Title: EEG SPECTRAL ANALYSIS AND BYPASS SHUNTING DURING CAROTID ENDARTERECTOMY

Authors: I.J. Rampil, M.S., J.A. Holzer, M.D., S.H. Rosenbaum, M.D., D.O. Quest, M.D., J.W. Correll, M.D.

Affiliation: Departments of Anesthesiology and Neurosurgery, College of Physicians and Surgeons, Columbia University, New York, New York 10032

Introduction. The use of an indwelling shunt during carotid endarterectomy (CE) is controversial. A shunt maintains some fraction of the internal carotid blood flow during the endarterectomy phase of the procedure but increases the probability of embolization (atheroma, thrombin-platelet or air), and increases the technical difficulty of the procedure. Intraoperative EEG monitoring has been shown to provide a sensitive index of cerebral perfusion (1); EEG changes have been used as an indication for shunt placement during CE. This study describes the use of a new simple, computerized method of EEG analysis to determine the need for bypass shunting and proposes new criteria for shunt placement.

Methods. One hundred fifteen CEs were performed on 105 patients. All patients were neurologically examined preoperatively, and again immediately postoperatively looking for motor, sensory, and speech changes. General anesthesia was maintained with either halothane or fentanyl + nitrous oxide. Ventilation was set to maintain slight hypocapnea (30-40 mmHg $PaCO_2$). A bypass shunt was planned for all patients and placed in all except 5 cases due to technical difficulties. Institutional Review Board approval was obtained for this study.

A single bipolar EEG signal (frontal-contralateral mastoid) was filtered (5 - 30 Hz bandpass), displayed on a CRT, and input to a Bio-Medical Computer (BMC). The BMC performed a real time, continuous analysis of the EEG, producing a Density Spectral Array display on a strip chart recorder. The arterial blood pressure, EKG, and heart rate were also recorded on the strip chart. Hypoxic EEG events were recognized manually by a sudden decrease in the Spectral Edge Frequency (SEF) (2). The EEG was continuously analyzed from pre-induction to post-extubation. The carotid artery clamping intervals were noted, along with the duration of any resulting EEG events. No interventions were made on the basis of the EEG.

Results. In 115 CEs there were 27 hypoxic EEG events during 225 clamping episodes (12%). Three of the 5 non-shunted cases had hypoxic EEG events during carotid clamping. The average clamping interval of the shunted cases was 9.23 min., with a range of 4 to 29 min. The average clamping interval of the non-shunted cases was 87 min. The range of duration of EEG events was 0.3 to >60 min. Eighteen events persisted less than 5 min, 4 events between 5 and 10 min, and 5 events 10 min or longer.

Twenty out of the 27 EEG events which occurred during clamping resolved before blood flow was restored. Of the 7 events which persisted until after the clamp was released, none resolved within less than 2 min after flow was restored, 4 resolved within 2 to 5 min, 2 resolved after more than 5 min, and 1 persisted until the patient died several hours later. Of the 5 EEG events which lasted 10 min or longer, 1 resolved before shunt flow was achieved, and 3 resolved 4, 6, and 22 min after restoration of carotid flow.

All 5 patients with a hypoxic EEG event lasting 10 min or longer developed a new postoperative neurologic deficit; none of the other patients did. The neurologic deficits seen postoperatively were transient, lasting 1 to 3 days, except in the one case who died with bilateral hemispheric infarctions. None of the non-shunted patients had an EEG event lasting 10 min or longer, and none developed a new neurologic deficit.

Discussion. In patients undergoing CE there is 12% incidence of hypoxic EEG changes during the period of carotid artery clamping (before flow is established), although there was only a 4% postoperative incidence of new neurologic deficits. EEG events lasting 10 or more min beginning during carotid artery clamping were all associated with new neurologic deficits. No EEG event lasting less than 10 min was associated with a new neurologic deficit.

Once an arteriotomy site has been prepared an indwelling shunt can be placed within a few minutes. Our data suggests that if the SEF is continuously monitored, and the shunt available, the surgeon can proceed without actually inserting the shunt unless hypoxic EEG changes occur. Furthermore it seems there is a several minute "grace period" during which hypoxic EEG events can be observed without shunting, and yet not incur the risk of a postoperative deficit. In this series, at best only 3 out of 27 events may have been held to less than 10 min duration by reperfusion through the shunt. Since 20 out of the 27 EEG events that we observed resolved before the shunt was placed, and 18 resolved within 5 minutes, we propose that if a hypoxic EEG is observed during clamping the surgeon may delay up to 5 min to see if the EEG changes resolve spontaneously before proceeding with shunt placement.

References.

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