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Subdural and Depth Electrodes in the Presurgical Evaluation of Epilepsy

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Summary

From 1987 to 1992, invasive EEG studies using subdural strips, grids or depth electrodes were performed in a total of 160 patients with medically intractable epilepsy, in whom scalp EEG was insufficient to localize the epileptogenic focus. Dependent on the individual requirements, these different electrode types were used alone or in combination. Multiple strip electrodes with 4 to 16 contacts were implanted in 157 cases through burrholes, grids with up to 64 contacts in 15 cases via boneflaps, and intrahippocampal depth electrodes in 36 cases using stereotactic procedures. In every case, localization of the electrodes with respect to brain structures was controlled by CT scan and MRI.

Visual and computerized analysis of extra-operative recordings allowed the localization of a resectable epileptogenic focus in 143 patients (89%), who subsequently were referred for surgery, whereas surgery had to be denied to 17 patients (11%). We did not encounter any permanent morbidity or mortality in our series.

In our experience, EEG-monitoring with chronically implanted electrodes is a feasible technique which contributes essentially to the exact localization of the epileptogenic focus, since it allows nearly artefact-free recording of the ictal and interictal activity. Moreover, grid electrodes can be used for extra-operative functional topographic mapping of eloquent brain areas.

Keywords: Epilepsy; epilepsy surgery; subdural electrode; depth electrode.

Introduction

Pre-operative evaluation of patients with medically intractable epilepsy requires a number of different data. These include non-invasive EEG recordings, sizure semiology, neuropsychological tests as well as morphological (MRI) and functional (PET, SPECT) studies. All these examinations are undertaken with the main aim of localizing a resectable epileptogenic area. There is consensus among most investigators that electrophysiological data are most important. However, non- or semi-invasive EEG frequently do not allow adequate seizure focus localization[6]. Therefore, invasive techniques have been introduced. Except for intra-operative electro-corticography, a technique which has been abandoned in recent years in many centers, long-term recording of the interictal and ictal activity is possible with chronically implanted epidural, subdural or depth electrodes. We have started our epilepsy surgical program in 1987 based on the concept of extra-operative electrophysiological evaluation with subdural strip and grid electrodes. More recently, stereotactic depth electrodes have been used in addition. The present report summarizes our experience with 160 patients.

Patients and Methods

This study comprises 160 consecutive patients who were included in the epilepsy surgical programme from 1987 to 1992. There ere 78 males and 82 females with ages ranging from 3 to 55 years and an average age of 28 years. All patients had medically intractable epilepsy. Patients were considered for electrode implantation, when results of non-invasive studies were not conclusive as to the exact location of the epileptogenic area.

The following procedures were performed. Strip electrodes with 4 to 16 contacts were used in 157 patients, and grid electrodes of up to 64 contacts in 15 patients. In 36 patients, intrahippocampal depth electrodes were implanted. Subdural electrodes were used alone in 124 patients, and depth electrodes in 2 patients. In the remaining 34 cases, subdural and depth electrodes were implanted in combination (Fig. 1).

All procedures were performed under general anaesthesia. Strip electrodes were inserted through temporal and frontal burrholes using linear skin incisions. Grid electrodes required larger craniotomies. Depth electrodes were inserted stereotactically through occipito-parietal burrholes, thus running longitudinally through the hippocampus with the tip ending at the level of the amygdaloid nucleus. Except for grids, all implantations were carried out bilaterally. Antibiotic prophylaxis with cefazolin was started with induction of anaesthesia and maintained throughout the implantation period in most patients. Postoperatively, the position of the electrodes with respect to brain structures was checked by CT and MRI (Fig. 2a and b).

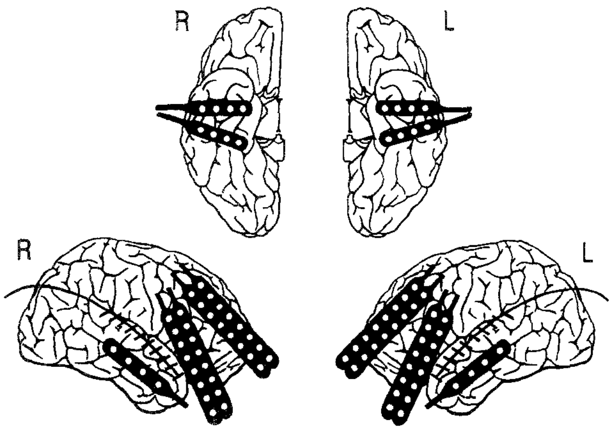

Fig. 1. Typical implantation of subdural and depth electrodes for differential diagnosis of temporal vs. frontal lobe foci. The schema shows two temporobasal strips and one temporolateral, one frontopolar and one frontolateral 16 contact double strip electrodes as well as intrahippocampal depth electrodes. The implantation is usually symmetrical

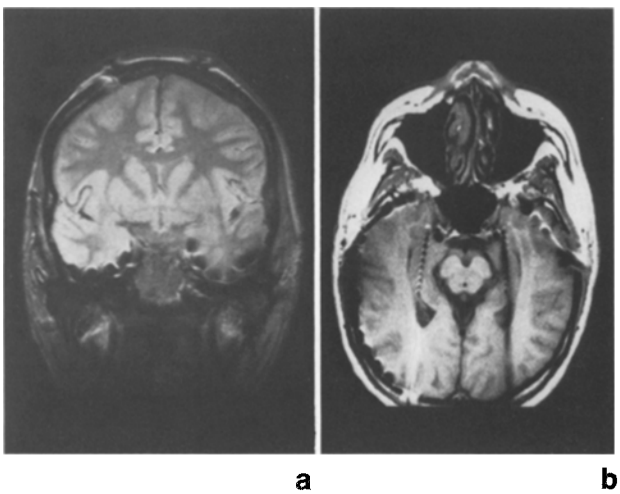

Fig. 2. (a, b) Postoperative MRI-controls: exact placement of subtemporal strip electrodes (a) and of intrahippocampal depth electrodes (b)

Strip and depth electrodes were removed transcutaneously during a short intravenous barbiturate anaesthetic. The time interval between removal of electrodes and the resective surgery was at least 6 weeks. Grid electrodes were removed at the time of resective surgery at most 18 days after implantation.

Results

The period of implantation ranged from 9 days to 26 days and was 12 days on average. Recordings obtained from implanted electrodes were usually of high quality and free of elctromyographic or other artefacts both for the ictal or interictal activity. Moreover, these

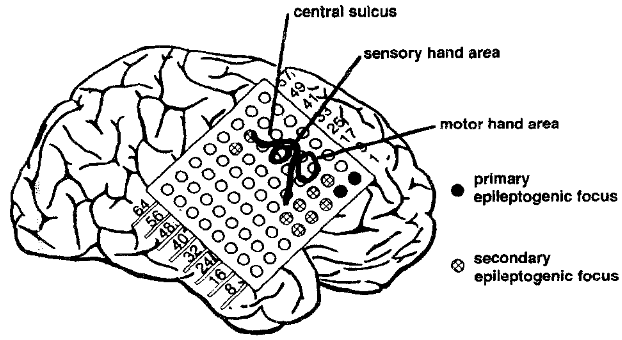

Fig. 3. Functional topographic mapping using a 64 contact grid electrode for identification of the central sulcus and the precentral cortex in correlation with the adjacent epileptogenic zone

electrodes were also used for electrical stimulation with the aim of inducing epileptiform afterdischarges or habitual seizures. Grid electrodes allowed functional mapping of sensorymotor and speech areas by direct cortical stimulation and recording of evoked activity (Fig. 3).

By means of visual and computerized analysis of the ictal and interictal epileptogenic activity and simultaneous video-monitoring[1–3], invasive recordings allowed exact localization of the epileptogenic area in 143 out of 160 patients (89%). All these patients subsequently were referred for resective surgery. According to the results of invasive studies, 17 patients (11%) had to be excluded from surgery.

There was no mortality in our series. Four patients had distinct menigeal signs in the postoperative period coinciding with moderately increased CSF cell counts, thus meningitis was suspected despite negative microbial cultures. All these infective complications resolved under antibiotic therapy, and EEG-monitoring was continued until sufficient results were available. One patient had a clinically silent subdural haematoma after grid implantation, and the haematoma was evacuated at the time of the resection procedure. Another patient had an asymptomatic haematoma within the temporal horn of the lateral ventricle after implantation of depth electrodes.

Discussion

The aim of presurgical evaluation of candidates for resective procedures are the precise localization of the epileptogenic area and – in extratemporal epilepsies – the definition of topographical relationships between the epileptogenic focus and eloquent brain areas (functional topographic mapping). Basically, two approaches exist in order to achieve these goals. Invasive recording and stimulation can be done intra-operatively just before resective surgery is commenced, or they can be done extra-operatively. There is a general tendency in most epilepsy centers to separate diagnostic from resective procedures, e.g., to use invasive diagnostic studies extra-operatively. The main reason for prefering extra-operative monitoring is to have sufficient time for recording of seizure.

The diagnostic significance of implanted electrodes is shown by the following statistics. In 160 patients non-invasive methods were insufficient to clearly localize the epileptogenic focus. With results of invasive techniques, 143 of 160 patients subsequently were referred for resective surgery, whereas 17 cases had to be denied such treatment. Thus, invasive recordings provided essential data for surgical treatment in 89%.

The influence of extra-operative invasive recordings on surgical decision making has also been emphasized by others. Rosenbaum *et al.*[7] reported that subdural electrodes enabled surgical decisions in 43 out of 50 patients (86%). Wyler *et al.*[10] found a resectable focus in 20 out of 28 patients (71%) evaluated using subdural electrodes. In a review of the literature, Spencer[8] concluded that EEG depth recordings enabled selection of 36% more patients for surgery as compared to scalp EEGs. Furthermore, depth EEGs prevented surgery in another 18%.

The results of invasive recordings do not only facilitate selection of surgical candidates, but may also influence the surgical strategy. Particularly in temporal epilepsy, the combined implantation of strip and depth electrodes has proved to be helpful. With this approach, both the anterior-posterior and the mesial-lateral extent of the epileptogenic area can be defined more precisely, thus allowing more tailored or even selective resection procedures.

Grid electrodes have proved to be useful in extratemporal epilepsies. By exact topographic localization of seizure onset and spread, they allow circumscribed cortical resections (topectomy). In addition, grid electrodes enable extra-operative cortical mapping of sensorymotor and language areas by direct electrical stimulation and recording of evoked potentials. Thus, resective procedures around the areas of higher function are possible with a minimum risk of permanent neurological deterioration.

We encountered surgical complications in 6 patients (4%). None of them caused permanent morbidity or mortality. Besides 4 infections there were 2 asymptomatic bleedings. Wyler *et al.*[11] recently reported a complication rate of 0.85% with 350 subdural strip electrodes. Rosenbaum *et al.*[7] observed no complications in 50 patients with subdural strips. Lüders *et al.*[6] noted in a series of 26 subdural strip and grid electrodes a "still disturbing high rate of infection". No haematomas were observed by Goldring and Gregorie[5] with 100 epidural grid electrodes. Reviewing the literature, there is no mortality attributable to subdural electrodes. With depth electrodes, however, two deaths from intracerebral haemorrhage (1.4%) have been reported by Engel *et al.*[4] in a series of 140 patients. Spencer[9] noted an incidence of 1% major complications from depth electrodes.

In conclusion, chronically implanted electrodes are of high value in the presurgical evaluation of extratemporal and temporal lobe epilepsies. They allow nearly artefact-free recordings of ictal and interictal activity, and thus essentially contribute to the precise definition of the epileptogenic area. Moreover, grid electrodes enable functional topographic mapping, thus facilitating resections around areas of eloquent cortical function. Compared to the benefits of these invasive techniques, the risks seem to be acceptably low.

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