

Investigation of paediatric occipital epilepsy using stereo-EEG reveals a better surgical outcome than in adults, especially when the supracalcarine area is affected*

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ABSTRACT – Aims. Occipital epilepsy is the least common among surgical series because: (1) the location makes it hard to assess by EEG; (2) the seizure semiology often reflects propagation; and (3) surgery entails a high risk of neurological deficits. In children, subjective symptoms are harder to assess, adding to the difficulty of a proper diagnosis. **Methods.** We aimed to determine electroclinical characteristics of occipital lobe epilepsy in a paediatric population by reviewing 20 children between one and 16 years, who had undergone intracranial recordings with depth electrodes.

Results. Eight patients had pure occipital epilepsies and 12 had “occipital plus” epilepsies. We identified four different seizure spreading patterns: (1) pure occipital (40%) with oculomotor symptoms; (2) temporal (30%) with hypomotor behaviour and automatisms; (3) frontal (20%) with movements of the limbs; and (4) spasms (10%). Two thirds of the children above 11 years reported visual aura, but this was probably underestimated in younger children as some seizures began with non-specific motion arrest. Automatisms were only observed when the lateral temporal lobe was involved. Patients with a pure occipital form had a seizure onset zone strictly in the occipital lobe. Lingual and cuneus gyri were the most epileptogenic structures. Scalp EEG showed diffuse EEG abnormalities in two thirds of the patients and 25%

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of these led to false lateralization of the SOZ. Although MRI lesions were always visible, imaging and scalp EEG could be misleading and often not sufficient to guide surgery. After surgery, 68% of the patients were classified as Engel Class I, and surgical outcome was even better for patients in whom the supracalcarine area was affected, with 87.5% reaching seizure freedom.

Conclusions. Seizure spread patterns in occipital epilepsy are similar in paediatric and adult populations, even though it is often impossible to obtain subjective symptoms in children. Postsurgical outcome is better than in adults, especially in patients in whom the supracalcarine area is affected.

Key words: occipital epilepsy, epilepsy surgery, paediatrics, invasive EEG, stereo-EEG

The semiology of occipital lobe seizures consists mainly of visual and oculomotor symptoms (Salanova *et al.*, 1992; Bien *et al.*, 2000; Fogarasi *et al.*, 2003; Taylor *et al.*, 2003; Kun *et al.*, 2005; Adcock and Panayiotopoulos, 2012; Liava *et al.*, 2014). However, there are some particular challenges when diagnosing occipital lobe epilepsy; the location makes it difficult to assess by scalp EEG and the ictal semiology often reflects propagation to surrounding brain areas, thus mimicking temporal or even frontal lobe seizures (Ludwig and Ajmone Marsan, 1975; Salanova *et al.*, 1992; Williamson *et al.*, 1992; Palmini *et al.*, 1993; Liava *et al.*, 2014).

In the paediatric population, it is more difficult to suspect an occipital onset zone, as children often cannot accurately describe visual phenomena that are considered a hallmark of this type of seizure, and objective manifestations are often late and can be misleading regarding the actual seizure onset zone (SOZ). Therefore, even though most occipital lobe epilepsies begin in childhood (Fogarasi *et al.*, 2003; Marchi *et al.*, 2016), there are very few case series dedicated to this specific population, especially in younger children. Moreover, in the paediatric population when the brain is immature, neuroplasticity may account for a better functional outcome following more extensive resections.

Materials and methods

The aim of this study was to determine the clinical characteristics, surgical outcome, and seizure spread patterns of occipital epilepsy in a paediatric population. We retrospectively reviewed all patients whose SOZ was confirmed in the occipital lobe by stereotactic electroencephalography (SEEG), between 2007 and 2014. The SOZ was defined based on ictal electrographic features according to results of stereotactic intracerebral EEG recordings. The SOZ was defined as the region of primary organization of ictal discharge (Kahane *et al.*, 2006). The propagation of the discharge was defined by cortical regions involved in the ictal

discharge after onset. We adapted this from the electroclinical definition of the epileptic zone, as proposed by Talairach and Bancaud, which took into account not only the anatomical location of the “site of the beginning and of the primary organization” of the epileptic discharge, but also how this discharge gives rise to the accompanying clinical symptoms. In our population of young children and regarding the particular localisation of the discharge, symptoms were too rarely reported to be used in the definition.

Patients were referred to our neurosurgery unit when the epilepsy was presumed focal, lesional, and drug-resistant, and were therefore considered as potential candidates for neurosurgery. Nineteen of the patients were evaluated at the Rothschild Ophthalmological Foundation in Paris, between 2008 and 2014, and one patient was evaluated at Rennes University Hospital in 2007.

All patients underwent pre-surgical evaluation, consisting of detailed medical history and neurological examination, prolonged video-EEG monitoring with at least 19 surface electrodes placed according to the 10-20 system, high-resolution MRI, neuropsychological testing adapted to age and mental status, and visual field testing for children over five years of age without intellectual disability. A PET scan was performed for 10 patients. SEEG was decided when data obtained with scalp EEG, MRI, and PET were insufficient to define the SOZ and thus insufficient to propose a surgical scheme. For example, Patient 6 had a well-defined DNET on MRI, but presented only with infantile spasms and isolated loss of consciousness with diffuse EEG abnormalities on scalp EEG. We decided to perform SEEG to ensure that these unusual symptoms could be related to this small occipital lesion.

The planning of the SEEG relied on non-invasive data and aimed to cover as much of the supposed epileptogenic network as possible. The intracerebral depth electrodes used were either DIXI® or ALCIS® and were implanted with a frameless stereotactic robot-guided system (MedTech®), based on high-resolution contrast-enhanced MRI. A CT scan was performed after

the implantation to control the location of the electrodes and was then merged with the preoperative MRI, as previously described (Taussig *et al.*, 2014).

The video-EEGs of the seizures recorded with depth electrodes were reviewed by two experienced child neurophysiologists. Results were discussed in a multidisciplinary staff meeting which decided the indication of surgery and its limits. For a standardized description of the ictal semiology, we used the “Glossary of descriptive terminology for ictal semiology” (Blume *et al.*, 2001).

The neuropsychological examination was performed by a neuropsychologist or neuropaediatrician, either with clinical evaluation or with neuropsychological scales adapted to age and mental status. Behavioural issues were reported by parents, carers, and/or teachers and measured using Conners scales. Post-surgical evaluation was performed at least one year after surgery.

All patients who underwent surgery also underwent at least 12 months of post-operative follow-up (the mean follow-up period was 2.6 years, ranging from 12 months to five years), consisting of neurological examination, scalp EEG, post-operative MRI, and an ophthalmological consultation to determine possible visual field defects. The surgical outcome was evaluated according to the Engel Epilepsy Surgery Outcome Scale (Engel *et al.*, 1993) and the results published relate to the last available visit. For all the operated patients, specimens of the removed brain tissue were analysed by an experienced pathologist.

First, we analysed the topography of the SOZ that allows us to define two groups of occipital epilepsy, as stated by Marchi *et al.* (2016). A pure occipital group corresponded to pure occipital seizures and an “occipital +” group included seizures originating from the occipital and extra-occipital cortices (occipitotemporal and occipitoparietal). Then, we analysed the pattern of diffusion of the ictal discharge, and found that the two ventral and dorsal patterns described by Takeda *et al.* were identical in children and adults (Takeda *et al.*, 1969). We separated our patients into two groups, as follows: 12 patients exhibited ventral diffusion (VD) to temporal structures (VD group), and eight patients exhibited dorsal diffusion (DD) to parietal and frontal structures (DD group) (Takeda *et al.*, 1969).

Since our patients were very young and some of them had different degrees of cognitive impairment, we decided not to include the data obtained from electrical stimulations, which did not provide reliable information.

Qualitative and quantitative variables are presented as number of patients (%) and mean \pm standard deviation (minimum-maximum), respectively. Univariate analysis was conducted to explore predictors of surgery success, defined using Engel classification. Pearson’s

chi-square tests or Fisher non-parametric tests were used to compare categorical variables. Mann-Whitney tests or Kruskal-Wallis tests were used to analyse quantitative variables between groups. *P* values of less than 0.05 based on tow-tailed tests were considered to be statistically significant. Possible correlation between the duration of evolution of the epilepsy and the number of affected structures was investigated using the Spearman rank correlation coefficient. Bivariate comparisons of continuous variables were performed using a Mann-Whitney test, and in order to compare multiple groups, a Kruskal-Wallis test was used. Bivariate comparisons for categorical data were performed using a Fisher test. Multivariate analysis was not performed due to the small number of patients.

Results

The general and demographic data are summarised in *table 1*, the clinical characteristics of the 20 included patients are described in *table 2*, and surgical outcome are indicated in *table 3*.

Demographic and clinical data (*tables 1, 2*)

Our study included 20 children: eight males and 12 females, with a mean age at the time of investigation of 7.8 years (1-16 years); 16/20 children were less than 14 years old and 11/20 were between one and seven years old (*table 1*).

Three of the patients had a history of hypoxic-ischaemic injury at birth, and none of the patients had a personal history of febrile convulsions or head trauma. The neurological and ophthalmological examination was within normal limits for the majority of the patients, but showed visual field deficits (hemianopsia) in two children. Five of our patients were too young or had intellectual disability and could not undergo adequate evaluation of the visual field.

With regards to lateralization, 15 of the patients were right-handed and three were left-handed. The two youngest children, aged two and three years old, were not yet lateralized.

MRI was positive for all children, showing lesions restricted to the occipital lobe in 10 patients, over two adjacent lobes in nine patients, and extended, involving almost an entire hemisphere but prominent in the occipital cortex, in one patient.

Based on the extent of the interictal and ictal discharges, we classified scalp EEGs as: localizing (*n*=2) (limited to the occipital region), lateralizing (*n*=13) (involving multiple derivations over one hemisphere), and falsely localizing (*n*=5) (involving regions other than the occipital lobe). EEG was falsely localizing,

Table 1. General demographic and clinical data (n=20).

		General population	DD group	VD group
No of patients		20	8	12
Age at SEEG (years)		7.8 (1-16)	6.37 (2-13)	10.2 (3-16)
Age at seizure onset (years)		3.4 (0.1-9)	3.18 (0.3-10)	4.18 (0.1-9)
Seizure frequency (per week)		52.9	60.7	50.3
Seizure duration (minutes)		2.4	2.7	2.2
Secondary generalization		4	1	3
History of spasms		8 (40%)	4 (50%)	4 (33.3%)
Sex	Female	12	4	8
	Male	8	4	4
Hand dominance	Right	15 (75%)	5 (62.5%)	10 (83.3%)
	Left	3	2	1
	non-lateralized	2	1	1
Cognitive examination	Normal	9	3	6
	Abnormal	11	5	6
MRI	Unilobar	10	4	6
	Bilobar	9	4	5
	Extended	1	0	1
PET	Occipital	3	1	2
	Occipital-Parietal	2	0	2
	Occipital-Temporal	3	1	2
	Occipital-Temporal-Parietal	2	0	2
	Not done	10	6	4
EEG	Localizing	2	2	0
	Lateralizing	16 (80%)	6 (75%)	10 (83.3%)
	Falsely localizing	2	0	2

pointing to extra-occipital regions in 25% of the children (5/20). None showed photosensitivity.

Seizure history

The mean age at seizure onset was 3.4 ± 2.9 years (0.1-9 years). This dropped to 1.4 ± 2.5 years (0.1-7 years) in the case of infantile spasms ($n=7$), and increased to

4.7 ± 2.8 years (0.2-9 years) for the non-spasm population ($p=0.01$) (see *table 1*). Eight patients (40%) had a history of infantile spasms. The mean duration of epilepsy was 5.3 years (1.2-12 years).

The mean reported seizure frequency was 53 seizures per week; between one seizure per week to 50 seizures every day. Four of the patients (20%) had a history of secondary generalized seizures.

Table 2. Main characteristics of each case of the series.

Patient	Sz onset (years)	Age at SEEG (years)	History of spasms	Topography of the lesion	SOZ	Surgery	Duration of follow-up (years)	Engel Class
Patient 1	4.5	7	0	Right intracalcarine occipital blurring	Occipital, predominant in lingual gyrus and cuneus	Right occipital resection	3	1
Patient 2	9.0	14	0	Left occipital atrophy	Occipital, predominant in lingual gyrus or lingual gyrus and cuneus	Left occipital resection	3	1
Patient 3	6.5	6	0	Right mesial occipital dysplasia	Cuneus	Right occipital resection	3	2
Patient 4	1.5	7	1	Left occipito-temporal porencephalia	Lingual gyrus and posterior temporal, next to a vast temporo-occipital porencephalic cavity	Left temporal resection and parietal-occipital disconnection	4	1
Patient 5	2.2	13	0	Left occipital dysplasia	Cuneus and rarely lingual gyrus	Left occipital resection	3	1
Patient 6	7.0	11	1	Left occipital DNET	Cuneus and sometimes lingual gyrus	Left occipital resection	3	1
Patient 7	7.0	11	0	Right occipital intraparenchymatous hematoma	Cuneus and angular gyrus	None		Non-applicable
patient 8	8.0	6	0	Right occipital dysplasia	Occipital bilateral: right cuneus, lingual gyrus and left occipital lobe	None		Non-applicable
Patient 9		16	0	Right temporal occipital dysplasia	Lingual gyrus and sometimes cuneus	Right parietal-occipital resection	8	1
Patient 10	5.0	16	0	Right temporal-occipital gyral abnormality	Lingual gyrus and temporal posterior onset	Right temporal-occipital resection	13	3
Patient 11	4.0	9	0	Right occipital atrophy	Mesial occipital or hippocampal onset	None		Non-applicable

Table 2. Main characteristics of each case of the series (*Continued*).

Patients	Sz onset (years)	Age at SEEG (years)	History of spasms	Topography of the lesion	SOZ	Surgery	Duration of follow-up (years)	Engel Class
Patient 12	0.2	5	0	Right temporal-occipital blurring	Middle temporal gyrus then 3 years later: angular gyrus and occipital onset	Right temporal resection completed 3 years later with right parietal-occipital resection	7	1
Patient 13	0.3	2	1	Left occipital dysplasia	Cuneus, hippocampus and angular gyrus	Left occipital resection then 3 years later, temporal resection and parietal disconnection	5	2
Patient 14	0.8	4	1	Left temporal-occipital dysplasia	Middle and superior temporal gyri, and second onset in cuneus and angular gyrus	Left temporal resection and parietal-occipital disconnection	6	1
Patient 15	0.1	3	1	Left temporal-occipital dysplasia	Anterior and middle temporal gyri and lingual gyrus	Left temporal resection and parietal occipital disconnection	7	1
Patient 16	1.5	4	0	Left parietal temporal occipital dysplasia	Multifocal on cuneus, lingual, supramarginal and angular gyri, parietal opercular	Left temporal-occipital resection and parietal-temporal disconnection	4	3
Patient 17	0.1	14	1	Right temporal-occipital dysplasia	Cuneus, lingual gyrus, parahippocampal gyrus, then 4 years later, parietal insular onset	Right parietal disconnection and occipital resection then 4 years later, parietal operculo-insular right resection	7	3
Patient 18	0.1	4	1	Right post-ischaemic parietal-occipital lesions	Cuneus, lingual, angular, inferior temporal and supramarginal gyri	Temporal resection and parietal occipital disconnection	6	1
Patient 19	0.8	13	0	Right temporo-occipital dysplasia	Occipital	Right occipital resection	5	1
Patient 20	5.0	7	0	Right temporal-parietal-occipital blurring	Occipital and temporal posterior	Temporal occipital resection	5	1

Table 3. Seizure history and outcome of surgery ($n=16$).

		General population ($n=16$)	DD group ($n=8$)	VD group ($n=8$)
Age at surgery (years)		7.8 (2-16)	6.9 (2-12)	9.4 (3-16)
Surgery	Unilobar	7	4	3
	Bilobar	2	1	1
	Extended	7	3	4
Pathological examination	FCD IIa	6	4	2
	FCD IIb	1	0	1
	FCD I	1	1	0
	DNET	2	1	1
	Gliosis	2	1	1
	Normal	3	1	2
	Hippocampal sclerosis	1	0	1
Outcome	Engel Class 1	10 (68.7%)	7 (87.5%)	3 (37.5%)
	Engel Class 2	3	1	2
	Engel Class 3	3	0	3

FCD: focal cortical dysplasia; DNET: dysembryoplastic neuroepithelial tumour.

Seizure semiology

The mean age at SEEG was 7.8 ± 4.3 years (18 months-16 years), but only 6.1 ± 5.2 years in the case of a history of infantile spasms. We reviewed a total of 510 seizures, with a mean of 25 seizures per patient. The average duration of recordings was six days (2-12 days).

The mean number of electrodes was nine (8-13). SEEGs were bilateral for five patients, four for the VD group and one for the DD group. A total of 475 plots recorded occipital cortical activity, with an average of 24 plots per child (*figure 1*). Because more than half of our patients had intellectual disability, we decided not to take into account data from electrical stimulation during SEEG, as many children were not able to answer properly. The mean seizure duration was 143 seconds (10-250 seconds), excluding spasms, secondary generalization, and status epilepticus.

In our series, we recorded four seizure patterns (*figure 2*):

- pure occipital ($n=8$; 40%) with visual, oculomotor symptoms (eye deviation, blinking, and nystagmus) and head turning;

- temporal ($n=6$; 30%) with hypomotor behaviour and automatisms;
- frontal ($n=4$; 20%) with prominent tonic-clonic movements;
- and asymmetrical spasms ($n=2$; 10%).

The two children with recorded infantile spasms were two and 13 years old. Symptoms were considered to be representative of a seizure type based on data available from the literature, correlated with the topography of the ictal discharge (*figure 2*). In the DD group, five patients (62.5%) exhibited an occipital pattern, two patients (25%) a frontal pattern, and one patient had only infantile spasms. In the VD group, six patients (50%) showed a temporal pattern, three patients (25%) an occipital pattern, two patients (16.6%) a frontal pattern, and one patient had spasms. None reported headaches.

Objective symptoms

The most frequent motor manifestation was eye deviation ($n=15$; 65%), followed by head turning ($n=11$; 50%), blinking ($n=5$; 25%), tonic contraction of the upper

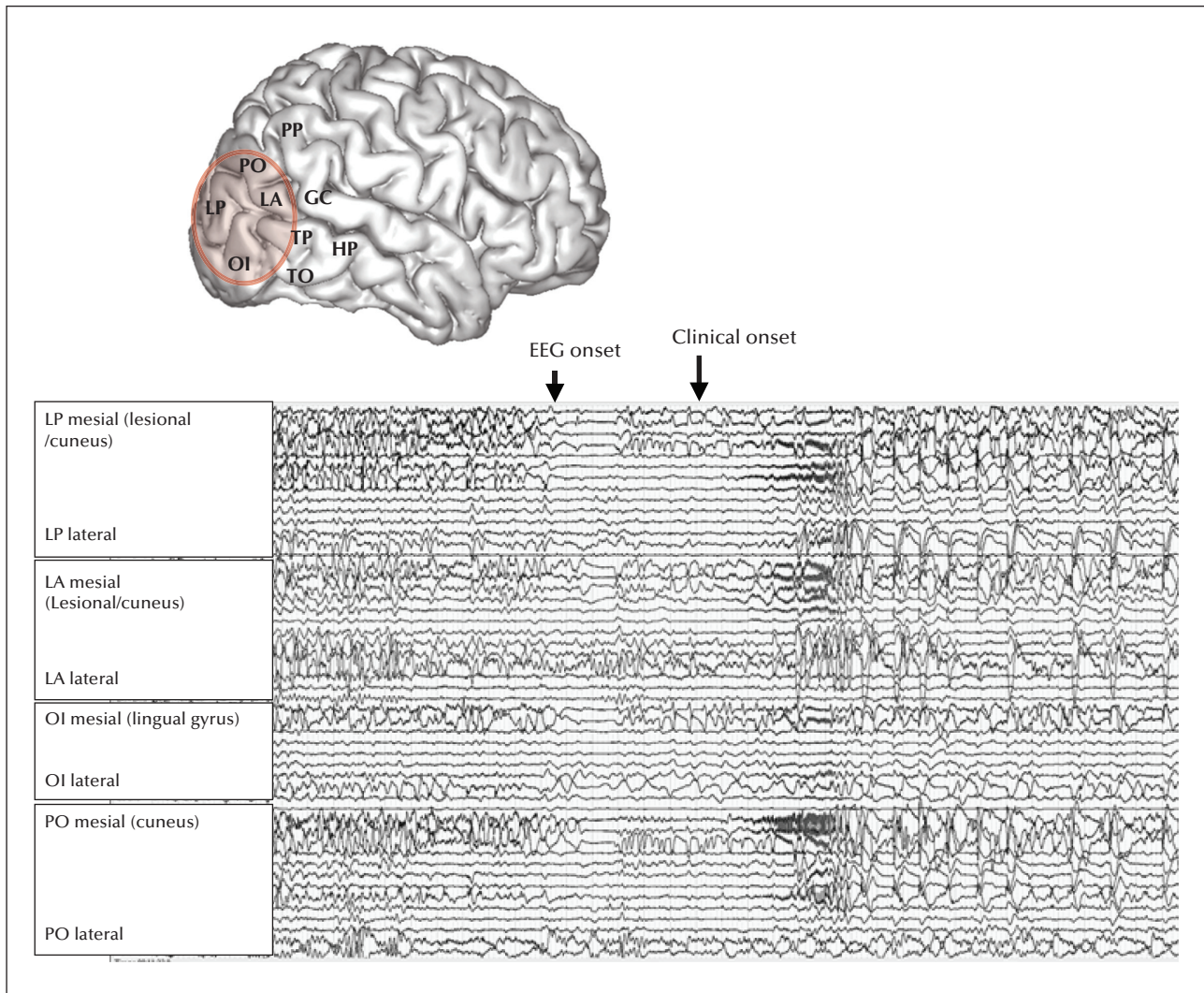


Figure 1. Implantation scheme and example of ictal “pure occipital” discharge during invasive EEG monitoring. Note the rapid rhythms of discharge in the occipital lobe, predominant in the lingual gyrus and cuneus. Seizure onset zone is depicted in red. Visual subjective symptoms began two seconds after the onset of the discharge. Low filter: 0.530 Hz; high filter: 120 Hz, 35 sec; amplitude: 600 μ V/cm. LP and LA mesial plots correspond to within the MRI lesion in the cuneus, OI mesial plots correspond to within the lingual gyrus, and PO mesial plots correspond to within the cuneus gyrus outside the MRI lesion.

limbs ($n=4$; 20%), clonic contraction of the upper limbs ($n=4$; 20%), nystagmus ($n=3$; 15%), tonic contraction of the lower limbs ($n=2$; 10%), and dystonic posturing of the upper limb ($n=2$; 10%) (figure 3).

Contralateral eye deviation was seen with similar frequency in both groups and was the initial manifestation of the seizure in three quarters of the patients, but could also be ipsilateral (26.6%). For three patients, the direction of the forced gaze changed during their seizure.

Contralateral head deviation was the second most frequent sign (58.3% of patients in the VD group

and 25% of patients in the DD group). This occurred early in 100% of the seizures in the DD group and in only 66.6% of the VD group. There was no correlation between the time of occurrence and side of deviation.

Blinking was the third most common sign in the DD group, in 37.5% of patients, as opposed to 16.6% in the VD group. This was always early and contralateral to the SOZ in the majority of cases (60%).

The tonic/clonic contraction was less frequent in the DD (12.5%) than the VD group (25%). Tonic contraction

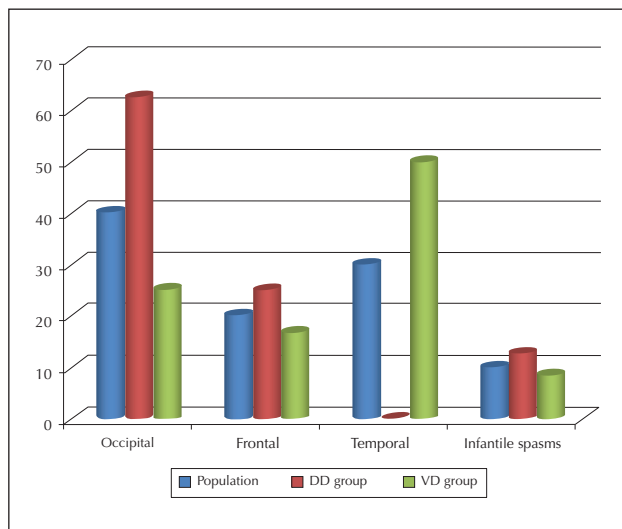


Figure 2. Number of different seizure semiology patterns according to dorsal or ventral propagation pathways ($n=20$), in the global population ($n=20$), DD group ($n=12$), and VD group ($n=8$).

was always bilateral, probably reflecting involvement of the supplementary motor area, while clonic contractions were always contralateral.

Nystagmus was always contralateral and observed mostly in the DD group (66.6 %), appearing early

during seizures. In the VD group, nystagmus was observed only once.

Contralateral dystonic posturing of the upper limb and ipsilateral automatisms were recorded only in the VD group, reflecting propagation to the temporal lobe.

Subjective visual symptoms (figure 4)

Eight patients (40%), aged 7-16 years old, reported a visual aura, consisting of both positive (simple and complex visual hallucinations) and negative (visual field deficits) phenomena. Visual hallucinations occurred in five patients and had a lateralizing value each time. Four patients had simple visual hallucinations, consisting of coloured or transparent geometric shapes or flickering lights in the contralateral visual field. One patient had complex visual hallucinations of strange faces and unknown people, limited to the contralateral visual field. In this case, the SOZ was within the lingual gyrus and spread rapidly to the fusiform gyrus. Two other patients had visual field deficits; one with hemianopsia and the other with "blurring". Only one of these patients had seizures limited to visual symptoms. The latter patient reported a complex aura with a moving visual field, as if she was on a merry-go-round, without vertigo. Auras appeared to be more frequent in the VD ($n=5$) compared to the DD group ($n=2$) ($p=0.6$).

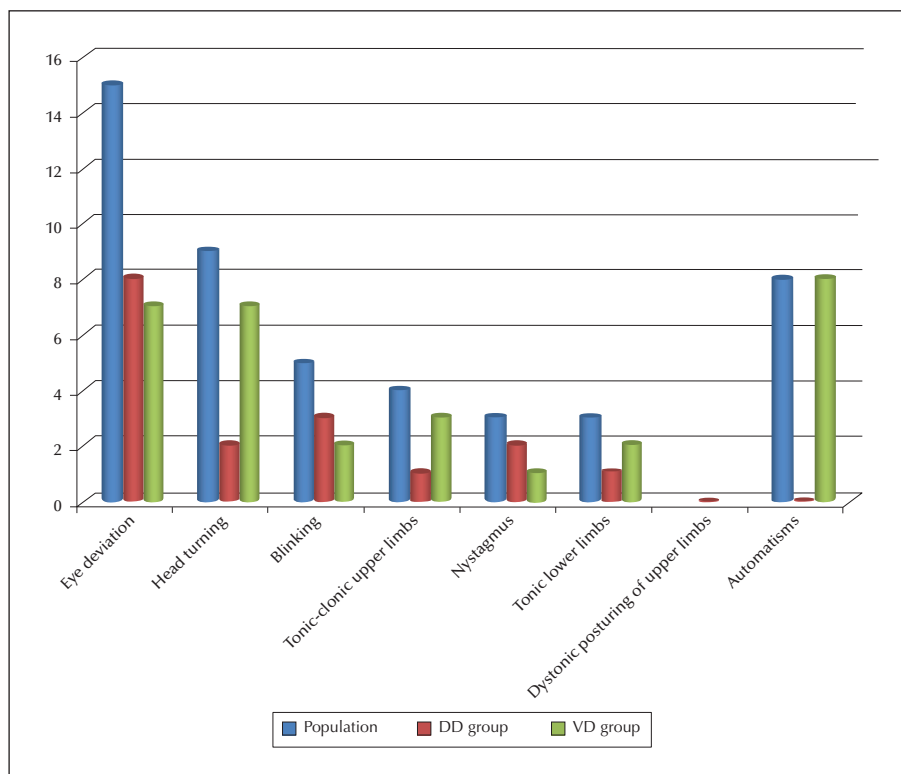


Figure 3. Objective seizure semiology in the global population (blue), DD group (red) and VD group (green), expressed as number of patients. The subjective symptoms (aura) are not listed.

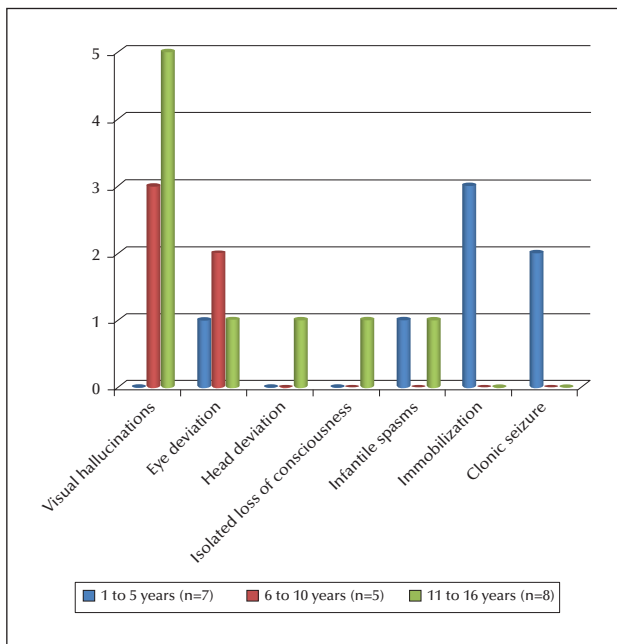


Figure 4. Earliest ictal symptom according to age. One child aged 13 years old had two types of seizures: infantile spasms and isolated loss of consciousness.

Moreover, three of seven children before six years started their seizures with immobilization/motion arrest. This could be linked to visual aura which was not reported because the children were too young, and this may have led to an underestimation of the presence of aura in our population.

Automatisms

Automatisms were observed in eight patients (40%), all in the VD group ($p=0.0014$), either oral automatisms ($n=5$; 25%) or hyperkinetic automatisms ($n=4$; 20%), gestural automatisms ($n=3$; 15%), vocalization ($n=3$; 15%), grimacing ($n=2$), ictal smiling ($n=1$), or pedalling ($n=1$).

Oral automatisms, such as chewing ($n=3$) and lip smacking ($n=2$), appeared rather discretely and in the early and late stages of the seizure. On the contrary, hyperkinetic automatisms, such as pelvic thrusting ($n=2$), pedalling ($n=1$), and body rocking ($n=1$), were seen in the late part of the seizure (75%). Short vocalizations only occurred early on during seizures, originating from the non-dominant hemisphere.

Spasms (figures 2, 4)

Occipital epilepsy in children can manifest as infantile spasms; 40% of our patients had a history of spasms. Asymmetric spasms were recorded in two of the eight patients with a history of infantile spasms. These

represented the only seizure type in one child, whereas the other child had also hypomotor seizures, consisting of loss of consciousness with rhythmic diffuse 2.5-Hz spike-and-wave discharges. The discharges rapidly involved other sampled areas.

Postictal symptoms

Postictal automatisms, consisting of nose wiping, were only observed in one patient, when the SEEG showed involvement of the right temporal lobe. Postictal deficits were observed in three patients; two with postictal confusion and aphasia and one with hemianopsia lasting for a minute.

Maturation effect (figure 4)

We did not find any difference in semiology according to age. Automatisms were recorded over the entire age range. Auras were relatively rare in this series (8/20; 40%), however, visual auras are difficult to report and describe, even in adults, and were likely to be under-estimated in young children and children with intellectual disability. As previously stated, three of seven children before six years started their seizures with immobilization/motion arrest. This could be linked to visual aura that was not reported either due to the fact that they were too young or due to a particularity of occipital epilepsy in children. No association was identified between the duration of epilepsy and size of SOZ based on non-parametric Spearman correlation.

Electroclinical correlations

Seizures originating from the lingual gyrus showed a preferential propagation following a ventral stream through the temporo-basal lobe, hippocampus, and amygdala, while seizures from the cuneus propagated more frequently through a dorsal stream involving the precuneus ($n=7$; 87.5%), angular and supramarginal gyri ($n=5$; 62.5%), posterior cingulate gyrus ($n=5$; 62.5%), inferior temporal gyrus ($n=2$; 25%), and middle and superior temporal gyri ($n=2$; 25%). The ventral pathway involved the inferior temporal gyrus ($n=7$; 58.3%), middle temporal gyrus ($n=7$; 58.3%), angular and supramarginal gyri ($n=7$; 58.3%), precuneus ($n=6$; 50%), posterior cingulate gyrus ($n=6$; 50%), inferior temporal gyrus ($n=5$; 41.6%), superior temporal gyrus ($n=4$; 33.3%), insula ($n=4$; 33.3%), contralateral occipital lobe ($n=4$; 33.3%), and frontal lobe ($n=1$; 8.3%). Compared to the DD group, the VD group showed significantly more ictal propagation to the precuneus ($p=0.01$), whereas the propagation to angular and supramarginal gyri was identical for both pathways (62.5% for the VD versus 50% for the DD group). The superior and middle temporal gyri were

frequently involved in seizures from the VD group ($n=8$; 66.6%) and only infrequently in the DD group ($n=3$; 37.5%). Automatisms occurred only when the propagation of the ictal discharge reached the temporal lobe ($p=0.0014$).

PET data

A PET scan was performed for 10 patients (two from the DD and eight from the VD group). Hypometabolism was restricted to the occipital lobe only in three patients, and extended over two lobes in five patients and over three lobes in two patients. In 4/10 patients, PET indicated a more widespread lesion relative to MRI. In contrast, for two other patients, MRI indicated a more widespread lesion relative to PET. The lack of correlation between MRI, PET, and scalp EEG precluded a decision to perform surgery at this stage of the presurgical evaluation.

Regarding the extent of surgery, there was a correlation between PET and surgical planning in 6/10 patients. In 2/10 patients, PET hypometabolism was beyond surgical limits, whereas, in two other patients, PET hypometabolism was more restrictive than surgical limits.

Surgery and epileptic outcome (table 3 and figure 5)

Sixteen of 20 patients received surgery. The four patients not considered as surgical candidates belonged to the VD group; for three patients, post-surgical visual field deficits (quadrantopia or hemianopsia) were a greater handicap than seizures. A fourth child had bilateral occipital discharges on SEEG and this child was also not considered as a surgical candidate.

The mean age at time of surgery was 7.8 ± 4.2 years (2-16 years). We categorized surgery as:

- unilobar resection ($n=7$) (limited to the occipital lobe);
- bilobar resection/disconnection ($n=2$) (involving parietal or temporal lobes);
- and disconnection involving more than two lobes ($n=7$) (affecting parts of both parietal and temporal lobes).

Of the patients, 68.7% were classified as Engel Class I and 31.3% as Engel Class II/III. Outcome was significantly better in the DD, compared to the VD group (7/8 [87.5%] vs. 3/8 [37.5%] patients classified as Engel Class I) ($p=0.04$).

A history of spasms was a risk factor for more extensive resections ($p=0.01$), however, this was not associated with a worse post-surgical outcome. No correlation

was identified between outcome and the following factors: age at seizure onset, duration of epilepsy, or frequency of seizures. The only factor associated with an Engel Class I outcome was limited focal hypometabolism based on PET ($p=0.04$). We were unable to confirm whether early surgery during the course of the disease was associated with a better outcome.

Post-surgical deficits occurred in eight patients: contralateral quadrantopia ($n=4$), hemianopsia ($n=2$), and hemiparesis ($n=2$). These deficits were expected and were discussed before surgery with parents and children.

Focal cortical dysplasia (FCD) was found in 56.3% of patients ($n=8$) (tables 2, 3). Among FCD, FCD IIa was the most frequent (75%; $n=6$), followed by FCD IIb and I (each affecting one patient). Because of the disconnective technique, pathological examination was falsely negative in three children; the cortex removed was too small and damaged. DNET and gliosis were each found in two patients, and hippocampal sclerosis in one child.

Neuropsychology

The neuropsychological examination was normal for nine patients. Eleven children had cognitive impairment: mild intellectual disability (IQ: 50-70) and behavioural problems ($n=6$) or severe intellectual disability (IQ < 50) ($n=5$). A history of spasms was significantly associated with worse cognitive outcome ($p=0.009$).

Four patients (25%) showed a post-operative improvement in their behaviour (reported by the parents or carers) as well as better verbal skills (2/4). One patient with autistic features showed a marked improvement at the six-month follow-up visit, however, this could not be confirmed as the patient was not investigated using an autistic scale.

Discussion

In occipital epilepsy, visual auras and oculomotor manifestations are considered to be a hallmark of this type of epilepsy with a localizing value (Salanova et al., 1992; Bien et al., 2000; Fogarasi et al., 2003; Taylor et al., 2003; Kun et al., 2005; Adcock and Panayiotopoulos, 2012; Liava et al., 2014), but propagation to the surrounding cortex can occur very fast and may mimic other seizure types (Ludwig and Ajmone Marsan, 1975; Salanova et al., 1992; Liava et al., 2014). In children, especially young or with intellectual disability, subjective symptoms are not reliable and localizing elements can be missed.

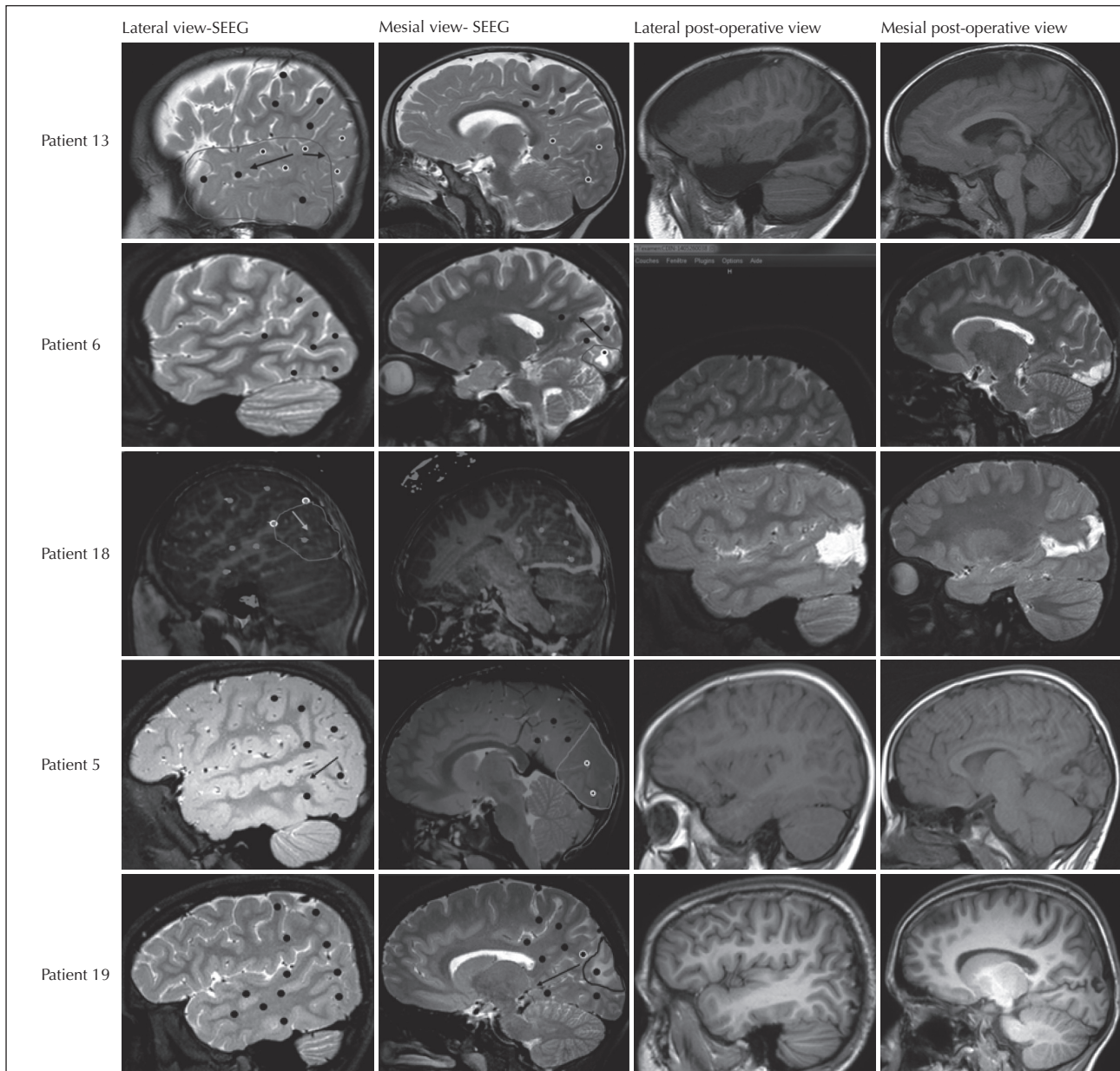


Figure 5. MRI (sagittal view) of five patients from the series. Left: during SEEG with depth electrodes; the SOZ is delineated in grey and arrows symbolize the seizure propagation pathway. Right: after surgery.

Absence of negative MRI

The proportion of MRI-negative patients in reported epilepsy surgery cohorts ranges from 16 to 47% (Eltze *et al.*, 2005; Cossu *et al.*, 2006; Bulacio *et al.*, 2012; Bast, 2013). This rate is higher in adult than in paediatric series, in up to one third of adult cases (Blume *et al.*, 1991; Semah *et al.*, 1998; Fogarasi *et al.*, 2003; Lee *et al.*, 2014; Liava *et al.*, 2014). In our group of patients, MRI showed a lesion in 100% of the children, in accordance with the literature (Eltze *et al.*, 2005; Cossu *et al.*,

2006). The higher rate of lesions should facilitate diagnosis and a decision for referral to an epilepsy surgery centre.

EEG and imaging can be misleading

Five patients (25%) had false lateralization of their SOZ based on scalp EEG, pointing to extra-occipital regions, and bilateral invasive monitoring was required. Thirteen other patients (65%) had diffuse EEG

abnormalities without clear focus. As previously stated (Salanova *et al.*, 1992; Williamson *et al.*, 1992; Aykut-Bingol and Spencer, 1999; Kun *et al.*, 2005; Caicoya *et al.*, 2007; Jobst *et al.*, 2010; Adcock Panayiotopoulos, 2012; Liava *et al.*, 2014), scalp EEG did not prove to be a very precise tool in determining the seizure onset in occipital epilepsy, showing localized interictal epileptiform discharges in only 10% of patients. Our study did not find any correlation between localizing interictal scalp EEG and surgical outcome, probably because of the small number of patients with this pattern ($n=2$).

Regarding MRI, previous reports have shown that the SOZ often extends beyond the epileptogenic lesion (Barba *et al.*, 2005; Tandon *et al.*, 2009; Marchi *et al.*, 2016). It is difficult to compare adult and paediatric data, as young children often have extensive lesions, and we reported 11/20 children below seven years old. These extensive lesions are easier to diagnose on MRI than small lesions in adults, but the lesion can host more than one SOZ.

Data on adults show that temporal hypometabolism based on PET is correlated with automatisms during seizures (Wong *et al.*, 2014), suggesting that temporal hypometabolism is a reflection of the ictal propagation pattern. Automatisms were too rare in our paediatric population ($n=8$) to allow the same correlation, but a correlation between temporal hypometabolism and ictal temporal diffusion was identified, suggesting that PET adult data may be extrapolated to children. Children are often incapable of describing auras and the accuracy of EEG is poor in occipital epilepsy, therefore, presurgical evaluation and particularly PET can be misleading with regards to temporal resection in occipital epilepsies in children. Moreover, PET and surgical limits were correlated in only 6/10 patients. Large areas identified by PET exceeded surgical limits in 2/10 patients, and the surgery would have been too extensive based solely on PET data. In contrast, for two other patients, PET-based surgery would have been insufficient to cure the patients.

To conclude, imaging and scalp EEG can be misleading in refractory occipital epilepsy in children and are often insufficient to guide surgery. In such cases, as well as lesional cases, invasive recordings may therefore be needed.

Epileptogenic networks

The epileptogenic structures differed between the pure occipital group and the “occipital +” group, as defined by Marchi *et al.* (2016) (figure 6). Their pure occipital group corresponded to pure occipital seizures and their “occipital +” group included seizures originating within occipital and extra-occipital

cortices. Lingual and cuneus gyri were the most epileptogenic structures. In our “occipital +” group, the epileptogenic structures were wider ($p=0.025$) than in the “pure occipital” group and included extra-occipital structures. Compared with previous studies (Palmini *et al.*, 1993; Marchi *et al.*, 2016), the epileptogenic zone appeared to be wider in children than in adults. We may hypothesise that “occipital +” forms are likely to begin earlier in age, however, we did not find any difference in age at onset between pure occipital and “occipital +” forms (Marchi *et al.*, 2016). No correlation between the duration of evolution of the epilepsy and the number of affected structures was identified based on non-parametric Spearman correlation ($p=0.65$). Marchi *et al.* (2016) stated that the most epileptogenic structures in the pure occipital form were the occipital part of the fusiform gyrus, followed by the occipital dorsolateral region and the lingual gyrus. The cuneus showed a low profile of epileptogenicity. In our series, the most implicated structure was the cuneus in the pure form as well as in the “occipital +” form. Moreover, cuneus and lingual structures of both groups were equally implicated. To date, our series is the only strictly paediatric series published and our patients were very young, as the age at onset was 3.4 years (from 0.1 to 9 years) and the age at recording was 7.8 years. Future studies are needed to explore the hypothesis that cuneus dysplasia could be responsible for early-onset epilepsy rather than dysplasia in other occipital structures.

Epileptogenic networks have a different architecture according to the spread pattern (Bartolomei *et al.*, 2017). Seizures from the DD group showed a preferential propagation to the precuneus and only infrequently involved distant structures, whereas epileptogenic networks in the VD group were more complex, with the ictal discharge spreading most frequently to mesial structures and the inferior temporal gyrus, but also to the lateral temporal lobe, angular and supramarginal gyri, insula, and contralateral occipital lobe. This difference is reflected in seizure semiology, with an occipital pattern (visual aura, oculomotor symptoms, and head deviation) in the DD group and a predominantly temporal (hypomotor behaviour and automatisms) pattern in the VD group. Overall, the semiology of the seizures in the DD group appeared to be less complex than that observed in the VD group. Automatisms occurred only in the VD group and reflected an involvement of the lateral temporal lobe. Even though eye deviation often had a localizing value, being contralateral to the SOZ in 75% of the cases, we also found it to be ipsilateral, in agreement with previous studies (Jobst *et al.*, 2010; Chen *et al.*, 2014; Liava *et al.*, 2014), and it should be kept in mind that the side of deviation does not always pinpoint the SOZ.

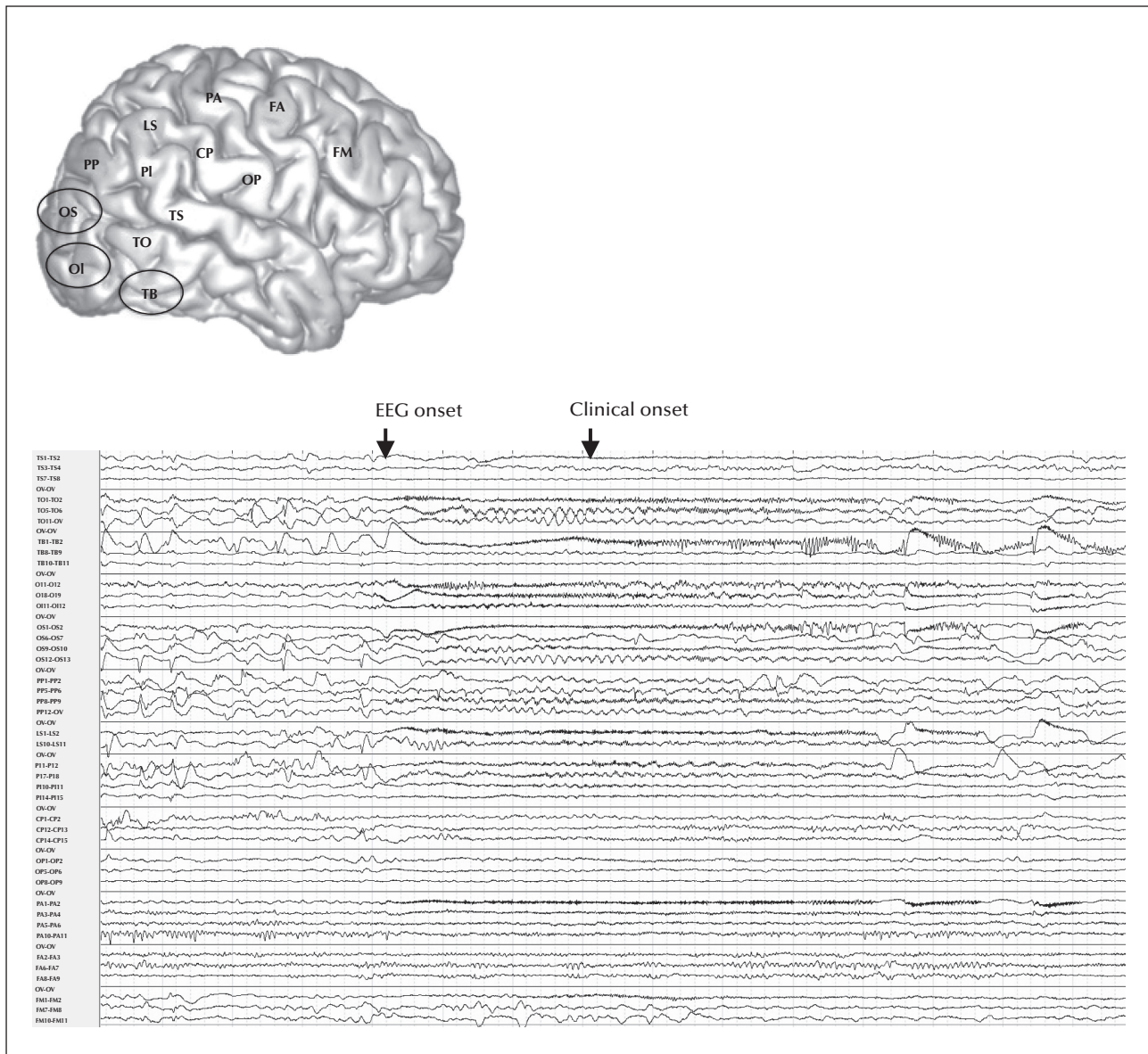


Figure 6. Implantation scheme and example of “occipital +” ictal discharge during invasive EEG monitoring. Note the rapid rhythms of discharge on internal plots for TB, PA, OI, OS and PA electrodes, maximal on the internal plots for OI, OS and TB. The discharge is wider than for the “pure occipital” SOZ (see Figure 1). On the implantation scheme, electrodes included in the SOZ are circled in grey. Objective visual symptoms (head and left eye deviation) began three seconds after the onset of the discharge, as indicated by the second arrow. The first arrow indicates the beginning of the ictal discharge. Low filter: 0.530 Hz; high filter: 120 Hz, 15 seconds; amplitude: 600 μ V/cm.

Maturation and clinical semiology

Only 40% of our patients (8/20) had visual auras; the youngest was seven years old with normal cognitive development, while the others were older than 11 years. Children above 11 years reported auras consisting of visual modifications in 62.5% of the cases (5/8). This result is in line with reported adult series (8–73%) (Williamson *et al.*, 1992; Sveinbjornsdottir and

Duncan, 1993; Dalmagro *et al.*, 2005; Caicoya *et al.*, 2007; Adcock and Panayiotopoulos, 2012; Liava *et al.*, 2014). This heterogeneous range of auras in adult series (8–73%) underlines the difficulties in reporting visual aura, even in the adult population. In our series, at the time of recording, we reported only 12 children older than seven years and 55% of children were uncooperative with intellectual disability, mostly unable to report visual symptoms. Aura was more frequently

reported by older children without intellectual disability, but was also reported in children below 4-5 years of age, even though they were unable to report the aura themselves. Three children aged 1-4 years began their seizures with motion arrest that could be triggered by visual modifications. Thus, aura was present but underestimated in younger children. Moreover, visual modifications are indeed more difficult to report and describe than, for example, abdominal pain in temporal lobe epilepsy (Fogarasi *et al.*, 2007). Motor symptoms are linked to the dorsal pathway (Marchi *et al.*, 2016). Some studies have shown an age dependency of automatism frequency (Olbrich *et al.*, 2002; Fogarasi *et al.*, 2007). In our series, automatisms were linked to a temporal propagation but did not seem to be modified by maturation. However, it should be noted that this study was not aimed at changes associated with temporal progression, and our series was too small to draw any relevant conclusions due to the rarity of surgical candidates with occipital epilepsies. In a study published in 2007, Fogarasi *et al.* (2007) also reported no impact of maturation on automatisms.

Infantile spasms are a hallmark of epilepsy during the maturation of young children. Infantile spasms triggered by a posterior lesion were frequent in our series (40%) and spasms were the only type of seizures in 1/20 children (10%). This could mislead the diagnosis of focal epilepsy and/or the indication of focal resective surgery, and/or lead to extra-occipital surgery, especially in the motor cortex. Previous studies have reported 9.8-14.6% of patients with occipital lesions based on a series of infantile spasms of focal origin (Kang *et al.*, 2013; Chipaux *et al.*, 2017). Ibrahim *et al.* reported six children with infantile spasms among a population of 41 children with occipital epilepsy (Ibrahim *et al.*, 2012). A history of infantile spasms was correlated with a younger age at seizure onset, a longer duration of epilepsy, a worse cognitive outcome, and more extensive resections. However, there was no correlation with surgical outcome or histopathological findings.

Maturation and age at onset

The age at onset of occipital seizures in our series was relatively young (3.4 ± 2.9 years), and this is in accordance with previous series (2.9-8.2 years old) (Cossu *et al.*, 2008; Ibrahim *et al.*, 2012; Teutonico *et al.*, 2013; Mühlebner *et al.*, 2014; Yang *et al.*, 2014; Marchi *et al.*, 2016; Ramantani *et al.*, 2017). We hypothesise that a posterior SOZ initiates at an early stage in life, in parallel to maturation. Since the maturation gradient begins early on within the posterior parts of the cortex, extending later to the anterior part, we believe that epileptic discharges could be influenced by this gradient. The maturation gradient takes into account the relative

excess of excitative over inhibitive synapses in the cortical network (Huttenlocher *et al.*, 1983; Luhmann *et al.*, 2016) and the variations of activity with age (Chiron *et al.*, 1992). However, cortical lesions and in particular dysplasia appear independent regarding the maturation of the normal environmental cortex. Surprisingly, we do not corroborate the influence of the maturation gradient on age at seizure onset in posterior epilepsies. Moreover, other series did not find an influence of maturation on age at onset (Ibrahim *et al.*, 2012; Yang *et al.*, 2014; Marchi *et al.*, 2016; Ramantani *et al.*, 2017).

Surgical outcome and the supracalcarine region

Surgery in extra-temporal cortical regions is known to have a worse outcome than temporal lobe surgery (Aykut-Bingol *et al.*, 1998; Ansari *et al.*, 2010; Englot *et al.*, 2013), because FCD is less accessible to the surgeons and/or because of the presence of eloquent cortex. FCD is more frequent in the posterior cortex (Kral *et al.*, 2007) and could be linked to a poorer outcome (Aykut-Bingol *et al.*, 1998; Lee *et al.*, 2014). In our series, surgery was more extensive, consisting of temporal or occipital resection and often parieto-occipital disconnection, and 68.7% of patients were classified with Engel Class I outcome, in line with previous studies (40-77.5%); a better outcome than that from adult series (22-55.5%) (Blume *et al.*, 1991; Blume *et al.*, 2001; Fogarasi *et al.*, 2003; Dalmagro *et al.*, 2005; Cossu *et al.*, 2006; Jobst *et al.*, 2010; Yum *et al.*, 2011; Ibrahim *et al.*, 2012; Liu *et al.*, 2012; Bast, 2013; Teutonico *et al.*, 2013; Taussig *et al.*, 2014; Yang *et al.*, 2014; Chugani *et al.*, 2015; Ramantani *et al.*, 2017). This could be explained by the higher prevalence of lesional cases and more extensive surgery (Yang *et al.*, 2014) due to the young age of the patients and the neuroplasticity of their maturing brains, thus removing the entire epileptogenic network. The higher seizure frequency and the number of patients with severe intellectual disability among paediatric patients make the benefits of a larger resection outweigh possible complications. Moreover, FCD was our leading pathological finding (in 43.7% of the patients). Some studies state that FCD is associated with a better outcome (Ansari *et al.*, 2010) and others with a poorer outcome (Blume *et al.*, 1991; Aykut-Bingol and Spencer, 1999), but we found no difference between outcomes of patients with FCD compared to the other pathologies.

Surprisingly, epilepsy affecting the supracalcarine region was associated with a significantly better outcome (87.5% Engel Class 1) compared to the intracalcarine region, without clear explanation. This is probably related to a more complex epileptogenic network in the temporal structures involving more eloquent areas, thus leading to more functional constraints when discussing surgery. The greater

frequency of type 2a FCD in the DD ($n=4$) compared to the VD group ($n=2$) might also have improved post-surgical outcome.

No prognostic factors associated with good outcome have so far been found, except for limited hypometabolism based on PET. In concordance with previous studies (Blume *et al.*, 1991), we found a positive correlation between limited hypometabolism and Engel Class I outcome. Again, this probably is associated with the extent of the epileptogenic network and the complete and successful removal of the SOZ during surgery. Previous studies have found that younger age at seizure onset is linked to a poorer outcome (Dalmagro *et al.*, 2005; Liava *et al.*, 2014) and a shorter duration of epilepsy is correlated with better prognosis (Elsharkawy *et al.*, 2009; Englot *et al.*, 2013). We found no correlation between postsurgical outcome and age at onset, duration of epilepsy, seizure frequency, history of infantile spasms, size of the resection, or extent of the lesion on MRI. The limited number of patients included should be taken into account, as well as the multitude of possible predictive factors tested. However, refractory occipital epilepsy in children is a rare disease and patient recruitment for studies is difficult. Therefore, a multicentric study should be planned.

Conclusion

In paediatric occipital epilepsies, the first symptom is often non-specific regarding occipital topography. Oculomotor symptoms and head deviation are the most frequent ictal motor manifestations. Infantile spasms can be triggered by occipital lesions, even if the lesion is far from the motor and premotor cortex. On the other hand, subjective visual initial symptoms can be obtained from six years of age. Seizure spread patterns in occipital epilepsy are similar between paediatric and adult populations, even though it is often impossible to obtain subjective initial visual symptoms from young children or those with intellectual disability. However, automatisms are much less frequent than in adult occipital epilepsies and appear only if the discharge propagates to the temporal lobe. Objective visual symptoms should be recorded during video-EEG to guide the clinicians towards the correct SOZ, as scalp EEG can be misleading. SEEG is a safe and useful method for presurgical evaluation of children with occipital epilepsy, whereas scalp EEG is not a very useful instrument for clinicians attempting to determine the exact extent of the SOZ and leads to surgeons performing limited resections with maximum benefit to the patient. Finally, epilepsy surgery can be a very effective treatment to cure seizures for these patients, especially when the SOZ is within the supracalcarine region, leading to more than 80% seizure freedom.

Post-surgical outcome in children is better than in the adult population and this should encourage early surgery when possible. However, even so, the benefits should always be weighed against the risk of new or aggravated visual field deficits. □

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References

- Adcock J, Panayiotopoulos C. Occipital lobe seizures and epilepsies. *J Clin Neurophysiol* 2012; 29: 397-407.
- Ansari S, Maher C, Tubbs R, Terry C, Cohen-Gadol A. Surgery for extratemporal nonlesional epilepsy in children: a meta-analysis. *Childs Nerv Syst* 2010; 26: 945-51.
- Aykut-Bingol C, Spencer S. Nontumoral occipito-temporal epilepsy: localizing findings and surgical outcome. *Ann Neurol* 1999; 46: 894-900.
- Aykut-Bingol C, Bronen R, Kim H, Spencer D, Spencer SS. Surgical outcome in occipital lobe epilepsy: implications for pathophysiology. *Ann Neurol* 1998; 44: 60-9.
- Barba C, Doglietto F, De Luca L, *et al.* Retrospective analysis of variables favouring good surgical outcome in posterior epilepsies. *J Neurol* 2005; 252: 465-72.
- Bartolomei F, Lagarde S, Wendling F, *et al.* Defining epileptogenic networks: contribution of SEEG and signal analysis. *Epilepsia* 2017; 58: 1131-47.
- Bast T. Outcome after epilepsy surgery in children with MRI-negative non-idiopathic focal epilepsies. *Epileptic Disord* 2013; 15: 105-13.
- Bien C, Benninger F, Urbach H, Schramm J, Kurthen M, Elger C. Localizing value of epileptic visual auras. *Brain* 2000; 123: 244-53.
- Blume W, Whiting S, Girvin J. Epilepsy surgery in the posterior cortex. *Ann Neurol* 1991; 29: 638-45.
- Blume W, Lüders H, Mizrahi E, Tassinari C, van Emde Boas W, Engel J. Glossary of descriptive terminology for ictal semiology: report of the ILAE task force on classification and terminology. *Epilepsia* 2001; 42: 1212-8.
- Bulacio J, Jehi L, Wong C, *et al.* Long-term seizure outcome after resective surgery in patients evaluated with intracranial electrodes. *Epilepsia* 2012; 53: 1722-30.
- Caicoya A, Macarrón J, Albísua J, Serratosa J. Tailored resections in occipital lobe epilepsy surgery guided by monitoring with subdural electrodes: characteristics and outcome. *Epilepsy Res* 2007; 77: 1-10.
- Chen H-H, Chen C, Hung S-C, *et al.* Cognitive and epilepsy outcomes after epilepsy surgery caused by focal cortical dysplasia in children: early intervention may be better. *Childs Nerv Syst* 2014; 30: 1885-95.

- Chipaux M, Dorfmueller G, Fohlen M, et al. Refractory spasms of focal onset: a potentially curable disease that should lead to rapid surgical evaluation. *Seizure* 2017; 51: 163-70.
- Chiron C, Raynaud C, Maziere B, et al. Changes in regional cerebral blood flow during brain maturation in children and a regional cerebral blood flow during brain maturation in children and adolescents. *J Nucl Med* 1992; 33: 696-703.
- Chugani H, Ilyas M, Kumar A M, et al. Surgical treatment for refractory epileptic spasms: the Detroit series. *Epilepsia* 2015; 56: 1941-9.
- Cossu M, Cardinale F, Castana L, Nobili L, Sartori I, Lo Russo G. Stereo-EEG in children. *Childs Nerv Syst* 2006; 22: 766-78.
- Cossu M, Lo Russo G, Francione S, et al. Epilepsy surgery in children: results and predictors of outcome on seizures. *Epilepsia* 2008; 49: 65-72.
- Dalmagro C, Bianchin M, Velasco Jr. V, et al. Clinical features of patients with posterior cortex epilepsies and predictors of surgical outcome. *Epilepsia* 2005; 46: 1442-9.
- Elsharkawy A, El-Ghandour N, Oppel F, et al. Long-term outcome of lesional posterior cortical epilepsy surgery in adults. *J Neurol Neurosurg Psychiatry* 2009; 8: 773-80.
- Eltze C, Chong W, Bhate S, Harding B, Neville B, Cross JH. Taylor-type focal cortical dysplasia in infants: some MRI lesions almost disappear with maturation of myelination. *Epilepsia* 2005; 46: 1988-92.
- Engel JJ, Van Ness P, Rasmussen T, Ojemann L. Outcome with respect to epileptic seizures. In: *Surgical treatment of the epilepsies*. Engel J. New York: Raven Press, 1993: 609-12.
- Englot D, Breshears J, Sun P, Chang E, Auguste K. Seizure outcomes after resective surgery for extra-temporal lobe epilepsy in pediatric patients. *J Neurosurg Pediatr* 2013; 12: 126-33.
- Fogarasi A, Boesebeck F, Tuxhorn I. A detailed analysis of symptomatic posterior cortex semiology in children younger than seven years. *Epilepsia* 2003; 44: 89-96.
- Fogarasi A, Tuxhorn I, Jansky J, et al. Age-dependent seizure semiology in temporal lobe epilepsy. *Epilepsia* 2007; 48: 1697-702.
- Huttenlocher PR, De Courten C, Garey LJ, et al. Synaptic development in human cerebral cortex. *Int J Neurol* 1983; 16-17: 144-54.
- Ibrahim GM, Fallah A, Albert GW, et al. Occipital lobe epilepsy in children: characterization, evaluation and surgical outcomes. *Epilepsy Res* 2012; 99: 335-45.
- Jobst B, Williamson P, Thadani V, et al. Intractable occipital lobe epilepsy: clinical characteristics and surgical treatment. *Epilepsia* 2010; 51: 2334-7.
- Kahane P, Landre E, Minotti L, Francione S, Ryvlin P. The Bancaud and Talairach view on the epileptogenic zone: a working hypothesis. *Epileptic Disord* 2006; 8: S16-26.
- Kang JW, Rhie SK, Yu R, et al. Seizure outcome of infantile spasms with focal cortical dysplasia. *Brain Dev* 2013; 35: 816-20.
- Kral T, von Lehe M, Podlogar M, et al. Focal cortical dysplasia: long-term seizure outcome after surgical treatment. *J Neurol Neurosurg Psychiatry* 2007; 78: 853-6.
- Kun LS, Young LS, Kim D-W, Soo Lee D, Chung C-K. Occipital lobe epilepsy: clinical characteristics, surgical outcome, and role of diagnostic modalities. *Epilepsia* 2005; 46: 688-95.
- Lee Y-J, Lee J, Kang H-C, et al. Outcomes of epilepsy surgery in childhood-onset epileptic encephalopathy. *Brain Dev* 2014; 36: 496-504.
- Liava A, Mai R, Tassi L, et al. Paediatric epilepsy surgery in the posterior cortex: a study of 62 cases. *Epileptic Disord* 2014; 16: 141-64.
- Liu S-Y, An N, Yang M-H, et al. Surgical treatment for epilepsy in 17 children with tuberous sclerosis-related West syndrome. *Epilepsy Res* 2012; 101: 36-45.
- Ludwig B, Ajmone Marsan C. Clinical ictal patterns in epileptic patients with occipital electroencephalographic foci. *Neurology* 1975; 25: 463-71.
- Luhmann HJ, Sinning A, Yang JW, et al. Spontaneous neuronal activity in developing neocortical networks: from single cells to large-scale interactions. *Front Neural Circuits* 2016; 10: 40.
- Marchi A, Bonini F, Lagarde S, et al. Occipital and occipital "plus" epilepsies: a study of involved epileptogenic networks through SEEG quantification. *Epilepsy Behav* 2016; 62: 104-14.
- Mühlebner A, Gröppel G, Dressler A, et al. Epilepsy surgery in children and adolescents with malformations of cortical development-outcome and impact of the new ILAE classification on focal cortical dysplasia. *Epilepsy Res* 2014; 108: 1652-61.
- Olbrich A, Urak L, Groppel G, et al. Semiology of temporal lobe epilepsy in children and adolescents, Value in lateralizing the seizure onset zone. *Epilepsy Res* 2002; 48: 103-10.
- Palmini A, Andermann F, Dubeau F, et al. Occipitotemporal epilepsies: evaluation of selected patients requiring depth electrodes studies and rationale for surgical approaches. *Epilepsia* 1993; 34: 84-96.
- Ramantani G, Stathi A, Brandt A, et al. Posterior cortex epilepsy surgery in childhood and adolescence: predictors of long-term seizure outcome. *Epilepsia* 2017; 58: 412-9.
- Salanova V, Andermann F, Olivier A, Rasmussen T, Quesney L. Occipital lobe epilepsy: electroclinical manifestations, electrocorticography, cortical stimulation and outcome in 42 patients treated between 1930 and 1991. *Brain* 1992; 115: 1655-80.
- Semah F, Picot M-C, Adam C, et al. Is the underlying cause of epilepsy a major prognostic factor for recurrence. *Neurology* 1998; 51: 1256-62.
- Sveinbjornsdottir S, Duncan JS. Parietal and occipital lobe epilepsy: a review. *Epilepsia* 1993; 34: 493-521. Erratum: 1994; 35: 467.
- Takeda A, Bancaud J, Talairach J, Bonis A, Bordas-Ferrer M. Epileptic seizures of occipital origin. *Rev Neurol (Paris)* 1969; 121: 306-15.

Tandon N, Alexopoulos AV, Warbel A, Najm IM, Bingaman WE. Occipital epilepsy: spatial categorization and surgical management. *J Neurosurg* 2009; 110: 306-18.

Taussig D, Chipaux M, Lebas A, et al. Stereoelectroencephalography (SEEG) in 65 children: an effective and safe diagnostic method for pre-surgical diagnosis, independent of age. *Epileptic Disord* 2014; 16: 280-95.

Taylor I, Scheffer I, Berkovic S. Occipital epilepsies: identification of specific and newly recognized syndromes. *Brain* 2003; 126: 753-69.

Teutonico F, Mai R, Veggiotti P, et al. Epilepsy surgery in children: evaluation of seizure outcome and predictive elements. *Epilepsia* 2013; 54: 70-6.

Williamson P, Thadani V, Darcey T, Spencer D, Spencer S, Mattson R. Occipital lobe epilepsy: clinical characteristics, seizure spread patterns, and results of surgery. *Ann Neurol* 1992; 31: 3-13.

Wong C, Mohamed A, Wen L. Metabolic changes in occipital lobe epilepsy with automatisms. *Front Neurol* 2014; 5: 135.

Yang P-F, Mei Z, Lin Q, et al. Disconnective surgery in posterior quadrant epilepsy: a series of 12 paediatric patients. *Epileptic Disord* 2014; 16: 296-304.

Yum M-S, Ko T-S, Lee J, Hong S, Kim D, Kim J. Surgical treatment for localization-related infantile spasms: excellent long-term outcomes. *Clin Neurol Neurosurg* 2011; 113: 213-7.

TEST YOURSELF



- (1) What are the most frequent symptoms in paediatric occipital epilepsy?
- (2) Can infantile spasms be observed in lesional occipital epilepsy in children?
- (3) Can surgery be performed for children with refractory occipital epilepsy?

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com, under the section "The EpiCentre".