STEREOTACTIC ELECTROENCEPHALOGRAPHY IN PATIENTS WITH DRUG-RESISTANT EPILEPSY

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Abstract

Stereotactic electroencephalography (SEEG) is an important method for invasive presurgical exploration of candidates for epilepsy surgery by means of stereotactic implantation of intracerebral electrodes without craniotomy. Implantations of intracerebral electrodes through craniotomy in drug-resistant epileptic patients have been performed in Bulgaria in the 1980s, but no further development of epilepsy surgery followed. The aim of our study is to present the first Bulgarian series of patients with drug-resistant epilepsy explored by SEEG.

Our study included 53 patients with drug-resistant epilepsy explored by SEEG. Stereotactic Leksell frame, stereotactic software for avascular trajectory planning and depth electrodes with diameter of 0.8 mm and 8–18 contacts were used in all patients. Subsequently, long-term video-SEEG monitoring of various duration was performed and registered interictal and ictal EEG activity in order to evaluate the putative epileptogenic zone.

Fifty-three patients were explored by 62 SEEGs because one patient underwent three SEEG procedures and seven patients – two SEEG procedures. We implanted 753 electrodes in these 62 SEEGs (mean: 12 electrodes per exploration; range: 5–20 electrodes). The mean age in our cohort was 23.6 years (4–60 years). The main indication for SEEG was MRI-negative epilepsy (20 patients). Focal cortical dysplasia was found in 17 cases, and hippocampal sclerosis in 8 cases. Surgical intervention was done in 48 patients (91%). Surgical resection of the epileptogenic zone (EZ) as defined by the SEEG was performed
in 27 patients; radiofrequency stereotactic thermocoagulation (RFTC) on selected electrode contacts was applied in seven patients, and both procedures (i.e. RFTC followed by resective surgery) were performed on 14 patients. Full seizure control (Engel class I) was achieved in 28 patients (58.3%) and significant improvement – in 17 patients (35.4%). Three patients (6.2%) had no effect from surgery. No complications were observed in our series of 62 SEEGs.

SEEG is a major tool for the determination of the EZ in patients with drug-resistant epilepsy who are candidates for epilepsy surgery, including MRI-negative cases or such without congruent data from the clinical, neurophysiological and neuroimaging perspectives. SEEG is a low-risk invasive diagnostic and even a therapeutic method when performed by experienced epilepsy surgery team.

Key words: epilepsy, drug-resistant epilepsy, epilepsy surgery, MRI-negative epilepsy, SEEG, focal cortical dysplasia, hippocampal sclerosis

Introduction. Stereotactic electroencephalography is a method for invasive exploration of epilepsy patients by intracerebral electrodes implanted using a stereotactic technique without performing craniotomy. The first SEEG was performed in May 1957 in Paris by Bancaud [1] and Talairach et al. [2]. The first Bulgarian implantations of intracerebral electrodes were performed in the Epilepsy centre of Iskrets in the 1980s [3]. Done by craniotomy, these implantations were significantly more invasive than the stereotactic technique introduced in France. This first step in epilepsy surgery in Bulgaria was, unfortunately, not followed by further development of this treatment option. The first stereotactic implantation of intracerebral electrodes for diagnostic purpose in a patient with drug-resistant epilepsy was performed by our team in “St. Ivan Rilski” University Hospital in February 2011. After seven years of experience, the aim of this paper is to present the indications, risks and results in the first Bulgarian series of SEEGs.

Materials and methods. Our study included 62 SEEG implantations in 53 patients performed between 2011 and 2018. Leksell stereotactic frame and dedicated set for intracerebral implantation of depth electrodes Dixi® were used in all patients (Fig. 1). Dixi® electrodes have a diameter of 0.8 mm, 8 to 18 recording contacts, 2 mm contact length and 1.5 mm intercontact distance (Fig. 2). Avascular trajectory planning was achieved using Framelink, the Medtronic planning software for the first 20 interventions, and Surgiplan, the Elekta software for the next 42 procedures. The electrode positions were verified by a postoperative MRI scan in six SEEG implantations and postoperative CT scan fused with preoperative MRI in the remaining 47 (Fig. 3). SEEG registration was performed in a dedicated room for long-term video-EEG monitoring using a 128-channel video-EEG system, the Micromed Brain Quick LTM 128 System Plus Evolution software (Fig. 4).

Results. The mean age of the patients at the time of the SEEG procedure was 23.5 years (range 4–60 years). Sixteen SEEGs were performed in patients under 18 years of age (25.8%). Fifty-three patients were explored by 62 SEEGs
Fig. 1. Leksell stereotactic frame

Fig. 2. Dixi® SEEG electrode and final view after Dixi-electrode implantation

Fig. 3. Visualization of the electrode position by CT and MRI co-registration
Fig. 4. SEEG of a 29-y. old female with long-lasting (25 y.) focal (left frontal) epilepsy. The ictal recording demonstrates very focal low-voltage tonic fast activity (electrode contacts in the mid left F1-F2 sulcus only, labelled with “ONSET” in red). Usually, this finding is consistent with the exact EZ localization and carries a favourable post-operative prognosis (the patient is seizure-free for $>1$ year after a very small resection of “bottom-of-sulcus” dysplasia).
Table 1

Lobar distribution of depth electrodes during 62 SEEGs with 753 electrodes

<table>
<thead>
<tr>
<th>Localization</th>
<th>Number of electrodes (%)</th>
</tr>
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<tbody>
<tr>
<td>Left</td>
<td>330 (43.8%)</td>
</tr>
<tr>
<td>Right</td>
<td>423 (56.2%)</td>
</tr>
<tr>
<td>Frontal</td>
<td>219 (29%)</td>
</tr>
<tr>
<td>Central</td>
<td>50 (6.7%)</td>
</tr>
<tr>
<td>Parietal</td>
<td>95 (12.6%)</td>
</tr>
<tr>
<td>Occipital</td>
<td>47 (6.2%)</td>
</tr>
<tr>
<td>Temporal</td>
<td>175 (23.2%)</td>
</tr>
<tr>
<td>Insular</td>
<td>166 (22%)</td>
</tr>
</tbody>
</table>

Fig. 5. Histopathological diagnosis in 53 patients explored with 62 SEEGs

because one patient underwent three SEEGs and seven patients – two SEEGs. Sixty-two SEEGs were performed using 753 electrodes (mean: 12 electrodes per exploration; range: 5–20 electrodes). The ratio between left and right hemisphere implantations was 330/423 (43.8%/56.2%). Seventeen SEEGs explored only the left hemisphere, 24 – only the right hemisphere, and 21 SEEGs explorations were bilateral. The frontal lobe was the most explored – 219 electrode trajectories, followed by the temporal lobe – 175, and the insula – 166. Lobar distribution of the depth electrodes number is presented in Table 1. The mean SEEG duration was 6.8 days (3–13 days).

The primary indication for SEEG was MRI-negative epilepsy (20 patients), i.e. MRI without any obvious pathologic change. Other main indications were focal cortical dysplasias (17 patients) and hippocampal sclerosis, including cases with bi-temporal seizures (8 patients). In the latter group, the semiological characteristics and the data from the EEG and MRI did not correlate and accordingly, did not allow a straightforward surgical intervention. The main indications according to the preoperative MRI findings are shown in Fig. 5.

Surgical treatment based on the SEEG data was performed in 48 out of 53 patients. Surgery consisted in resection of the epileptogenic zone in 27 patients, RFTC on selected electrode contacts before electrode explantation in seven patients, and RFTC followed by resection in 14 patients. Excellent outcome with full seizure control was achieved in 28 patients – Engel Class I (58.3%), significant improvement was reported by 11 patients – Engel Class II and III (35.4%), and no effect from the treatment was noticed in three patients – Engel Class IV (6.2%). There were no postoperative complications in our series of 62 SEEGs explorations.

Discussion. SEEG indications and results. The main goal of SEEG was to determine the extent and margins of the epileptogenic zone (EZ) in patients with severe drug-resistant epilepsy when seizure semiology, EEG, MRI, PET-CT and other non-invasive diagnostic methods provide non-congruent data. The EZ
is considered the area of the cerebral cortex, which is necessary and sufficient for seizure initiation and whose resection or disconnection leads to seizure freedom [4]. Nowadays, the evolving concept of epilepsy networks prompt us to consider the EZ to be that part of the cerebral cortex where seizures originate (current EZ), or would potentially originate (potential EZ) [5]. Therefore, the challenge is to understand not only the size but also the dynamics of the EZ and in this regard SEEG proved to be the major tool [6–9].

In 33 out of 53 patients, SEEG was indicated because of discrepancy or insufficient congruency between the MRI lesion and the semiological and ictal scalp EEG characteristics, while in the other 20 patients the reason was a normal MRI. As is well known, the presence of an MRI lesion does not necessarily correlate with the EZ and even with the ictal onset zone (IOZ) [5,10,11]. The EZ might be significantly larger than the presumably culprit brain structural pathology or could be even localized elsewhere.

SEEG information allowed us to reasonably delineate the limits of the epileptogenic zone and to propose respective surgical intervention in 48 patients. Nevertheless, surgery after SEEG led to seizure control in only 58.3% of the operated patients, which is less than in our group operated without SEEG where complete seizure control was achieved in 72% [12]. These results can be explained by the absent correlation between MRI (especially in negative cases), clinical and EEG characteristics leading to uncertain localization of the EZ in these difficult to treat patients. Another reason could be, in line with the contemporary concept of epileptogenic networks, that EZ is not a static zone in a given brain region and this could be particularly true in long-lasting, drug-resistant epilepsies as most of our patients were.

**SEEG advantages and disadvantages compared to subdural strips and grids.** SEEG remained relatively confined to France and Italy until the end of the 20th century. The rest of the world adopted the technique of Penfield and Jasper of subdural strips and grids implantation after craniotomy. Subdural exploration represented the ideal evaluation tool for an EZ according to the classical definition: extensive cortical coverage allowed meticulous pick-up of all spikes (irritative zone), the ictal patterns (IOZ) with their contiguous cortical spread, and also sufficient functional mapping of eloquent cortex; ultimately facilitating the delineation of the five cortical zones [5,11]. In the last decade, however, SEEG gained a lot of territory worldwide and many classical “subdural” epilepsy centres implemented this technique because of its clear advantages [13,14]. SEEG has much less risks of hemorrhagic and infectious complications and allows exploration of cortical sulci and critical depth structures such as hippocampus and amygdala, cingulate gyrus, and the hidden 5th brain lobe – the insula. Still, it is accepted that subdural strips and grids are more suitable for mapping eloquent cortices and their relations to the EZ because of its high surface density (electrode contacts usually 1 cm apart) [15].
Our experience with invasive EEG included few subdural strips and grids explorations in 2010 and 2011. Although we did not have any major complications in those patients, our team has chosen SEEG technique because of its capabilities of larger and deeper brain explorations. SEEG procedure is significantly more comfortable for the patient and allows long-term video-SEEG recording up to 3 weeks, and is also a convenient tool for performing RFTC in patients with very well delineated and limited IOZ and EZ [16–18].

SEEG complications. There were no complications in our series of 62 SEEG with 753 depth electrodes. Certainly, one has to take into consideration that our series is relatively small compared to the largest series, e.g. the Milan group experience comprising of 500 SEEG implantations [19,20]. According to the results of other centres as well, the hemorrhagic risk is from 0.08 to 0.2% per electrode and 1–3% per patient [14,19]. A recent review of the SEEG-associated risks found 35 major complications and four death cases in 4000 implantations which means 0.8% and 0.1% risk of each for these two most severe adverse events, respectively [20].

Conclusion. SEEG provides important information for the definition of the epileptogenic zone in patients with drug-resistant epilepsy and normal MRI, or patients with conflicting data from semiology, EEG and MRI. SEEG is a low-risk invasive diagnostic method when performed by an experienced stereotactic team and may have a therapeutic value in selected patients.

REFERENCES


