# A comparison of regional and general anesthesia in patients undergoing carotid endarterectomy

Caron B. Rockman, MD, Thomas S. Riles, MD, Mark Gold, MD, Patrick J. Lamparello, MD, Gary Giangola, MD, Mark A. Adelman, MD, Ronnie Landis, RN, and Anthony M. Imparato, MD, *New York, N.Y.*

*Purpose:* The optimal anesthetic for use during carotid endarterectomy is controversial. Advocates of regional anesthesia suggest that it may reduce the incidence of perioperative complications in addition to decreasing operative time and hospital costs. To determine whether the anesthetic method correlated with the outcome of the operation, a retrospective review of 3975 carotid operations performed over a 32-year period was performed.
*Methods:* The records of all patients who underwent carotid endarterectomy at our institution from 1962 to 1994 were retrospectively reviewed. Operations performed with the patient under regional anesthesia were compared with those performed with the patient under general anesthesia with respect to preoperative risk factors and perioperative complications.
*Results:* Regional anesthesia was used in 3382 operations (85.1%). There were no significant differences in the age, gender ratio, or the rates of concomitant medical illnesses between the two patient populations. The frequency of perioperative stroke in the series was 2.2%; that of myocardial infarction, 1.7%; and that of perioperative death, 1.5%. There were no statistically significant differences in the frequency of perioperative stroke, myocardial infarction, or death on the basis of anesthetic technique. A trend toward higher frequencies of perioperative stroke (3.2% vs 2.0%) and perioperative death (2.0% vs 1.4%) in the general anesthesia group was noted. In examining operative indications, however, there was a significant increase in the percentage of patients receiving general anesthesia who had sustained preoperative strokes when compared with the regional anesthesia patients (36.1% vs 26.4%; $p < 0.01$). There was also a statistically significant higher frequency of contralateral total occlusion in the general anesthesia group (21.8% vs 15.4%; $p = 0.001$). The trend toward increased perioperative strokes in the general anesthesia group may be explicable either by the above differences in the patient populations or by actual differences based on anesthetic technique that favor regional anesthesia.
*Conclusions:* In a retrospective review of a large series of carotid operations, regional anesthesia was shown to be applicable to the vast majority of patients with good clinical outcome. Although the advantages over general anesthesia are perhaps small, the versatility and safety of the technique is sufficient reason for vascular surgeons to include it in their armamentarium of surgical skills. Considering that carotid endarterectomy is a procedure in which complication rates are exceedingly low, a rigidly controlled, prospective randomized trial may be required to accurately assess these differences. (J Vasc Surg 1996;24:946-56.)

From the Division of Vascular Surgery, Department of Surgery, and the Department of Anesthesiology (Dr. Gold), New York University Medical Center.
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Reprint requests: Thomas S. Riles, MD, Department of Surgery, New York University Medical Center, 530 First Ave., Suite 6F, New York, NY 10016.

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The choice of anesthetic for use during carotid endarterectomy has remained a matter for debate for more than three decades. The techniques of local and cervical-block anesthesia for carotid surgery have been described and used since before 1962.[1] The initial reason for using regional or local anesthesia rather than general anesthesia at our institution in 1962 was to observe the neurologic status of the patient during carotid clamping. The observation that a small but significant group of patients were

intolerant to clamping of the internal carotid artery, and who therefore required a shunt for cerebral protection during the endarterectomy, led to a dilemma for those surgeons who were more comfortable performing carotid surgery with the patient under general anesthesia. To ensure that unconscious patients would not have a stroke while the operation was being performed, one of two methods could be used: a shunt could be used routinely, or some monitoring technique could be used to differentiate patients who are at risk for cerebral ischemia so that a shunt could therefore be used selectively. Regional anesthetic was an essential tool to aid in the evaluation of various cerebral monitoring techniques and protective measures.[2] However, as experience grew with carotid shunting and with cerebral monitoring with the patient under general anesthesia, some investigators concluded that keeping the patient awake was unnecessary in most cases.[3]

Although advocates of one technique or another often use perioperative stroke and mortality rates to support their positions, it has become increasingly clear that these complications are more often related to causes other than clamping ischemia, and include postoperative thrombosis at the endarterectomy site, intraoperative embolization, and reperfusion injuries.[2,4] The causes of perioperative stroke have been analyzed in detail at our institution, and only 15% of all perioperative strokes have been found to be definitively related to cerebral ischemia during clamping. Because the inability to directly monitor the patient's neurologic status during clamping is obviously related to the anesthetic method used, presumably only those strokes that are caused specifically by clamping ischemia should vary with the anesthetic route. Nonetheless, experienced surgeons at major centers for carotid surgery have demonstrated excellent results both with general and with regional anesthesia. With perioperative complication rates of less than 2.0% becoming the standard, comparisons using stroke and death as the endpoints would only be meaningful with thousands of patients being randomized and prospectively studied.

Regional anesthesia has been the preferred technique when performing carotid endarterectomy at our institution for more than 30 years.[4] Over the past 32 years, we have used regional anesthesia in 3382 carotid operations. Although this represents the majority of the carotid operations performed during this time (85.1%), another 593 operations were performed under general anesthesia. Recently there has been a renewed focus on regional anesthesia for additional reasons. As regional anesthesia has come to be preferred for lower extremity vascular reconstruction, several other investigators have argued that this technique for carotid endarterectomy will similarly decrease operative time, length of hospital stay, and hospital costs, issues that have achieved increased attention in current times. In light of the recent resurgence of interest in regional anesthesia, we believed it was timely again to review our experience with this technique, to compare it with our experience with general anesthesia, and to determine whether the choice of anesthetic technique was a factor in the outcome of the operation. For these purposes, a retrospective review of all carotid artery surgeries performed at our institution from 1962 to 1994 was undertaken.

## PATIENTS AND METHODS

From the computerized database compiled on all patients who undergo cerebral vascular surgery in the Division of Vascular Surgery of the New York University Medical Center, the records of all patients who underwent carotid surgery from 1962 to 1994 were reviewed. During this period, 3975 operations were performed. Operations performed on the awake patient were compared with those performed with the patient under general anesthesia with respect to postoperative complications, including perioperative stroke, myocardial infarction, and death. Perioperative stroke was defined as any new neurologic deficit that appeared in the perioperative period, whether transient or permanent, that was accompanied by either a new infarction appearing on a computed tomographic scan of the brain, a positive angiographic finding, or a duplex scan result that required reoperation, or a positive reexploration of the carotid artery that required revision. Any permanent neurologic deficit that appeared in the perioperative period was considered to be a perioperative stroke even if none of the above qualifications proved to be true. Patients who had perioperative myocardial infarction were defined as any patient who had any clinical symptoms consistent with myocardial infarction accompanied by appropriate electrocardiogram findings or cardiac enzyme increases. The two patient populations were compared with respect to preoperative risk factors, including age, gender, coronary artery disease, hypertension, smoking history, diabetes mellitus, and preoperative symptoms. A patient was considered to have coronary artery disease if there was any history of myocardial infarction, coronary artery bypass grafting, anginal symptoms, or an abnormal preoperative stress test or cardiac catheterization.

**Table I.** Comparison of regional and general anesthesia

| | *General anesthesia (N = 593)* | *Regional anesthesia (N = 3382)* | | *All operations (N = 3975)* |
|---|---|---|---|---|
| Patient characteristics | | | | |
| Age (mean ± SD) | 66.1 ± 9.6 years | 65.6 ± 8.8 years | NS | 65.7 ± 9.0 years |
| Coronary artery disease | 44.2% | 44.8% | NS | 44.7% |
| Diabetes mellitus | 20.1% | 20.3% | NS | 20.2% |
| Smoking | 48.7% | 48.2% | NS | 48.3% |
| Hypertension | 55.9% | 54.8% | NS | 55.0% |
| Asymptomatic | 17.3% | 18.0% | NS | 17.9% |
| Transient ischemic attack | 46.6% | 55.6% | $p < 0.001$ | 54.4% |
| Stroke | 36.1% | 26.4% | $p < 0.001$ | 27.7% |
| Contralateral occlusion | 21.8% | 15.4% | $p < 0.001$ | 16.3% |
| Postoperative complications | | | | |
| Perioperative stroke | 3.2% | 2.0% | NS | 2.2% |
| Perioperative myocardial infarction | 1.7% | 1.7% | NS | 1.7% |
| Perioperative mortality rate | 2.0% | 1.4% | NS | 1.5% |

The determination of which type of anesthetic to use in an individual patient was made before surgery in all cases by the best judgment of the operating surgeon, with input from both patient, anesthesiologist, or both, when appropriate. In the earlier years of this experience (approximately 1962 through 1987), general anesthesia was used most often in patients who did not tolerate carotid clamping under the regional anesthetic. More specifically, general anesthesia was nearly always used if convulsive movements developed with test clamping of the internal carotid artery; these would clearly complicate the management of shunt insertion. In the later years of this experience (approximately 1987 through 1994), general anesthesia was most often selected for patients who were considered to have relative indications for prophylactic intraarterial shunting, most commonly a recent previous ipsilateral stroke, occlusion of the contralateral carotid artery, or both. General anesthesia has also been chosen when it was believed that a patient would not be able to cooperate with instructions under regional anesthesia. All patients who required general anesthetic underwent operation with an empirically placed intraarterial shunt. All awake patients who demonstrated signs of ischemia with test clamping of the internal carotid artery (convulsions, loss of consciousness, aphasia, extremity weakness, confusion, or slowing of mentation) were selectively treated with intraarterial shunting during endarterectomy. Patients whose procedures were converted from regional anesthesia to general anesthesia during the course of the operation were included in the general anesthesia group for data analysis.

All data were analyzed by means of the statistical software package SPSS (SPSS Inc., Chicago, Ill.). Categoric variables between the two groups were compared using the $\chi^2$ test or Fisher's exact test, when appropriate. A result was considered significant with a $p$ value less than 0.05.

## RESULTS

Of the 3975 carotid endarterectomies performed, regional anesthesia was used in 3382 (85.1%). The remaining 593 operations were performed with the patient under general anesthesia (14.9%). Regional anesthesia was used in 86.9% of patients who underwent surgery for asymptomatic high grade stenosis, 88.4% of patients who had preoperative transient ischemic attacks, and 82.4% of patients who had preoperative strokes.

An analysis was also performed after breaking down the entire set of operations into three subgroups to examine recent trends: operations performed from 1962 to 1974 (n = 566), from 1975 to 1984 (n = 1646), and 1985 to 1994 (n = 1763). The percentage of operations performed with the patient under regional anesthesia in each of these subgroups was 89.4%, 88.6%, and 80.2%, respectively.

**Patient characteristics and risk factors.** Patients who underwent surgery under regional anesthesia were compared with those who received general anesthesia with respect to preoperative risk factors. There were no significant differences in the incidences of hypertension, coronary artery disease, diabetes mellitus, smoking history, or age of these two populations (Table I).

**Symptoms and indications for surgery.** Among operations performed with the patient under regional anesthesia, the indications for surgery were asymptomatic high-grade stenosis in 18%, transient

**Table II.** Analysis of perioperative complications under regional and general anesthesia by year of operation

| | *1962 to 1974 (566 operations)* | | *1975 to 1984 (1646 operations)* | | *1985 to 1994 (1763 operations)* | |
|---|---|---|---|---|---|---|
| | Regional (89.4%) | General (10.6%) | Regional (88.6%) | General (11.4%) | Regional (80.2%) | General (19.8%) |
| Perioperative stroke | 2.8% | 1.7% | 2.5% | 3.2% | 1.2% | 3.2% |
| Perioperative myocardial infarction | 3.0% | 6.7% | 2.4% | 1.1% | 0.6% | 1.2% |
| Perioperative mortality rate | 3.2% | 5.0% | 1.3% | 3.2% | 0.9% | 0.9% |
| | $p$ = NS | | $p$ = NS | | $p < 0.01$ for perioperative stroke, $p$ = NS for perioperative myocardial infarction and mortality | |

ischemic attacks in 55.6%, and preoperative stroke in 26.4%. Of procedures performed with the patient under general anesthesia, the indications for surgery were asymptomatic high-grade stenosis in 17.3%, transient ischemic attacks in 46.6%, and preoperative strokes in 36.1%. There was a statistically significant increase in the proportion of patients who received general anesthesia for which the surgical indication was stroke when compared with the regional anesthesia cases (36.1% vs 26.4%, $p < 0.001$). Conversely, there was a corresponding decreased percentage of patients who received general anesthesia for which the surgical indication was a transient ischemic attack (46.6% vs 56.6%, $p < 0.001$). The number of procedures performed for asymptomatic high-grade stenosis in each group was nearly equivalent (17.3% vs 18.0%, $p$ = NS). There was, in addition, a statistically significant higher frequency of contralateral total occlusion in the general anesthesia group (21.8% vs 15.4%, $p = 0.001$; Table I). These findings are consistent with the fact that general anesthesia was often selected when a patient had strong indications for prophylactic shunting, that is, a prior recent ipsilateral stroke or total occlusion of the contralateral carotid artery.

**Postoperative complications and outcome.** The overall frequencies of complications were perioperative stroke in 2.2%; myocardial infarction in 1.7%; and death in 1.5%. There were differences in the frequency of perioperative stroke and death on the basis of anesthetic technique, although these were not statistically significant. A trend was noted toward higher incidences of perioperative stroke (3.2% vs 2.0%) and perioperative death (2.0% vs 1.4%) in the general anesthesia group (Table I).

The entire group was again broken down into three subgroups on the basis of the year of operation (1962 to 1974, 1975 to 1984, and 1985 to 1994). In the earliest subgroup (1962 to 1974, N = 566) the incidence of perioperative strokes among cases performed under general anesthesia was 1.7% compared with 2.8% under regional anesthesia; this was not statistically significant. The opposite trend prevailed in the later two subgroups. In the middle subgroup (1975 to 1984, N = 1646) the incidence of perioperative strokes among cases performed under general anesthesia was 3.2% compared with 2.5% under regional anesthesia; this again was not statistically significant. In the last 10 years (1985 to 1994), however, there was a statistically higher incidence of perioperative stroke in the cases that received general anesthesia (3.2% vs 1.2%, $p < 0.01$). There were no statistically significant differences in the rates of postoperative death or myocardial infarction in any of these subgroups (Table II).

Because of the significantly increased stroke rate under general anesthesia in the last 10 years, these cases were analyzed in greater detail. In this most recent subgroup, 33.1% of the patients had a history of preoperative stroke and 21.7% of the patients had total occlusion of the contralateral carotid artery. Therefore, it appears that the patient population who underwent surgery under general anesthesia over the past 10 years was not different from the general anesthesia patients in the entire series with respect to these two specific risk factors (Table I). Patients who had both a history of preoperative stroke and contralateral total occlusion comprised 5.7% of this subgroup. Of the 11 perioperative strokes that occurred in this period under general anesthesia, five were in patients who had a history of perioperative stroke, one in a patient who had contralateral total occlusion, and one in a patient who had both a preoperative stroke and contralateral total occlusion. Patients during this period who had a history of preoperative stroke and who underwent surgery under general

anesthesia did not have a significantly increased perioperative stroke rate when compared with patients who had a preoperative stroke and underwent surgery under regional anesthesia (6.9% vs 2.3%, $p = 0.08$, Fisher's two-tailed exact test).

**Frequency of selective shunting.** An intraarterial shunt was used in 372 (11.0%) of the operations that were performed with the patient under regional anesthesia. In 339 of these cases (91%), for an overall incidence of 10.0%, the shunt was placed because the patient demonstrated signs of cerebral ischemia during test clamping of the internal carotid artery. In the remaining 33 operations (9.0%), for an overall incidence of 1.0%, the shunt was placed empirically in patients who had contraindications to or strong reservations regarding the use of general anesthesia, but who were thought to require prophylactic intraarterial shunting for the reasons mentioned previously.

**Factors affecting perioperative stroke rate.** Univariate analysis was performed for the following factors to see whether they had any significant effect on the perioperative stroke rate: the method of anesthesia, gender, coronary artery disease, diabetes, hypertension, smoking history, contralateral total occlusion, and preoperative stroke. When this analysis was performed for the entire 32-year series, only hypertension ($p < 0.02$) and a history of preoperative stroke ($p < 0.001$) were found to be associated with perioperative stroke. The use of a general anesthetic was nearly statistically significant in this regard ($p = 0.057$). These three factors were then entered into a multivariate analysis, which identified only a history of preoperative stroke as an independent predictor of perioperative stroke. A similar analysis was performed for the most recent 10-year period (1985 through 1994). By univariate analysis in this subgroup, the use of a general anesthetic ($p < 0.02$) and a history of preoperative stroke ($p < 0.01$) were found to be significantly associated with perioperative stroke. A multivariate analysis was again performed, which once more identified only a history of preoperative stroke to be independently associated with perioperative stroke.

## DISCUSSION

Observing the neurologic status of conscious patients was originally adapted at our institution as a means of evaluating monitoring and protective techniques as they were described and introduced over the past three decades.[5-8] Although excellent results have been achieved with general anesthesia and a variety of monitoring approaches, historically no single technique has correlated well with the neurologic status of the conscious patient.[5-8] All of the direct methods (electroencephalography, evoked potential responses) and indirect methods (carotid stump pressure, transcranial Doppler ultrasound, jugular venous oxygen tension) of detecting cerebral ischemia during carotid clamping have been found at one time or another to lack either sensitivity or specificity when compared with the neurologic status of the awake patient. Electroencephalography, for example, may lead to as high as a 20% to 25% incidence of intraluminal shunting[5]; the rate of selective shunting in a similar population of conscious patients is reported as low as 7%.[2] Conversely, perioperative strokes have clearly occurred in the absence of any electroencephalographic changes. Performing carotid endarterectomy with the patient under local or regional anesthesia has also provided invaluable lessons regarding the efficacy of various practices that have been hypothesized to provide cerebral protection, such as induced hypertension, carbon dioxide inhalation, acetazolamide administration, hypothermia, and general anesthesia itself. The technique of carotid intraluminal shunting, conceivably the ultimate protective mechanism against clamping ischemia, was also originally evaluated and perfected through knowledge acquired from operating on the awake patient. Perhaps most importantly, operating on the conscious patient has allowed accurate differentiation between the various mechanisms of perioperative stroke, especially the distinction between clamping ischemia and nonspecific cerebral embolization.[2,5-8]

In their enthusiasm to defend or oppose the use of regional anesthesia for carotid surgery, many authors have looked at perioperative complications as a measure to compare. Advocates have reasoned that among several advantages of regional anesthesia, neurologic complications should be less frequent, because with regional anesthesia the need for shunting can be most accurately assessed.[2,5-22] In addition, patients who have coronary and pulmonary disease should presumably fare better without endotracheal intubation and general anesthesia. Of nine reports in the literature that specifically compare local or regional anesthesia with general anesthesia for carotid surgery,[14-22] six found no differences in perioperative strokes or death on the basis of anesthetic technique (Table III).[14-16,19,21,22] However, two reports did detect an increased rate of perioperative stroke in the general anesthesia group.[17,20] Three studies revealed an increased incidence of cardiopulmonary complications or myocardial infarction in patients who undergo surgery under general anesthesia.[14,18,21] Most dramatically, Peitzman et al.[18] demonstrated a signif-

**Table III.** Reports comparing loco-regional with general anesthesia

| *Series* | *No. of general cases* | *No. of regional cases* | *Significant results* |
|---|---|---|---|
| Shah et al. 1994[22] | 419 | 654 | No difference in perioperative strokes or mortality rates |
| Allen et al. 1994[14] | 361 | 318 | Decreased operative time, cardiopulmonary complications and hospitalization time in regional group, no difference in perioperative strokes or mortality rates |
| Becquemin et al. 1991[21] | 242 | 145 | Higher incidence of perioperative myocardial infarction in general group, no difference in perioperative strokes or mortality rate |
| Bergeron et al. 1991[20] | 250 | 106 | Increased perioperative strokes in general group |
| Corson et al. 1987[17] | 242 | 157 | Increased perioperative strokes in general group, also increased hemodynamic instability and intersive care unit stay |
| Muskett et al. 1986[15] | 45 | 30 | Increased hospitalization with general anesthesia, no difference in postoperative complications |
| Gabelman et al. 1983[16] | 46 | 54 | Decreased intersive care unit stay, hospitalization, and hospital charges in regional group; no difference in perioperative strokes or mortality rates |
| Peitzman et al. 1981[18] | 62 | 252 | Increased non-neurologic complications in general anesthesia group |
| Andersen et al. 1980[19] | 189 | 232 | No difference in perioperative strokes or mortality rates |

icantly increased incidence of non-neurologic complications among those patients who received general anesthesia when compared with those who received regional anesthesia (12.9% vs 2.8%). These findings are in conflict with those of several excellent large series reported in the literature that demonstrate equally low neurologic and cardiopulmonary complication rates with general anesthesia, using various forms of intracerebral monitoring.[23-27]

One obvious pitfall that is inherent in performing a retrospective analysis of clinical data that spans a 32-year period is that it does not consider the many changes, some drastic, in the diagnosis, the surgical technique, and the indications for performing carotid surgery during these three decades. Certainly there are many variables that we cannot completely account for in this broad analysis, and therefore the conclusions drawn from this data must reflect this fact. Only a randomized prospective trial could absolutely determine the small, but possibly clinically significant, differences between regional and general anesthesia.[28]

In our current series the risk of myocardial infarction was identical between the two anesthetic groups. A trend toward increased perioperative mortality rates was noted in the general anesthesia group (2.0% vs 1.4%), although this increase did not reach statistical significance. The same was true of perioperative strokes (3.2% vs 2.0%) over the entire 32-year period. In the most recent 10 years (1985 to 1994), however, the difference in perioperative strokes between the two anesthetic groups did reach statistical significance (3.2% vs 1.2, $p < 0.01$). Unfortunately, it is evident that the two patient populations did not have equivalent risk factors; those who underwent surgery under general anesthesia appear to be a group at an increased risk for perioperative stroke, having a higher incidence of contralateral total occlusion (21.8% vs 15.4%, $p < 0.001$) and stroke as the indication for surgery (36.1% vs 26.4%, $p < 0.001$). Although it is possible that the differences found are a result of the anesthetic method used, the significant differences in the risk factors of the patient populations are likely at least partially responsible for the higher incidence of perioperative stroke found with operations performed with the patient under general anesthesia.

To explain the higher complication rate with general anesthesia in recent years entirely on the selection of patients may, however, be overly simplistic. Likewise, to conclude that in earlier years there was no significant difference between the techniques may be open to criticism. Because the overall incidence of complications is very low, in some instances the outcome of a single case may determine the statistical significance. Without a detailed analysis of the causes of the complications, it is hazardous to assume that the choice of anesthetic was the only determining factor.

With respect to other significant topics, the operative time, cost, and length of stay were not specifically examined in this series, although it has been our impression that regional anesthesia certainly does not increase the operative time. Although we are aware that data regarding these issues would be important, especially in the managed care era, there have been too many changes, alluded to above, in the management of carotid artery stenosis over this lengthy period to make this information meaningful. Patients no longer undergo extensive inpatient preoperative

evaluation including cerebral arteriographic evaluation, the great majority are currently admitted the morning of surgery, and most are discharged the second morning after surgery; these critical transformations have transpired over the last several years alone. Because of these discrepancies, we chose to focus this analysis on the specific postoperative complications of stroke, myocardial infarction, and death, the frequencies of which have remained relatively stable over this time period. In examining several other series that compared anesthetic techniques, three demonstrated decreased hospitalization time, cost, or both,[14-16] one demonstrated decreased operative time,[14] and two demonstrated decreased intensive care unit stay[16,17] when regional anesthesia was used (Table III).

Regional anesthesia with selective shunting has obviously been, and currently still is, the preferred method of carotid surgery at our institution. In our practice there are no absolute contraindications to regional anesthesia. If a patient expresses a strong preference for general anesthesia, an effort is made to accommodate the patient's wishes. Claustrophobia, neurologic disorders including stroke, and language barriers have been relative contraindications to regional anesthesia if these factors make cooperation and communication difficult. The trend toward using general anesthesia for patients who have contralateral occlusion and prior stroke in recent years has come from the earlier observation that these patients are more likely to require a shunt. The feeling among some surgeons is that if a shunt is likely to be necessary anyway, there is no particular reason to monitor cerebral function; this belief is likely somewhat responsible for the increased use of general anesthesia in these patients. However, we are not suggesting that general anesthesia is superior for these patients; in fact, the opposite may indeed be true. These are simply cases in which the operating surgeon would feel uncomfortable performing the operation without a shunt in place during carotid clamping.

It has been interesting to note that even at an institution that clearly prefers regional anesthesia for carotid surgery, the percentage of patients who receive general anesthesia has steadily increased over the past three decades. Of greater concern is the fact that it is in this most recent time period that the perioperative stroke rate is clearly increased with general anesthesia. It is conceivable that we are currently selecting our highest-risk patients for general anesthesia to an even greater extent than in earlier years. However, we cannot prove that the general anesthesia patient population as a whole is a higher-risk group currently than it was in previous years; these patients have an almost identical frequency of preoperative stroke and contralateral total occlusion when compared with patients who underwent surgery more remotely. The perioperative stroke rate for patients in the past 10 years with a preoperative stroke who received general anesthesia is somewhat higher than the same category of patients who received regional anesthesia (6.9% vs 2.3%), although not significantly so. Albeit, these results suggest that perhaps it is just this category of higher-risk patients that would fare better with regional anesthesia and selective shunting. We cannot then present one simple reason why the use of general anesthesia for carotid surgery has increased at our institution. The higher stroke rate among the general anesthesia patients in recent years has led us to reconsider our practices. It is likely that as a result of this review, regional anesthesia will be used more frequently in the future, even if a shunt is clearly indicated.

Although the data reported here does not definitively prove that regional anesthesia reduces the rate of perioperative complications after carotid endarterectomy, we believe that there are useful and important advantages to this technique that are unrelated to the issues of perioperative complications. No specialized equipment or intraoperative monitoring of cerebral function is required. The need for intraarterial shunting appears to us from our own experience and from available reported data to be most accurately assessed with the patient awake; this may make some anatomically difficult cases more manageable in that a prophylactic shunt may not be absolutely necessary. Assessment of the neurologic status of the patient after surgery and in the recovery room is simplified without the aftereffects of a general anesthetic.

We conclude from this review that regional anesthesia can be used safely for carotid endarterectomy in the vast majority of patients with good clinical results. Unexpected conversion to general anesthesia during the course of surgery occurs in approximately 3% of cases, based on a recent prospective study of this topic at our institution. The incidence of serious complications related to the administration of the anesthetic itself is extremely low. Although the data in our series clearly suggests that regional anesthesia may actually be better than general anesthesia with regard to perioperative stroke, patient selection may account for these differences. Even if used only selectively, however, we believe that the ability to perform carotid surgery under regional anesthesia is crucial and should be a part of the armamentarium of skills of every vascular surgeon.

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## DISCUSSION

**Dr. Richard F. Neville** (Washington, D.C.). Regional anesthesia used during carotid surgery has been advocated as a method that allows accurate intraoperative evaluation of the patient's neurologic status while decreasing both cardiac morbidity and interference with regulatory mechanisms of blood pressure control. Dr. Rockman and colleagues have reported on their experience with regional anesthesia in the performance of carotid endarterectomy. Their retrospective review includes almost 4000 cases over a 30-year span. However, this was not a randomized trial, and only 15% of the patients received general anesthesia and 85% received regional anesthesia. There was a 3% rate of conversion from regional to general anesthesia in the most recent 255 patients. There were no significant demographic differences between the two groups of patients, and postoperative results showed no statistically significant dif-

ferences in the rate of perioperative stroke, myocardial infarction or death, with very admirable 2.2%, 1.7%, and 1.5% incidences, respectively.

There was a trend toward higher perioperative stroke and mortality rates for those patients who were given a general anesthetic; however, these patients were seemingly at higher risk, with preoperative stroke as a more common indication for surgery and an increased incidence of contralateral carotid occlusion. On the basis of this retrospective data, the authors conclude that the anesthetic technique does not have a significant effect on the perioperative outcome for carotid endarterectomy. This conclusion is not overly surprising; however, the vast experience reflected in this paper is important and creates the opportunity for several very interesting questions.

First of all, how was a decision made during the study to use regional versus general anesthesia? The regional technique was used six times more frequently, and one can only assume that the authors were much more comfortable with regional anesthesia and have become expert in its use over the years. Does the group use an anesthesiology team dedicated to this technique?

What prompted the intraoperative conversion to general anesthesia, which was partially addressed, and does this subset have more complications when there is urgent conversion to a general anesthetic?

This experience also provides an excellent opportunity to examine the need for intraoperative shunt placement. How often do those patients under regional anesthesia require intraoperative shunting, and did these patients have increased complications as a result of urgent shunt placement?

Finally, in these days of cost containment, does regional anesthesia decrease the need for monitoring and blood pressure control in the postoperative period? Given today's emphasis on financial considerations, which we're all feeling, it would be interesting to know of any of the differences you noted in length of stay, either in the ICU or in the hospital, between these two groups of patients.

I currently use general anesthesia routinely for carotid surgery and reserving regional anesthesia for those patients with excessive cardiopulmonary risk. Although this paper has not convinced me to change this approach, I agree with the authors that regional anesthesia is a worthwhile skill to have in your armamentarium for the treatment of carotid occlusive disease.

**Dr. Caron B. Rockman.** To clarify our conclusions, we are not definitively advocating that any surgeon should change their preferred technique from general anesthesia to regional anesthesia on the basis of the data that is presented in this article. In fact, one could argue that because it appears that the anesthetic choice did not have a significant effect on perioperative outcome, each surgeon should use whichever technique they feel most comfortable with. We do believe, however, that the versatility and safety of this technique is sufficient reason for vascular surgeons to include it in their armamentarium of skills.

Although this is not a randomized prospective trial, we would have anticipated that if general anesthesia did indeed produce more perioperative strokes and, in addition, we were selecting our higher-risk for general anesthesia, we would have found a clear increase in the percentage of perioperative strokes under general anesthesia; this was not so.

The decision to use general anesthesia versus regional anesthesia was made before surgery on the basis of the judgment of the operating surgeon. Most recently, general anesthesia is often selected in patients who we consider to have a high indication for prophylactic shunting; not surprisingly, these are often patients who have had preoperative stokes or who have contralateral total occlusion. Another important consideration is the ability of the patient to cooperate with instructions under regional anesthesia.

We do have anesthesiologists at our institution who are highly experienced in performing this technique for carotid surgery. This is mainly because the surgeons have historically preferred regional anesthesia for carotid endarterectomy at our institution.

In the prospective study of 255 operations with general anesthesia, the patients who were converted during surgery to general anesthesia had no increase in their complication rate. Only one was converted because of difficulty with intraoperative exposure. I do not have data on the entire series of 3975 operations regarding whether patients converted during surgery to general anesthesia had an increased complication rate.

We use selective intraarterial shunting under regional anesthesia based on the response of the patient to test clamping of the internal carotid artery; shunts were used in 11% of the procedures with regional anesthesia. If any neurologic signs or symptoms developed in the patient during that period, the clamp was removed and preparations were made for shunting. Patients in whom shunts were placed did not have an increased perioperative stroke rate when compared with those in whom shunts were not placed.

Finally, we do not change our monitoring processes after surgery based on the anesthetic technique. I do not have specific data on whether regional anesthesia in fact decreases the need for monitoring and blood pressure control in the postoperative period. Very few of our carotid endarterectomy patients go to the intensive care unit after surgery no matter what kind of anesthesia they have had.

**Dr. John A. D'Anna** (Staten Island, N.Y.). How long is the test clamping time to see whether the patient has any neurologic symptoms, and were there ever any cases during the endarterectomy itself that neurologic complications developed and a shunt did have to be inserted urgently, and did any neurologic complications develop in that subset of patients?

**Dr. Rockman.** Test clamping of the internal carotid artery is performed for about 3 minutes. Although there are certainly occasional cases in which neurologic complications occur during the endarterectomy after internal carotid artery clamping has been tolerated, this is most often been

related to hypotension; correction of the hemodynamics often restores the baseline neurologic function. I do not have specific information on these cases and whether these patients had a higher complication rate.

**Dr. Kenneth Granke** (Morgantown, W.Va.). You mentioned that a difference in the anesthetic you use may reduce operative time, and I wonder whether you could comment if you saw any big difference there. Because I think to be cost-effective is an important issue to address.

This is a great number of patients who underwent carotid endarterectomy in general, regardless of the anesthetic technique. Can you comment on high lesions or difficult extended plaques up the internal carotid artery with the use of local anesthetic? How is that addressed in your practice? Do you have to add extra local anesthetic around the field?

**Dr. Rockman.** We did not specifically examine in our series whether the operating time is reduced, although this has been demonstrated in some of the other series I mentioned that have compared the two anesthetic techniques.

In answer to your second question, if the operating surgeon believes for whatever reason that the anatomic situation might cause a particularly difficult or lengthy dissection, that might very well be a reason to choose general anesthesia. This is clearly based on the judgment of the operating surgeon. In the prospective evaluation of 255 patients, only one was converted during surgery to general anesthesia because of difficulty with intraoperative exposure.

**Dr. Granke.** Do you do many with ultrasound and then find yourself backpedaling because it is a higher lesion than you suspected when you did your preoperative ultrasound scan?

**Dr. Rockman.** Almost all of our carotid endarterectomy patients have either undergone magnetic resonance or conventional angiography, so we generally can anticipate an unusually high lesion.

**Dr. Paul M. Leand** (Lutherville, Md.). I hesitate to make any comments on a subject as controversial, and probably will remain as controversial, as this is. I don't know any operation that has more equally successful spectrum of techniques, other than maybe the 889 published inguinal hernia repair techniques, than carotid surgery has. And I don't think we probably will resolve this because of a certain amount of pride of authorship; and what works for a surgeon, he is relatively unwilling to change. We must keep examining our own results to know this and to look at other people's results. Even if it's a good result, if someone does a carotid endarterectomy with a 1.5% better success rate, then you better look at it hard even if it's a small difference.

I've probably run the spectrum of techniques, starting in my training, and for 15 years I did all my carotid endarterectomies under general anesthesia and shunted all of them. It wasn't until Dr. Dale Bookbinder came to Baltimore, and then Dr. Bob Leather came down to give a lecture, and I talked with him personally about postoperative immediate hypertensive problems, which over the years was my impression as being the single major problem that I encountered with carotid endarterectomies. It usually was 20 minutes after the operation was over and you'd be having a cup of coffee and you'd get the call from the recovery room that there was a problem. And everyone would race to try and do something about hypertension. Now, I don't want to overestimate this, but it was something that bothered me a lot. He told me at that time that although there was nothing ever published to document that hypertension was reduced significantly in cervical blocks, it was his impression, from many years of using this technique. And Dr. Imparato, I think, felt the same way for years.

With Dale's encouragement, being a Leather disciple, I decided to change something I had done for years; and in the last 6 years I have done all my carotid endarterectomies under cervical block. I cannot tell you the statistical evidence, although we are trying to look at it in our hospital, because we have equally talented surgeons doing them both ways, that there is in my opinion a significant lessening of postoperative hypertension problems.

In addition, it is amazing how many patients in whom you do not need to place a shunt that you would think you would and who you definitely would shunt if they were asleep, even those with total contralateral occlusions. So we find a less than 10%, but a definite number of patients that need to be shunted. We have the shunts, not open but all ready. It's not a problem if you're used to and skilled in shunting. So I can say that in my evolution of this technique, I am very impressed.

Some of the arguments I hear for why people use one or the other mainly has to do with their own security in something that works well for them. But I think the biggest change came in regional anesthesia with two things: the perfection of intravenous sedation, which we have used in many outpatient procedures of other types, and have really allowed patient comfort but with an alert patient. So you don't have this experience that you used to have with doing your first case with the patient under local anesthesia, have a claustrophobic patient go wild, and have to try to convert it to general anesthesia and swear you'll never do another one under cervical block.

Secondly, the expertise, the ease, and the short amount of time it takes for an anesthesiologist to obtain a cervical block are quite good. It takes five minutes. When we first started doing this, there were only two or three anesthesiologists who really wanted to do it or felt comfortable with it. Now they all do it; it's routine. So there is a learning process with this technique. I think that most people who have gone through what I have will probably give the same kind of testimonial, and I only encourage people to look hard and at least to think about trying this, because I think it's the way to do the operation, but not necessarily better.

**Dr. John R. Ricotta** (Buffalo, N.Y.). At what point do you decide to convert the patient? You can have a problem when the conversion is after you've made the arteriotomy. So what do you do and what parameters do you use?

How much trouble do you have with distortion of anatomy because of the cervical block? We've taken to actually marking out the sternocleidomastoid muscle and also marking out the external jugular vein, which we use for a patch, because on occasion we'll get in there and we'll have a significant hematoma in the sternocleidomastoid muscle.

Do you think that there is better patient acceptance or better physician acceptance with regional anesthetic? One of the things we found is that our referring physicians and the patients are much more inclined to accept an operation that doesn't mean they have to go to sleep, whether there is any value to that or not.

**Dr. Rockman.** The decision to convert during surgery is clearly based on the judgment of the operating surgeon and is individualized with respect to each patient. However, on the few occasions when general anesthesia was required in the middle of a procedure it has usually been induced together with endotracheal intubation without undue difficulty.

We have not really found distortion of anatomy as a result of the cervical block to be a major problem. Perhaps this is just because our anesthesiologists and surgeons are so familiar with the technique.

We do think that there is better patient acceptance with regional anesthesia. Often patients are more concerned about the anesthetic risks with general anesthetic than with the operation itself; they are comforted to learn that it can be performed with a regional anesthetic. For those patients who require staged bilateral endarterectomies, it has been exceedingly rare that a patient requests not to have regional anesthesia with the second operation after having successfully undergone the first procedure with this technique.

**Dr. Thomas S. Riles.** Just to answer one of the questions by Dr. D'Anna; occasionally it will occur that somebody will require a shunt after the clamps have been in place for some time. Usually this occurs when the blood pressure has dropped and there is a decrease in the collateral flow. So you have to be very careful that the anesthesiologist keeps the blood pressure up, and also that's why we keep monitoring them throughout the operation.