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INVASIVE EEG ASSOCIATED COMPLICATIONS

INTRODUCTION

The employment of invasive EEG monitoring constitutes a valuable methodology in the evaluation of patients suffering medically refractory epilepsy. It provides the opportunity for more detailed investigation of seizure activity, better analysis of seizure spreading pattern, as well as more accurate localization of the seizure focus/i. Invasive EEG monitoring requires the implantation of depth and/or subdural strip/grid electrodes for covering any suspicious epileptogenic areas. More recently, the methodology of stereo-encephalography (SEEG) has regained popularity among epileptologists, mostly due to the introduction of this modality to the North American epilepsy surgery community.

The implantation of depth and/or strip/grid subdural electrodes has been associated with the development of rare but bothersome complications, which may affect the preoperative evaluation of patients with medically intractable epilepsy, and even influence their overall surgical outcome. Early recognition of any such complications allows their prompt and efficient management therefore meticulous knowledge of any potential invasive EEG-associated complications is of paramount importance.

The purpose of our current contribution is to review the pertinent literature, outline the most common complications and their incidence rates, and identify any factors predisposing to their occurrence. The retrieved data are presented in two categories: a) those associated with subdural/depth electrode implantation, and b) those associated with stereoencephalography.

A. SUBDURAL/DEPTH ELECTRODE COMPLICATIONS

There are several reports in the literature describing subdural/depth electrode complications from small clinical series, but a limited number of articles reporting

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on large epilepsy series. Fountas and Smith in a retrospective study reported their complications rates after implanting subdural strip/grid electrodes in patients with medically refractory epilepsy. They found that the formation of epidural hematoma was the most common complication in their cohort, occurring in 1.6% of their cases. Development of post-implantation subdural hematoma occurred in 1.1% of their series. Other complications included the development of an infection (1.1%), post-implantation brain edema (1.1%), and post-implantation transient dysphasia (1.1%). They also reported the recording of atypical seizures in 2.7% of their cases, which could be associated with the irritation of the underlying cortex caused by the implanted subdural electrodes, and could be a misleading finding especially for an inexperienced epilepsy surgeon. Interestingly, they reported that their mortality rate in their series was 1.1%, and this was caused by the development of massive brain edema in a pediatric case after implanting numerous inter-hemispheric grid electrodes.

Fountas in a systematic review article in 2011 summated the reported until that time electrode implantation complications. He concluded that subdural electrodes were more commonly associated with complications compared to depth electrodes. He found that the reported mortality rate varied between 0 and 2.1%. He also found that the development of post-implantation CSF leakage was the most common complication, occurring from 0-20% in the previously reported series. The occurrence of subdural hematoma varied from 1.1 to 14%, while that of an epidural hematoma was 1.8 to 2.5%. The reported infection rates varied between 1.1 and 17%, and that of brain edema development between 0.5 and 14%.

Likewise, Wellmer et al. reported in a retrospective study their complications from a series of 260 patients undergoing implantation of subdural strip/grid, and/or depth electrodes. Their most common complication was the development of a subdural hematoma in 6.6% of their cases, while an epidural hematoma occurred in 0.7% of their patients. Intracerebral hematomas and/or cerebral contusions occurred in 0.4%, while brain edema was encountered in 0.4% of their cases. They had no infections in their series, while their cumulative complication rate was 23.1%. They postulated that the number of the implanted electrodes, the number of the electrode contacts, the number of the employed burr holes and trepanations, and the duration of invasive EEG monitoring were correlated with complication occurrence. Furthermore, subdural electrodes were more commonly associated with complications than depth electrodes in their series. Interestingly, the authors concluded that the development of any electrode-associated complications had no impact on the overall seizure outcome of their patients.

Hedegard et al. reported in a prospective study their complications from implanted depth and/or subdural electrodes. Their cumulative complication rate was 4.8%, their subdural and epidural hematoma rates were 2.6% and 1.1%, respectively. Other complications included infection development in 0.7%, and electrode dislocation in 0.4%. They identified as complication predisposing factors the patients' age, the pre-implantation administration of valproic acid, and the implantation of subdural electrodes. They also reported that the development of any electrode-associated complications affected the seizure surgical outcome of their patients.

Similarly, Vale et al. reported their complications from a prospectively studied series of 91 patients undergoing implantation of depth and/or subdural electrodes. Their cumulative complication rate was 9.9%, while the occurrence of post-implantation hematomas was 8.8%, and their infection rate 1.1%. They identified again increased complication rates with subdural electrodes, however they claimed that the number of the implanted electrodes played no statistically significant role in the development of complications. Likewise, Vadera et al. reported cumulative complication rate of 7%, while Bekelis et al. reported a cumulative complication rate of 6% (temporary neurological deficit 4%, infection 2%) in a series of 50 patients undergoing implantation of subdural inter-hemispheric grid electrodes. Abuelem et al. reported that their complication rate in patients undergoing implantation of subdural inter-hemispheric grid electrodes was comparable to the one observed after implanting convexity subdural grids. They also reported that mass effect was observed in 8.3% of their cases.

Arya et al. in their recent meta-analysis study including 21 previously published series and 2,542 patients found that infection was the most common complication occurring in 5.3% of the cases. These infection cases could be differentiated into central nervous infections (2.3%), and superficial wound infections (3%). Intracranial hematomas occurred in 4%, while post-implantation increased intracranial pressure was observed in 2.4% of the included cases. They also reported that a total of 3.5% of the patients undergoing implantation of subdural electrodes required additional surgical intervention for managing the observed complications. They also concluded from the analysis of the collected data that the number of the electrode contacts (>67 contacts) was the strongest predisposing factor for complication development.

The most recently published series reported significantly lower complication rates. Falowski et al. reported cumulative complication rate of 3.9% from a series of 127 patients undergoing electrode implantation. They encountered subdural hematoma in 0.8%, infection in 0.8%, and pulmonary embolism in 1.6% of their cases. Raftopoulos et al. reported no complications from a series of 38 consecutive patients undergoing subdural grid implantation through a linear craniectomy technique.

B. STEREOENCEPHALOGRAPHY COMPLICATIONS

There are two recent reports from the Cleveland Clinic regarding the occurrence of any complications. Gonzalez-Martinez et al. reported initially their experience from a series of 100 patients undergoing implantation of 1310 electrodes, and then of 122 patients with 1586 implanted electrodes. Their hemorrhagic complication rate was 0.2%, while their cumulative morbidity was 2.5% in their reported series.

CONCLUSIONS

Thorough knowledge of any potential complication is of paramount importance for its early recognition and its prompt management. It has been postulated that

subdural electrodes demonstrate increased tendency for developing complications compared to the depth electrodes. Infection and hematoma formation are the most common complication in the vast majority of the published series. However, it remains to be defined the exact percentage of these complicated cases, that require another surgical intervention. Moreover, the number of the implanted electrode contacts appears to be the strongest predisposing factor for post-implantation complication development. Optimization of the implantation surgical technique along with the introduction of novel design hybrid electrodes (contacts with micro-wire arrays) may further minimize the occurrence of any complications.