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Original research article

Intracranial video-EEG monitoring in presurgical evaluation of patients with refractory epilepsy

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ARTICLE INFO

Article history:
Received 14 July 2016
Accepted 9 February 2017
Available online 2 March 2017

Keywords:
Refractory epilepsy
Presurgical evaluation
Depth electrodes
Streoelectroencephalography
Electrocorticography

ABSTRACT

Objective: Reviewing our experience in intracranial video-EEG monitoring in the presurgical evaluation of patients with refractory epilepsy.

Methods: We report on 62 out of 202 (31%) patients with refractory epilepsy, who underwent a long term video-EEG monitoring (LTM). The epileptogenic zone (EZ) was localised either based on the results of LTM or after intracranial EEG recordings from depth, subdural or foramen ovale electrodes. The decision on the location of the electrodes was based upon semiology of the seizures, EEG findings and the lesions visualised in MRI brain scan. Intraoperative corticography was carried out before and right after the resection of the seizure onset zone.

Results: The video-EEG monitoring could localise EZ in 43 (69%) cases based. The remaining patients underwent invasive diagnostics: 10 (53%) had intracerebral depth electrodes, 6 (31%) depth and subdural and 3 (16%) foramen ovale electrodes. Intracranial video EEG recordings showed seizure focus in all the patients. Ten of them had EZ in mesial temporal structures, 4 in accessory motor area, 3 at the base of the frontal lobe and 2 in parietal lobe. There was one case of an asymptomatic intracerebral haematoma at the electrode. All patients were subsequently operated on. In 15 (79%) cases the seizures subsided (follow-up from 2 to 5 years), in 4 (21%) they decreased.

Conclusions: The intracranial EEG is required in all patients with normal MRI (so-called nonlesional cases) in whom EZ is suspected to be located in the hippocampus, insula or in the basal parts of the frontal lobe.

1. Introduction

Patients with refractory epilepsy are potential candidates for epilepsy surgery. Precise preoperative identification of the epileptogenic zone (EZ) is crucial for achieving satisfactory surgical results and hence for the prognosis [1].

Patients with refractory epilepsy require long term video-EEG (LTM) lasting for at least 24 h [2]. In order to localise EZ one begins with preoperative non-invasive tests such as LTM, high

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http://dx.doi.org/10.1016/j.pjnns.2017.02.002

resolution MRI, functional imaging (fMRI, PET, ictal SPECT, MRS or MEG, Wada test) and neuropsychological testing [3]. When those noninvasively obtained data are insufficiently concordant, discordant or inconclusive and/or suggested an early involvement of eloquent areas, then the invasive recordings are necessary [4]. This requires an intracranial EEG recording from depth or/and subdural or foramen ovale electrodes. Indications for the invasive tests may differ among various epilepsy centres, probably depending on individual experience in planning, implantation of the electrodes as well as interpretation of the obtained results [5–7]. However, there are some general recommendations for intracranial recording, namely: non-lesional extratemporal epilepsy, discordant data, seizures originating at the contralateral side to the MRI abnormality, dual pathology, seizures with undetermined side of the onset, mesial versus neocortical onset, mesial onset versus onset in the neighbouring structures, ''temporal plus epilepsies'', occipitotemporal epilepsy and neocortical epilepsy (lesional or non-lesional) with suspected EZ in the close vicinity to the eloquent cortex (motor or language) [8–12].

In his paper we wanted to present our experience in the field of invasive tests in presurgical evaluation of patients with refractory epilepsy.

2. Materials and methods

In the last 5 years in our Epilepsy Monitoring Unit, long term video-EEG monitoring (LTM) was performed in 202 patients with refractory epilepsy in an attempt to establish or confirm the diagnosis, modify the treatment and/or identify candidates for epilepsy surgery. Each LTM lasted for minimum 72 h. For EEG recording we used Beehive Horizon LTM system (Grass Technologies, USA), with amplifiers Aura 32 or Aura 64 LTM (32- and 64-channel digital video-EEG system). Surgery was advised in 62 (31%) patients. There were 27 males and 35 females with age ranging from 21 to 52 years (average 33 years, median 32).

In the presurgical evaluation, EZ was localised based on the results of LTM or after intracranial EEG recordings from depth, subdural strip or foramen ovale (FO) electrodes. The type and the location of the electrodes was planned according to the semiology of the seizures, LTM findings and abnormalities seen on MRI scan. For planning and implantation the depth electrodes (with 5, 10 or 18 leads) BrainLab Neuronavigation System (Germany) was used. Subdural strip electrodes (with 4 or 6 contacts) were implanted through burr holes, using linear skin incision. FO electrodes with 5 or 10 leads were implanted transcutaneously under fluoroscopy. All procedures were performed under general or local (FO) anaesthetic. All types of intracranial electrodes (DIXI, France) were MRI compatible. As a rule, on the day following the implantation, MRI was carried out to check up the position of the electrodes and to rule out possible complications. Intracranial EEG recordings lasted for 168–216 h (7–9 days) and minimum 3 seizures in every patients had to be recorded. The epilepsy surgery was performed at least 6 weeks after removal of the intracranial electrodes. Before and right after the EZ resection, corticography was performed using strip or grid electrodes. Postoperative follow-up was from 2 to 5 years and Engel's classification [13] was used to evaluate the postoperative outcome.

3. Results

In 43 (69%) patients noninvasive evaluation was sufficiently conclusive to localise the EZ, whereas 19 (31%) patients required the invasive tests and the intracranial recordings. In the latter group, 10 (53%) patients had depth electrodes implanted, 6 (31%) – both depth and a single subdural (strip) electrode and 3 (16%) – FO electrodes. We implanted 3–5 depth electrodes per case, so a single patient had from 30 to 66 leads. The strip electrode had from 4 to 6 leads. Only 3 patients had the electrodes implanted bilaterally. The number of the intracranial electrodes and their target were determined based on the results of the previous noninvasive studies. In 16 patients there was no abnormality on MRI scan and EEG did not localise EZ. As to the other 3 cases, one patient had an arachnoid cyst, one DNT and one a focal cortical malformation, nevertheless in all these cases the seizures symptomatology was not consistent with the lesions. The intracranial LTM successfully localised EZ in all the cases. The locations were as follows: mesial temporal lobe (MTLE) – 10 cases, supplementary motor area (SMA) – 4, base of frontal lobe – 3 and parietal lobe – 2. There was one case of clinically uneventful minor intracerebral bleeding around a tip of the depth electrode. No other complications were observed. The location of EZ was confirmed by means of intraoperative corticography in all the patients. The surgical results (the follow-up from 2 to 5 years) were as following: 15 patients (79%) are seizure free (Engel class I) and 4 (21%) have a worthwhile improvement (Engel class III). In the latter group, 3 cases presented with frontal lobe epilepsy and 1 with parietal lobe epilepsy.

3.1. *Illustrative case*

A male patient who at age of 10, in 1992 sustained a minor head injury and had a CT scan which showed an arachnoid cyst in the left Sylvian fissure (Fig. 1). He was operated on – a cysto-cardiac shunt was inserted and later in 1996 replaced for

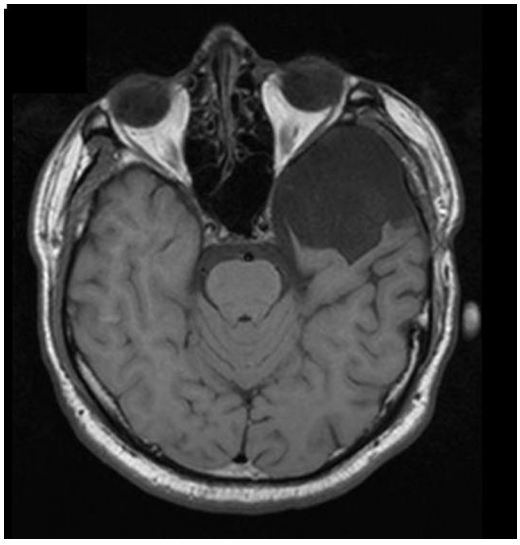

Fig. 1 – MRI scan, T1 weighted image. A arachnoid cyst (Galassi 2) is seen in the left Sylvian fissure.

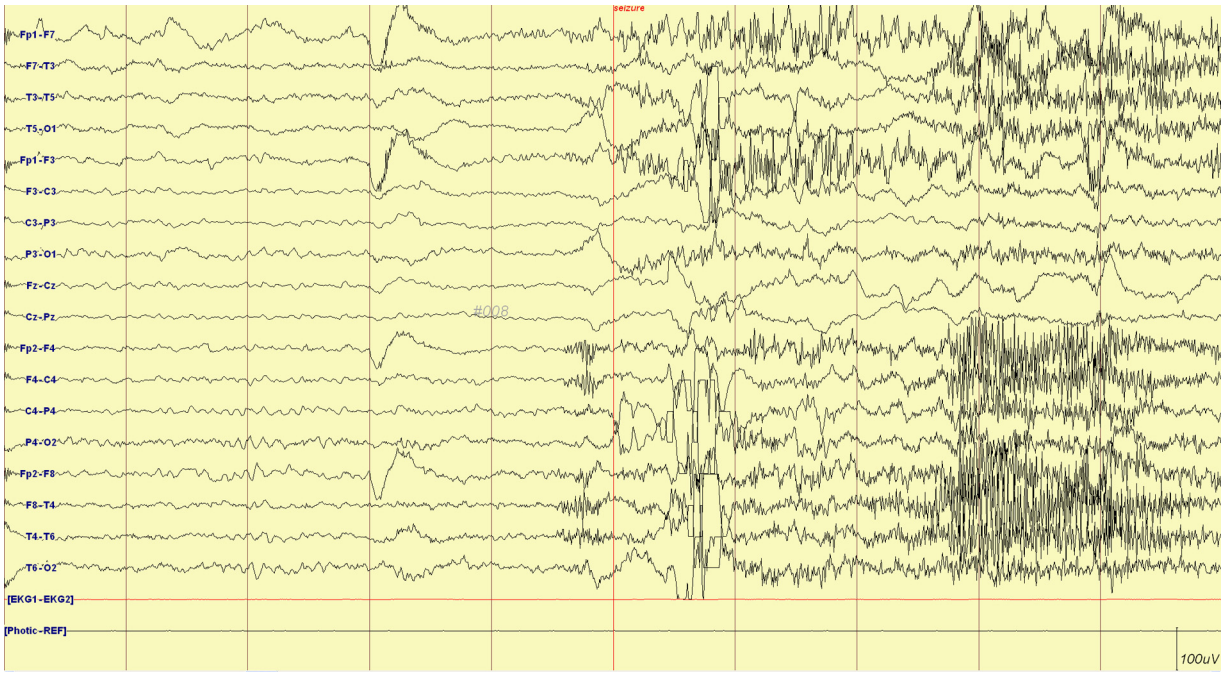

Fig. 2 – Scalp EEG (10–20 system) taken during the preoperative LTM: the seizure onset is obscured by movement and EMG artefacts. One vertical line = 1 s, LFF 1 Hz, HFF 70 Hz.

a cysto-peritoneal shunt. In 1999 he had an epileptic seizure and commenced AED. In 2002 the shunt was removed and cysto-cisternotomy was carried out. Despite AED mono- and polytherapy (CBZ, OXC, OXC + VPA, VPA + LTG, LTG + TPM, TPM + LEV) the seizures continued – up to 5–7 per month. Multiple EEGs did not show epileptiform discharges.

In 72-h LTM, 2 complex partial, secondarily generalised seizures of frontal lobe semiology were noted. The EEG failed to show the EZ since the ictal onset was obscured by movement and EMG artefacts (Fig. 2).

As clinical semiology was not consistent with the MRI findings, the invasive tests were performed. He had 3 depth electrodes implanted – two with 10 leads at the base of the left frontal lobe and one 5 leads in left temporal mesial structures (Figs. 3–5). During the invasive LTM, 4 seizures beginning in the orbitofrontal cortex were recorded (Fig. 6). They all had the identical semiology as those previously observed in the scalp EEG.

Consequently, the EZ was localised in the left frontal lobe. The patient was operated on – the frontal lobectomy was done. The postoperative course was uneventful. The follow-up period is now 5 years and since 4 years he is seizure free (Engel 1).

4. Discussion

From our 202 patients with refractory epilepsy, 62(31%) underwent resective surgery, the number similar to the reported in the literature – 25–36% [14–16].

The only candidates for resective epilepsy surgery are those with partial seizures because in those cases the goal of the operation is to excise the EZ which is defined as the brain region generating the patient's habitual seizures and the area which must be resected to achieve seizure freedom [3]. The more precise preoperative mapping of EZ, the better is the outcome.

The gold standard for delineating EZ is the invasive (intracranial) EEG recording [17,18], which is absolutely a unique technique to study propagation pattern of seizure or the correlation of seizure activity to clinical symptoms [10]. Subdural strips or grids, implanted when neocortical seizure onset is suspected, provide the accurate identification of EZ located on the cortical surface of the brain, whereas depth electrodes appear more appropriate for investigating deeply located EZ such as in the insula, mesial aspects of the frontal, temporal, parietal and occipital lobe or the botton of deep sulci [19,20]. On the other hand foramen ovale electrode recordings from mesial aspect of the temporal lobe are indicated in patients with TLE [10].

Compared to the scalp EEG, the intracranial EEG recording has greater sensitivity and space specificity [17,18], so the resection of the EZ mapped with this method is associated with excellent outcome [21]. The placement of subdural or depth electrodes and their number is individualised according to all available presurgical data [20]. The final decision concerning the number and position of the electrodes depends on a common decision reached by the epileptologist and the epilepsy neurosurgeon [17]. First, the epileptologist, taking into consideration the results of noninvasive tests, determines which electrodes, in which number and position are needed to adequately pinpoint EZ and presents his or her view to the surgeon. The surgeon uses a neuronavigation station for planning the stereotactic implantation of the electrodes whilst assessing safety and feasibility of the procedure. The elements such as training, prior surgical experience, anatomical

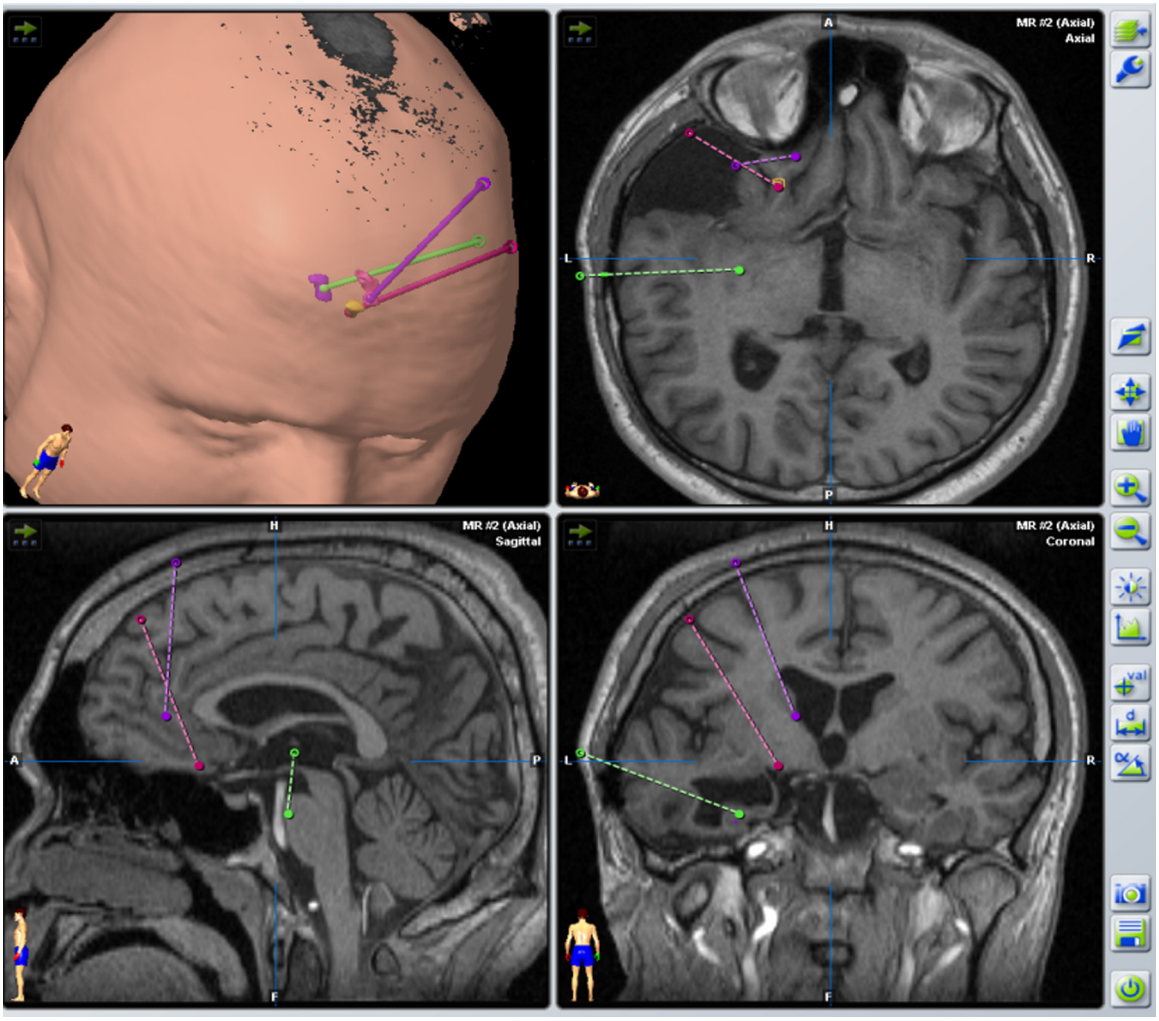

Fig. 3 – A view from the planning station – three electrodes and their trajectories are seen. Details in the text.

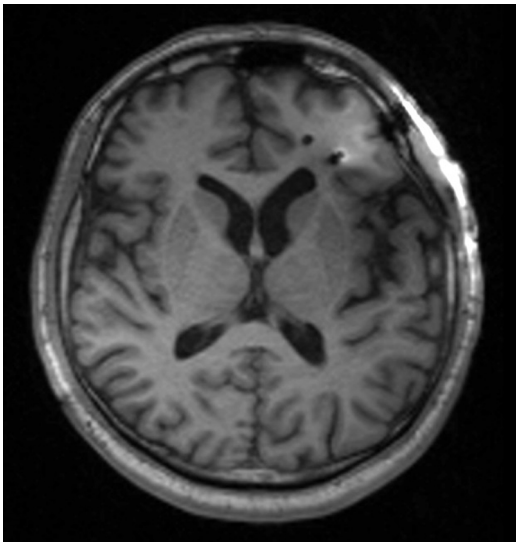

Fig. 4 – Postoperative check-up MRI shows the position of the frontal electrodes.

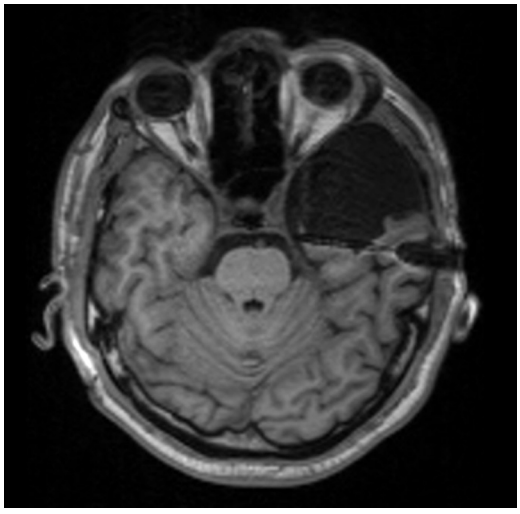

Fig. 5 – The electrode in the left mesial temporal region shown on the postoperative check-up MRI.

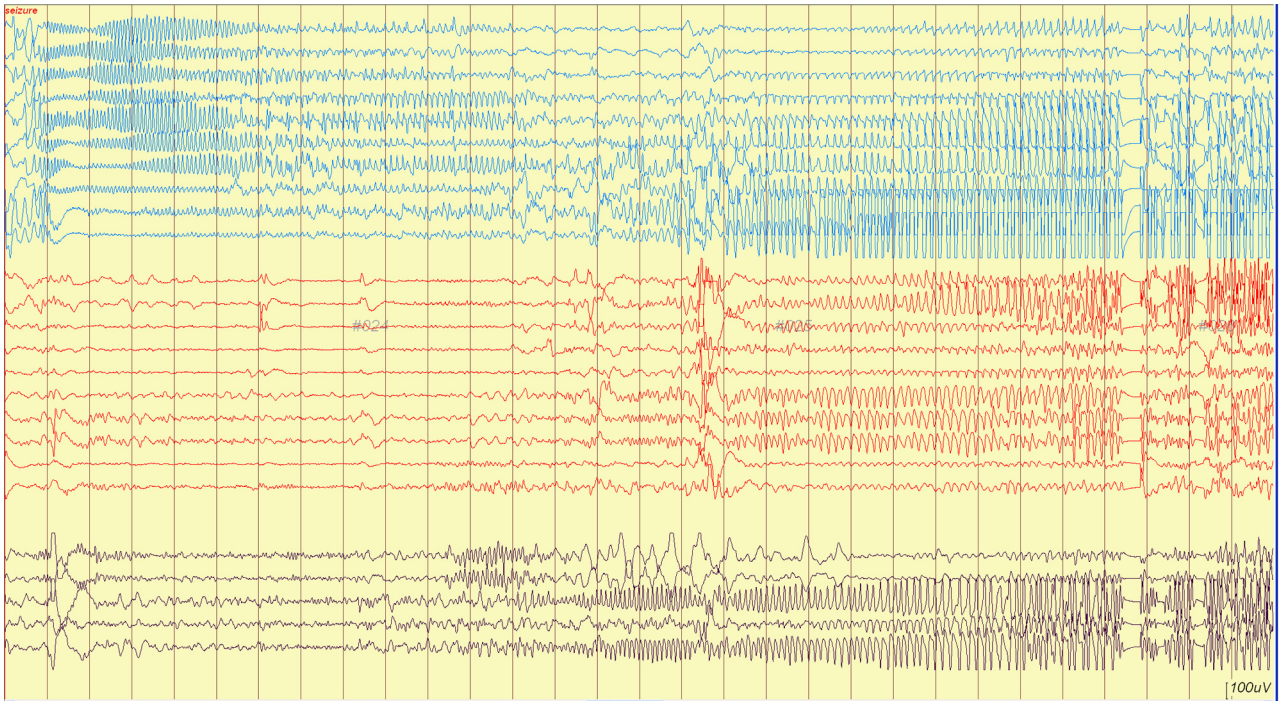

Fig. 6 – Intracranial EEG recorded from the depth electrodes: the ictal discharges begin at the depth electrode located in the left orbitofrontal cortex (10 upper channels) and after about 7 s is also seen at other electrodes, i.e. in the medial frontal lobe (10 middle channels) and in the mesial temporal region (5 bottom channels). One vertical line = 1 s, LFF 1 Hz, HFF 70 Hz.

findings, namely presence of large draining veins or areas of focal arachnoiditis and adhesion, are all taken into consideration, so that if at this point of time there are any concerns as to the safety of the procedure, the position and number of the electrodes could be modified.

Intracranial EEG recordings from implanted depth and/or subdural electrodes is mandatory in nonlesional and extratemporal lobe epilepsy and in the cases of temporal epilepsy – MTLE, in which the onset of seizure is invisible in the surface EEG, e.g. due to spreading of the discharges to the opposite temporal lobe [22–24].

Our illustrative case of refractory epilepsy shows the particular role of the preoperative invasive tests. This patient had good indications for the intracranial EEG, namely, the results of noninvasive tests were discordant – the patient had seizures of frontal lobe semiology, whereas there was a lesion in the temporal lobe and the onset of the seizures was not visible in the scalp EEG. The precise localisation of the EZ in this patient was challenging and probably impossible without the invasive tests, which in turn warranted the successful surgery. This view is supported by the literature – a comprehensive metaanalysis showed that although in non lesional epilepsy, modern functional neuroimaging studies could reduce the need for presurgical invasive monitoring, but so far PET, ictal SPECT or MEG alone or in combination still cannot replace intracranial EEG, whilst being helpful for targeting the depth electrodes [25–27].

In our study, in 43 (69% from 62) patients the seizure focus was localised on surface LTM and in 19 (31% from 62), further invasive tests were required. Invasive intracranial EEG recording is used in about 25–40% of surgical cases in majority of large epilepsy centres [28]. In all the cases, we managed to record the focal onset of the seizure, thus localising EZ. In 10 cases it was located in mesial temporal lobe, in 4 in the SMA, in 3 at the base of the frontal lobe and in 2 in non-eloquent brain (parietal lobe). According to the literature, 10–26% of patients who underwent the invasive tests turn out not to be candidates for surgical treatment since they are the cases of multifocal or unlocalised epilepsy [23,29]. Our results seem to be better which can be explained by a statistical bias due to the small number of patients.

There was one case of an asymptomatic small intracerebral haemorrhage (ICH) at the depth electrode. Fernandez et al. had 2 ICHs in their series of 115 patients with depth electrodes [30], whereas van Veelen et al. observed one case of permanent neurological deficit due to an ICH in 70 patients [31]. The complication rates are low (1–4%, usually not exceeding 1%) and in most cases the complications do not lead to permanent neurological deficits [32,33].

After surgery, our 15 (79%) patients were seizure-free (Engel I) over the follow-up period of from 2 to 5 years, whilst a worthwhile seizure reduction (Engel III) was noted in the other 4 (21%) cases. Results of epilepsy surgery reported in the literature are comparable – 78–81% of seizure-free patients in series without distinction between medial-temporal and neocortical resection, and up to 97% in MTLE with hippocampal sclerosis [14]. The patients with MTLE make the best candidates for epilepsy surgery and there is a clinical level A evidence (ERSET) that in the case of MTLE surgery is more effective than prolong medical treatment [34]. Nonetheless, in

the cases with extratemporal epilepsy the outcome of surgery is not as good [35,36]. Seizure freedom occurs only in 55% patients with frontal lobe epilepsy in the first postoperative year and declines to 30% in the fifth year, being still worse (25%) in the cases without MRI identifiable lesion [37,38]. The last-named cases need utmost care and precision in preoperative mapping of the epileptogenic zone [39,40]. Preoperative identification of an epileptogenic lesion in the MRI predicts good seizure outcome after resection both in temporal and extratemporal epilepsies [41].

5. Conclusions

Our study confirms that invasive, intracranial EEG monitoring is a valuable and often indispensable tool in the planning of resective epilepsy surgery. In our material the intracranial EEG was required in all the patients with normal MRI (so-called nonlesional cases) in whom EZ was allegedly located in the hippocampus, insula or in the basal parts of the frontal lobe.

Conflict of interest

None declared.

Acknowledgement and financial support

This work has not been financially supported for the conduct of the research and/or preparation of the article by any sponsors or outside sources. All this has been done within the hospital and the Medical University budget.

Ethics

The work described in this article has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

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