Published in final edited form as:

Ann Vasc Surg. 2020 November ; 69: 158–162. doi:10.1016/j.avsg.2020.06.002.

Identifying a Safe Carotid Stump Pressure Threshold for Selective Shunting during Carotid Endarterectomy

Matthew C. Chia, MD^a, Gabriel A. Wallace, MD^a, Brian T. Cheng, BA^a, Karen J. Ho, MD^a, Mark K Eskandari, MD^a

^a676 N St Clair Street, Suite 650, Division of Vascular Surgery, Department of Surgery, Feinberg School of Medicine, Chicago, IL 60611

Abstract

Background—There is no current consensus on the best criteria for selective shunting during carotid endarterectomy (CEA). The choice of continuous neurologic assessment during awake CEA, intraoperative electroencephalogram (EEG), or carotid stump pressure monitoring as the basis for shunt placement is primarily dependent on surgeon preference. Our goal was to define a safe stump pressure threshold as a guide for selective shunting.

Methods—The study is a single-surgeon retrospective review of consecutive patients who underwent CEA under general anesthesia with selective shunting based on intraoperative stump pressure measurements from 2001–2019. Demographic and periprocedural variables were analyzed using standard statistical techniques.

Results—Among 399 patients, 68% were male with a mean age of 70. A third were symptomatic, with amaurosis fugax in 12%, TIA in 7%, and stroke in 16%. In total, 60 (15%) patients underwent shunting: 34 for a confirmed preoperative acute ischemic stroke, 22 for a stump pressure < 30 mmHg, and 4 for other indications. Overall 30-day death, ischemic ipsilateral stroke, myocardial infarction, and cranial nerve palsy rates were 0.5%, 0.8%, 1.8%, and 1.0% respectively. No strokes occurred due to hypoperfusion, and all stroke symptoms resolved prior to discharge with a mean length of stay of 1.6 days.

Conclusion—This is one of the largest contemporary series of CEA using a 30 mmHg threshold for selective shunting that demonstrated exceedingly low 30-day death and stroke events. Intraoperative carotid stump pressure measurements are a useful guide for selective shunting and reduction of perioperative stroke complications after CEA.

1 Introduction

Perioperative stroke is a known complication of CEA, although stroke prevention remains the primary benefit of the surgical procedure. Important strategies to reduce perioperative

Corresponding Author: Mark K. Eskandari, M.D., Division of Vascular Surgery, Northwestern University Feinberg School of Medicine, 676 N St Clair, Suite 650, Chicago, IL, 60611, Phone: 312-926-7775, Fax: 312-695-4955, meskanda@nm.org.

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stroke during CEA include shunting to minimize the interruption of antegrade blood flow. Prior work has advocated for routine shunting, selective shunting with a variety of strategies, and never shunting approaches^{1–4}. The decision to place a shunt while using a selective shunting approach can be based on preoperative risk factors or intraoperative monitoring, which includes neurologic monitoring on an awake patient, EEG, and intraoperative carotid stump pressure measurement. Although awake CEA has been demonstrated to be effective in prior work⁵, not all patients are able to tolerate this strategy. Intraoperative EEG monitoring may be limited in its ability to detect cerebral hypoperfusion⁶ and has significant associated cost⁷, although some have demonstrated favorable results with this technique^{8,9}. By contrast, measurement of carotid stump pressure^{10–12} is a simple intraoperative maneuver that yields an objective surrogate measure of cerebral perfusion pressure. There is variability in described thresholds of intraoperative stump pressure below which a shunt should be placed using either systolic blood pressure (SBP) or mean arterial pressure (MAP)^{1, 13–15}. The aim of this study was to demonstrate the safety of a 30 mmHg MAP threshold for selective shunting.

2 Methods

This is a single-center, single-surgeon retrospective study of patients undergoing CEA at Northwestern Memorial Hospital between January 2001 and January 2019. The study was conducted under a waiver of informed consent as determined by the Northwestern University Institutional Review Board. Data were obtained from the electronic health record and the institutional Vascular Quality Initiative (VQI) dataset for all consecutive patients undergoing CEA from a single surgeon (M.K.E.) over the study period. Patients were excluded if carotid bypass, carotid stenting, eversion endarterectomy, or concomitant coronary bypass surgery was performed. Data on demographics, preoperative imaging, operative characteristics, and 30-day postoperative complication rates were collected. All patients were on antiplatelet and statin therapy prior to surgery. Shunt indication and stump pressure measurements were reported in operative dictations and maintained in a prospective spreadsheet.

All procedures were performed under general anesthesia, with shunting typically performed for preoperative acute ischemic stroke or for mean arterial stump pressure measurement less than 30 mmHg. Briefly, once the common, external, and internal carotid arteries were exposed and isolated, systemic intravenous heparin was administered, and the systemic MAP was raised to at least 80 mmHg during clamping for all patients regardless of contralateral carotid patency. The common carotid and external carotid arteries were clamped, and a 20-gauge needle in the carotid artery was connected to a continuous arterial pressure transduction system to assess the arterial waveform along with systolic, diastolic, and mean arterial blood pressure measurements. A Sundt shunt (Integra LifeSciences, Princeton, NJ) was the preferred shunt type, and shunt patency was confirmed with intraoperative Doppler assessment.

Descriptive statistics were performed using Stata MP 16.1 (College Station, TX).

3 Results

A total of 399 patients met the study criteria, with 15% undergoing endarterectomy with shunt placement. Patient demographics and preoperative characteristics are noted in Table 1. Patients had a mean age of 70 years old, were predominantly male (68%), and had high rates of hypertension (72%), coronary artery disease (24%), diabetes (26%), and smoking history (54%). The indication for the procedure was symptomatic carotid stenosis in 34% of patients. Of the patients who underwent endarterectomy with shunting, 57% (34/60) were for recent ischemic stroke, 37% (22/60) were for stump pressure < 30 mmHg, and 7% (4/60) were for other indications. Stump pressures were performed in 90% of the cohort (Figure 1), yielding a mean pressure measurement of 52 mmHg (range 0–125). Only 9.2% of the cohort had an intraoperative stump pressure less than 30 mmHg. Contralateral carotid artery occlusion was present in 19 (4.8%) patients and was not unexpectedly associated with lower stump pressures (41 versus 52 mmHg, $p = 0.02$).

The 30-day death, stroke, myocardial infarction, and cranial nerve palsy rates were 0.5% ($n = 2$), 0.8% ($n = 3$), 1.8% ($n = 7$), and 1.0% ($n = 4$), respectively (Table 2), with a mean length of stay of 1.6 days. All postoperative strokes occurred in symptomatic patients who were undergoing CEA for a recent stroke yielding a rate of 2.2% (3/137) within the symptomatic patient subgroup. Of the three postoperative strokes, one was in a patient shunted for a recent stroke, one was a small hemispheric stroke whose symptoms resolved prior to discharge, and one was secondary to acute thrombosis in the recovery unit whose symptoms resolved after re-exploration and revision of the patch angioplasty. This patient had an occluded contralateral internal carotid artery and was also shunted in the index operation without stump pressure measurement for the indication of recent preoperative stroke. The patient was also shunted during the re-exploration operation. The former two patients with postoperative stroke had patent contralateral carotid arteries. No postoperative strokes occurred in the eleven patients with stump pressure < 30 mmHg who were not shunted based on surgeon preference. Importantly, no patients developed ischemic stroke symptoms secondary to hypoperfusion. Of the two postoperative deaths, both patients developed a postoperative myocardial infarction and underwent coronary angiography without intervenable lesions. One patient died in-hospital secondary to cardiovascular collapse, and the other died after discharge. There were three palsies of the marginal mandibular nerve and one of the vagus (recurrent laryngeal) nerve. All cranial nerve palsies resolved by one month postoperatively.

4 Discussion

This single-surgeon retrospective study demonstrates the safety of CEA with selective shunting utilizing a threshold mean stump pressure of 30 mmHg. Our rate of postoperative ischemic stroke was 0.8%, which is similar to rates observed in the VQI regardless of shunting strategy². Guidelines from the Society for Vascular Surgery emphasize the importance of low perioperative stroke rates when offering CEA, particularly for asymptomatic patients¹⁶. Furthermore, of the three ipsilateral ischemic strokes in our cohort, two patients were shunted for a preoperative indication of a recent acute ischemic stroke. It is possible that shunt placement could contribute to postoperative stroke by dislodging

emboli during insertion or removal. However, prior work did not demonstrate differences in rates of stroke between routine and selective shunting strategies³, suggesting against a high risk of stroke caused directly by shunting. Of note, eversion endarterectomies were excluded from analysis as none of these patients underwent shunting during their procedure. Our overall low stroke rate and low shunting rate suggest the safety of this approach.

To our knowledge, we report the first modern, real-world experience of CEA and selective shunting with this stump pressure threshold regardless of the status of the contralateral carotid. The original technique description of carotid stump pressure by Moore et al initially explored a stump pressure threshold of 25 mmHg in symptomatic patients undergoing CEA with local anesthesia¹¹. The subsequent experience of using this threshold for patients undergoing CEA under general anesthesia demonstrated no perioperative death or stroke, although patients with preoperative neurologic deficits had higher rates of postoperative neurologic deficit¹². In contrast to this experience with primarily symptomatic patients, our cohort was comprised of 65.7% asymptomatic patients. Further work to establish a threshold included comparison of stump pressures with EEG changes, which suggested a threshold of 40 mmHg was safe in patients without recent stroke¹⁰. However, correlation of EEG with neurologic changes under cervical block anesthesia demonstrated limited sensitivity and an approximately 40% false negative rate⁶. Given these considerations, our threshold of 30 mmHg was chosen to be more conservative than the initial technique description, and patients with recent stroke were shunted routinely. Our rates of postoperative stroke and death were similar to other reported outcomes using mean stump pressure thresholds of 40 or 50 mmHg^{14, 15, 17}. Although many patients in our study were shunted for indications other than low stump pressure, our 15% overall rate of shunting was approximately half the rate of shunting (28%) in the selective shunting arm of a prospective, randomized trial of CEA under general anesthesia using a threshold of 40 mmHg³. Our rate of shunting was comparable to prior reported rates ranging from 7–21%¹ with favorably low rates of perioperative stroke and death. Furthermore, studies correlating stump pressure measurements with neurologic changes during awake CEA found that thresholds of 31 and 40 mmHg were consistent with shunting based off of symptoms^{7, 13}. Our lower rate of shunting based on a threshold of 30 mmHg may shorten operative time and did not appear to have increased rates of postoperative complications, particularly ischemic stroke due to hypoperfusion.

Alternatives to stump pressure measurement have also been previously explored. Continuous cerebral monitoring using cerebral oximetry and near infrared spectroscopy have been explored, but require specialized equipment and have limited evidence to support their use^{14, 17}. EEG monitoring has been well-described, and has the advantage of continuously monitoring patients throughout the procedure, whereas carotid stump pressure measurement represents an isolated snapshot of cerebral perfusion. However, continuous EEG monitoring is resource-intensive, requiring specialized equipment, staff, and a neurologist to interpret EEG changes. An analysis of a large cohort of patients undergoing CEA with EEG monitoring demonstrated that the vast majority of EEG changes occurred during initial cross clamping, at the same time when stump pressure measurement is performed⁹. The remainder of EEG changes seen in this study were associated with systemic hypotension, administration of specific drugs, or when the procedure was nearly completed, all of which

obviate a need for shunting. Others describe the use of a “wake up test,” whereby a general anesthetic is lightened during carotid cross-clamping to allow for gross assessment of neurologic function¹⁸. By comparison, intraoperative carotid stump pressure assessment can be performed with minimal additional equipment, and has been demonstrated to reliably correlate with anatomic patterns of concomitant cerebrovascular disease¹⁵.

There are several limitations to our study. This is a single-surgeon experience at an academic medical center, and this practice may not be generalizable to other settings. Additionally, our practice was to routinely shunt patients with a recent acute ischemic stroke and to selectively shunt all other patients based on intraoperative stump pressure measurement. A recent study of CEA after recent stroke in the VQI demonstrated that routine shunters had significantly lower risk of perioperative stroke than those who selectively shunt for any reason¹⁹. These findings suggest that a surgeon’s comfort with shunt placement may impact the effectiveness of shunting to reduce perioperative stroke. However, our low rate of perioperative stroke would suggest that this effect was not seen in our experience. Additional perioperative maneuvers are likely to contribute to stroke reduction, including raising of the systemic blood pressure during clamping to optimize cerebral perfusion via collateral pathways. Increased systemic blood pressure is likely to increase stump pressure depending on patency of the contralateral carotid artery, vertebrobasilar system, and circle of Willis. However, stump pressure measurement has the advantage of quantifying the net effect of many of the variables that would affect cerebral perfusion pressure, simplifying operative decision making. Finally, as our study was performed as a descriptive review of a real-world experience, there is no direct comparison to a different shunting strategy that could control for confounding factors that may impact another practitioner’s experience with a mean stump pressure threshold of 30 mmHg.

5 Conclusions

In this retrospective single-center, single-surgeon review of carotid endarterectomy performed with selective shunting based on a 30 mmHg mean arterial stump pressure threshold, we demonstrated an exceedingly low postoperative ischemic ipsilateral stroke rate and no incidence of stroke due to hypoperfusion. Intraoperative carotid stump pressure measurements are a useful guide for selective shunting and reduction of perioperative stroke complications after CEA.

Acknowledgments

Funding:

Author MCC and research reported in this work was supported by the National Heart, Lung, and Blood Institute of the National Institutes of Health in the form of partial stipend support under Award Number T32HL094293-11. The funding source had no role in the study design, collection/analysis/interpretation of data, writing of the report, nor the decision to submit for publication. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Declaration of Conflicting interests

Author MKE has received honoraria from Silk Road Medical, Inc. for service on the Roadster Clinical Events Committee; and from W. L. Gore & Associates as a TEVAR course director. Neither of these entities had any

influence over the conception, design, or conduct of the research contained here. All other authors declare no conflicting interests.

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Figure 1. Distribution of Carotid Stump Pressures during Carotid Endarterectomy.

* denotes ischemic ipsilateral stroke event.

Table 1.

Demographics and Preoperative Characteristics of Patients Undergoing Carotid Endarterectomy

Characteristic	Cohort (n = 399)	%
Mean Age, days (range)	70 (45 – 91)	
Male	272	38.2
ASA Class		
1–2	54	20.1
3	203	75.5
4–5	12	4.5
Hypertension	276	72.4
Coronary Artery Disease	93	24.4
CHF	14	3.7
Diabetes	100	26.3
COPD	37	9.7
Any Smoking History	205	53.8
Symptomatic	137	34.3
Amaurosis Fugax	47	34.3
Transient Ischemic Attack	28	20.4
Stroke	62	45.3
Shunt	60	15.0
Preoperative Acute Stroke	34	56.7
Stump Pressure < 30	22	36.7
Other	4	6.7
Mean Length of Stay, days (range)	1.6 (1 – 14)	

Table 2.

Postoperative Complications after Carotid Endarterectomy with Stump Pressure Threshold of 30 mmHg

Complication	Cohort (n = 399)	%
Death	2	0.5
Ischemic Ipsilateral Stroke	3	0.8
Myocardial Infarction (MI)	7	1.8
Cranial Nerve Palsy	4	1.0
Neck Hematoma Requiring Evacuation	4	1.0
Any Complication *	21	5.3

* Death, MI, any stroke, cranial nerve injury, neck hematoma