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Outcome and complications of chronically implanted subdural electrodes for the treatment of medically resistant epilepsy

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ABSTRACT

Background: Surgery for medically resistant epilepsy is safe and effective. However, when noninvasive techniques are insufficient, then consideration is given to invasive electrocorticography (EcoG).
Objective: The aim of the study was to analyze results and complications of subdural electrodes placement in the treatment of intractable epilepsy.
Methods: Ninety-one consecutive patients who underwent placement of subdural electrodes (1999-2010) were considered for this study. All patients underwent a standardized pre-operative evaluation. Invasive subdural electrode placement was considered when there were inadequate ictal recordings, there was discordance between EEG and neuroimaging or the epileptogenic zone was localized near eloquent cortex.
Results: Resective epilepsy surgery was performed in 70/91 patients (76.9%). Twenty-four out of seventy (34.3%) who underwent surgical resection were seizure-free (CL-I) at last follow-up. A statistical evaluation revealed a very strong trend for patients with positive lesional pre-operative MRI to have improved outcomes compared to normal brain MRI population ($p = .028$). There were 10 surgical related complications (11%), but no mortality or permanent morbidity. Statistical analysis demonstrated that placement of a subdural grid in any combination was statistically significant ($p = .01$) for surgical complications.
Conclusions: Invasive monitoring is a useful and necessary technique for the surgical treatment of intractable epilepsy. Careful surveillance is required during the monitoring period especially when the patient has undergone large subdural grid placement. A good working hypothesis can minimize complications and achieve better outcomes.

1. Introduction

Surgery for medically refractory epilepsy is frequently performed when high resolution brain magnetic resonance imaging (MRI), scalp electrode encephalogram (EEG) and seizure semiology are concordant. The goal of surgery is to remove the cortical tissue responsible for the generation of seizures; the epileptogenic zone [1–5]. The purpose of the presurgical evaluation is to localize the epileptogenic zone responsible for the seizures. However, brain MRI, scalp EEG, positron emission tomography (PET) and ictal single-photon emission tomography (SPECT) have limitations [6,7].

When noninvasive techniques are insufficient, then consideration is given to invasive electrocorticography (EcoG). The main advantage of surface electrodes is their close approximation to the source of activity which therefore results in a higher amplitude signal [8]. This also avoids the recording of electrical signals through the relatively high impedance of the skull and the interference from muscular contraction as seen on electromyography (EMG). Invasive EEG is utilized when there is a lack of lateralization or localization of epileptogenic focus or foci, the presence of an epileptogenic zone near eloquent cortex, the epileptic localization is discordant with radiographic apparent lesions or discordant noninvasive information is identified [9–14]. In addition, invasive monitoring can be used for intraoperative mapping of functional cortex utilizing direct cortical stimulation and is beneficial for tailored resections of the epileptic zone (localization of epileptic spikes) [15,16].

Subdural strips and grids allow for an increased density of recording electrodes with much greater spatial resolution than scalp electrode EEG. Invasive monitoring can significantly increase our ability to localize the epileptogenic focus or foci, allowing for surgical resection. However, the ideal patient for invasive studies remains a challenge. Outcomes after invasive studies lag behind

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lesional surgery [3,11,12,14,17]. The potential for complications and lessened outcomes requires a comprehensive evaluation. Here we describe our results and the complications of subdural electrode placement for intractable epilepsy. The goal of this series is to identify the subset of patients who will be the best candidates for surgical resection as well as to minimize complication rates.

2. Methods

A prospective database of patients with refractory epilepsy was established at our institution in 1998. Ninety-one consecutive patients who underwent placement of subdural electrodes (1999-2010) were considered for this study. Patients with depth electrodes were excluded for this cohort due to parenchymal penetration and potential for a unique set of complications such as intracerebral hemorrhage. This study includes patients who had a follow up time of 18 months or longer. The collection of data for this study was approved by the university hospital's Internal Review Board (IRB) and was performed in accordance with HIPPA requirements.

All patients underwent a standardized pre-operative evaluation that included a thorough clinical assessment as well as a scalp (phase I) video-EEG monitoring. Video-EEG recordings were performed in our dedicated long-term monitoring unit. All results were interpreted by certified epileptologists both independently and during our weekly multi-disciplinary surgical planning conferences. A pre-operative neuropsychological assessment was performed routinely for all patients who underwent evaluation.

All patients had a high resolution brain MRI (1.5 T or higher), which was done following a standardized protocol. Axial images were obtained with 4 mm thickness and 1.0 mm slice spacing in DW1, T2, FLAIR and GRE sequences. Sagittal images are obtained with 4 mm thickness and 0.5 mm slice spacing in T1 sequences. Coronal images are obtained perpendicular to the main axis of the hippocampi or cortical surface with 3 mm thickness and 0.5 mm slice spacing in STIR (Short T1 Inversion Recovery), FLAIR (Fluid Attenuated Inversion Recovery) and FSPGR/3D (Fast Spoiled Gradient). Lesional cases were defined when any abnormal radiographic finding(s) were identified in the pre-operative MRI. Also, interictal PET or ictal SPECT brain scan was performed to localize a physiologic abnormality.

Decisions regarding surgical therapy were made following a review of all the clinical data for each patient performed by the neurosurgeon and neurologists in conjunction with the neuroradiologist of the epilepsy center. Invasive subdural electrode placement was considered when there were inadequate ictal recordings due to extensive muscle artifact or poorly localized ictal onset, there was discordance between EEG and neuroimaging in the pre-operative evaluation and/or the epileptogenic zone was localized near eloquent cortex. Neuronavigation was used routinely for placement of subdural electrodes. Platinum contact electrodes embedded in 0.5 mm thick flexible silicone plate (AD-Tech Medical Instrument Corporation, Racine, Wisconsin) were used in all cases. The bone flap was routinely placed back in the craniotomy site. Patients were located in the intensive care unit post-operatively (24 h) for assessment and management. Peri-operative antibiotics were given for 48 h. Peri-operative corticosteroids were not given routinely in this population. A follow-up head CT scan was performed 24 h after initial surgery to document placement of the electrodes and to identify any potential complications. After an adequate period of intra-cranial recordings, patients were taken back to the operating room for removal of the electrodes and possible cortical resection with intra-operative electrocorticography. Post-operative MRI was performed in all patients who underwent surgical resection 3 months postoperatively to document the extent of resection.

Table 1
Demographic of 91 patients with subdural electrode placement (phase II – evaluation).

	Proportion	Percentage
Sex		
Female	55/91	60.4%
Male	36/91	39.6%
Age at time strips/grids placement (in years)		
Average	32.3	
Range	11-60	
Median	31.0	
Lesional		
Yes	28/91	30.8%
No	63/91	69.2%
Resective surgery		
Yes	70/91	76.9%
No	21/91	23.1%
Surgical complications		
Yes	10/91	11.0%
No	81/91	89.0%
Outcome		
I	24/91	26.4%
II	22/91	24.2%
III	17/91	18.7%
IV	7/91	7.7%
No resection	21/91	23.1%

Clinical outcome was based on the Engel modified classification (4), as follows: Class I, seizure free or residual aura (CL-I); Class II, rare disabling seizures (<3 complex partial seizures per year) (CL-II); Class III, worthwhile seizure reduction; and Class IV, no worthwhile improvement. All patients were followed up postoperatively at 3, 6, 12, and yearly thereafter (minimum timeframe: 18 months).

Clinical data was stored prospectively in Microsoft Excel (Microsoft Corp., Redmond, WA) files. Descriptive statistics was reported as means and standard deviations for continuous variables and as frequencies and percentages for categorical variables. Categorical variables were analyzed using the Chi-Square and Fisher Exact tests.

3. Results

A total of 508 patients underwent surgical intervention for the evaluation and treatment of medically resistant epilepsy from 1999 to 2010 (excluding vagus nerve stimulator placement). Ninety-one consecutive patients (18%) required invasive subdural electrode placement and met our institutional inclusion criteria (see Table 1). Fifty-five females (60.4%) and thirty-six males (39.6%) were part of this cohort. Median age at intervention was 32.3 (range: 11-60). Mean length of follow-up was 42 months (range: 18-96 months). Fifty-two (57.1%) patients underwent strip placement only, five (5.5%) patients underwent grid placement only and thirty-four (37.4%) patients underwent placement of subdural strips and grids. Temporal lobe was the most common location for subdural electrode placement (see Fig. 1). Previous surgery was performed in 3 patients (3.2%). Two patients returned to the operating room for readjustment of the subdural electrodes. Mean duration of monitoring session was 7 days (range: 4-14 days).

Twenty-eight patients (30.8%) had a radiographic lesion on pre-operative high-resolution MRI. Thirteen patients (14.2%) had evidence of neuronal migrational disorder such as cortical dysplasia, or periventricular nodular heterotopia. Nine patients (9.8%) had radiographic evidence of gliosis or encephalomalacia of unknown