Evoked potential monitoring in carotid surgery: A review of 994 cases

Walter F. Haupt, MD, and Svante Horsch, MD

**Article abstract**—Intraoperative monitoring of brain function is desirable in carotid artery surgery to detect possible complications, but the monitoring methods must be simple to perform, sensitive, and reliable. Median nerve somatosensory evoked potential (SEP) monitoring fulfills these criteria. Between 1985 and 1990, we performed 994 operations of the carotid artery with SEP monitoring. In 92% of the cases, we were able to obtain viable SEP tracings. In seven cases, irreversible SEP loss was followed by a new neurologic deficit. In one case only, neurologic complications ensued without SEP loss. Although immediate intraoperative therapeutic options are limited, the monitoring enhances patient security by allowing intraoperative detection and postoperative analysis of complications. SEP monitoring appears to be at least as effective as conventional EEG monitoring. The viability, sensitivity, and reliability of newer methods, such as modified spectral EEG analysis, must be measured by this established procedure.

**Methods.** Between 1985 and 1990, our group performed 994 operations of the carotid artery in 888 patients. In 92% of the cases, endarterectomies of the stenotic carotid artery were performed; in the remaining 8%, other reconstructive procedures of the carotid artery were done. In all cases, we attempted SEP monitoring. The operations were performed with general anesthesia using thiopental and fentanyl for induction and droperidol with small amounts of isoflurane for sustaining anesthesia. In 677 cases, intraluminal shunts were used during cross-clamping of the carotid artery. SEP stimulation was delivered with 0.2-msec rectangular electrical impulses to the median nerve at the wrist, with a frequency of 2.96 Hz and an intensity above the motor threshold. Steel EEG needles over the contralateral somatosensory cortical representation region in the positions C3' (2 cm posterior to C3) and F3 or C4' and F4, according to the EEG 10-20 system, were used for registration. Amplification and documentation were performed by a Nicolet Compact Four system or other electrophysiologic systems. The SEPs were graded normal when the N20/P25 amplitude did not show more than a 50% decrease compared with the baseline value determined before anesthesia. Since neither our group nor other investigators encountered significant latency changes of the N20 potential and amplitude alterations were invariably more prominent, we did not employ latency measurements for assessment. SEPs were graded abnormal when amplitudes decreased more than 50% of the baseline value or the SEP could not be resolved.

**Results.** The recording of SEP was attempted in all cases. Due to technical problems, no clearly resolved SEPs could be obtained in 9.9% of the cases. In 78.7% of the operations, SEPs showed no significant intraoperative alterations; in 10.5%, reversible SEP changes occurred; and in 0.7% of
the cases, we encountered irreversible loss of the SEP signal over the corresponding hemisphere. The SEP monitoring demonstrated irreversible loss of SEP in seven cases, and all of them developed a new irreversible postoperative neurologic deficit. This finding constitutes a positive predictive value of 100%. In only one case, a new postoperative neurologic deficit was found without intraoperative change in SEP. Hence, the sensitivity of SEP monitoring for the prediction of complications was 87% of the total number of complications or 99.9% with respect to the total number of operations. No mortalities occurred during the operation or up to discharge, usually 2 weeks after the operation.

Figure 1a demonstrates the registration of normal SEP during the course of carotid endarterectomy without complications. The tracings in figure 1b show significant reversible amplitude reduction of SEP during cross-clamping of the carotid artery. The most common cause of reversible amplitude changes is concomitant stenosis of the contralateral carotid artery. This effect is demonstrated by the chart, which shows a strong correlation between the occurrence of amplitude reduction and degree of contralateral stenosis (figure 2). In cases of amplitude reduction during cross-clamping without significant contralateral stenosis, the most probable cause is poor collateralization of cerebral arteries. Figure 1c demonstrates acute SEP loss during endarterectomy as a result of probable embolic complication. This finding was associated with postoperative hemiparesis and CT abnormalities consistent with ischemia in the supply area of the middle cerebral artery.

Even though only limited therapeutic options can be initiated intraoperatively after the loss of SEP, the surgeon should be notified of the complication and can consider the insertion of a shunt in patients undergoing surgery without prior shunting. The anesthesiologist should optimize the cardiovascular functions in an attempt to keep damage to a minimum. Also, patients with intraoperative SEP loss should be considered high-risk patients and should be admitted to intensive care units postoperatively to reduce secondary cerebral damage. Furthermore, the SEP data can be utilized for postoperative analysis of complications to improve perioperative management strategies.

Discussion. | 1,000 operative investigators, six methods. Compared to other methods, SEP monitoring is the most widely used technique for the evaluation of cerebral ischemia. The SEP data can be utilized for postoperative analysis of complications to improve perioperative management strategies.
It is true that cases of embolic stroke are infrequent.

Arterial emboli may occur during carotid endarterectomy, usually with shunt insertion. Without shunt placement, it is impossible to perform the operation safely. 

Now, let's consider the pathologic SEP during clamping and the degree of contralateral stenosis.

**Pathologic SEP during clamping and degree of contralateral stenosis**

![Pathologic SEP during clamping and degree of contralateral stenosis](image)

Figure 2. Incidence of pathologic SEPs during cross-clamping of carotid artery in relation to degree of contralateral carotid stenosis.

**Discussion.** Based on our findings from almost 1,000 operative procedures and the reports of other investigators, intraoperative SEP monitoring can be considered an alternative to other monitoring methods. Conventional EEG monitoring is still the most widely used method and many groups have gathered extensive experience with this procedure. SEP monitoring has the advantage of requiring only four recording electrodes, whose correct positions are easier to control than those of the 10 to 21 electrodes necessary for EEG monitoring. Furthermore, SEP evaluation reduces the measurements to one latency and one amplitude reading from a cortical area most endangered by ischemia during the procedure. This provides less but more specific information than EEG tracings from the total area of both hemispheres. The monitoring data can be updated every 2 to 5 minutes. Anesthetic drugs produce only minor amplitude alterations. In 1984, Markand et al. described the results of 38 endarterectomies followed by SEP in which one case showed dramatic clinical deterioration and SEP attenuation following cross-clamping of the carotid artery, which was reversed by shunt placement. In three other patients, transient SEP changes were noted during clamping. No permanent new postoperative neurologic deficits were noted. Gigli et al. followed 40 operations and found significant SEP changes in 10 cases. Subcortical SEPs were also registered and showed no changes. In five cases, the flattened SEP returned to normal before the end of the operation, and no new neurologic deficits ensued. In the remaining five cases, persistent SEP abnormalities correlated to new neurologic sequelae. These findings show a 100% positive prediction rate and a complication rate of 12.5%, significantly higher than in our series.

Harris et al. reported one of the earliest series of carotid endarterectomies in which 88 patients were monitored by EEG. They based their decision to place a shunt in the carotid artery on the time elapsed until EEG changes appeared during a 5-minute test-clamping period. Only one patient developed mild reversible paresis; however, two operations were aborted following the appearance of EEG changes immediately after test clamping. In a large series of 1,145 carotid endarterectomies reported by Sundt et al., the operations were monitored by EEG and also followed by intraoperative monitoring of CBF. In all cases, it was possible to predict postoperative complications; however, they found EEG changes in 130 cases, of which 120 were considered to be minor and were attributed to the effects of varying anesthesia levels, demonstrating the higher sensitivity of EEG to anesthetic agents. In 10 cases, they encountered marked persistent EEG alterations that correlated to new postoperative neurologic deficits. The identification of EEG changes and their attribution to effects of anesthesia or critical perfusion deficit require a high amount of expertise on the part of the person performing the EEG tracings. This problem does not pertain to evoked potential monitoring, especially since SEPs are less susceptible to alteration by drugs. Mola et al. followed
143 carotid endarterectomies with EEG monitoring in 1986 and found one patient with a postoperative deficit, but also reported one further patient with postoperative deficit without EEG changes. Chiappa et al. reported 367 intraoperative monitoring procedures, using conventional EEG and also a dedicated minicomputer for EEG analysis in 35 of these cases. During the monitoring, a number of artifacts and alterations of the EEG due to pre-existing focal EEG abnormalities and varying concentrations of anesthetic agents were noted. These problems usually are not encountered in SEP monitoring. In 36 (9.8%) EEGs, changes occurred that were considered to be secondary to the clamping procedure. Only six patients suffered postoperative deficits. This amounts to 30 (8.1%) false-positive findings. On the other hand, 331 EEGs showed no changes, and three (0.9%) of these patients showed postoperative neurologic deficits (false-negative results). Our SEP registrations show 0.1% false-negative findings. We cannot determine the cause of this one case of postoperative neurologic deficit without intraoperative loss of SEP. The cerebral infarction may not have caused major damage to the somatosensory cortex, leaving the SEP unaffected; however, the complication may also be due to a postoperative event after discontinuation of SEP monitoring. Rampil et al. reported 111 computerized EEG monitorings in 1983 with one case of postoperative deficit and correct prediction by EEG. In 1985, Russ et al. described 43 operations that were monitored with an EEG spectral array system with 11 intraoperative changes but only two postoperative deficits. These findings constitute nine (20.9%) false-positive findings; false-negative findings were not reported.

References