 30 | 8 | 0.513 |
| Age at seizure onset | 0.95 ± 1.48y | 1.03 ± 1.59y | 0.49 ± 0.57y | 0.196 |
| Age at surgery | 3.33 ± 2.72y | 3.30 ± 2.87y | 3.47 ± 1.97y | 0.393 |
| Duration of seizures | 2.38 ± 2.12 y | 2.27 ± 2.12y | 2.95 ± 2.17y | 0.226 |
| Seizure types | | | | |
| Spasm only | 41 (64%) | 34 | 7 | 1 |
| Spasm + other type | 23 (36%) | 19 | 4 | |
| Spasm semiology | | | | |
| Symmetric | 32 (50%) | 25 | 7 | 0.508 |
| Asymmetric | 32 (50%) | 28 | 4 | |
| MRI (lesion) | | | | |
| Positive | 53 (83%) | 43 | 10 | 1 |
| Negative | 11 (17)) | 10 | 1 | |
| PET (hypometabolism) | | | | |
| Focal | 43 (67%) | 37 | 6 | 0.53 |
| Bilateral | 21 (33%) | 16 | 5 | |
| IEDs | | | | |
| Focal | 38 (59%) | 33 | 5 | 0.487 |
| Bilateral | 26 (41%) | 20 | 6 | |
| Ictal onset | | | | |
| Focal | 22 (34%) | 20 | 2 | 0.371 |
| Diffuse | 42 (66%) | 33 | 9 | |
| Interictal high γ frequency | | | | |
| Yes | 43 (75%) | 39 | 4 | 0.041* |
| No | 21 (25%) | 14 | 7 | |
| Concordance between lesion and IEDs | | | | |
| Yes | 50 (78%) | 45 | 5 | 0.013* |
| No | 14 (22%) | 8 | 6 | |
| Concordance between PET and IEDs | | | | |
| Yes | 52 (81%) | 46 | 6 | 0.039* |
| No | 12 (19%) | 7 | 5 | |
| Concordance between PET and lesion | | | | |
| Yes | 54 (90%) | 45 | 9 | 1 |
| No | 10 (10%) | 8 | 2 | |
| SEEG | | | | |
| Yes | 13 (20%) | 11 | 2 | 1 |
| No | 51 (80%) | 42 | 9 | |
| Side of surgery (left) | 29 (45%) | 25 | 4 | 0.747 |
| Intraoperative continuous occasional/ intermittent discharges on ECoG | | | | |
| Yes | 37 (61%) | 34 | 3 | 0.031* |
| No | 24 (39%) | 16 | 8 | |

IED: interictal epileptic discharge; MRI: magnetic resonance imaging; PET: positron emission tomography; SEEG: stereo-electroencephalography; ECoG: electrocorticography. *$p < 0.05$.

## Surgery

For 61 (95%) patients, intraoperative electrocorticography (ECoG) monitoring was performed. Twenty-nine (45%) patients underwent left-side surgery, and 35 (55%) underwent right-side surgery. Thirteen (20%) patients received SEEG due to non-localizing data, and 11 of them had favourable outcome. There was no significant correlation between surgical result and whether or not SEEG was used. We performed 22 (34%) unlimber resections, 17 (27%) hemispherotomies (total/subtotal), 15 (23%) tuberectomies, and seven (11%) multilobar resections; the remaining three cases received RF-TC treatment. Among the 64 patients, the frontal lobe was operated on in 16 (25%), 12 of whom had favourable surgical results; multiple lobes were operated on in 13 (20%) patients, 12 of whom had favourable results; and 13 (20%) patients underwent hemispheric surgery, 12 of whom had favourable results. In addition, the parietal lobe, temporal lobe, and occipital lobe were operated on in 11, eight, and three patients, respectively. There were no significant differences in surgical type or resective site between the favourable and unfavourable groups (*figure 1*).

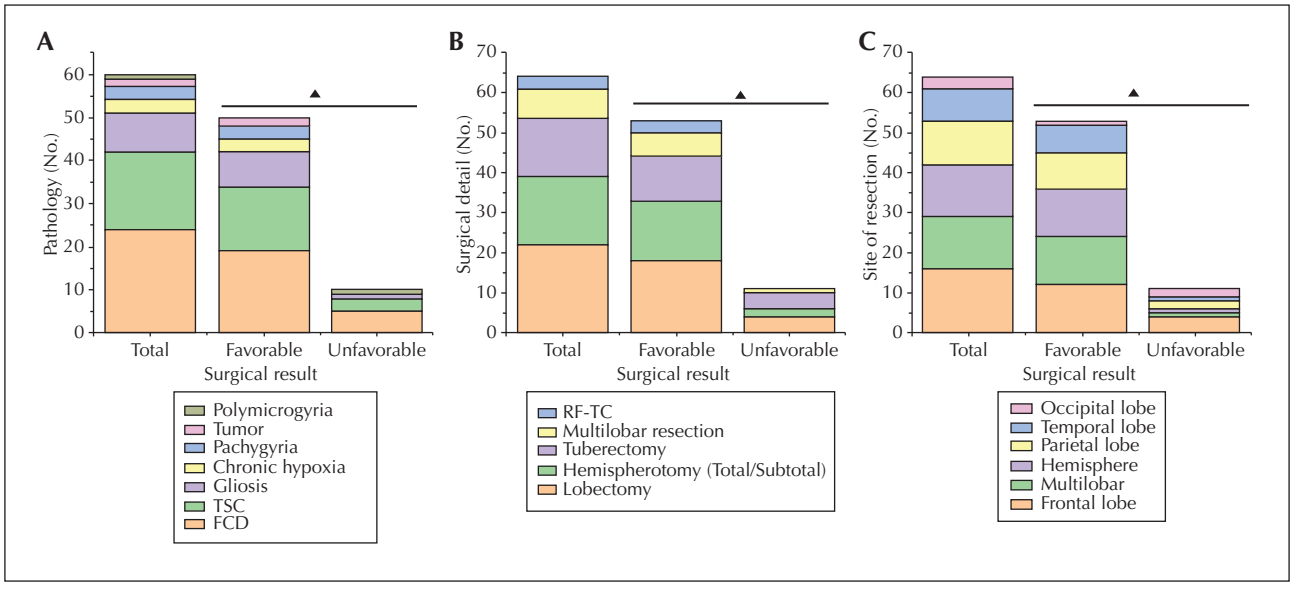
## Surgical outcome and analysis of prognostic factors

The mean follow-up time of the 64 patients after surgery was 3.1 ± 2.4 years. Fifty-three (82.8%) patients had favourable outcome, and 11 (17.2%) had unfavourable outcome. The following factors were associated with seizure outcome based on univariate analysis (*table 1*): interictal high γ frequency ($\chi 2 = 4.161$; $p = 0.041$), concordance between MRI and IEDs ($\chi 2 = 6.148$; $p = 0.013$), and concordance between PET and IEDs ($\chi 2 = 4.281$; $p = 0.039$). The other factors listed in *table 1* were not associated with seizure outcome. The factors with statistical significance were entered into the multivariate logistic regression model, which showed that concordance between MRI and IEDs (OR: 0.083, 95% CI: 0.014-0.483; $p = 0.006$) and continuous discharges on ECoG (OR: 0.109, 95% CI: 0.019-0.639; $p = 0.014$) were independent risk factors for favourable surgical outcome (*table 2*).

## Analysis of influencing factors in patients without seizures after surgery

In order to further elucidate the contribution of various influencing factors in patients without seizures after surgery, we divided these patients into three groups according to imaging, aetiology, and whether SEEG was performed:

– MRI-negative group versus MRI-positive group. The proportions of patients with ECoG continuous discharges, limited resection, and SEEG application among the MRI-positive and MRI-negative group were 55.8% and 100%, 41.9% and 80%, and 25.6% and 40% respectively. The proportions of patients with interictal high γ frequency, concordance




■ **Figure 1.** Data on pathology (A), type of surgery (B) and site of resection (C) in patients with favourable or unfavourable outcome.

▼ **Table 2.** Predictors of seizure outcome after surgical treatment for refractory epileptic spasms in 64 children based on multivariate analysis.

| Variable | OR | 95% CI | *p* |
|---|---|---|---|
| Concordance between MRI and IEDs | 0.083 | 0.014-0.483 | 0.006* |
| ECoG (continuous discharges) | 0.109 | 0.019-0.639 | 0.014* |

CI: confidence interval; OR: odds ratio. *P < 0.05.

between PET and IEDs, and focal hypometabolism on PET were 79.1% and 50%, 90.7% and 70%, and 67.4% and 60% respectively.

- FCD group versus TSC group. The proportions of patients with ECoG continuous discharges, SEEG application and limited resection among the FCD group and TSC group were 78.6% and 42.9%, 7% and 33.3%, and 42.9 and 61.1%, respectively. The proportions of patients with interictal high γ frequency, concordance between PET and IEDs, concordance between MRI and IEDs, and concordance between MRI and PET were 85.7% and 77.8%, 85.7% and 94.4%, 92.6% and 77.8%, and 100% and 94.4%, respectively.
- SEEG group versus non-SEEG group. The proportions of patients with focal IEDs, focal PET hypometabolism, and a focal lesion among the SEEG group and non-SEEG group were 45.5% and 66.7%, 36.3 and 73.8%, and 27.3 and 64.3%, respectively. The proportions of patients with limited resection and patients receiving focal lobotomies among the two groups were 90.1% and 33.3%, and 63.6% and 16.7%, respectively.

### Pathology

Histopathology was available in 60 patients, while tissue specimens were not available after hemispherotomy or RF-TC in four patients. Pathology revealed FCD in 24 (40%) patients, tubers in 18 (30%), gliosis in nine (15%), chronic hypoxia in three, pachygyria in three, tumour in three, and polymicrogyria in one. There was no significant difference in pathologies between the favourable and unfavourable groups (*figure 1*).

## Discussion

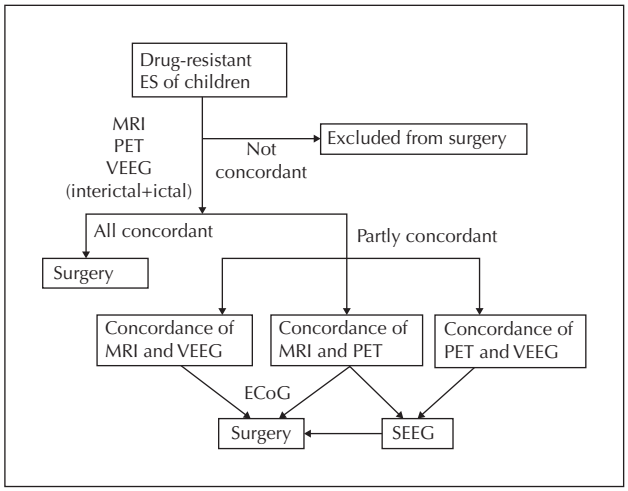
Many studies have indicated that ES may potentially be a focal-type seizure, and some have reported similar postsurgical results between focal ES and other focal seizures, therefore surgery may provide these patients with an opportunity to become seizure-free [13, 14]. The features of focal seizures include a focal lesion, focal discharges or onset, focal hypometabolism on PET, and asymmetry of symptomatology; surgical results may be highly correlated with these features. In addition, surgical outcome may also be affected by aetiology, surgical type, and surgical site. Few studies have examined the influence of these factors on the prognosis of ES [15, 16]. The present case series from Beijing, involving 64 children with refractory ES, provides a deeper understanding of these factors and may help guide future surgical treatment.

Approximately 83% of the patients in our study had favourable surgical outcomes, a much higher proportion than we expected and also higher than the average success rates in recent studies from other centres [17, 18]. We did not find any differences in sex, age at first seizure, age at surgery, or duration of seizures between the groups with favourable and unfavourable surgical outcome. Although children with intractable ES who had surgery within three years of their first seizure tended to have better outcome based on a previous study [19], we did not find such a result in our study. However, according to our data, the seizure onset age in 53 (82.8%) cases was less than one year of age, and the duration between seizure onset and surgery in 48 (75%) cases was less than three years, which may account for the good surgical results. The reason for achieving better outcomes at a younger age is not clear. A possible explanation is that ES are more active in young children. It is easier to establish a large epileptic network and form secondary epileptic foci in infants and young children. Surgical treatment should be performed as soon as possible, which can provide early relief and promote the resumption of brain developmental progression. Meanwhile, larger resections in these patients can reduce injury due to functional compensation at a later stage [6]. Some studies have suggested that symmetric spasms or the coexistence of symmetric and asymmetric spasms are adverse factors for long-term prognosis, as they are usually associated with extensive lesions. Whether asymmetrical symptomatology suggests a better prognosis is unclear. In our study, we did not find a correlation between surgical outcome and asymmetrical symptomatology or a combination of other types of seizure. This suggests that symptomatology is not very reliable in indicating prognosis, but asymmetry in the intensity of jerking or face twitching during spasms

does help us to lateralize the hemisphere responsible for producing ES [20]. In the present study, 53 (83%) children with ES had a definite lesion on MRI, which also accounts for the good surgical results. It has been reported that about half of children with ES have identifiable lesions on MRI [6].

Although postoperative results are not associated with any specific imaging features, the concordance between imaging and EEG has important clinical implications. VEEG plays an important role in determining surgical prognosis. Studies have suggested that if hypometabolism on PET is consistent with ictal or interictal abnormalities on EEG, resection of that region would result in seizure cessation and improved cognitive behaviour [21, 22]. In our study, there was very good correlation between surgical outcome and concordance between MRI and IEDs and concordance between PET and IEDs. The results of multivariate regression analysis in the present study also support this finding, which further confirm the importance of combining imaging and EEG data in preoperative evaluation. However, we should be cautious to not exclude patients who have negative MRI or EEG presenting non-localized discharges, especially in children. Children with epileptic spasms and diffuse epileptic discharges, that have been shown to be compatible with focal lesions, may achieve good surgical outcome after surgical resection. Furthermore, the development of imaging and EEG postprocessing techniques may provide new focal evidence. Additionally, interictal high γ frequency was found to be correlated with favourable surgical outcome. Asano *et al*. showed that spasms are associated with either a "leading" spike followed by fast bursts or fast bursts without a "leading" spike [23, 24]. Recent studies have shown detectable focal HFOs, especially in the high γ band (around 60-90 Hz) on scalp EEG recordings in children with epileptic spasms. Asymmetric ictal γ activity in the centroparietal area is associated with observable asymmetry of the spasms. Thus, resection of cortical areas, represented by high γ frequency, highly correlated with good surgical outcomes [25, 26]. In our study, we found no significant correlation between surgical outcome and surgical type or resection site. The most commonly used surgical procedures in our patients were unilobar resection, hemispherotomy (total/subtotal), and tuberectomy, demonstrating that ES are initiated as cortical epileptic discharges which, during a "critical" developmental period, undergo secondary generalization in an age-dependent mechanism to emerge as spasms, despite the complex mechanisms and brain network associated with ES [27]. The focal cortical origin of spasms has also been demonstrated by invasive EEG recordings as well as favourable outcomes following removal of discrete epileptogenic lesions [6, 22, 28]. No studies have shown a correlation between surgical site and surgical outcome. The most common surgical site in our study was the frontal lobe, even after SEEG. This is consistent with a previous finding showing that these complex clusters of axial attacks are more likely to form in the frontal lobes; the exact mechanism requires further study of brain networks [29]. We found no significant correlation between surgical outcome and whether or not SEEG was performed, suggesting that there are limitations in the application of this technique for ES.

By grouping the patients with no seizure after surgery, we can provide a clinical basis for future surgical strategies. First, whether ES patients with negative MRI can undergo surgical treatment and the extent of surgical resection have always been concerns of surgeons. Our data indicate that in MRI-positive cases, due to extensive cortical injury, such as generalized cortical dysplasia, TSC, or perinatal hypoxia, being a common cause of spasm seizures, localized resection is relatively rare. The surgical decision mainly depends on the preoperative EEG and imaging data, especially low focal metabolism on PET and its concordance with interictal discharges, therefore the range for resection is generally wide. In MRI-negative cases, SEEG is performed at a higher rate, leading to a corresponding increase in limited and tailored resection, which also accounts for a favourable outcome. Therefore, if accurate resection and functional protection are considered, the SEEG is still a necessary monitoring tool. In addition, we found that the MRI-negative group was more dependent on intraoperative ECoG monitoring, which was also one of the main indexes for surgical resection range and surgical result. However, in the MRI-positive group, due to the extensive lesions and dispersed discharge, intraoperative ECoG monitoring had some limitations. For the two most common causes of ES, FCD and TSC, we found that concordance between MRI, PET, and scalp EEG was an important factor in determining surgical strategy. Therefore, preoperative high-resolution MRI, precise interpretation of EEG, and fusion technologies of PET and MRI all provide an important basis for surgical decision-making. In addition, the proportion of SEEG application in the TSC group was much higher than that in the FCD group, suggesting that although TSC patients have clear lesions on imaging, intracranial electrodes are often needed to help identify the true epileptic nodules due to the multiple lesions. As imaging techniques have improved, FCD has become more recognized, and SEEG is performed less. However, the proportion of patients with limited resection in the FCD group was lower than that in the TSC group, perhaps because the boundaries of FCD were sometimes relatively unclear; the extent of resection was often beyond our expectation, involving the




■ **Figure 2.** Proposed workflow for presurgical evaluation in children with epileptic spasms.

corresponding cortical or subcortical structures. According to our data, the proportion of patients with continuous discharges on ECoG was relatively high in the FCD group, therefore the intraoperative ECoG could be an important index for the surgical resection range for FCD. Whether intracranial electrodes are needed for ES is of more concern to surgeons and patients because the onset of ES usually involves a widespread slow wave, and the ictal discharges are also diffuse even after electrode implantation. We found that with less valuable information based on preoperative evaluation, such as focal lesions, focal interictal discharges, and focal hypometabolism, SEEG tended to be performed in order to identify epileptogenic foci, consistent with previous studies [30]. In our study, although SEEG was not the main factor in determining the prognosis, the implantation of intracranial electrodes narrowed the range of resection, which was more consistent with the concept of accurate resection, particularly beneficial regarding functional protection of older children.

Based on the above factors, a workflow for presurgical evaluation in children with epileptic spasms is proposed (*figure 2*). We hope that the preoperative evaluation process for children with ES can be simplified and a reasonable surgical plan can be made accordingly.

## Limitations

The neurodevelopmental outcomes, behavioural outcomes, and postoperative complications associated with ES surgery were not discussed in our study due to challenges in the longitudinal assessment of large numbers of ES patients, and the number of surgical cases of ES is still limited. Larger studies with multicentre collaboration may reveal clinically relevant associations and identify correlations between presurgical variables and outcomes.

## Conclusion

Our study shows that surgical resection can be effective for children with drug-resistant ES when certain indications are met. Concordance between MRI and IEDs, concordance between PET and IEDs, interictal high γ frequency, and continuous discharges on ECoG are important factors associated with a favourable surgical outcome. We propose a workflow for presurgical evaluation in children with ES to simplify the process and help provide a reasonable surgical plan. ■

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We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines. We thank LetPub (www.letpub.com) for its linguistic assistance during the preparation of this manuscript. None of the authors have any conflict of interest to declare.

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