

# Localization of Epileptic Foci in Children

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**ABSTRACT:** Electroencephalographic and neuro-imaging data were correlated with the lobe of cortical resective surgery among 48 patients age 16 years or less with medically intractable partial seizures. Decisions about surgery were determined by clinical judgement and therefore our results reflect the weight of these factors in clinical practise. Neuro-imaging disclosed a lesion over the operated lobe in 32 patients (67%). Multiple EEGs demonstrated a most active spike focus over the operated lobe in 32 patients (67%). Although only 34 patients had a recorded seizure, this clearly arose over the operated lobe in 23 (68% of the 34 patients; 48% of series). Persistent focal delta activity appeared in 20 of the 48 patients (42%). No instance was encountered in which false lateralization of regional or focal interictal EEG spikes or delta when normal apiculate phenomena were excluded. Thus, the scalp EEG remains a valuable guide to epileptogenesis, even among young patients, and should continue to play a major role in determining the region of cortical resection. Effectiveness of cortical resection for seizure control was clearly better among patients with a single major lesion and among those with normal intelligence.

**RÉSUMÉ:** Localisation de foyers épileptiques chez les enfants. Les données neuroradiologiques et électroencéphalographiques ont été corrélées avec le site de résection corticale chez 48 patients âgés de moins de 16 ans souffrant d'épilepsie partielle réfractaire à la médication. Dans chaque cas, l'indication chirurgicale a été basée sur le jugement du clinicien et nos résultats reflètent l'importance de ce facteur dans notre pratique courante. Chez 32 patients (67%), les tests d'imagerie ont démontré une lésion au niveau du lobe opéré. Chez 32 patients (67%), de multiples enregistrements EEG ont démontré une activité épileptique inter-ictale maximale au niveau de lobe opéré. Parmi les 34 patients chez qui une crise épileptique a été enregistrée, celle-ci provenait du lobe opéré dans 23 cas (68% des 34 patients, 48% du groupe total). Une activité lente (delta) focale persistante est apparue chez 20 des 48 patients (42%). Aucun cas de latéralisation erronée de l'activité épileptique interictale ou de l'activité lente (delta) n'a été rencontré. L'enregistrement EEG de surface demeure un instrument valable de détection du foyer épileptogène, même chez les patients jeunes, et devrait conserver un rôle premier plan dans la délimitation de la zone de résection corticale.

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In honour of the 50th anniversary of the MNI EEG Laboratory and of the importance of properly selecting children for epilepsy surgery, the following data are presented. This study of patients undergoing epilepsy surgery at age 16 years or less shows that interictal and ictal EEG help localize epileptogenic foci in children and do not give falsely lateralizing information.

## METHOD

All 48 patients undergoing regional corticectomies for medically uncontrolled partial seizures in the Epilepsy Unit, University Hospital from 1974 to 1988 who were 16 years of age or less at the time of operation were included. Hemispherectomies and corpus callosotomies were excluded.

Epilepsy Unit files and the EEG Department database system<sup>1</sup> gave clinical and EEG data. An average of 10 EEGs (range: 1-28) were carried out on these patients. All EEG data were obtained by visual assessment. Information about the effectiveness of surgery for seizure control with a minimal follow-up period of one year was available for all patients.

The decision about the site of surgery was based on a compilation of clinical and laboratory data including seizure symptoms, neurological examination, electroencephalography, and radiology. No decision making protocol was followed.

## RESULTS

### Most Active Focal Spikes

Considering all awake and sleep recordings together, the most active focal spikes correlated with the surgery site in 32 of the 48 patients (67%). As seen in Table 1, the correlation was highest for temporal lobe resections and lowest for those in the frontal lobe. Ten of the 11 patients (91%) with most active spikes in an adjacent lobe or simply ipsilateral to the surgical site had a radiologically demonstrable lesion at the surgical site. The other patient had no radiology.

### Ictal EEG

Twenty-three of the 48 patients (48%) had EEG-recorded clinical seizures clearly arising from the ultimately-resected lobe (Table 2). In the 2 patients whose seizures apparently arose

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adjacent to the operated lobe, clinical ictal and neuro-imaging data suggested occult propagation to the adjacent lobe. The seizures of 5 patients arose simply ipsilateral to the surgery site and 3 had electrographically recorded seizures whose origins were ambiguous. Seven of these 8 patients (87%) had focal lesions as disclosed by neuro-imaging.

Fourteen of the 48 patients (29%) did not have a recorded seizure. Some of these patients were operated on prior to the introduction of prolonged telemetered recordings and others were unable to cooperate for telemetry. Eight of these 14 patients (57%) had lesions at the operated site as disclosed by MRI or CT.

**Seizure Origin and Most Active Spikes**

Thirty patients had both a clearly defined seizure origin and a predominant spike focus (Table 3). These sites were congruent in 21 of the 30 patients (70%) whereas the seizure origin was at least ipsilateral to the most active spikes in 7 (23%). Considering all recordings together, no patient had a most active spike focus which falsely lateralized seizure origin.

**Focal Delta**

Twenty of the 48 patients (42%) demonstrated focal or at least focally accentuated diffuse delta over the surgery site which appeared on two or more awake recordings. In 9 patients (19%), delta appeared either over an adjacent lobe or was simply ipsilateral to the surgical site. Thus, among 29 patients with excessive regional delta, it resided in the surgery site in 20 (69%). In no instance did the most prominent regional delta activity appear contralateral to the operated site.

**Table 1: Most Active Focal Spikes and Surgery Site (48 pts)**

Spikes → Surgery ↓	Same	Adjacent	Ipsilateral	Other	No Maximum	No Spikes
Frontal (14 pts)	7 (50%)	3	3	1		
Temporal (21)	16 (76%)	1	2		1	1
Other (13)	9 (69%)	1	1	1	1	
<b>Total</b>	<b>32 (67%)</b>	<b>5 (10%)</b>	<b>6 (12%)</b>	<b>2</b>	<b>2</b>	<b>1</b>

Headings for Tables 1, 2, 4 pertain to lobe of EEG or neuro-imaging phenomenon in relation to surgery site.

**Table 2: Ictal EEG and Surgery Site (48 pts)**

Seizure → Surgery ↓	Same Lobe	Adjacent Lobe	Ipsilateral Lobe	Other	Generalized or Ambiguous	None
Frontal (14 pts)	9		1			4
Temporal (21)	6	2	2	1	3	7
Other (13)	8		2			3
<b>Total</b>	<b>23 (48%)</b>	<b>2</b>	<b>5 (10%)</b>	<b>1</b>	<b>3</b>	<b>14 (29%)</b>

**Neuro-Imaging and Surgery Site**

Neuro-imaging disclosed lesions in the to-be-operated lobe in 32 of the 48 patients (67%) (Table 4). Of the 10 patients with normal imaging studies, 8 had recorded seizures and 9 had active spikes over the operated lobe.

**FOLLOW-UP DATA**

All 48 patients were followed for at least one year post-operatively, (median 6 years 3 months; range 12 months - 15 years 5 months). Twenty-seven of the 48 patients (56%) were either seizure-free or had an over 90% reduction in seizure quantity (Table 5). Ten patients (21%) had a 50-90% improvement while 11 patients (23%) were unimproved, worse or died. Both deaths related to malignant changes in brain tumors.

Success of surgery correlated highly with the presence of a single major lesion (SML) as disclosed by clinical examination

**Table 3: Seizure Origin and Most Active Spikes (30 pts)**

Spikes → Seizure Origin ↓	Same	Adjacent	Ipsilateral
Frontal (10 pts)	6	1	3
Temporal (10 pts)	6	1	3
Other (10 pts)	9		1
<b>Total</b>	<b>21 (70%)</b>	<b>2 (7%)</b>	<b>7 (23%)</b>

Includes only patients with focal or hemispheric EEG seizure origins.

**Table 4: Neuro-Imaging and Surgery Site**

Radiology → Surgery ↓	Same	Adjacent	Ipsilateral	Diffuse	Normal	Not Done
Frontal (14 pts)	11	1			2	
Temporal (21)	14			1	4	2
Other (13)	7		2		4	
<b>Total</b>	<b>32 (67%)</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>10 (21%)</b>	<b>2</b>

**Table 5: Effect of Surgery and Single Major Lesion (SML)**

	Number of Patients	Seizure Free	> 90% Improvement	50 - 90% Improvement	No Effect	Worse	Died
	35	17	5	9	2	0	2
SML	49%	14%	26%	6%	6%	0	6%
No SML	13	4	1	1	4	3	0
	48	31%	6	10	31%	23%	
<b>Total</b>	<b>48</b>	<b>21</b>	<b>6</b>	<b>10</b>	<b>6</b>	<b>3</b>	<b>2</b>
		<b>44%</b>	<b>12.5%</b>	<b>21%</b>	<b>12.5%</b>	<b>6%</b>	<b>4%</b>

SML = single major lesion on clinical examination or on neuro-imaging (CT and/or MRI).

and/or neuro-imaging (Table 5). Of 35 patients with a SML, 31 (89%) obtained at least a 50% improvement in their seizures whereas only 4 (11%) failed to obtain any benefit. In contrast, only 6 of 13 (46%) patients without a SML obtained at least a 50% improvement and 7 (54%) obtained no benefit ( $p < .01$ ).

Twenty-six of 29 intellectually normal patients (90%) achieved at least a 50% reduction in seizure quantity following surgery of which 19 (65%) are seizure-free. In contrast, only 11 of 19 patients (58%) who were mentally subnormal attained this benefit, of which only 2 (11%) are seizure-free ( $p < .01$ ).

## DISCUSSION

As Pierre Gloor<sup>2</sup> has written, partial seizures are caused by a structural abnormality of the brain. Therefore, if a lesion is demonstrated in a patient with partial seizures, the likelihood that the seizures are in some way caused by this lesion is high even though experienced epileptologists will have encountered exceptions to this. Therefore, it is not surprising that neuro-imaging would have disclosed a lesion in the same lobe at the site to be operated upon in 32 of 48 patients (67%). An additional 3 patients had adjacent or ipsilateral lesions. Similarly, the effectiveness of surgery was greater among the 35 patients who had clinical and/or neuro-imaging evidence of a single major lesion as compared to 13 patients without such evidence. This principle would explain the better results among the 29 patients with normal intelligence as compared to the 19 mentally subnormal patients. Multifocal or diffuse abnormalities, possibly epileptogenic, more likely exist in the latter group. Nonetheless, 11 of the 19 patients with subnormal intelligence gained 50% improvement or better from the procedure.

That less than 90% seizure improvement was obtained among 13 of 35 patients (37%) with a single major lesion underscores a second principle outlined by Gloor<sup>2</sup>: that the epileptogenic area lies in the vicinity of the lesion but its precise anatomical distribution is not necessarily congruent with the structural abnormality. Thus, there may be multiple foci in this area or in an adjacent region, or less prominent cortical developmental abnormalities may be present elsewhere in the brain. Thus, Blume et al.<sup>3</sup> found multiple independent spikes arising from at least 3 non-contiguous electrode positions with at least one focus in each hemisphere in 12 of 16 children whose medically intractable seizure disorders were due to focal brain tumors.

Persistent focal polymorphic delta activity suggests an associated cortical destructive lesion;<sup>4</sup> this applies also to children.<sup>5</sup> Therefore, it is also not unexpected that persistent focal delta activity, when present, would correlate well with the ultimate surgery site (Table 4). Thus, of the 29 patients with such regional or hemispheric delta, it resided in the lobe ultimately resected in 20 (69%). In the additional 9 patients (31%) delta resided in an adjacent lobe or at least ipsilateral to the surgery. In no instance in our material did persistent focal delta appear primarily contralateral to the ultimate surgical site.

The most convincing way to determine the region of epileptogenesis in a patient with partial seizures is to adequately record electrographically a clinically typical seizure. This was achieved in 34 of our 48 patients (71%). In 23 of these (68%) the seizure electrographically arose from the ultimate surgical

site. In the 2 patients whose seizures on EEG apparently arose adjacent to the surgery, clinical ictal and neuro-imaging data suggested occult propagation to the adjacent lobe. Only an ipsilateral, i.e. hemispheric, origin could be determined in 5 patients.

Although the interictal focal spike is the most commonly found specific electrographic correlate of partial seizures, the localizing value of this apiculate phenomenon has never been fully determined. Among adults Ajmone Marsan and Goldhammer<sup>6</sup> and Ludwig and Ajmone Marsan<sup>7</sup> found a significant correlation between the clinical features of partial seizures and the location of interictal spikes. Borghesi and Blume<sup>8</sup> found interictal spikes to be exclusively or predominantly over the temporal lobe of seizure origin in 53 of 56 patients with unilaterally-originating temporal lobe seizures. Equal quantities of interictal spikes appeared in either temporal lobe in the other 3 patients. When taken over several recordings, a principal spike focus never appeared contralateral to seizure origin in that series. Similarly, the most active focal spikes appeared over the surgery lobe in 32 of 48 patients (67%) in this study. Eleven additional patients had adjacent or ipsilaterally originating principal spikes whereas in only 2 patients were the most active spikes distant from the operative lobe. This relatively high correlation may have been achieved by assessing a considerable number of pre-operative EEGs. Despite such encouraging correlations, focal spikes remain only presumptive indicators of seizure origin.<sup>2</sup> Confirmation of their value should be sought in the clinical seizure description, the ictal recording (if possible), background focal abnormalities (such as delta), and neuro-imaging.

Finally, as Gloor<sup>2</sup> has emphasized, it is the high congruence of clinical and laboratory data which likely augurs best for ultimate benefit from resective surgery.

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## REFERENCES

1. Lemieux JF, Vera RS, Blume WT. Database system for EEG laboratories. American EEG Society Annual Meeting, New Orleans, Louisiana, October 20-22, 1983.
2. Gloor P. Commentary: Approaches to localization of the epileptogenic lesion. *In*: Engel J, ed. *Surgical Treatment of the Epilepsies*. New York: Raven Press, 1987: 97-100.
3. Blume WT, Girvin JP, Kaufmann JCE. Childhood brain tumors presenting as chronic uncontrolled focal seizure disorders. *Ann Neurol* 1982; 12: 538-541.
4. Goldenshon ES. Use of the EEG for evaluation of focal intracranial lesions. *In*: Klass DW, Daly DD, eds. *Current Practice of Clinical Electroencephalography*. New York: Raven Press, 1979: 307-341.
5. Blume WT. *Atlas of Pediatric Electroencephalography*. New York: Raven Press, 1982: 265.
6. Ajmone Marsan C, Goldhammer L. Clinical ictal patterns and electrographic data in cases of partial seizures of fronto-central-parietal origin. *In*: Brazier MAB, ed. *Epilepsy. Its Phenomena in Man*. New York: Academic Press, 1973: 235-258.
7. Ludwig B, Ajmone Marsan C. Clinical ictal patterns in epileptic patients with occipital electroencephalographic foci. *Neurology* 1975; 25: 463-471.
8. Borghesi JL, Blume WT. Interictal determinants of seizure origin. Presented at the Central EEG Society, Cedar Rapids, Iowa, March 20-22, 1986.