From the Eastern Vascular Society

Predictors of cross-clamp-induced intraoperative monitoring changes during carotid endarterectomy using both electroencephalography and somatosensory evoked potentials

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ABSTRACT

Objective: The efficacy of selective shunting during carotid endarterectomy (CEA) using intraoperative monitoring (IOM) for detection of cerebral ischemia is well established. There is mounting evidence that monitoring of both electroencephalography (EEG) and somatosensory evoked potentials (SSEPs) increases the sensitivity of cerebral ischemia detection. Predictors of cerebral ischemia requiring selective shunt placement using IOM of both EEG and SSEPs have not been previously identified.

Methods: Consecutive patients who underwent CEA between January 1, 2000, and December 31, 2010, were retrospectively analyzed. Primary end points were IOM changes at any time during the operation or IOM changes with carotid cross-clamping. Risk factors assessed included demographics; baseline comorbidities; severity of ipsilateral and contralateral disease; symptomatic status; and use of statin, antiplatelet, and beta-blocker medications. Univariate and multivariate logistic regression was used for analysis.

Results: During the 11-year study period, a total of 758 patients underwent 804 CEAs (mean age, 70.6 ± 9.5 years; 59.8% male; 39.2% symptomatic) using IOM of both SSEPs and EEG for selective shunting guidance. Postoperative stroke rate was 1.37%; 27.1% of patients had significant SSEP or EEG changes, and 49.1% of these were clamp induced (within 5 minutes of cross-clamping). Of these patients, 83.2% received a shunt (11.4% overall). The most common reason that a shunt was not placed after cross-clamp-induced changes was that the changes resolved with further blood pressure elevation (8 of 17 patients). Clamp-induced IOM changes were predictive of postoperative stroke (odds ratio [OR], 5.5; $P = .005$). Risk factors for clamp-induced IOM changes were contralateral carotid occlusion (OR, 2.5; $P = .01$), symptomatic stenosis (OR, 1.8; $P = .006$), and diabetes (OR, 1.6; $P = .03$), whereas there was a trend toward increased risk with female sex (OR, 1.5; $P = .08$). Risk factors for any IOM change (clamp and nonclamp induced) were symptomatic carotid stenosis (OR, 1.8; $P < .001$), use of beta blockers (OR, 1.5; $P = .03$), and female sex (OR, 1.5; $P = .02$).

Conclusions: Whereas some patients can be expected to experience IOM changes by monitoring of SSEPs and EEG, a much smaller percentage will receive a shunt. Contralateral carotid occlusion, symptomatic stenosis, diabetes, and female sex increase the risk of clamp-induced IOM changes and should be anticipated to need a shunt. Patients receiving beta blockers are likely to experience IOM changes during the operation that are not associated with clamping. (J Vasc Surg 2017;■:1-8.)

The efficacy of carotid endarterectomy (CEA) for stroke risk reduction has been established through landmark randomized trials on both symptomatic and asymptomatic patients.[1] Surgical risks are low and have continued to decline over time.[2,3] However, intraoperative cerebral ischemia remains an ongoing concern during this operation. Many surgeons treat intraoperative cerebral ischemia, when detected, with selective carotid shunt placement. The efficacy of selective shunting during CEA using intraoperative monitoring (IOM) for detection of cerebral ischemia is well established.[4]

Shunting, however, is not without its own set of risks; embolization, dissection, and stroke are all known

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consequences.[5] Thus, the most accurate method of cerebral ischemia detection in the nonawake patient is desirable to minimize unnecessary shunt placement. There is mounting evidence that monitoring with both electroencephalography (EEG) and somatosensory evoked potentials (SSEPs) increases the sensitivity *and* specificity of cerebral ischemia detection.[6,7] We have previously reported a maximum sensitivity obtained with multimodality monitoring with an IOM change in either EEG or SSEPs of 50.00% (95% confidence interval, 30.66-69.34) and specificity of simultaneous EEG and SSEP changes of 93.95% (95% confidence interval, 92.28-95.35).[7] Such dual-modality IOM has increased the ability to detect cerebral hypoperfusion and to predict perioperative stroke.[8]

Predictors of dual neurophysiologic IOM changes using these modalities that require shunt placement have not been previously identified. We reviewed our experience with monitoring of both SSEPs and EEG to identify the rate of selective shunt placement with this monitoring strategy. In addition, we sought to identify predictors of cerebral ischemia under dual monitoring of SSEPs and EEG to characterize patients at risk of intraoperative cerebral ischemia. Whereas previous research has shown possible predictors for cerebral ischemia to include such factors as circle of Willis anatomy and angiographic criteria, we have chosen to focus on the predictive value of more easily available clinical data points. Based on previous studies looking at risk factors of intraluminal shunt placement, we hypothesized that a number of clinical factors, including severe contralateral carotid disease, degree of ipsilateral carotid stenosis, symptomatic disease, age, diabetes, sex, and antihypertensive medication, would be possible risk factors for IOM changes. Identification of patients with increased chances of requiring shunt placement could help the surgical team anticipate neuromonitoring changes, prepare for intraluminal shunting, and decrease anxiety during the procedure.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective cohort study
- **Take Home Message:** In 804 carotid endarterectomies, 11.4% had shunt placement. Contralateral carotid occlusion, symptomatic stenosis, diabetes, and female sex increased the risk of clamp-induced changes in electroencephalography and somatosensory evoked potential monitoring and the need to place a shunt.
- **Recommendation:** This study suggests that changes in electroencephalography and somatosensory evoked potential monitoring are increased in patients with a contralateral carotid occlusion, symptomatic stenosis, diabetes, and female sex.

METHODS

Study design. The Institutional Review Board at the University of Pittsburgh approved this study protocol. Informed consent was not required for this retrospective review. Consecutive individuals who underwent CEA by the Division of Vascular Surgery at the University of Pittsburgh between January 1, 2000, and December 31, 2010, were identified by the *Current Procedural Terminology* code 35301. The records were reviewed for demographics, baseline risk factors, medications, carotid duplex ultrasound studies, operative indications, and intraprocedural data including shunt placement and IOM changes. Additional imaging, such as computed tomography angiography and magnetic resonance angiography, was not included because these are available for only a small minority of patients and would not constitute a readily available clinical predictor. Patients were included if they had undergone CEA under dual-modality (SSEPs and EEG) neurophysiologic monitoring with plans for selective shunt placement as needed. Patients who underwent concomitant cerebrovascular procedures (eg, carotid to subclavian bypass) or concomitant coronary artery bypass grafting were excluded from the study.

Definitions. All baseline risk factors were recorded on the basis of established diagnoses identified in the medical records. Preoperative parameters of interest included age, sex, carotid ultrasound results bilaterally, and history of any of the following: hypertension, diabetes mellitus, chronic renal insufficiency, smoking, coronary artery disease, and congestive heart failure. Chronic renal insufficiency was defined as serum creatinine concentration consistently >1.5 mg/dL. Preoperative medications were also documented. Symptomatic carotid stenosis was defined as a preprocedural ipsilateral ischemic stroke or transient ischemic attack occurring in the 6 months before operation.[9] The primary outcomes were changes of SSEPs or EEG during any time of the operation, changes of SSEPs or EEG at the time of clamp placement, and shunt placement.

CEA. CEA was performed under general anesthesia in all cases. Closure technique (primary, patch, or eversion) was variable and based on the physician's preference. CEAs performed by surgeons who practice routine shunt placement were not included as these shunts were not placed on the basis of cerebral ischemia or preoperative characteristics of the patient. A clamp test of 1 minute was performed for each patient, after which the monitoring neurophysiologist alerted the surgeon of the absence of significant IOM changes.

Neurophysiologic monitoring. All patients underwent monitoring of both EEG and SSEPs. EEG was recorded

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