Perioperative Management of Carotid Endarterectomy: A Survey of Clinicians' Backgrounds and Practices

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Objective: To examine current trends in anesthetic practice for management of carotid endarterectomy (CEA) and how practice may differ by groups of practitioners.

Design: An online survey was sent to the Society of Cardiovascular Anesthesiologists and Society of Neuroscience, Anesthesiology, and Critical Care e-mail list servers. Responses were voluntary.

Setting: Academic medical centers and community-based hospitals providing perioperative care for a CEA in the United States and abroad.

Participants: Anesthesiologists who provide perioperative care for patients undergoing a CEA.

Interventions: None

Measurements and Main Results: Of 664 responders (13% response rate), most (66%) had subspecialty training in cardiovascular anesthesiology, had been in practice more than 10 years (68%), and practiced in the United States (US, 81%). About 75% of responders considered general anesthesia as a preferable technique for CA, and about 89% of responders provided it in real life, independent of subspecialty training. The most preferable intraoperative neuromonitoring was cerebral oximetry (28%), followed by EEG (24%), and having an awake patient (23%). Neuroprotection was not considered by 33% of responders, and upon conclusion of a case, 59% preferred an awake patient for extubation, while 15% preferred a deep extubation. Neuroanesthesiologists and non-US responders more often risk stratify patients for perioperative cerebral hyperperfusion syndrome, compared with cardiac anesthesiologists and US responders ($p = 0.004$ and $p < 0.005$, respectively). Additionally, reported management strategies vary substantially from anesthetic practice 20 years ago.

Conclusions: Although there are areas of perioperative management in which there seems to be agreement for the CEA, there are also areas of divergent practice that could represent potential for improvement in overall outcomes. There are many potential reasons to explain divergence in practice by location or subspecialty training, but it remains unclear what the "best practice" may be. Future studies examining outcomes after carotid endarterectomy should include perioperative anesthetic management strategies to help delineate "best practice."

KEY WORDS: *carotid endarterectomy, perioperative outcomes, stroke, neuromonitoring*

STROKE REMAINS one of the leading causes of death in the United States, responsible for approximately 134,000 deaths annually.[1] Carotid artery stenosis is a significant cause of stroke, and the risk of subsequent stroke is related directly to the degree of stenosis. Carotid endarterectomy (CEA) was developed to alleviate surgically correctable atherosclerotic plaque-induced carotid artery stenosis. CEA is still the most frequently performed procedure to treat carotid artery stenosis, although the number of carotid artery stenting procedures has been increasing in the past 10 years.[2]

Despite improvements in surgical technique, CEA carries a relatively high risk of perioperative stroke (3%) that seems to double the 4-year mortality rate (from 11% to 21%).[2] Most perioperative strokes associated with CEA may be preventable.[3] Despite the availability of various anesthetic techniques for CEA, there is a paucity of research that has specifically addressed the association between anesthetic techniques for CEA and perioperative stroke. A survey completed nearly 20 years ago showed that anesthetic techniques varied greatly between practitioners and could range from regional anesthesia on an awake patient to general anesthesia with time- and resource-intensive neuromonitoring.[4] Since the time this survey was conducted in 1995, the practice of anesthesiology has changed substantially; more neuromonitors are available, the laryngeal mask airway is more commonly used, and patients undergoing surgery carry more comorbid conditions. Because of the high morbidity and mortality associated with the procedure, it is reasonable to speculate that perioperative outcomes of these patients could improve further, and developing an optimal anesthetic technique could prevent a significant number of complications annually.

The goal of this survey was to measure the variability of anesthetic practice. The authors hypothesized that anesthesiologists, defined by various groups including subspecialty training and location of practice, would have significantly different practice preferences.

METHODS

This study surveyed practicing anesthesiologists about their practice preferences and surgical characteristics when providing anesthesia for a carotid endarterectomy. A survey of 31 questions regarding the demographic characteristics, professional background of participants, and perioperative anesthetic and surgical management of CEA was built online using the University of Washington Catalyst Web Tools software (the full survey is shown in the Appendix). A link to the survey was sent out to members of the Society of Cardiovascular Anesthesiologists and Society for Neuroscience in Anesthesiology and Critical Care e-mail list servers. Surveys were completed online by all participants anonymously. The survey was available online between June 2012 and December 2012.

In addition to describing overall practice preferences and trends, the survey also was designed to test for differences in practice by subspecialty. Two comparative analyses were conducted: A primary analysis comparing neuroanesthesiologists to cardiac anesthesiologists, and a secondary analysis that separately compared anesthesiologists with subspecialty training and those who were practicing in the US with those without subspecialty training and those who were practicing abroad. Of all the questions asked in the survey, a subset of 5 questions was selected

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to assess for comparisons a priori. Level of significance was adjusted to a Bonferroni adjusted level of 0.01 accordingly. Differences were assessed using chi-squared analysis for binary variables, logistic regression for ordinal variables, and a *t* test when assuming unequal variances between groups for continuous variables. All analyses were conducted in Stata Intercooled 12 (Statacorp, College Station, TX).

RESULTS

There were 664 responders out of approximately 5,000 individuals (13% response rate), all of whom were independently practicing and certified anesthesiologists. An exact number is not known, because both societies provided the investigators with estimates only. Most of the respondents were cardiac anesthesiologists (66%), were in practice for longer than 10 years (68%), and were practicing in the United States (81%) (Table 1).

Respondents varied greatly in their anesthetic and surgical technical preferences. Most respondents preferred a general to a regional anesthetic for CEA (75% *v* 25%) (Table 2). Cerebral oximetry (28%) was the preferred neuromonitor among practitioners, followed by EEG and, lastly, maintaining an awake patient (24% and 23%, respectively). A method of neuroprotection was used by most practitioners (68%). Most respondents (59%) preferred an awake extubation rather than a deep extubation (15%). Considerable variation was noted among practitioners in the preferred technique of airway management for postoperative neck hematoma evacuation. For this postoperative complication, respondents most often preferred an asleep direct laryngoscopy (35%). Only a minority of respondents never performed risk stratification for cerebral hyperperfusion syndrome before surgery (40%).

Perioperative goals of blood pressure management were assessed at 4 time points: Before, during, and after carotid cross-clamping, and in the immediate postoperative period in terms of comparisons to baseline blood pressure (Table 3). During clamping, the most common blood pressure goal was at 10% to 20% above patient's baseline; before and after clamping, and postoperatively, most respondents preferred to keep blood pressure at the patient's baseline. Beta-blockers were the most commonly used antihypertensive agents in the ICU and floor. Most respondents thought that patients should stay in the hospital and have their blood pressure monitored for 24 to 48 hours postoperatively (Table 1).

Table 1. Study Participants

		n	%
Subspecialty	Cardiac anesthesiology	440	66.3
	Neuroanesthesiology	47	7.1
	Vascular anesthesiology	18	2.7
	Critical care	28	4.2
	Other	23	3.5
	None	108	16.3
Years in practice	1-2 years	40	6.0
	2-5 years	68	10.2
	5-10 years	107	16.1
	> 10 years	449	67.6
Practice setting	Private practice	317	47.7
	Academic institution	251	37.8
	Both	96	14.5
Practice location	US	531	80.6
	Non-US	128	19.4

Table 2. Survey Responses: Selected Anesthetic Practice Preferences

	n	%
Ideal Anesthetic Technique		
General	493	75.4%
Regional	161	24.6%
Preferred Neuromonitor		
Transcranial Doppler	22	3.5%
Cerebral oximetry	178	28.3%
EEG	149	23.7%
BIS	74	11.7%
Evoked potentials	27	4.3%
Awake patient	143	22.7%
Stump pressure	37	5.9%
Intraoperative Neuroprotection*		
No neuroprotection	210	32.6%
100% oxygen	219	34.0%
Increase in blood pressure	392	60.9%
Sodium thiopental	21	3.3%
Propofol	62	9.6%
Etomidate	0	0.0%
Mannitol	16	2.5%
Hypertonic Saline	3	0.5%
Phenytoin	3	0.5%
Extubation Technique		
Deep extubation	98	14.9%
Awake and following commands	385	58.6%
Delayed extubation in ICU	3	0.5%
No specific extra requirements	137	20.9%
Varies	34	5.2%
Airway Management of Postoperative Neck Hematoma		
Awake fiberoptic intubation	151	23.3%
Asleep fiberoptic intubation	12	1.8%
Awake direct laryngoscopy	47	7.2%
Asleep direct laryngoscopy	230	35.4%
Awake video laryngoscopy	85	13.1%
Asleep video laryngoscopy	119	18.3%
LMA or supraglottic device	5	0.8%
Risk Stratification of Cerebral Hyperperfusion Syndrome		
Routinely	102	15.5%
Occasionally	129	19.7%
Rarely	166	25.3%
Never	259	39.5%

*More than one choice allowed

Table 4 illustrates the primary analysis. Although there were measured differences between individuals who identified themselves as neuroanesthesiologists or cardiac anesthesiologists, the only statistically significant difference was with risk stratification of patients for cerebral hyperperfusion syndrome ($p = 0.004$). There was a trend toward a difference between these 2 groups in optimal anesthetic technique, with 30% of neuroanesthesiologists versus 22% of cardiac anesthesiologists preferring a regional technique and 6% of neuroanesthesiologists versus 15% of cardiac anesthesiologist preferring deep extubation, although these comparisons did not reach statistical significance ($p = 0.231$ and 0.100, respectively).

Table 4 also shows the secondary analysis, which compares anesthesiologists with a claimed subspecialty with those without and compares anesthesiologists practicing in the US with those practicing outside the US. The only measured difference

Table 3. Survey Responses: Perioperative Blood Pressure Management

Perioperative Blood Pressure Goals	At Patient's Baseline (%)	10%-20% Above Patient's Baseline (%)	10%-20% Below Patient's Baseline (%)	Systolic BP >140 mmHg (%)	Systolic BP <110 mmHg (%)	No Specific Goals (%)	Varies (%)
BP goal before carotid cross-clamping	54.8	22.2	11.1	5.2	0.3	3.5	3.0
BP goal during carotid cross-clamping	19.5	61.4	2.6	8.8	0.6	2.1	5.0
BP goal after carotid cross-clamping	49.5	8.0	28.5	2.4	2.0	3.2	6.3
BP goal immediately postoperatively	52.6	7.5	28.4	3.7	2.6	5.2	0.0

Perioperative Blood Pressure Agents	Beta Blocker (%)	Hydralazine (%)	Nitroglycerin (%)	Nitroprusside (%)	Calcium Channel Blocker (%)	ACE Inhibitor (%)
ICU first choice BP control agent	53.9	3.9	15.3	9.9	16.6	0.4
Ward first choice BP control agent	73.6	6.4	3.0	0.4	10.7	5.8

Postoperative Blood Pressure Monitoring	<24 Hours (%)	24-48 Hours (%)	48-96 Hours (%)	>96 Hours (%)
Recommended Postoperative stay	20.9	66.1	12.0	0.9
Recommended Postoperative BP Monitoring	34.8	59.4	5.5	0.3

Abbreviations: ACE, angiotensin converting enzyme; BP, blood pressure.

in those with a claimed subspecialty was the practice of risk stratification for cerebral hyperperfusion syndrome, with the practice being less common among those without a claimed subspecialty ($p = 0.001$). There seemed to be more differences between anesthesiologists practicing in the US compared with those practicing outside the US. More non-US anesthesiologists practiced risk stratification for cerebral hyperperfusion syndrome ($p < 0.0005$), and there was a trend toward preferring a regional anesthetic ($p = 0.073$) and deep extubation ($p = 0.054$), although these results were not statistically significant.

DISCUSSION

This study showed substantial variability in the conduct of anesthesia for CEA among practicing anesthesiologists, some of which might be explained by their background and clinical training. The main areas of disagreement tended to be in perioperative blood pressure management, risk stratification for cerebral hyperperfusion syndrome, and intraoperative neuromonitoring.

The results of this survey also reflected, substantial differences when compared with the last survey done 18 years ago. Since the time of the last survey,[4] 3 surgical societies have reported guidelines for this procedure,[5–7] and clinicians have the results of a very large randomized controlled trial examining local anesthesia versus general anesthesia (the GALA trial), which did not seem to show any significant differences between the 2 techniques.[8] Anesthesiologists still seem to prefer general anesthesia for this procedure, but methods for neuromonitoring and neuroprotection have changed substantially. EEG used to be the

Table 4. Comparisons Between Groups: Statistical Analysis

		Primary Analysis			Secondary Analysis					
Question	Answer	Neuro	Cardiac	p Value	None	Fellowship	p Value	US	Non-US	p Value
Better anesthetic technique	% regional (vs. general)	30%	22%	0.231	21%	25%	0.371	23%	31%	0.073
Anesthetic actually provided	% general (vs. regional)	89.8%	87.8%	0.648*	87.5%	87.3%	0.931*	89.1%	77.7%	0.003*
Risk stratify patients CHS	Routinely	30%	14%	0.004†	7%	17%	0.001†	13%	26%	<0.0005†
	Occasionally	17%	22%		11%	21%		17%	32%	
	Rarely	33%	24%		27%	25%		26%	23%	
	Never	20%	40%		54%	37%		45%	18%	
BP goal during clamping	% above baseline (*v* at baseline or below baseline or other choice)	57%	62%	0.558	59%	62%	0.660	62%	59%	0.483
Preferable extubation technique	% Deep extubation (*v* other choice)	6%	15%	0.100	17%	14%	0.541	14%	20%	0.054

NOTE. All other p values calculated using chi-squared analysis.

Abbreviations: BP = blood pressure; CHS, cerebral hyperperfusion syndrome.

*Calculated from two group 2-sided *t* test assuming unequal variance.

†Calculated using ordinal logistic regression.

most commonly used monitor, and now practice is much more variable, with cerebral oximetry being used as the most common neuromonitor. Neuroprotection is now used by 68% of anesthesiologists today compared with 22% of anesthesiologists in 1995, and although previously the most common method of neuroprotection, barbiturates rarely are used now.

Fellowship training seems to be a potential cause of variation in practice as well as practice location. Neuroanesthesiologists, compared with cardiac anesthesiologists, were more likely to risk stratify a patient for the development of cerebral hyperperfusion syndrome,[9,10] a rare but devastating complication after CEA that can cause hemorrhagic stroke and subsequent death. They also trended toward preferring an awake extubation. Given the focus of their subspecialty training, this is predictable, considering that neuroanesthesiologists might focus more on brain perfusion and autoregulation while cardiac anesthesiologists might focus more on cardiac perfusion and preventing myocardial ischemia. When comparing those with fellowship training to those without, the only notable difference was how often risk stratification was undertaken for cerebral hyperperfusion syndrome. This may be a reflection of patient disease or whether or not patients are taken care of in academic medical centers where risk stratification procedures can be obtained easily. Anesthesiologists practicing in the US tended to do fewer deep extubations, prefer and perform more general anesthetics, and risk stratify for cerebral hyperperfusion syndrome less often. These differences probably are based on localized training practices, but also may be reflective of surgeon preferences in the United States and elsewhere.

The limitations of this survey should be considered when interpreting the results of the survey. This survey was sent out only to those on select subspecialty anesthesiology e-mail lists, which is not representative of all anesthesiologists providing care for CEA procedures. Despite this fact, it is reasonable to predict variation in care among those not included in the survey, because such a high degree of variation was seen in those to whom the survey was sent. Also, the response rate was lower than anticipated; thus, results were interpreted assuming that the likelihood of an anesthesiologist to respond to a survey is not associated with any particular practice preference, which the authors believe to be a reasonable assumption. As surveys in anesthesiology are moving to be online instead of mail based, lower response rates are seen,[11,12] and a recent review of the online survey methodology suggests that sending reminders to complete surveys will not change the outcome of survey findings.[13] Most responders were anesthesiologists with cardiac fellowship training, but it may be true that this case is typically assigned to an anesthesiologist with cardiac fellowship training because these patients usually share similar pathophysiology to those undergoing cardiac surgical procedures. Additionally, respondents were asked in the survey if they had a particular subspecialty, and the answer to this question was used as an indicator of subspecialty training. It is likely that if a particular respondent selected a subspecialty, then they would be still often providing anesthetics in a particular specialty area and would have similar behaviors to others in the specialty. It should also be noted that this was a survey of providers' practice preferences and not patient outcomes. This data should not be used to advise anesthetic practice but, hopefully, will inspire future outcome-based studies.

Future prospective studies that focus on outcomes based on anesthetic technique likely will help decrease the observed variation in this survey. Without such evidence, it is difficult to strongly support one method of practice over another. Only well-designed research will change long-held practice preferences, but it is clear this is a topic worthy of future inquiry given the variation observed and the considerable morbidity associated with this procedure.

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