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Outcome of epilepsy surgery in patients investigated with subdural electrodes

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Summary Invasive intracranial electrodes (IE) are an important part of the work-up in many patients being considered for epilepsy surgery. Because IE are usually reserved for cases where seizure localization is ambiguous, one might expect that the eventual outcome of epilepsy surgery in these patients would be worse than in patients who did not require IE as part of their work-up. The purpose of this study was to specifically examine those patients who underwent insertion of subdural electrodes, to determine how many of these patients eventually underwent resective surgery of any type and to assess the eventual outcome. All cases admitted for subdural electrodes between January 2000 and June 2005 were reviewed. Surgical outcomes were reported using the Engel classification and a multivariate analysis was used to determine which factors were associated with successful surgery. 177 IE implantations were performed in 172 patients. Of these, 130 patients went on to have surgery. In the 113 of the 130 surgical patients in whom 1-year follow-up was available, 47% were seizure free at 1 year. Age was a major predictor of outcome with only 21% of patients over age 40 becoming seizure free with surgery compared to 58% in patients aged under 40 years ($p = 0.0004$). Other predictors of an Engel I outcome included having a temporal lobectomy or supplementary motor area resection. Good results from eventual resective surgery can be achieved in patients needing invasive recordings. Younger patients with temporal lobe epilepsy seem to have the highest likelihood of seizure freedom.

Introduction

The successful performance of resective epilepsy surgery depends on the pre-operative identification of the epileptogenic zone. In many patients, this can be achieved with a standard non-invasive pre-surgical work-up that includes a detailed history and physical examination, long-term scalp

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video electroencephalography (EEG), magnetic resonance imaging (MRI), functional neuroimaging, and a neuropsychological evaluation (Sperling and Shewmon, 1997). However, even with this extensive work-up, it is not always possible to identify the epileptogenic zone, particularly in those patients with ambiguous or discordant scalp EEG data. In these patients, implanted intracranial electrodes (IE) can often provide further information and facilitate effective epilepsy surgery. This form of monitoring is generally carried out using subdural electrodes (Adelson et al., 1995; Cohen-Gadol and Spencer, 2003; Gonzalez-Feria and Garcia-Marin, 1993; Lüders et al., 1989; Nair et al., 2008; Steven et al., 2007; Wyler et al., 1984), depth electrodes (Bancaud et al., 1969, 1970; Olivier et al., 1983; Pillay et al., 1992; Spencer, 1981) or a combination of both (Behrens et al., 1994; Spencer et al., 1990; van Veelen et al., 1990). At our center, most of the invasive monitoring is carried out using subdural strip electrodes.

Although the outcomes for most types of resective epilepsy surgery are well known (Engel et al., 1993), less is known specifically about the outcome in those patients who require intracranial electrodes as part of their evaluation. Because IE are often utilized when the data from the non-invasive work-up is either ambiguous or discordant one could hypothesize that patients who require IE might be less likely to have a successful outcome following resective surgery.

The purpose of this study was to specifically assess patients who underwent placement of subdural electrodes and to determine how many eventually underwent resective surgery of any type. In those who had surgery, we wished to examine the eventual outcome.

Methods

All cases who underwent insertion of subdural electrodes between January 2000 and June 2005 were reviewed. Patients from this cohort who eventually had a resective surgical procedure and in whom at least 1 year of follow-up was available were included in the study. Relevant data was extracted from the patients' charts.

The indications for intracranial monitoring at our center include: bilateral, multifocal, normal or ambiguous EEG data in suspected cases of focal epilepsy; discordance between EEG and neuroimaging data; for mapping purposes when the seizure onset zone is suspected to be within or near an area of eloquent cortex; and in cases of suspected extra-temporal lobe onset with normal MRI findings. We do not routinely use IE in cases of temporal lobe epilepsy when the onset is clear on scalp EEG, even if the MRI is normal. The majority of our patients are investigated with subdural strip electrodes inserted through burr holes. We have found that this technique allows for excellent coverage of multiple locations without the need for craniotomy (Burneo et al., 2006b; Steven et al., 2007). This is particularly useful in cases where multilobar or bilateral coverage is desired. We have not routinely used subdural grids unless a detailed focal cortical localization is needed to plan surgery, particularly in peri-rolandic or tumor related cases. Our technique for inserting temporal subdural strip electrodes has been described elsewhere (Steven et al., 2007). Three lines of eight contacts each are inserted via a posterior temporal burr hole to cover the mesial, inferior and lateral surfaces of the temporal lobe. For frontal coverage, multiple subdural strips are inserted through a parasagittal precoronal burr hole. Typically, four 8—12 contact strips are placed over the lateral frontal convexity with the distal contacts of the more anterior electrodes placed such that they are beneath the orbitofrontal surface. If midline coverage is desired, multiple bilaterally recording strips are placed along the falx. Electrodes covering the mesial or lateral parietal or occipital surfaces are similarly inserted via a posterior parasagittal or posterior temporal burr hole. In all cases, the placement of the strips is individualized to suit the hypothesis being tested. For example, when the seizure onset is suspected to be from the supplementary motor area (SMA), multiple strips are inserted over this area in addition to general frontal and parietal coverage. When used, subdural grids are inserted by craniotomy and depth electrodes are inserted with a Leksell stereotactic frame (Elekta AB, Stockholm, Sweden). Prior to August 2003, all subdural and depth electrodes were manufactured ''in house.'' Since January 2004, we have been using Ad-Tech subdural strip electrodes and grids (Ad-Tech Medical, Racine, WI). Following electrode implantation, patients were monitored with 24-h video EEG for a variable length of time that was predicated solely on the completeness of the invasive EEG data. The electrodes were removed after sufficient information had been gathered to make a decision regarding a resective operation. Resective surgery was usually offered if the non-invasive and invasive investigations revealed a surgically amenable epileptic focus.

For the purposes of determining which variables might predict seizure freedom post-operatively, charts for all patients were reviewed to ascertain the location, size, type, and duration of electrode coverage. Information was also collected regarding the type of surgery performed, the resulting surgical pathology, and MRI findings. The seizure outcome from the resective procedure was classified using the Engel classification (Engel et al., 1993).

A univariate analysis was carried out for each variable to test its association with an Engel I outcome. The unpaired Student's t-test was used for the continuous variables and a Pearson χ^2 statistic was used for the categorical variables. For the categorical variables, if at least one cell on a 2×2 table had an expected value of less than 5, Fisher's exact test was used to obtain p-values. The unadjusted odds ratio and 95% confidence intervals were obtained for each of the categorical variables. A significance level of $\alpha = 0.05$ was chosen for all statistical tests and all p-values in this report are two-tailed.

Multivariate analysis using logistic regression was then used to obtain odds ratios for factors that predicted an Engel I outcome. For this analysis, standard demographic data (age and sex) as well as any risk factor identified as significant in the univariate analysis was included in the regression model. Adjusted odds ratios with 95% confidence intervals were used to summarize the results. All statistical analysis was completed with SAS® 8.02 (SAS Institute, Cary, NC).

Results

One hundred and seventy-two patients underwent insertion of intracranial electrodes between January 2000 and June 2005. Eighty-four (49%) of the patients were females and the mean age at the time of implantation was 32.3 years (range 9—65). Five patients had electrodes inserted on two separate occasions in this period for a total of 177 cases.

Multicontact subdural strip electrodes were placed in all 177 cases. The average number of strip electrodes was 8.2 (range 1—19) per case. In addition to strip electrodes, subdural grids were placed in 12 cases and depth electrodes in 5 cases. All combined, these implantations resulted in an average of 65.4 contacts per patient (range 16—174). Coverage was unilateral in 46 cases and bilateral in 131 cases. Temporal lobe electrodes were placed in 143 cases, frontal electrodes in 113 cases, parietal electrodes in 48 cases and occipital electrodes in 35 cases. The average duration of electrode implantation was 13.0 days (range 3—35). Com-