Summary

Intraoperative electrocorticography (ECoG) has been used as a complementary method in the surgical management of medically refractory partial epilepsies to identify the location and limits of the epileptic region at the time of the resection. This summary will describe technical aspects as well as advantages as limits in interpretation. The actual application in temporal and frontal lobe epilepsy as well as in highly epileptogenic tissue will be discussed, with particular interest in cortical dysplasia. Although the method has been used for several decades one must bear in mind that ECoG cannot be used to predict the outcome of surgery.

Peroperative Corticography (ECoG)

Introduction

Surgical treatment in medically refractory epilepsy is a therapeutic option if there is evidence of a focalisation. However the demonstrated lesion by magnetic resonance imaging is not always corresponding to the epileptic zone where the seizures start. The scalp EEG and corresponding video further identifies the origin of the seizures. PET and ictal and interictal SPECT findings are other non-invasive methods helping to further define the focus. The key to successful surgery depends on the total resection of the epileptogenic tissue. In this sense preoperative electrocorticography (ECoG) can be of some potential help to guide the surgical resection of the lesion as well as of the epileptogenic zone. However, following the technological development in imaging, the identification of the epileptic syndrome, the improved comprehension of the epileptogenic process, the surgical strategy will be clearly defined prior to surgery, and will rely less on not benefit from intraoperative recordings. Furthermore, in instances where recording appears necessary to guide the extent of surgery, on our days, this will be obtained in a Phase II investigation, through implantation of subdural grids or intracerebral electrodes.

Neurophysiological considerations

Corticography (ECoG) consists in the same type of registration of brain potentials as the scalp electroencephalogram (EEG) but without attenuation by scalp and skull tissue. Penfield and Jasper [1] pioneered this technique in the 1930, recording interictal spiking to decide the extent of the resection in epilepsy surgery. Since then, the intraoperative ECoG has been used to localise the epileptic zone; stimulating through the cortical electrode allows the possibility to map cortical functions. Despite the widespread use of the technique, corticography does not help to predict results of surgery [2, 3, 4].

Technical aspects

The recording of ECoG is made in the operating room and is interpreted on line by the neurophysiologist in close communication with the surgeon. The position of the electrodes as well as the montages can be adapted progressively. There exists different equipment used for corticography, consisting either of flexible electrodes mounted on a frame fixed to the skull, while some use grids layed over the cortex. A standard EEG
equipment with minimum 20 channels is used to register 16 electrodes and ECG. The electrodes are mounted on a frame with a flexible system to reduce artefacts from pulsation (Montreal corticography frame). Usually 4 electrodes are positioned with equidistance in 4 horizontal rows with the possibility to make horizontal and vertical bipolar montages. Interpretation is done both with monopolar and bipolar montages. The registration time varies around 15-30 minutes.

Peroperative recording of electrical activity directly on the brain surface offers some advantages: 1) flexibility concerning the localisation of the electrodes, 2) recordings that can be done before as well as after the resection, to estimate the potential residual epileptic activity in the neighbouring of the resection zone, 3) use of electrodes for intraoperative electrical stimulation to map cortical functions, identify and spare eloquent cortex.

However there are several non-negligible disadvantages: 1) the limited placement of the electrodes to the craniotomy, 2) the limited sampling time, 3) recording almost exclusively of spontaneous interictal epileptic activity and very rarely epileptic seizures, 4) the difficulty to differentiate between primary epileptic discharges from secondarily propagated discharges from a distant epileptic zone, 5) the alterations by anaesthetics and analgetics as well as the surgery, of both the background activity as well as the epileptic discharges, 6) ambient artefacts in the operating room.

What has emanated from the previous application is that this technique can never substitute the presurgical investigation but can be applied in the surgical phase to confirm or adapt the strategy of excision. One must remember that the scalp electrode recording of interictal or ictal activity has a very defined role to determine the lateralisation and the epileptogenic zone. The cortical electrodes are very sensitive in recording the electrical activity on the brain surface, thus eliminating the attenuation of surrounding tissue like the scalp and bone. The signal is of higher voltage (400-800 microvolts) and withholding an increased amount of rapid frequencies as compared to the scalp EEG.

Anaesthesia

Another confounding factor to take into consideration is the effect of anaesthesia on brain activity and especially regarding epileptic activity [6]. In a minority of cases, when one can obtain the collaboration of the patient, the ECoG can be done in local anaesthesia. In this situation it is possible to stimulate electrically certain areas and obtain a functional mapping of eloquent brain areas. However in the majority of operations it is often necessary to induce general anaesthesia to obtain an optimal condition during the planned resection. Concerning the halogenated inhalation anaesthetics (for example halothane, nitrous oxide, and isoflurane), they all reduce both frequency and amplitude of the EEG after an initial activation. Concerning narcotics, most of them do not influence brain activity. However one exception is remifentanyl, which is used very frequently, a short acting opioid with a half-life less than 10 minutes, which has been shown to increase spikes in the epileptogenic zone as opposed to suppress activity in normal tissue. This can give some helpful indices to minimise the resection of brain tissue. Intravenous sedative-hypnotic drugs (barbiturates, benzodiazepines, propofol) all induce a dose related depression of EEG activity after an initial activation. In this way, enhancement of spike activity can in certain situations be obtained by low doses of either methohexitol or etomidate to study persistent spike activity, especially in border tissue where the resection can be adapted. In the case of muscle relaxants, they do not have any significant effect on EEG.

Temporal lobe epilepsy

Resection of the anterior temporal lobe in mesial temporal sclerosis is a standardised operation with anatomical landmarks, developed by Falconer [7] 50 years ago. Even if ECoG was undertaken during the operation, before and after resection, this information was not initially included in the strategy of the resection. Schwarz [8] proceeded with pre- and post-resection intraoperative ECoG in 29 patients with a follow up of 25 months. Almost half (48%) of the patients had active interictal discharges outside the area of planned resection (revealed by pre-resection ECoG). They observed an increase of frequency in spikes in all outcome groups. They found no relation either between the increase of spikes and the mean frequency of spikes, regarding seizure outcome.

The extension of the hippocampal resection is of great concern. A maximal resection is thought to improve the outcome with respect to seizures. However the extended hippocampal resection can potentially increase the risk of verbal and non-verbal memory impairment in dominant versus non-dominant temporal resection, respectively. Studies indicate that the lack of pathologically confirmed hippocampal neuronal loss is closely related to postoperative memory decline. The integrity of the hippocampus can be assessed during phase I presurgical evaluation using MRI and neuropsychology. These non-invasive methods in experienced centers allowed to predict eventual memory deficits. In this sense some surgeons have advocated that intraoperative hippocampal ECoG could theoretically indicate the limit of resection, in order to spare as much as possible the functional hippocampus [9]. It is also important to point out that during selective amygdalohippocampectomies there is an important increase of interictal spiking (so called green spikes) without relation to sei-
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Frontal lobe resection or cortectomies in different up to 75% to 91% of the patients undergoing either seizure control. Interictal spikes have been observed in relationship to the amount of resected tissue to obtain spread distribution of interictal spikes without any clear lobe epilepsy. Results from ECoG often show a wide-out focal interictal findings as compared to temporal discharges or secondary generalised discharges (without interictal abnormalities) or showing multifocal epileptic discharges, pereventricular heterotopias or porencephalic cyst, are not uncommon and represent a challenge in the surgical strategy.

Frontal lobe epilepsy is the second largest group after temporal lobe epilepsy. The preoperative investigation with interictal and ictal EEG can be sparse (no interictal abnormalities) or showing multifocal epileptic discharges or secondary generalised discharges (without focal interictal findings) as compared to temporal lobe epilepsy. Results from ECoG often show a widespread distribution of interictal spikes without any clear relationship to the amount of resected tissue to obtain seizure control. Intercital spikes have been observed in up to 75% to 91% of the patients undergoing either frontal lobe resection or cortectomies in different locations.

However more promising results of ECoG have been reported in pathologies like cortical dysplasia. Palmini [12] has reported continuous or frequent epileptic discharges in peroperative recordings. He described 3 patterns: 1) repetitive electrographic seizures, 2) repetitive bursting discharges and 3) continuous or almost continuous rhythmic spiking. The latter pattern was observed in up to 67% of the patients but only recognized in 2.5% of patients with intractable partial epilepsy with other aetiology than cortical dysplasia. The outcome was favourable in 75% of the patients where the cortical tissue showing continuous spiking could be included in the resection. These results were compared to the group showing remaining post resection continued spiking, where the clinical outcome was uniformly poor. Thus, ECoG of highly epileptogenic developmental, neoplastic or scar lesions can substantially help to define the epileptogenic surrounding tissue and improve the clinical outcome. The evidence that the resection of the whole lesion or/and epileptogenic area correlates with a good seizure outcome is clearly emphasized.

Electrical stimulation and functional mapping have shortly been mentioned before and are often applied in the presurgical phase when chronic subdural grids or depth electrodes are implanted. This will not further be discussed here. Similarly, stimulating through the electrodes placed over the cortex intraoperatively remains an option for functional mapping.

ECoG in Lausanne

We report our personal experience at Lausanne University Hospital (CHUV) where we have conducted 32 ECoG since 1999. The age of the patients ranged from 4 months to 39 years. There were 29 children in this group. All patients presented medically refractory epilepsy evaluated in the Lausanne-Geneva presurgical epilepsy program (presurgical evaluation at University Hospital of Geneva (HUG)). The most frequent pathologies, found in 12 of 32 patients, was cortical dysplasia (focal, lobar or multilobar). Temporal lobe epilepsy (with or without mesial sclerosis) was found in 5 patients. Another 5 patients presented a tumour (dysembryoblastic tumour, gangliogioma, tuberous sclerosis). 5 patients presented lesions due to a probable perinatal vascular lesion (porecephaly, post hemorrhagic gliosis). The other 5 patients presented various lesions (Rasmussen’s encephalitis, arteriovenous malformation, Sturge-Weber, contusion and severe hemispheric atrophy of unknown cause). The operations varied from lobectomy with or without amygdalohippocampectomy, cortectomy, lesionectomy, peri-insular hemisphero- tomy (functional hemispherectomy) or partial so called hemi-hemispherectomy. The ECoG were all made during general anaesthesia with sevoflurane and fentanyl. We used the Montreal designed cortiography frame with 16 electrodes. In a selected number of cases, presenting contralateral independent or generalised discharges, a restricted number of scalp electrodes were positioned contralateral to monitor changes after callosal section (in hemispherectomy). Recording time varied between 15 to 35 minutes depending on the condition (anomalies, artefacts). In selected cases ethomidate (0.1mg/kg) was administered looking for regional increase in spike activity. We have interpreted the focal absence of pharmacological activation as evidence for damaged tissue being unable to generate potentials. We observed regional physiological changes in background activity, for example relative increase in rapid frequencies in frontal region, while slowing was observed either in relation to abnormal tissue like dysplasia or mesial sclerosis. Cortical dysplasia showed very variable patterns from the absence of spike activity to repetitive or rhythmic continuous spike activity. This latter pattern was only rarely found in other pathologies. No ictal spike activity has been observed in any of these cases. Not only the major spike activity,
such as bursts or rhythmic spikes, was recorded but also asynchronous spike activity. Of particular interest were not only the site of maximal spike activity but also the border zone of the planned resection. Exceptionally, it changed the initial surgical plan.

Conclusions

ECoG has been used for several decades in the management of patients with medically refractory epilepsy. There are many restrictions in the use; the limited registration time and area of recording, the impact of anaesthesia, and the interpretation of the spike activity. Quesney and Niedermeyer [2] concluded that ECoG hold a firm place as an explorative method in the mapping of interictal activity during seizure surgery, although interpretation of findings can be difficult. Since then ECoG is still used as a complementary method in epileptic surgery, where it may help to characterize highly epileptogenic tissue, e.g. cortical dysplasia known to exhibit a particular ECoG pattern. It can also give information of spike activity of the resection border and provide the possibility to tailor the surgical strategy. However one must bear in mind that so far ECoG cannot be used to predict the outcome of surgery.

References


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