Review article

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Facing the hidden wall in mesial extratemporal lobe epilepsy

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ABSTRACT – Refractory extratemporal lobe epilepsy (ETLE) tends to have a less favourable surgical outcome in comparison to temporal lobe epilepsy. ETLE poses specific diagnostic and therapeutic challenges, particularly in cases where seizures develop from the midline. This review focuses on the diagnostic challenges and therapeutic strategies in mesial ETLE. The great diversity of interhemispheric functional areas and extensive connectivity to extramesial structures results in very heterogeneous seizure semiology. Specific signs, such as ictal body turning, can suggest a mesial onset. The hidden cortex of the mesial wall furthermore gives rise to specific diagnostic difficulties due to the low localizing value of scalp EEG. Advanced imaging, as well as targeted intracranial studies, can substantially contribute to depict the seizure onset zone since electroclinical findings are difficult to interpret in most cases. Surgical accessibility of the interhemispheric space can be challenging, both for the placement of subdural grids, as well as for resective surgery. When facing the hidden cortex on the mesial wall of the hemispheres, targeted intra- or extra-operative intracranial recordings can lead to satisfactory outcomes in properly selected cases.

Key words: epilepsy surgery, extratemporal lobe epilepsy, seizure semiology, multimodal imaging, midline epilepsy

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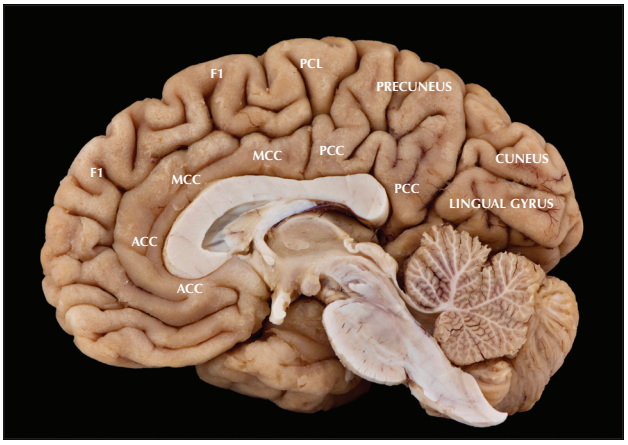

Figure 1. Mesial extratemporal lobe areas. The mesial extratemporal cortex encompasses the superior frontal gyrus (F1), including the SMA, pre-SMA and mesial prefrontal cortex, the paracentral lobule (PCL), the precuneus, the cingulate cortex (ACC, MCC and PCC), and the mesial occipital cortex (cuneus and lingual gyrus). The cingulate gyrus is divided into its anterior (ACC), middle (MCC), and posterior part (PCC).

Effectiveness and superiority of surgical treatment has been demonstrated for drug-resistant temporal lobe epilepsy (TLE). Extratemporal lobe epilepsy (ETLE) makes up a heterogeneous entity but is approached with much greater care since the outcome tends to be inferior to temporal lobe epilepsy surgery (Cascino *et al*., 1992; Tellez-Zenteno *et al*., 2005; Spencer and Huh, 2008). However, while the number of mesial TLE surgeries is declining, the proportion of MRI-negative and ETLE surgery has increased during the last decade (Jehi *et al*., 2015).

Most reports on ETLE describe their results according to the presumed lobe of origin whether frontal, parietal, occipital or insular (Blume *et al*., 1991; Salanova *et al*., 1992; Williamson *et al*., 1992a; Williamson *et al*., 1992b; Salanova *et al*., 1995; Aykut-Bingol *et al*., 1998; Jobst *et al*., 2000; Binder *et al*., 2008; Binder *et al*., 2009; Von Lehe *et al*., 2009; Englot *et al*., 2012). Few studies only focus specifically on epilepsy surgery performed in mesial extratemporal areas (So, 1998; Blume *et al*., 2005; Leung *et al*., 2008; Kasasbeh *et al*., 2012; Unnwongse *et al*., 2012; von Lehe *et al*., 2012; Alkawadri *et al*., 2013; Theys *et al*., 2017). Epileptogenic zones encompassing the cortex of the mesial wall of the brain pose several difficulties since this hidden cortex is difficult to access, both diagnostically as well as therapeutically. The epileptogenic cortex can also overlap with a wide variety of functional areas including primary cortical areas (visual [V1], somatosensory [S1], and motor [M1]), the supplementary motor area (SMA), prefrontal areas, cingulate areas, and the precuneus (*figure 1*). Although mesial ETLE cases involve functionally heterogeneous areas, they share common diagnostic and surgical principles. Besides classic electroclinical diagnostics, defining the epileptogenic zone (EZ) often involves advanced multimodal imaging combined with intracranial EEG recordings, even more so for MRI-negative cases.

In this review, we focus specifically on mesial ETLE surgery and the different strategies to cope with the inherent diagnostic and surgical difficulties. After good diagnostic workup, satisfactory surgical results can be obtained in this difficult patient group. Defining the epileptogenic cortex and tailoring surgical resection is often based on targeted intra- or extra-operative intracranial recordings.

Diagnostic approach

Concordance of electroclinical findings: the exception rather than the rule

Routine clinical workup with a detailed history and the use of video-EEG remains indispensable in the assessment of ETLE, but congruent findings are certainly not the rule in ETLE (Remi *et al*., 2011). The epileptogenic cortex can either be symptomatogenic or silent, and although the localizing value of semiology can be low, semiological findings possess an important, but not absolute, lateralizing value (Boesebeck *et al*., 2002).

The functional diversity of the mesial cortex is complex, and the knowledge of these brain regions such as the cingulate has expanded rapidly (Vogt, 2005), however, there is a marked lag in terms of clinical epileptology. The diversity of ictal signs in mesial frontal lobe seizures reflects the complex long and short range connectivity of this region, since seizure semiology tends to reflect seizure spread. An urge to move and ictal body turning around the horizontal body axis have been specifically associated with mesial frontal epilepsy (Leung *et al*., 2008). Frontal hypermotor seizures (HMS) can have different presentations according to the location of the epileptogenic zone (EZ) along an antero-posterior gradient; while an EZ in the ventromesial prefrontal cortex is associated with fearful agitation, a location in the mesial premotor cortex can be associated with horizontal and rotational body movements (Rheims *et al*., 2008; Bonini *et al*., 2014). Supplementary motor area (SMA) seizures (Morris *et al*., 1988), preceded by a (mostly somatosensory) aura in half of the cases typically present with asymmetric tonic posturing. Other frontomesial seizure types include so-called frontal absence seizures, which can be co-existent with different seizure types (Bancaud *et al*., 1974; So, 1998; Chassagnon *et al*., 2009). Versive seizures and atonic seizures are less frequent manifestations of frontomesial epilepsy. Anterior cingulate cortex (ACC) epilepsy

also typically presents with frontomesial ictal semiology, such as hypermotor seizures, tonic posturing, and early loud vocalization (von Lehe *et al*., 2012; Alkawadri *et al*., 2013). A clinical sign typically ascribed to initial ACC involvement is the "*chapeau de gendarme*", a commonly used French epileptological term, typically regarded as a tonic bilateral contraction of the mouth with the corners of the lip down-turned (Souirti *et al*., 2014). The English term "ictal pouting", however, does not describe this mouth position and rather refers to pursing of the lips as if to blow a kiss. Laughter and mirth have also been associated with ACC and frontomesial seizures (Chassagnon *et al*., 2003; Unnwongse *et al*., 2010; Caruana *et al*., 2015;).

Posterior cingulate cortex (PCC) epilepsies can present as simple tonic or hypermotor seizures with typical auras being vestibular or dyscognitive (Alkawadri *et al*., 2013; Montavont *et al*., 2013; Enatsu *et al*., 2014). Central lobe epilepsy is associated with focal somatosensory manifestations or with clonic seizures and epilepsia partialis continua (EPC) (Chauvel *et al*., 1992; Tuxhorn, 2005). A somatosensory aura or a sensation of vertigo can direct towards a parietal lobe onset. Mesial parietal epilepsy is more often associated with automotor seizures than frontomesial epilepsy, but can also present with tonic or versive seizures (Bartolomei *et al*., 2011; Ristic *et al*., 2012). Manifestations in occipital lobe epilepsy can include negative or positive visual symptoms, blinking, and versive movements (Williamson *et al*., 1992b; Salanova *et al*., 1992; Jobst *et al*., 2010). Mesial occipital epilepsy is associated with visual hallucinations in 60-75% of cases (Boesebeck *et al*., 2002; Blume *et al*., 2005).

In cases where the ictal onset zone is clinically silent, seizures can rapidly spread and semiology will represent propagated activity. PCC epilepsy can often present as temporal lobe epilepsy (Koubeissi *et al*., 2009; Alkawadri *et al*., 2013). Other mesial ETLE, in particular posterior cortex epilepsies, can also present as pseudotemporal epilepsy (Jehi *et al*., 2009).

Not only can clinical symptoms result from propagation, scalp EEG often reveals propagated activity. Temporal EEG abnormalities are frequently found and can be misleading, even more so when the interhemispheric discharges are not picked up. In parasagittal epilepsies, the EEG can often lateralize but does not usually allow for localization. In frontal lobe epilepsy, rhythmic midline theta activity can be found (Beleza *et al*., 2009), as well as midline spikes, and secondary bilateral synchrony and abnormalities are present in the majority of cases (Salanova *et al*., 1995; Wieser and Hajek, 1995; Boesebeck *et al*., 2002). The EEG can thereby mimic multifocal or generalized epilepsy, which could inadvertently exclude patients that would benefit from resective surgery.

Overall, electroclinical findings have a relatively good lateralizing value but tend to have a poor localizing value, making the diagnosis of mesial ETLE challenging (Tukel and Jasper, 1952).

Multimodal imaging and advanced imaging

Since MRI-positive epilepsy is clearly associated with a better outcome (Chapman *et al*., 2005; Bien *et al*., 2009; Noe *et al*., 2013), it is of paramount importance not to overlook discrete cortical signal alterations. Indeed, small bottom-of-sulcus dysplasias or slight grey-white matter alterations can be easily overlooked on routine imaging. MRI postprocessing (Wang and Alexopoulos, 2016) and advanced imaging techniques can sometimes convert MRI-negative into MRI-positive cases and multimodal imaging can also optimize or confirm the working hypothesis (Knowlton *et al*., 2008).

The role of interictal positron emission tomography (PET), mainly using ^{18}F-FDG, in mesial epilepsy has not been studied. In TLE, there is no clear added value of FDG-PET in localizing the epileptogenic zone (Willmann *et al*., 2007). However several studies in TLE have shown that when focal FDG-PET hypometabolism is present in patients with normal MRI, surgical outcome is equivalent to those with clear MRI lesions (Carne *et al*., 2004; Lopinto-Khoury *et al*., 2012; Gok *et al*., 2013; Yang *et al*., 2014). PET seems more predictive in patients with TLE than in those with ETLE (Rathore *et al*., 2014).

Subtracted ictal SPECT co-registered to MRI (SISCOM) is a multimodal image which combines structural information, including the epileptic lesion, with ictal perfusion changes (Van Paesschen *et al*., 2007; Goffin *et al*., 2008). Results are heavily dependent on the timing of the tracer injection; when performed late it can be false localizing or non-contributory. Easy access to nuclear imaging is essential for implementation of this modality in the routine work-up of epilepsy surgery candidates. It remains the only imaging modality which is used to visualize the ictal onset zone on a routine basis. Since focal dysplastic lesions are intrinsically epileptic, hyperperfusion typically overlaps with these lesions (Dupont *et al*., 2006). The combination of SISCOM with morphometric analysis of the MR images (Wellmer *et al*., 2010; Wagner *et al*., 2011; House *et al*., 2015) is a powerful tool in the presurgical evaluation of patients with subtle cortical dysplastic lesions, often making it possible to delineate the epileptogenic zone non-invasively (*figure 2*). Epileptic lesions other than dysplastic lesions show ictal hyperperfusion immediately surrounding the epileptic lesion (*figure 3*). SISCOM can delineate the ictal onset zone in mesial extratemporal lobe epilepsy in a non-invasive manner (*figure 2 and 3*).

After imaging has demonstrated an epileptogenic lesion, intraoperative electrocorticography (ECOG)

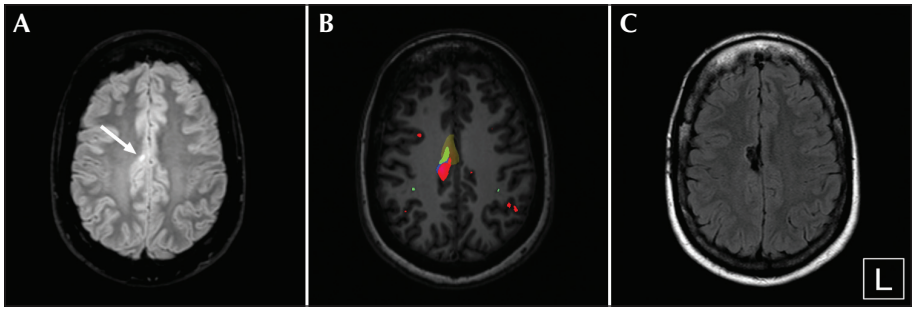

Figure 2. SISCOM in mesial frontal lobe epilepsy due to focal cortical dysplasia. This 46-year-old woman suffered from refractory frontal lobe epilepsy since the age of 7. Interictal EEGs showed right frontocentral (FP2, F8, F4, Fz and C4) sharp waves. Seizures started with eye and head deviation to the right, followed by hyperkinetic movements. Ictal EEGs showed rhythmic fast right frontocentral activity in some of the seizures. (A) FLAIR imaging showed a very discrete hyperintense region (arrow) in the right mesial frontal cortex. (B) Morphometric analysis showed an abnormal "extension" (blue), "junction" (green), and "thickness" (red) in this region, consistent with a focal dysplastic lesion. SISCOM (yellow), thresholded at +2 SD, showed a cluster of hyperperfusion overlapping with this structural abnormality. This non-invasive multimodal imaging enabled non-invasive delineation of the epileptogenic zone. (C) The patient underwent neurosurgery, targeting the focal dysplastic lesion in the anterior cingulate cortex overlapping the SISCOM hyperperfusion cluster. The neurosurgical resection was guided by intraoperative neuronavigation (Brainlab) and intraoperative neurophysiology (ECOG). Pathology showed focal cortical dysplasia type IIb. The patient has remained seizure-free (Engel IA after two years of follow-up). This example illustrates the possible use of a non-invasive approach with multimodal imaging to confirm a suspected epileptogenic zone.

may guide surgical resection, an approach which has been shown to be successful for focal cortical dysplasia (FCD) (Harvey *et al*., 2015).

The case for magnetoencephalography

Magnetoencephalography (MEG) is a non-invasive neurophysiological technique that is highly sensitive to cortical sources that are tangential to the skull and, in comparison with EEG, is almost blind to radial sources. The heightened sensitivity of MEG to fissural/tangential cortical sources, together with some differences in cortical signal to noise ratio (SNR) (Goldenholz *et al*., 2009), explains why MEG can detect epileptic activity which is not captured by EEG (and vice versa) (*see e.g.* Iwasaki *et al*. 2005 and Knake *et al*. 2006). When combined with structural MRI, MEG signals can be used to estimate the location of epileptic sources with a spatial resolution of a few millimetres (*i.e.* magnetic source imaging [MSI]). In epileptic patients, MEG investigations mainly provide information about the irritative zone as ictal recordings are seldom performed due to practical constraints (*e.g.* difficulty to maintain the patient in the magnetic shielded room for a prolonged time) (Medvedovsky *et al*., 2012; Badier *et al*., 2016). In the context of mesial ETLE, the capability of MEG to detect neural activity located in the mesial wall of the brain remains a matter of debate and crucially depends on SNR issues (*e.g.* level of noise in the data, extension of the activated cortical surface, depth of the activated cortical area, *etc.*) (Goldenholz *et al*., 2009; Huiskamp *et al*., 2010). Activity from cortical areas located close to the interhemispheric convexity appears to be clearly captured by MEG, while that from deeper sources (*i.e.* cingulate areas) is more difficult to detect (Goldenholz *et al*., 2009; Huiskamp *et al*., 2010). To the best of our knowledge, no study has specifically addressed the clinical added value of MEG in mesial ETLE. Still, several studies or case reports have highlighted the capability of MEG to detect interictal epileptic discharges from the mesial wall of the brain (Canuet *et al*., 2008; Garcia-Morales *et al*., 2009; Op de Beeck *et al*., 2011;

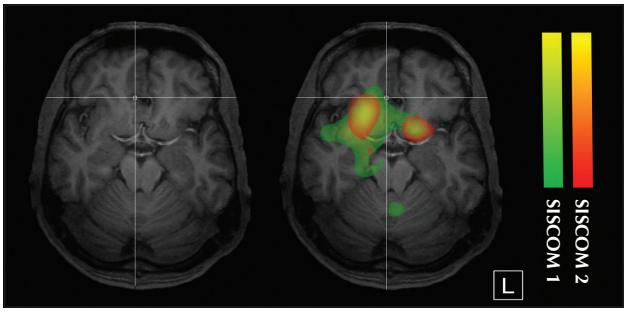

Figure 3. SISCOM in mesial frontal lobe epilepsy due to a tumour. This patient was a 45-year-old man who developed epilepsy at the age of 25 years. MRI showed a lesion with calcifications in the right mesial frontal lobe (white cross), consistent with a low-grade tumour. He was referred for ictal SPECT because both right and left temporal lobe seizures were documented during long-term video-EEG recordings. Two ictal SPECTs were obtained. SISCOM 1 (green yellow), thresholded at z=+1.5, showed a hyperperfusion cluster with the highest z-score near the lesion, but not overlapping it, and propagation towards the right and left temporal lobes. SISCOM 2 (red-yellow) showed two separate hyperperfusion clusters, with the highest z-score on the right. Using SISCOM, it was possible to resolve non-invasively an apparent discordancy between an epileptic lesion in the mesial frontal lobe and electroclinical data which suggested temporal lobe seizures, *i.e.* pseudotemporal lobe epilepsy.

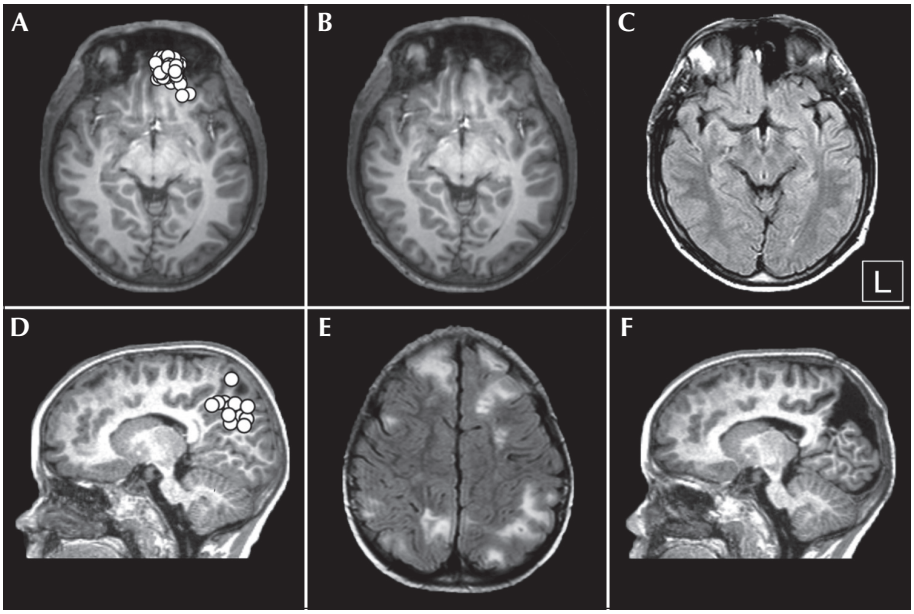

Figure 4. MEG in mesial ETLE. (A) MEG results from an 18-year-old man with refractory frontal lobe epilepsy (several seizures per night), with non-localizing interictal and ictal EEG at the sublobar level, MRI considered as negative, and non-contributory FDG-PET. MEG showed a focal cluster of epileptic sources at the level of the left gyrus rectus. (B) MEG-based reanalysis of MRI data revealed a subtle focal cortical dysplasia (FCD) at the level of the MEG cluster. The location of the seizure onset zone at the level of the FCD was confirmed by MEG-guided SEEG. (C) Post-operative MRI showing the resection cavity of the FCD type IIa. Outcome was Engel IA during the first 18 months post-surgery and Engel 1B (rare non-disabling seizures) for the next four years. (D) MEG results for a 4-year-old boy with tuberous sclerosis and refractory focal epilepsy (daily seizures) showing a focal cluster of epileptic sources at the level of a right mesial parietal tuber. (E) Flair MRI showing the multiple cortical tubers. (F) Post-operative MRI showing the resection cavity of the right mesial parietal tuber. Outcome was Engel IA with more than three years of follow-up. In this case, it was possible to differentiate between different possible epileptogenic lesions and determine the operative strategy non-invasively using MEG.

Ibrahim *et al*., 2012; De Tiege *et al*., 2012; Jung *et al*., 2013; Gavaret *et al*., 2014; Heers *et al*., 2014; Murakami *et al*., 2016), with a clear impact on surgical management in some cases, *i.e*. detection of irritative zones not captured by conventional EEG or identification of a brain lesion in MRI-negative patients (*figure 4*) (Garcia-Morales *et al*., 2009; De Tiege *et al*., 2012; Jung *et al*., 2013; Murakami *et al*., 2016). These data underline that MEG is of great interest for patients with extra-temporal lobe epilepsy (De Tiege *et al*., 2012), and more particularly in MRI-negative patients (for a review, see *e.g*. Bagic, 2016) or patients with inconclusive conventional non-invasive presurgical evaluation (De Tiege *et al*., 2012). MEG can therefore provide added value for non-invasive presurgical workup of patients with such refractory mesial ETLE. However, MEG is expensive and therefore has limited availability which makes it difficult to implement in routine clinical practice.

Intracranial recordings

As electroclinical findings are often discordant in mesial ETLE and imaging cannot always pinpoint the ictal onset zone, invasive EEG recordings are needed for suspected focal epilepsies, even more so for tailoring resections in cryptogenic or MRI-negative cases (Chapman *et al*., 2005; Noe *et al*., 2013). Ictal SPECT can sometimes be unreliable or inconclusive due to rapid propagation in ETLE (Laich *et al*., 1997).

Precise depiction of the ictal onset zone and delineation of the epileptic cortex remains the cornerstone in achieving success after epilepsy surgery. When a focal seizure onset is suspected, but the epileptogenic zone cannot be clearly defined on the basis of semiology, EEG, MEG and advanced imaging, and invasive intracranial studies should be considered. Both depth electrodes, as well as subdural electrodes, can serve this purpose. Although interhemispheric subdural strip and grid electrodes have been reported to be associated with acceptable morbidity and allow for a mapping of adjacent functional areas, *e.g*. the mesial central cortex (Bekelis *et al*., 2012; Delev *et al*., 2015), one has to keep in mind that bridging veins can hinder appropriate placement of grids and therefore impede adequate delineation of the EZ.

Stereo-electroencephalography (SEEG) is a safe method, associated with a lower level of risk relative to other invasive studies (Mullin *et al*., 2016). One of the advantages resides in the fact that the surgeon

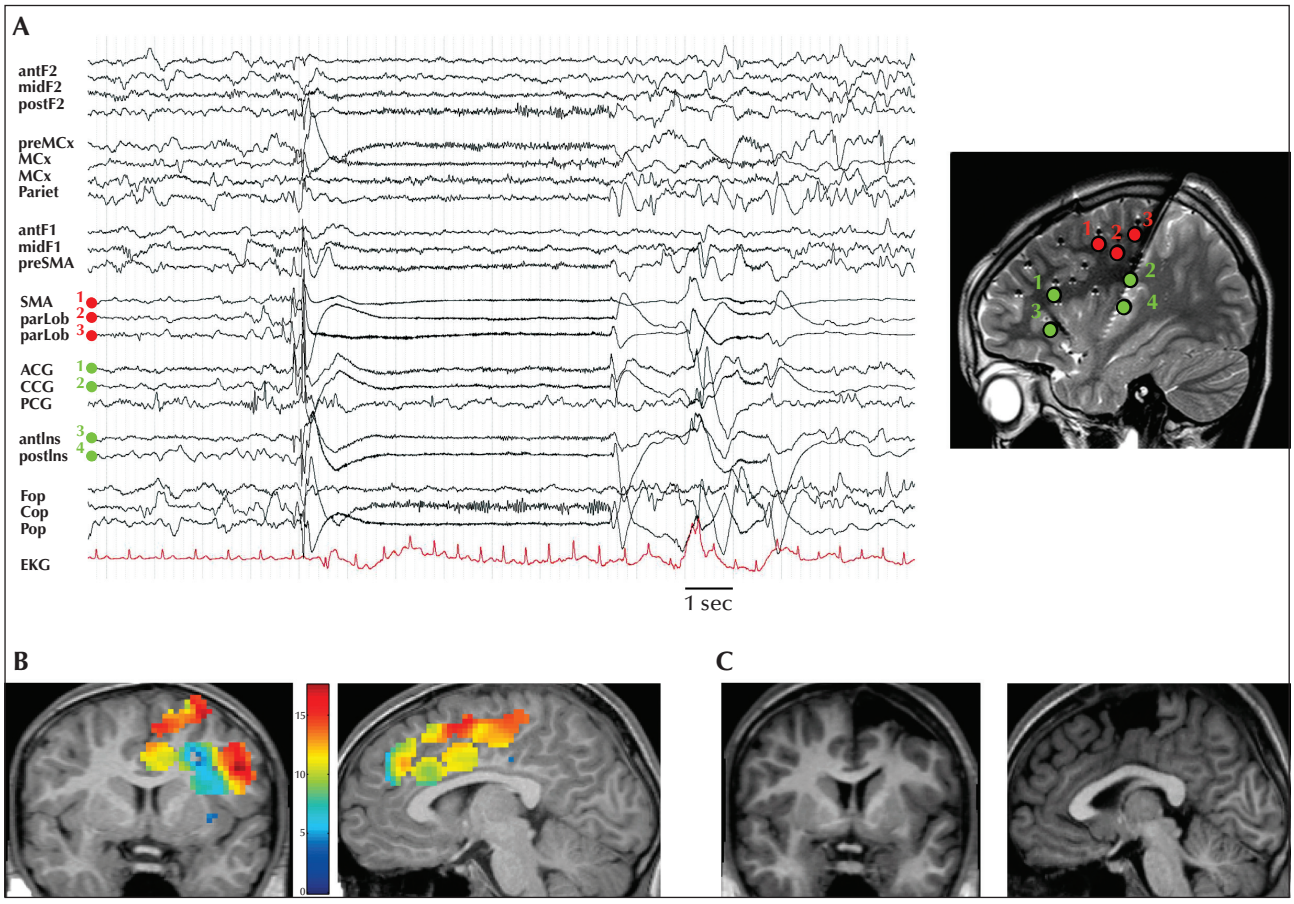

Figure 5. SEEG in SMA epilepsy. A right-handed, 12-year-old girl with no significant medical history developed epilepsy at the age of 5. Her seizures were characterized by a relatively brief right tonic posturing involving both upper and lower limbs, without loss of consciousness or speech impairment. Sudden tingling of the right leg could precede seizures. The interictal video-EEG pointed towards the left central region, as well as parietocentral and temporal areas. The first ictal EEG changes were apparent in the left precentral and frontopolar region. PET imaging revealed focal hypometabolism around the left superior frontal sulcus. (A) Since MRI did not show any lesion, SEEG was performed to investigate the left prefrontal and premotor regions, including the posterior insulo-opercular cortex. During SEEG, several typical seizures were recorded. Ictal low-voltage fast activity was more sustained on the premotor mesial cortex. SEEG implantation was performed under stereotactic conditions using a lateral orthogonal trajectory with the help of a computer-driven robotized arm for the oblique route; the left-sided electrode contacts are shown on both the MRI and the SEEG trace. Abbreviations: F1: superior frontal gyrus; F2: middle frontal gyrus; preMCx: premotor cortex; MCx: motor cortex; SMA: supplementary motor area (red contact 1); parLob: paracentral lobule (red contact 2/3); ACG: anterior cingulate gyrus (green contact 1); CCG: central cingulate gyrus (green contact 2); PCG: posterior cingulate gyrus; antins: anterior insula (green contact 3); postins: posterior insula (green contact 4); Fop: frontal operculum; Pop: parietal operculum; Cop: central operculum. (B) SEEG findings were further confirmed by the quantification of ictal high-frequency oscillations between 60 and 100 Hz. Epileptogenicity maps demonstrated the involvement of a larger network. The most significant activation was, however, found in the premotor mesial cortex, in line with the electroclinical findings. (**C**) Postoperative MRI illustrating the resection of the mesial premotor cortex. A frontomesial resection resulted in good functional and seizure outcome (Engel IB after four years of follow-up). Histopathology revealed FCD type IIa.

does not have to deal with bridging veins since a lateral approach is used to insert depth electrodes. Moreover, the same SEEG electrodes targeting the mesial cortex allow for coverage of intermediate sulci and (dorso-)lateral cortex, providing good spatial sampling, notably in frontal lobe epilepsies. SEEG also allows placement at the bottom of the sulci. Even before advanced imaging techniques, SEEG already provided a 3D approach to delineate the dysplastic cortex and therefore improved seizure outcomes after surgery (Chassoux *et al.*, 2000). Defining an appropriate SEEG scheme requires meticulous review and analysis of all available data including semiology, video-EEG, neuronuclear imaging, MEG, fMRI, and neuropsychological assessment. In mesial ETLE, scalp EEG will often result in a mislocalization of the EZ. In such cases, other clinical information is critical to target the epileptogenic cortex. SEEG findings can

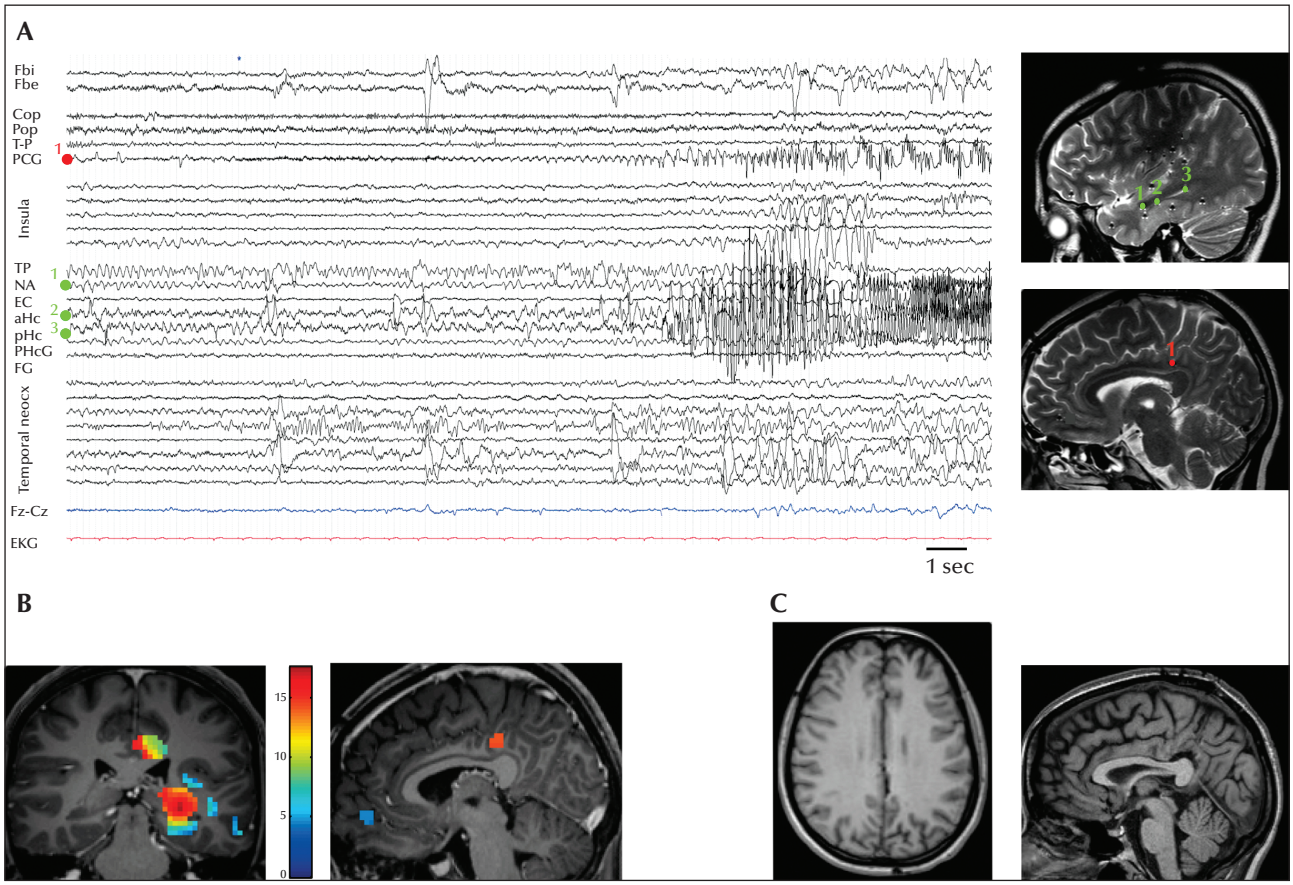

Figure 6. SEEG in posterior cingulate epilepsy. A 14-year-old, left-handed girl with drug-resistant epilepsy experienced epigastric sensations associated with a gustatory illusion, sometimes followed by a loss of consciousness and oro-alimentary automatisms. Speech was preserved during seizures. A focal lesion in the left thalamus, supposedly the result of a perinatal vascular event, was visible on MRI. FDG-PET showed clear left temporal hypometabolism. Interictal spikes were preferentially observed in the left temporal region. The typical ictal pattern involved rhythmic theta activity that was more posteriorly located, involving posterior temporal and centro-parietal regions. (A) Because of atypical findings on scalp EEG, and with no obvious lesion on MRI, an implantation with SEEG electrodes was proposed for this patient. An SEEG study was performed to investigate the left temporal and basal temporal regions, as well as the parietal and insulo-opercular cortex. During the seizure, SEEG revealed a low-voltage fast activity involving the parietal cingulate gyrus, which preceded the mesio-temporal discharge. SEEG implantation was performed; left-sided electrode contacts are shown on MRI and on the SEEG trace. Epileptic activity starts on the PCG (posterior cingulate gyrus) contact (red contact 1) and propagates to mesial temporal structures (NA: amygdala [green contact 1]; aHc: anterior hippocampus [green contact 2]; pHc: posterior hippocampus [green contact 3]). (B) The seizure onset zone was confirmed by epileptogenicity mapping, illustrating an important network involvement with rapid propagation to the mesial temporal region. (C) A very restricted parietal cingulate resection was performed. Neuropathology showed non-specific gliosis. The patient has been seizure-free since surgery (Engel IA with a follow-up of 33 months).

furthermore be confirmed by the quantification of ictal high-frequency oscillations (David *et al*., 2011) between 60 and 100 Hz. Two illustrative SEEG cases are presented in *figures 5 and 6*.

Therapeutic challenges

Surgical considerations

On accessing the interhemispheric wall, one can encounter specific difficulties; bridging veins can impede access to the parasagittal cortex, and destroying or sparing eloquent cortex can respectively compromise functional or epilepsy outcome. Delineation of the extent of resection can be guided by different aids. Neuronavigation can be of great value in localizing a specific target area and determining the extent of resection, although brain shift can lead to inaccuracy. Intraoperative neurophysiology can furthermore guide a tailored resection in two ways. First, dysplastic epileptogenic cortex can lead to typical interictal epileptiform discharges with almost continuous spiking, which can serve as a guide in tailoring resections based on intraoperative electrocorticography (Palmini *et al*., 1995; Guerrini *et al*., 2015; Harvey

et al., 2015). Secondly, intraoperative neurophysiology, with the use of motor and sensory evoked potentials as well as intraoperative electrical stimulation, can delineate the primary motor cortex and may lead to better post-operative seizure control (Neuloh *et al.*, 2010). Preoperative functional MRI can already provide the surgeon with an estimated vicinity of the eloquent cortex to the presumed EZ. Some centres advocate the use of preoperative cortical mapping using navigated transcranial magnetic stimulation (TMS), *e.g.* in children when fMRI is not feasible. Furthermore, diffusion tensor imaging (DTI) can delineate important white matter tracts, such as the corticospinal tract in relation to the presumed EZ. One has to take into account the surgical morbidity related to the resection of a certain functional area and discuss the implications with the patient and their relatives before surgery. Surgical morbidity can result both from direct damage (resection and retraction) as well as from indirect vascular injury (bridging veins and interhemispheric arteries). Motor or speech deficits associated with SMA syndrome, which occur relatively frequently following frontomesial resections, can be anticipated and are generally associated with a good prognosis. Motor, sensory or visual deficits after resection of primary cortical areas tend to have a dismal prognosis.

Different surgical techniques have been described for interhemispheric lesions and tumours. Rotating the patient's head to the ipsilateral side with the mesial cortex facing upwards will allow the brain to fall down with gravity and obviates the need for retraction with spatulas. Regardless of the surgical technique, one has to avoid important traction on (eloquent) cortical areas and respect the course of bridging veins running along the mesial cortex into the sagittal sinus.

Outcome after mesial ETLE surgery

Seizure outcomes after ETLE surgery are generally reported with respect to the resected lobe, most frequently in the frontal lobe. Engel I outcomes for ETLE vary between 30% and 72% (Schramm *et al.*, 2002; Kim *et al.*, 2004; Dalmagro *et al.*, 2005 ; Jeha *et al.*, 2007; Binder *et al.*, 2008; Elsharkawy *et al.*, 2008; Lee *et al.*, 2008; Binder *et al.*, 2009; Elsharkawy *et al.*, 2009; Jehi *et al.*, 2009 ; Yu *et al.*, 2009). ETLE surgery has been associated with inferior epilepsy outcomes, especially when considering MRI-negative cases (Smith *et al.*, 1997; Mosewich *et al.*, 2000; Chapman *et al.*, 2005; Noe *et al.*, 2013). Very few data are available on outcomes following resections in mesial extratemporal areas; when reported, overall, outcomes are good, with Engel IA outcome in over 60% of patients (mean follow-up: 5-9 years) (von Lehe *et al.*, 2012; Alkawadri *et al.*, 2013; Theys *et al.*, 2017). In MRI-negative cases, 42% of mesial ETLE patients achieved Engel I outcome (Theys *et al.*, 2017). This is comparable to a recent series of MRI-negative ETLE patients, of whom 38% had an excellent outcome after appropriate case selection (Noe *et al.*, 2013).

Parasagittal resections are associated with a high rate of motor and speech deficits, but these are mostly transient. Transient neurological morbidity can be seen in up to 25% of patients with frontomesial epilepsy (Von Lehe *et al.*, 2012). Permanent morbidity is mostly seen in central lobe and occipitomesial resections.

Conclusion

Mesial ETLE represents a challenging entity, both for the epileptologist as well as for the epilepsy neurosurgeon. Since the ictal onset zone can be clinically and electrographically silent and discordant findings are often present, a combination of imaging techniques with intracranial recordings are indispensable for obtaining good delineation of the EZ.

After extensive and invasive investigations, satisfactory outcomes can be obtained for this particular subgroup of extratemporal lobe epilepsies. For MRI-negative cases, this holds true for a selected subgroup of patients. □

Disclosures.

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References

Alkawadri R, So NK, Van Ness PC, Alexopoulos AV. Cingulate epilepsy: report of 3 electroclinical subtypes with surgical outcomes. *JAMA Neurol* 2013; 70: 995-1002.

Aykut-Bingol C, Bronen RA, Kim JH, Spencer DD, Spencer SS. Surgical outcome in occipital lobe epilepsy: implications for pathophysiology. *Ann Neurol* 1998; 44: 60-9.

Badier JM, Benar CG, Woodman M, *et al.* Ictal magnetic source imaging in presurgical assessment. *Brain Topogr* 2016; 29: 182-92.

Bagic A. Look back to leap forward: the emerging new role of magnetoencephalography (MEG) in nonlesional epilepsy. *Clin Neurophysiol* 2016; 127: 60-6.

Bancaud J, Talairach J, Morel P, *et al.* "Generalized" epileptic seizures elicited by electrical stimulation of the frontal lobe in man. *Electroencephalogr Clin Neurophysiol* 1974; 37: 275-82.

Bartolomei F, Gavaret M, Hewett R, *et al.* Neural networks underlying parietal lobe seizures: a quantified study from intracerebral recordings. *Epilepsy Res* 2011; 93: 164-76.

Bekelis K, Radwan TA, Desai A, *et al*. Subdural interhemispheric grid electrodes for intracranial epilepsy monitoring: feasibility, safety, and utility. *J Neurosurg* 2012; 117: 1182-8.

Beleza P, Bilgin O, Noachtar S. Interictal rhythmical midline theta differentiates frontal from temporal lobe epilepsies. *Epilepsia* 2009; 50: 550-5.

Bien CG, Szinay M, Wagner J, Clusmann H, Becker AJ, Urbach H. Characteristics and surgical outcomes of patients with refractory magnetic resonance imaging-negative epilepsies. *Arch Neurol* 2009; 66: 1491-9.

Binder DK, Von Lehe M, Kral T, *et al*. Surgical treatment of occipital lobe epilepsy. *J Neurosurg* 2008; 109: 57-69.

Binder DK, Podlogar M, Clusmann H, *et al*. Surgical treatment of parietal lobe epilepsy. *J Neurosurg* 2009; 110: 1170-8.

Blume WT, Whiting SE, Girvin JP. Epilepsy surgery in the posterior cortex. *Ann Neurol* 1991; 29: 638-45.

Blume WT, Wiebe S, Tapsell LM. Occipital epilepsy: lateral versus mesial. *Brain* 2005; 128: 1209-25.

Boesebeck F, Schulz R, May T, Ebner A. Lateralizing semiology predicts the seizure outcome after epilepsy surgery in the posterior cortex. *Brain* 2002; 125: 2320-31.

Bonini F, Mcgonigal A, Trebucho NA, *et al*. Frontal lobe seizures: from clinical semiology to localization. *Epilepsia* 2014; 55: 264-77.

Canuet L, Ishii R, Iwase M, *et al*. Cephalic auras of supplementary motor area origin: an ictal MEG and SAM(g2) study. *Epilepsy Behav* 2008; 13: 570-4.

Carne RP, O'brien TJ, Kilpatric CJK, *et al*. MRI-negative PET-positive temporal lobe epilepsy: a distinct surgically remediable syndrome. *Brain* 2004; 127: 2276-85.

Caruana F, Avanzini P, Gozzo F, Francione S, Cardinale F, Rizzolatti G. Mirth and laughter elicited by electrical stimulation of the human anterior cingulate cortex. *Cortex* 2015; 71: 323-31.

Cascino GD, Kelly PJ, Sharbrough FW, Hulihan JF, Hirschorn KA, Trenerry MR. Long-term follow-up of stereotactic lesionectomy in partial epilepsy: predictive factors and electroencephalographic results. *Epilepsia* 1992; 33: 639-44.

Chapman K, Wyllie E, Najm I, *et al*. Seizure outcome after epilepsy surgery in patients with normal preoperative MRI. *J Neurol Neurosurg Psychiatry* 2005; 76: 710-3.

Chassagnon S, Minotti L, Kremer S, *et al*. Restricted frontomesial epileptogenic focus generating dyskinetic behavior and laughter. *Epilepsia* 2003; 44: 859-63.

Chassagnon S, Hawk CS, Bernasconi A, Gotman J, Dubeau F. Coexistence of symptomatic focal and absence seizures: video-EEG and EEG-fMRI evidence of overlapping but independent epileptogenic networks. *Epilepsia* 2009; 50: 1821-6.

Chassoux F, Devaux B, Landre E, *et al*. Stereoelectroencephalography in focal cortical dysplasia: a 3D approach to delineating the dysplastic cortex. *Brain* 2000; 123: 1733-51.

Chauvel P, Trottier S, Vigna JP, Bancaud J. Somatomotor seizures of frontal lobe origin. *Adv Neurol* 1992; 57: 185-232.

Dalmagro CL, Bianchin MM, Velasco TR, *et al*. Clinical features of patients with posterior cortex epilepsies and predictors of surgical outcome. *Epilepsia* 2005; 46: 1442-9.

David O, Blauwblomme T, Job AS, *et al*. Imaging the seizure onset zone with stereo-electroencephalography. *Brain* 2011; 134: 2898-911.

De Tiege X, Carrette E, Legros B, *et al*. Clinical added value of magnetic source imaging in the presurgical evaluation of refractory focal epilepsy. *J Neurol Neurosurg Psychiatry* 2012; 83: 417-23.

Delev D, Send K, Malter M, *et al*. The role of subdural interhemispheric electrodes (IHE) in the presurgical evaluation of epilepsy patients. *World Neurosurg* 2015; 84: 1719-25.e1.

Dupont P, Van Paesschen W, Palmini A, *et al*. Ictal perfusion patterns associated with single MRI-visible focal dysplastic lesions: implications for the noninvasive delineation of the epileptogenic zone. *Epilepsia* 2006; 47: 1550-7.

Elsharkawy AE, Alabbasi AH, Pannek H, *et al*. Outcome of frontal lobe epilepsy surgery in adults. *Epilepsy Res* 2008; 81: 97-106.

Elsharkawy AE, El-Ghandour NM, Oppe LF, *et al*. Long-term outcome of lesional posterior cortical epilepsy surgery in adults. *J Neurol Neurosurg Psychiatry* 2009; 80: 773-80.

Enatsu R, Bulacio J, Nair DR, Bingaman W, Najm I, Gonzalez-Martinez J. Posterior cingulate epilepsy: clinical and neurophysiological analysis. *J Neurol Neurosurg Psychiatry* 2014; 85: 44-50.

Englot DJ, Wang DD, Rolston JD, Shih TT, Chang EF. Rates and predictors of long-term seizure freedom after frontal lobe epilepsy surgery: a systematic review and meta-analysis. *J Neurosurg* 2012; 116: 1042-8.

Garcia-Morales I, Maestu F, Perez-Jimenez MA, *et al*. A clinical and magnetoencephalography study of MRI-negative startle epilepsy. *Epilepsy Behav* 2009; 16: 166-71.

Gavaret M, Badier JM, Bartolomei F, Benar CG, Chauvel P. MEG and EEG sensitivity in a case of medial occipital epilepsy. *Brain Topogr* 2014; 27: 192-6.

Goffin K, Dedeurwaerdere S, Van Laere K, Van Paesschen W. Neuronuclear assessment of patients with epilepsy. *Semin Nucl Med* 2008; 38: 227-39.

Gok B, Jallo G, Hayeri R, Wahl R, Aygun N. The evaluation of FDG-PET imaging for epileptogenic focus localization in patients with MRI positive and MRI negative temporal lobe epilepsy. *Neuroradiology* 2013; 55: 541-50.

Goldenholz DM, Ahlfors SP, Hamalainen MS, *et al*. Mapping the signal-to-noise-ratios of cortical sources in magnetoencephalography and electroencephalography. *Hum Brain Mapp* 2009; 30: 1077-86.

Guerrini R, Duchowny M, Jayakar P, *et al*. Diagnostic methods and treatment options for focal cortical dysplasia. *Epilepsia* 2015; 56: 1669-86.

Harvey AS, Mandelstam SA, Maixner WJ, *et al*. The surgically remediable syndrome of epilepsy associated with bottom-of-sulcus dysplasia. *Neurology* 2015; 84: 2021-8.

Heers M, Hirschmann J, Jacobs J, *et al*. Frequency domain beamforming of magnetoencephalographic beta band activity in epilepsy patients with focal cortical dysplasia. *Epilepsy Res* 2014; 108: 1195-203.

House PM, Holst B, Lindenau M, *et al*. Morphometric MRI analysis enhances visualization of cortical tubers in tuberous sclerosis. *Epilepsy Res* 2015; 117: 29-34.

Huiskamp G, Agirre-Arrizubieta Z, Leijten F. Regional differences in the sensitivity of MEG for interictal spikes in epilepsy. *Brain Topogr* 2010; 23: 159-64.

Ibrahim GM, Fallah A, Albert GW, *et al*. Occipital lobe epilepsy in children: characterization, evaluation and surgical outcomes. *Epilepsy Res* 2012; 99: 335-45.

Iwasaki M, Pestana E, Burgess RC, Luders HO, Shamoto H, Nakasato N. Detection of epileptiform activity by human interpreters: blinded comparison between electroencephalography and magnetoencephalography. *Epilepsia* 2005; 46: 59-68.

Jeha LE, Najm I, Bingaman W, Dinner D, Widdess-Walsh P, Luders H. Surgical outcome and prognostic factors of frontal lobe epilepsy surgery. *Brain* 2007; 130: 574-84.

Jehi LE, O'dwyer R, Najm I, Alexopoulos A, Bingaman W. A longitudinal study of surgical outcome and its determinants following posterior cortex epilepsy surgery. *Epilepsia* 2009; 50: 2040-52.

Jehi L, Friedman D, Carlson C, *et al*. The evolution of epilepsy surgery between 1991 and 2011 in nine major epilepsy centers across the United States, Germany, and Australia. *Epilepsia* 2015; 56: 1526-33.

Jobst BC, Siegel AM, Thadani VM, Roberts DW, Rhodes HC, Williamson PD. Intractable seizures of frontal lobe origin: clinical characteristics, localizing signs, and results of surgery. *Epilepsia* 2000; 41: 1139-52.

Jobst BC, Williamson PD, Thadani VM, *et al*. Intractable occipital lobe epilepsy: clinical characteristics and surgical treatment. *Epilepsia* 2010; 51: 2334-7.

Jung J, Bouet R, Delpuech C, *et al*. The value of magnetoencephalography for seizure-onset zone localization in magnetic resonance imaging-negative partial epilepsy. *Brain* 2013; 136: 3176-86.

Kasasbeh AS, Yarbrough CK, Limbrick DD, *et al*. Characterization of the supplementary motor area syndrome and seizure outcome after medial frontal lobe resections in pediatric epilepsy surgery. *Neurosurgery* 2012; 70: 1152-68, discussion: 1168.

Kim DW, Lee SK, Yun CH, *et al*. Parietal lobe epilepsy: the semiology, yield of diagnostic workup, and surgical outcome. *Epilepsia* 2004; 45: 641-9.

Knake S, Halgren E, Shiraishi H, *et al*. The value of multichannel MEG and EEG in the presurgical evaluation of 70 epilepsy patients. *Epilepsy Res* 2006; 69: 80-6.

Knowlton RC, Elgavish RA, Bartolucci A, *et al*. Functional imaging: II. Prediction of epilepsy surgery outcome. *Ann Neurol* 2008; 64: 35-41.

Koubeissi MZ, Jouny CC, Blakeley JO, Berge GK. Analysis of dynamics and propagation of parietal cingulate seizures with secondary mesial temporal involvement. *Epilepsy Behav* 2009; 14: 108-12.

Laich E, Kuzniecky R, Mountz J, *et al*. Supplementary sensorimotor area epilepsy. Seizure localization, cortical propagation and subcortical activation pathways using ictal SPECT. *Brain* 1997; 120: 855-64.

Lee JJ, Lee SK, Lee SY, *et al*. Frontal lobe epilepsy: clinical characteristics, surgical outcomes and diagnostic modalities. *Seizure* 2008; 17: 514-23.

Leung H, Schindler K, Clusmann H, *et al*. Mesial frontal epilepsy and ictal body turning along the horizontal body axis. *Arch Neurol* 2008; 65: 71-7.

Lopinto-Khoury C, Sperling MR, Skidmore C, *et al*. Surgical outcome in PET-positive, MRI-negative patients with temporal lobe epilepsy. *Epilepsia* 2012; 53: 342-8.

Medvedovsky M, Taulu S, Gaily E, *et al*. Sensitivity and specificity of seizure-onset zone estimation by ictal magnetoencephalography. *Epilepsia* 2012; 53: 1649-57.

Montavont A, Kahane P, Catenoix H, *et al*. Hypermotor seizures in lateral and mesial parietal epilepsy. *Epilepsy Behav* 2013; 28: 408-12.

Morris HH, Dinner DS, Luders H, Wyllie E, Kramer R. Supplementary motor seizures: clinical and electroencephalographic findings. *Neurology* 1988; 38: 1075-82.

Mosewich RK, So EL, O'brien TJ, *et al*. Factors predictive of the outcome of frontal lobe epilepsy surgery. *Epilepsia* 2000; 41: 843-9.

Mullin JP, Shriver M, Alomar S, *et al*. Is SEEG safe? A systematic review and meta-analysis of stereo-electroencephalography-related complications. *Epilepsia* 2016; 57: 386-401.

Murakami H, Wang ZI, Marashly A, *et al*. Correlating magnetoencephalography to stereo-electroencephalography in patients undergoing epilepsy surgery. *Brain* 2016; 139(11): 2935-47.

Neuloh G, Bien CG, Clusmann H, Von LM, Schramm J. Continuous motor monitoring enhances functional preservation and seizure-free outcome in surgery for intractable focal epilepsy. *Acta Neurochir (Wien)* 2010; 152: 1307-14.

Noe K, Sulc V, Wong-Kisiel L, *et al*. Long-term outcomes after nonlesional extratemporal lobe epilepsy surgery. *JAMA Neurol* 2013; 70: 1003-8.

Op de Beeck M, Legros B, Gaspard N, *et al*. Supplementary motor cortex involvement in reading epilepsy revealed by magnetic source imaging. *Epilepsia* 2011; 52: e31-4.

Palmini A, Gambardella A, Andermann F, *et al*. Intrinsic epileptogenicity of human dysplastic cortex as suggested by corticography and surgical results. *Ann Neurol* 1995; 37: 476-87.

Rathore C, Dickson JC, Teotonio R, Ell P, Duncan JS. The utility of 18F-fluorodeoxyglucose PET (FDG PET) in epilepsy surgery. *Epilepsy Res* 2014; 108: 1306-14.

Remi J, Vollmar C, De Marinis A, Heinlin J, Peraud A, Noachtar S. Congruence and discrepancy of interictal and ictal EEG with MRI lesions in focal epilepsies. *Neurology* 2011; 77: 1383-90.

Rheims S, Ryvlin P, Scherer C, *et al*. Analysis of clinical patterns and underlying epileptogenic zones of hypermotor seizures. *Epilepsia* 2008; 49: 2030-40.

Ristic AJ, Alexopoulos AV, So N, Wong C, Najm IM. Parietal lobe epilepsy: the great imitator among focal epilepsies. *Epileptic Disord* 2012; 14: 22-31.

Salanova V, Andermann F, Olivier A, Rasmussen T, Quesney LF. Occipital lobe epilepsy: electroclinical manifestations, electrocorticography, cortical stimulation and outcome in 42 patients treated between 1930 and 1991. Surgery of occipital lobe epilepsy. *Brain* 1992; 115: 1655-80.

Salanova V, Andermann F, Rasmussen T, Olivier A, Quesney LF. Parietal lobe epilepsy. Clinical manifestations and outcome in 82 patients treated surgically between 1929 and 1988. *Brain* 1995; 118: 607-27.

Schramm J, Kral T, Kurthen M, Blumcke I. Surgery to treat focal frontal lobe epilepsy in adults. *Neurosurgery* 2002; 51: 644-54.

Smith JR, Lee MR, King DW, *et al*. Results of lesional vs. nonlesional frontal lobe epilepsy surgery. *Stereotact Funct Neurosurg* 1997; 69: 202-9.

So NK. Mesial frontal epilepsy. *Epilepsia* 1998; 39: S49-61.

Souirti Z, Landre E, Mellerio C, Devaux B, Chassoux F. Neural network underlying ictal pouting ("chapeau de gendarme") in frontal lobe epilepsy. *Epilepsy Behav* 2014; 37: 249-57.

Spencer S, Huh L. Outcomes of epilepsy surgery in adults and children. *Lancet Neurol* 2008; 7: 525-37.

Tellez-Zenteno JF, Dhar R, Wiebe S. Long-term seizure outcomes following epilepsy surgery: a systematic review and meta-analysis. *Brain* 2005; 128: 1188-98.

Theys T, Minotti L, Tassi L, *et al*. Mesial extratemporal lobe epilepsy: clinical features and surgical strategies. *Neurosurgery* 2017; 80: 269-78.

Tukel K, Jasper H. The electroencephalogram in parasagittal lesions. *Electroencephalogr Clin Neurophysiol* 1952; 4: 481-94.

Tuxhorn IE. Somatosensory auras in focal epilepsy: a clinical, video EEG and MRI study. *Seizure* 2005; 14: 262-8.

Unnwongse K, Wehner T, Bingaman W, Foldvary-Schaefer N. Gelastic seizures and the anteromesial frontal lobe: a case report and review of intracranial EEG recording and electrocortical stimulation case studies. *Epilepsia* 2010; 51: 2195-8.

Unnwongse K, Wehner T, Foldvary-Schaefer N. Mesial frontal lobe epilepsy. *J Clin Neurophysiol* 2012; 29: 371-8.

Van Paesschen W, Dupont P, Sunaert S, Goffin K, Van Laere K. The use of SPECT and PET in routine clinical practice in epilepsy. *Curr Opin Neurol* 2007; 20: 194-202.

Vogt BA. Pain and emotion interactions in subregions of the cingulate gyrus. *Nat Rev Neurosci* 2005; 6: 533-44.

Von Lehe M, Wellmer J, Urbach H, Schramm J, Elger CE, Clusmann H. Insular lesionectomy for refractory epilepsy: management and outcome. *Brain* 2009; 132: 1048-56.

Von Lehe M, Wagner J, Wellmer J, Clusmann H, Kral T. Epilepsy surgery of the cingulate gyrus and the frontomesial cortex. *Neurosurgery* 2012; 70: 900-10.

Wagner J, Weber B, Urbach H, Elger CE, Huppertz HJ. Morphometric MRI analysis improves detection of focal cortical dysplasia type II. *Brain* 2011; 134: 2844-54.

Wang I, Alexopoulos A. MRI postprocessing in presurgical evaluation. *Curr Opin Neurol* 2016; 29: 168-74.

Wellmer J, Parpaley Y, Von Lehe M, Huppertz HJ. Integrating magnetic resonance imaging postprocessing results into neuronavigation for electrode implantation and resection of subtle focal cortical dysplasia in previously cryptogenic epilepsy. *Neurosurgery* 2010; 66: 187-94.

Wieser HG, Hajek M. Frontal lobe epilepsy. Compartmentalization, presurgical evaluation, and operative results. *Adv Neurol* 1995; 66: 297-318.

Williamson PD, Boon PA, Thadani VM, *et al*. Parietal lobe epilepsy: diagnostic considerations and results of surgery. *Ann Neurol* 1992a; 31: 193-201.

Williamson PD, Thadani VM, Darcey TM, Spencer DD, Spencer SS, Mattson RH. Occipital lobe epilepsy: clinical characteristics, seizure spread patterns, and results of surgery. *Ann Neurol* 1992b; 31: 3-13.

Willmann O, Wennberg R, May T, Woermann FG, Pohlmann-Eden B. The contribution of 18F-FDG PET in preoperative epilepsy surgery evaluation for patients with temporal lobe epilepsy: a meta-analysis. *Seizure* 2007; 16: 509-20.

Yang PF, Pei JS, Zhang HJ, *et al*. Long-term epilepsy surgery outcomes in patients with PET-positive. MRI-negative temporal lobe epilepsy. *Epilepsy Behav* 2014; 41: 91-7.

Yu T, Wang Y, Zhang G, Cai L, Du W, Li Y. Posterior cortex epilepsy: diagnostic considerations and surgical outcome. *Seizure* 2009; 18: 288-92.

TEST YOURSELF

(1) Are clinical ictal signs and routine EEG in mesial extratemporal lobe epilepsies always localizing?

(2) What is the role of advanced MR postprocessing in mesial extratemporal lobe epilepsy?

(3) What is the role of invasive recordings in mesial extratemporal lobe 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".