J Neurosurg 92:291–296, 2000

Clinical outcomes after carotid endarterectomy: comparison of the use of regional and general anesthetics

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Object. The authors analyzed their series of carotid endarterectomies (CEAs), which were performed after administration of either a general or regional anesthetic, to determine whether the choice of anesthetic affected patients' clinical outcomes and length of hospital stay.

Methods. A series of 803 consecutive CEAs performed between July 1990 and February 1999 was reviewed. Cases were analyzed for patient demographics, comorbid medical states, and perioperative complications. Contingency-table statistical analysis was used to compare the incidence of comorbid medical states and perioperative complications between patients who underwent CEA in which either a regional or general anesthetic was used. Student's t-test was used to compare the length of hospital stay and mean patient age.

A regional anesthetic was used for 632 CEAs, and a general anesthetic was used for 171 operations. There were no statistically significant intergroup differences in demographics or comorbid medical states. The incidence of perioperative stroke and death did not differ significantly between the regional (2.7%) and the general anesthetic groups (2.3%). However, the incidence of nonneurological, nonfatal complications was significantly less in the regional anesthetic (1.6%) than in the general anesthetic group (14 .6%, $p < 0.0001$). Patients undergoing CEA in which a regional anesthetic was used had a significantly lower incidence of cardiopulmonary complications (myocardial infarction and postoperative intubation), cervical complications (neck hematomas and cranial nerve injuries), and urological complications (urinary retention) than patients who underwent surgery after receiving a general anesthetic.

Conclusions. Patients undergoing CEA in which a regional anesthetic was used had significantly fewer nonneurological, nonfatal complications, particularly cardiopulmonary complications, than similar patients surgically treated after induction of general anesthesia.

KEY WORDS • carotid endarterectomy • regional anesthetic • general anesthetic • complication

CAROTID endarterectomy has been shown to be beneficial for stroke prevention in appropriate patients with symptomatic and asymptomatic CA stenosis if the incidence of perioperative morbidity is kept acceptably low.[4,5,11,16,18,22] Whether the use of regional anesthetics can reduce the incidence of perioperative complications in patients undergoing CEA remains controversial.[1,3,6–8,15,17,19,20] The results of metaanalysis of the literature regarding this question indicate that there is benefit from the use of regional anesthetics for CEA, but no unequivocal data are available to answer this question.[22] The purpose of this study was to examine the incidence of neurological and nonneurological complications following CEA in which a regional or general anesthetic was used.

Abbreviations used in this paper: CA = carotid artery; CEA = carotid endarterectomy; EEG = electroencephalography; ICA = internal carotid artery; MR = magnetic resonance.

Clinical Material and Methods

Patient Population

A consecutive series of patients undergoing CEA by or under the direction of the senior author (R.E.H.) between July 1990 and February 1999 were reviewed for this analysis. Retrospective chart review was used to tabulate the data from the first 232 CEAs in this series. The data from the remaining 571 procedures were collected prospectively from July 1994 through February 1999. Patient demographics, comorbid medical states, type of anesthetic used, details of the operative procedures (use of a shunt or patch grafting, clamping time, and procedure performed by resident or staff surgeon), and all perioperative complications were recorded and analyzed.

Surgical Indications

Indications for surgery included symptomatic ICA

stenosis greater than 50% and asymptomatic ICA stenosis greater than 60%. Various diagnostic modalities, including carotid duplex scanning, MR angiography, and digital subtraction angiography were used to determine the severity of ICA stenosis. Studies of the brain were obtained using computerized tomography scanning or MR imaging before CEA in symptomatic patients. Asymptomatic patients were treated in 175 (21.8%) of the procedures. The mean age of the patients was 70 years. Men composed 62.6% of the series.

Anesthetic Techniques

General Anesthetic. Patients undergoing CEA while receiving a general anesthetic were monitored during and immediately after the procedure by a registered EEG technician who used standard-array scalp EEG. The general anesthetic regimen was chosen at the discretion of the staff anesthesiologist. Pentothal was administered intravenously just prior to crossclamping until a burst-suppression pattern was reported by the technician.

Regional Anesthetic. Although a number of variations exist for inducing regional anesthesia in the neck, our anesthesiologists most commonly use the following technique. A line is drawn from the tip of the mastoid process to Chassaignac's tubercle of the sixth cervical vertebra, which can be palpated lateral to the cricoid cartilage. With the patient's head held in a neutral position, the C-4 nerve root lies deep with respect to this line at the level of the lower border of the mandible. The C-3 and C-2 nerve roots are located on the same line one third and two thirds of the distance from the C-4 landmark to the mastoid tip. A long 22-gauge needle is inserted medially and slightly caudally at these landmarks until bone is encountered. At each level 3 to 4 ml of 1% lidocaine with epinephrine is injected. Equivalent doses of bupivicaine or a mixture of the two anesthetic agents may be used if a longer lasting block is desired. The complication of lidocaine injection into the carotid or vertebral artery is avoided by using the needle for aspiration before each injection to check for blood return. Following administration of the deep cervical plexus block, 5 to 10 ml of lidocaine is injected subcutaneously along the posterior border of the sternocleidomastoid muscle approximately halfway between its origin and insertion to achieve a superficial cervical plexus block.

Judicious use of intravenously administered medications such as midazolam or lorazepam may be necessary if the patient becomes restless or excessively anxious. Rarely, profound sedation with intravenously administered propofol has been used. Early in our experience, we made the mistake of routinely subjecting patients to what we now consider to be excessive sedation. This is not only unnecessary but is often counterproductive. A fully alert and interactive patient seems better able to tolerate CEA in which a regional anesthetic is used than a patient who is somewhat incoherent from sedation.

Surgical Technique

Our surgical technique has been previously described.[10] Loupe magnification was used for dissection, endarterectomy, and vessel closure. Selective shunting was used based on changes in EEG monitoring in the general anesthetic group or changes in neurological monitoring in the regional anesthetic group. Synthetic patch grafts were used at the discretion of the senior author, under whose guidance neurosurgical residents performed 421 (52%) of the CEAs.

Clinical Outcomes

The endpoints chosen for this analysis were death due to any cause within 30 days after CEA, stroke, and cardiopulmonary, cervical, and urological complications. These categories were chosen based on our review of the charts for the first 232 patients in the series. A stroke was diagnosed for any neurological deficit, ischemic or hemorrhagic, occurring within 30 days after CEA and lasting longer than 24 hours or lasting less than 24 hours with a new lesion found on MR or computerized tomography studies. Strokes were subdivided into ipsilateral (in the vascular territory of the surgically treated CA) and other (contralateral to the surgically treated CA or in a vertebrobasilar distribution). Cardiopulmonary complications included myocardial infarction, new dysrhythmia, congestive heart failure, cardiac arrest, pneumonia, and intubation or reintubation occurring within 30 days after CEA. Cervical complications included neck hematoma requiring a return to the operating room or delay of patient discharge, cranial nerve injury (seventh, 11th, or 12th nerve palsy or patient-reported dysphasia or dysphonia at the 6-week follow-up examination), and wound infection. Urological complications included renal failure within 30 days after surgery or postoperative urinary retention that delayed patient discharge because of an indwelling catheter or the need for intermittent catheterization.

Statistical Analysis

Contingency-table analysis (Fisher's exact test or the chi-square test) was used to compare the incidence of comorbid states and adverse clinical outcomes between groups. Student's t-test was used to compare patients' mean age and postoperative length of stay between the groups. Probability values less than 0.05 were used to determine statistical significance.

Follow-Up Review

All patients were evaluated postoperatively by neurological specialists in addition to the operating surgeon (neurosurgical residents, neurological or neurosurgical nurses, and/or medical neurologists). Patients were observed until a clinical endpoint was reached or were seen at a 6-week postoperative clinic visit. Patients who did not return for clinical follow-up examination were evaluated by telephone interview with the patient or caretaker.

Results

Clinical and Operative Data

From July 1990 through February 1999, 803 CEAs were performed by or under the direction of the senior author. Of these procedures, 632 were performed after induction of cervical block regional anesthetic and 171 were performed after administration of a general anesthetic. Table 1 lists the preoperative clinical data for these two groups of patients. No statistically significant differences were found between the groups.

TABLE 1

*Clinical data in patients who underwent CEA in which a regional or general anesthetic was used**

Clinical Data	Cervical Block No. (%)	General Anesthetic No. (%)
no. of patients	632	171
mean age (yrs)	70	67.9
males	395 (63)	108 (63)†
hypertension	467 (74)	104 (61)†
ASCVD	279 (44)	96 (56)†
tobacco use	281 (44)	81 (47)†
myocardial infarction	110 (17)	28 (16)†
diabetes mellitus	185 (29)	48 (28)†
hyperlipidemia	209 (33)	52 (30)†
age >80 yrs	99 (16)	19 (11)†

* ASCVD = atherosclerotic coronary vascular disease.
† Not significant ($p > 0.05$).

TABLE 2

Perioperative stroke and death in patients who underwent CEA in which a regional or general anesthetic was used

Complication	No. of Patients (%)	
	Cervical Block (632 patients)	General Anesthetic (171 patients)
ipsilat stroke	13 (2.1)	3 (1.8)*
other strokes	2 (0.3)	1 (0.6)*
all strokes	15 (2.4)	4 (2.3)*
deaths	2 (0.3)†	0 (0.0)*
all strokes & death	17 (2.7)	4 (2.3)*

* Not significant ($p > 0.05$).
† One case of fatal perioperative stroke and one case in which death occurred 3 weeks postoperatively as a result of mesenteric ischemia.

Complications From Regional Anesthetic

Complications related to the use of a regional anesthetic developed in four (0.6%) of 632 patients. Early in the series, one patient in the regional anesthetic group required conversion of regional to general anesthetic because of severe agitation. Another patient required placement of a laryngeal mask and propofol sedation for agitation. In two cases surgery had to be delayed for several hours because of changes in patients' mental status secondary to injection of a local anesthetic agent into the vertebral artery. These complications did not result in any incidence of morbidity or delay in hospital discharge in any of these patients.

Incidence of Stroke Morbidity and Mortality

There was no statistically significant difference in the incidence of perioperative stroke or perioperative death between the two groups (Table 2). The overall stroke rates in the general anesthetic group and the regional anesthetic group were 2.3% and 2.4%, respectively. The combined stroke plus perioperative mortality rates were also similar: 2.3% for the general anesthetic group and 2.7% for the regional anesthetic group.

Nonneurological Complications

Nonneurological, nonfatal complications are listed in Table 3. Cardiopulmonary, cervical, and urological complications occurred significantly more frequently in the general anesthestic group than in the regional anesthetic group. The incidences of perioperative myocardial infarction, postoperative intubation or reintubation, clinically relevant neck hematomas, cranial nerve injuries, and urinary retention were all statistically significantly greater in the group of patients who underwent CEA after receiving a general anesthetic. The overall incidence of nonneurological, nonfatal perioperative complications in the general anesthetic group (14.6%) was much higher than that in the regional anesthetic group (1.6%, $p < 0.0001$). The occurrence of a perioperative complication (stroke, death, or nonneurological complication) was almost four times as common in patients who underwent CEA after induction of general anesthesia (general anesthetic group 29 complications [17%], regional anesthetic group 27 complications [4.3%]; $p < 0.0001$).

Time to Hospital Discharge

The mean time to hospital discharge after CEA was significantly shorter in the regional anesthetic group (1.25 days) than in the general anesthetic group (3.48 days). The majority (84.2%) of patients who underwent CEA in which a regional anesthetic was used were discharged fewer than 24 hours after the procedure (Table 4).

Discussion

We have had extensive experience performing CEA with both general and regional anesthetics. The senior author was trained to perform CEA with general anesthetics and intraoperative EEG monitoring and continued to perform all CEAs while using these methods for more than 7 years following completion of residency training. Starting in October 1992, occasional patients who were thought to be at high risk from a general anesthetic because of severe cardiopulmonary disease underwent surgery in which a regional anesthetic was used. The smooth postoperative course in these patients generated an interest in a broader application of regional anesthetics and resulted in an increasing percentage of patients undergoing CEA while receiving a cervical block anesthetic agent. At present we perform all CEAs by using this technique. It was our perception that the choice of anesthetic agent had not greatly affected the incidence of stroke and death following CEA, but that regional anesthetics were associated with a lower incidence of perioperative complications and quicker postoperative recovery. The purpose of this study was to examine the effects of the anesthetic regimen on perioperative complications following CEA.

Incidences of Stroke Morbidity and Mortality

It has been demonstrated in many clinical studies that CEA can be performed with a low perioperative risk of stroke and death,[4,5,11,16,18] and there is no compelling evidence to indicate that the type of anesthetic used for CEA has an effect on the incidence of perioperative stroke morbidity or mortality.[1,3,6–8,14,15,17,18,20–23] For example, in a retrospective study conducted by Allen and colleagues,[1] in which 361 CEAs performed after administration of a general anesthetic and 318 performed after a cervical block anesthetic were compared, no statistically significant difference was found in the incidence of stroke and death between the groups. This concurs with our analysis.

TABLE 3

*Nonneurological, nonfatal perioperative complications in patients who underwent CEA in which a regional or general anesthetic was used**

Complication	No. of Patients (%)	
	Cervical Block (632 patients)	General Anesthetic (171 patients)
total cardiopulmonary	7 (1.1)	11 (6.4)†
myocardial infarction	2 (0.3)	3 (1.8)‡
postop CHF	2 (0.3)	1 (0.6)
postop intubation	1 (0.2)	4 (2.3)‡
pneumonia	0	2 (1.2)
cardiac arrhythmia	1 (0.2)	1 (0.6)
cardiac arrest	1 (0.2)	0
total cervical	3 (0.5)	8 (4.7)§
neck hematoma	2 (0.3)	4 (2.3)‡
wound infection	0	1 (0.6)
cranial nerve injury	1 (0.2)	3 (1.8)‡
total urological	0	6 (3.5)§
renal failure	0	1 (0.6)
urinary retention	0	5 (2.9)§
total complications	10 (1.6)	25 (14.6)†

* CHF = congestive heart failure.
† $p < 0.0001$.
‡ $p < 0.05$.
§ $p < 0.001$.

TABLE 4

Length of postoperative hospital stay for patients who underwent CEA in which a regional or general anesthetic was used

Discharge Data	No. of Patients (%)	
	Cervical Block (632 patients)	General Anesthetic (171 patients)
mean time to discharge (days)	1.25	3.48*
<24 hrs	532 (84.2)	43 (25.1)*
24–48 hrs	53 (8.4)	55 (32.2)*
>48 hrs	47 (7.4)	73 (42.7)*

* $p < 0.0001$.

Cardiopulmonary Complications

Our analysis did confirm our perception that the use of a regional anesthetic was associated with significantly fewer nonneurological complications, particularly cardiopulmonary complications. A reduction in cardiopulmonary complications as a result of using a regional anesthetic has been reported in previous studies.[1,7,10,17,20] In a multivariate analysis of patients who underwent CEA, the use of a general anesthetic, patient age older than 75 years, and operative time longer than 3 hours were all associated with cardiopulmonary complications after CEA.[1]

In the classic paper by Sundt, et al.,[21] on the assessment of risk in patients undergoing CEA in which a general anesthetic was used, the authors evaluated the effects of medical, neurological, and angiographic risk factors on the incidence of perioperative morbidity and mortality. Based on these factors, the authors retrospectively stratified patients into four groups. Their Group 3 was composed of patients with major medical risk factors. Six complications occurred in this group, providing a morbidity/mortality rate of 7%; however, five of these six complications were myocardial infarctions. Comorbid medical states, therefore, substantially increased the risk of myocardial infarction following CEA, but they did not increase the risk of stroke. The incidence of stroke in the series of Sundt, et al., is similar to the incidence in our series. The risk of perioperative myocardial infarction in their series (1.5%) was similar to the incidence in our general anesthetic group (1.8%), but was five times the incidence found in our regional anesthetic group (0.3%). We believe that it is in the group of patients with major medical risk factors that the use of a regional anesthetic offers the greatest benefit by decreasing the risk of perioperative cardiopulmonary morbidity resulting from CEA.[15]

Cervical Complications

We documented significantly fewer cranial nerve injuries in the regional anesthetic group. It is difficult to determine if this is due to the choice of anesthetic technique or increasing surgical experience because the regional anesthetic cases came later in the series. We have noted, however, that the use of a regional anesthetic allows somewhat better high-cervical exposure because the presence of an oral endotracheal tube requires depression of the mandible. It has been suggested that in patients with a high carotid bifurcation, nasotracheal intubation should be considered to avoid exposure problems caused by opening the mouth. A regional anesthetic can be used to accomplish the same goal.

A decreased incidence of clinically significant neck hematomas was also found in the regional anesthetic group. Once again, it is impossible to say with certainty whether this is because of our increased surgical experience or the choice of anesthetic, but we believe it is the latter. In our experience patients undergoing CEA after receiving a general anesthetic frequently cough violently in response to extubation. In addition, control of blood pressure is more difficult to achieve immediately after using a general anesthetic technique than after a regional anesthetic technique in these patients.[3] We speculate that the combination of the Valsalva effect associated with coughing and perioperative hypertension was responsible for the increased incidence of neck hematomas in patients undergoing CEA after receiving a general anesthetic. Early in the series (that is, during the period in which general anesthetics were used) it was the senior author's practice to reverse the effects of intraoperative heparin therapy by intravenously administering protamine at the end of surgery. This was not done for the majority of patients receiving a regional anesthetic agent. Despite this, the incidence of clinically significant neck hematomas was lower in the group treated later.

Urological Complications

One urological complication, urinary retention, occurred less frequently in the regional anesthetic group. We did not include patients in the analysis who required a single catheterization because of immediate postoperative urinary retention, but only those patients in whom discharge was delayed because of this problem. Although this complication does not result in persistent morbidity, it did contribute to a delay in hospital discharge for almost 3% of patients undergoing CEA after receiving a general anesthetic. The mean

age of our patients who underwent CEA was 70 years and more than 60% of the procedures were performed in men. Because urinary retention following induction of general anesthesia is a common surgical problem for elderly men, the population of patients requiring CEA represents a high-risk group for postoperative urinary retention.

Incidence of Perioperative Morbidity

As previously noted, because patients who received regional anesthetic agents were treated later in the series than those receiving general anesthetic agents, it is possible that greater surgical experience was responsible for the decreased incidence of morbidity in the regional anesthetic group. We do not think that this is the case, for the following reasons. The senior author had considerable experience with CEA before this series started and the perioperative stroke rate, the indicator that should be most sensitive to improved surgical technique, did not change over the course of the study. The decreased rate of morbidity was due primarily to fewer nonneurological complications, particularly cardiopulmonary complications, as the series progressed. We think this is unlikely to be a result of improved surgical technique. Having now had considerable experience in performing CEA in patients in whom regional and general anesthetics were used, it is our opinion that the nonneurological complications associated with this operation are primarily the result of the use of general anesthetic agents and can be reduced by the use of regional anesthetics. It must be stressed that this is only an opinion and a prospective, randomized study would be needed to document this in a scientifically rigorous fashion.

Time to Hospital Discharge

We also demonstrated a statistically significant decrease in the mean time to hospital discharge, from 3.48 days in the general anesthetic group to 1.25 days in the regional anesthetic group. Longer hospitalization may be due, in large part, to the fact that the patients in whom a general anesthetic was used were treated earlier in the series than the patients in whom a regional anesthetic was used. Earlier in the series, the socioeconomic pressures for earlier discharge were not as great as they have been recently. The greater incidence of perioperative morbidity in the general anesthetic group also contributed to the delay in discharge. Perioperative myocardial infarction, reintubation, clinically significant neck hematomas, and urinary retention all contribute to a longer hospital stay and all occurred significantly more frequently in the general anesthetic group. We realize that many patients undergoing CEA after receiving a general anesthetic can be discharged the next day and that managed care has had a profound impact on the length of hospital stay following many surgical procedures. It should be noted, however, that the results of other CEA series have also shown significant decreases in length of stay with the use of regional anesthetics.[1,7,17,19,20]

Cost Effectiveness

With more than 100,000 CEAs being performed annually in the United States, the economic implications of decreasing the rate of perioperative morbidity and the length of hospital stay following this procedure are considerable. Various authors have reported a reduction in hospital charges associated with the use of a regional anesthetic for CEA.[2,12] In a previous report, we demonstrated a greater than 40% reduction in hospital charges for CEA as a result of changing our perioperative regimen, which included a shift from general to regional anesthetics.[8,9]

Resident Training

The use of a regional anesthetic for CEA in this series was accomplished without compromising resident surgical training. Resident surgeons continued to perform approximately the same percentage of CEAs throughout the study period. Of the 171 surgeries performed while using a general anesthetic, 91 (53.2%) were performed by neurosurgical residents. Residents performed 330 (52.2%) of the 632 CEAs in the regional anesthetic group. The use of a regional anesthetic did not limit intraoperative teaching.

Incidence of Morbidity in Symptomatic Patients

Initially in this series, regional anesthetic agents were used in patients undergoing CEA, based on the presence of severe cardiopulmonary disease. However, the overall demographics and incidence of comorbid medical states in patients undergoing CEA after induction of regional anesthesia were very similar to these variables in the general anesthetic group. Patient selection did change after publication of results indicating a benefit from CEA in asymptomatic patients.[5,11] Early in this series, we rarely performed CEA in patients without symptoms of retinal or hemispheric ischemia. Since 1995 approximately 25% of our patients have had severe, asymptomatic ICA stenosis. Because more asymptomatic patients were surgically treated later in the series, when we were using regional anesthetic agents for all patients, we also focused on symptomatic patients who underwent CEA and compared the incidence of complications in the regional and general anesthetic groups. As was observed for the entire series, there was no significant difference in the incidence of perioperative stroke and death between the two groups, and the statistically significant increase in nonneurological, nonfatal, perioperative complications in cases in which a general anesthetic was used persisted when analysis was restricted to symptomatic patients.

Role of Regional Anesthetics in CEA

Patients who undergo CEA are frequently elderly, frail individuals with numerous medical problems and complex medical regimens. Our goal is to make surgery as minimally disruptive to their normal routines as possible. The CEA is a brief operation with minimal blood loss and a relatively superficial surgical target. By using a regional anesthetic and mobilizing the patient immediately postoperatively, CEA can be a minimally disruptive procedure. We believe that the risks inherent in the use of general anesthetic agents and invasive monitoring may be greater than the risks of the surgical procedure per se for many patients undergoing CEA.

It has been suggested that CA angioplasty and stent insertion may be more appropriate than CEA for patients

with significant comorbid medical states, advanced age, or contralateral ICA occlusion.[13] We believe that any benefit that may accrue from the use of angioplasty and stent placement in these high-risk patients may well be due to the routine use of a local anesthetic for endovascular carotid procedures. In another publication, we reported that the presence of comorbid medical states, advanced age, and contralateral ICA occlusion did not increase the risk of perioperative complications in our series of patients who underwent CEA in which a regional anesthetic was used.[15] At present, we reserve CA angioplasty and stent insertion for those patients with a surgically inaccessible stenosis (skull base or proximal common CA) and some patients in whom a previous ipsilateral CEA was performed, in whom we believe that the risk of cranial nerve injury is greater with operation and the risk of embolic complications with endovascular treatment is reduced.

Conclusions

Our analysis of a consecutive series of 803 CEAs demonstrates that the use of a regional anesthetic can reduce the incidence of perioperative complications associated with this procedure. Fewer nonneurological, nonfatal perioperative complications and rapid mobilization of patients who have undergone CEA results in earlier hospital discharge and a considerable decrease in resource utilization for these patients. In a highly competitive market these features are becoming increasingly important.

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Manuscript received June 17, 1999.
Accepted in final form October 5, 1999.
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