

possible complications of the intraluminal tube itself. 2) It thus appears unreasonable to subject all patients to a more complicated procedure when only one or two patients in ten require a shunt, particularly if such patients can be reliably identified. 3) Visual assessment of back flow, electroencephalographic monitoring, and venous oxygen saturation determinations are not exact methods for such patient selection. 4) Internal carotid back pressure or stump pressure is a useful intraoperative tool but cannot be depended upon absolutely as a criteria for shunting. 5) The only proven absolute method to assess the safety of carotid endarterectomy without shunting is continuous neurological monitoring of the patient in the conscious state. 6) Carotid endarterectomy can now be performed under local anesthesia without difficulty in almost any patient by adjunct use of Innovar and Sublimaze. 7) Continuous arterial pressures and blood gas determinations are mandatory during and immediately after the procedure. The patient's PCO_2 must be in normal ranges before and during crossclamping of the carotid vessels to assure optimal contralateral cerebral perfusion. Extreme post-operative hypertension should be treated but not excessively. 8) When shunts are employed, they should be discarded after each use. It may be advantageous to use shunts coated with heparin or other nonthrombogenic substances. 9) Crossclamping of the carotid vessels is least traumatic if elastomer tapes are used, controlled by small clamps. Crossclamping of the carotid vessels with conventional vascular clamps may be the source of currently unrecognized embolic material. The carotid bifurcation must not be palpated or compressed before crossclamping to avoid intraoperative embolization. 10) Completion angiogram would appear to be helpful in identifying the occasional patient with incomplete operation.

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DISCUSSION

DR. JESSE E. THOMPSON (Dallas, Texas): I would like to comment about general anesthesia for carotid surgery, since this is what we

presently use. We previously used local anesthesia, but some years ago switched over to general, and have found it most satisfactory. One of the chief causes of operative-related strokes is embolization from a necrotic plaque during manipulation of the artery. This

can occur under local or general, with or without a shunt, and bears no relationship to anesthesia. It is prevented by gentleness in surgical technique.

We are left, therefore, with those patients who develop strokes on the basis of ischemia; that is, who cannot tolerate temporary clamping of the artery, which is the reason Dr. Connolly prefers to operate on his patients awake, so that he can insert a shunt if the patient develops a neurologic deficit. This technique is not infallible, however, since we have observed on occasion that a patient who develops a deficit may not reverse the deficit after the shunt is inserted, and ends up with a permanent neurologic deficit.

One of the reasons we have preferred general anesthesia relates to the innate properties of inhalation anesthetics, especially halothane. First, there is a decrease in cerebral vascular resistance, with a resulting increase in cerebral blood flow; and second, there is a reduction in the cerebral metabolic demands for oxygen, by about 30%, on the average. Thus, general anesthesia is in itself a good means of cerebral protection. However, when general anesthesia is employed, one either uses no shunt, and risks a certain incidence of stroke, uses a shunt routinely, or uses a shunt selectively, based on the EEG or the level of carotid stump pressure. Routine shunting and selective shunting based on EEG and stump pressures have given excellent results, with the same low incidence of mortality and strokes as Dr. Connolly has shown with local anesthesia.

(Slide) Of our total twenty-year experience with 1259 operations, in the last 14 years we have used general anesthesia and routine shunting, which presents no technical problems when one becomes familiar with the technique. Here you see in this recent experience with 987 operations, that in patients with transient cerebral ischemia the operative mortality has been 0.7%, largely of cardiac origin. The incidence of operated-related strokes, both transient and permanent, has been 1.6%.

I have found that general anesthesia suits me better than local, and has been quite satisfactory for the patients. I think each surgeon doing carotid operations must work out for himself the type of anesthetic management that he feels comfortable with in his particular institution, and one that gives him results which are acceptable.

DR. W. STERLING EDWARDS (Albuquerque, New Mexico): This report of 102 carotid endarterectomies with only one death and no neurological residuals is certainly a remarkable feat, and will be hard to exceed. The authors must be doing something right. In fact, they are obviously doing a number of things right.

My question is: Can these results be attributed, mostly or entirely, to the use of local anesthesia and only using a shunt selectively?

It's been reported by many vascular centers that carotid endarterectomy results progressively improve with the experience of the team. Most centers have found that, as experience increases, their results improve; and yet surgeons at these centers are using many different techniques to protect the brain.

It's been my belief for a number of years that most of the post-operative deficits that occur are due to intraoperative emboli, either from too vigorous manipulation of the carotid arteries or from debris or AF air remaining in the lumen when blood flow is restored.

I firmly believe that much of the improvement in the reduction of neurologic complications on busy vascular services has been due to reduction in these mechanical causes of intraoperative emboli, as well as to improved monitoring of the adequacy of cerebral blood flow. And I would suspect that the same thing may be true in Dr. Connolly's situation, that not only has better monitoring improved his results, but that better technique has been employed.

This is not said to detract in any way from his excellent results, but to stress again the importance of a careful handling of the carotid arteries and avoidance of emboli.

DR. PAUL NEMIR, JR. (Philadelphia, Pennsylvania): I believe this operation is going to be performed with increasing frequency. There is good evidence that embolization from an ulcerating plaque is a more common remedial cause of TIA's than hemodynamically significant stenosis.

We recently completed a study of the plaques removed in just over 200 operations. Ulcerations ranging from one centimeter in

diameter to microscopic size were present in 72% of examined specimens, and our indications for operation have widened. Anything, therefore, that would add to the safety of the procedure is welcome.

We presently have utilized an internal shunt routinely, but the impressive results reported in this paper, especially with respect to the total absence of neurologic complications, is strong encouragement for returning to local anesthesia.

We have been concerned about another apparent complication. During 1976 five of 27 patients undergoing carotid endarterectomy exhibited electrocardiographic evidence of subendocardial infarction. All were, and have remained, completely asymptomatic. There was no apparent hypotensive episode, and serial enzyme studies were, and have remained, essentially negative. Two of the patients had bilateral procedures, but three had only unilateral operations.

We have been inclined to attribute this to neurogenic electrocardiographic changes which have been reported in various nervous system diseases or to partial carotid sinus denervation. However, our cardiologists have felt that it does represent myocardial damage, and this has led to a running battle in postoperative management.

I would like to ask Dr. Connolly if they have experienced similar complications, and, if so, whether there was any difference between the two series?

DR. LOUIS L. SMITH (Loma Linda, California): We too have been employing selective carotid shunting, since we believe endarterectomy is technically easier, and the likelihood of embolization is less likely if a shunt can be avoided. General anesthesia is employed. (Slide)

We have studied blood gases and carotid stump pressure as factors in stroke risk. (Slide) Our study began in June of 1972, and has continued through September of 1975. You will note there were 269 patients. Sixty-three patients had bilateral operations, giving a total number of endarterectomies of 332.

We analyzed our data, (slide) and have three groups based on the PCO_2 level hypocarbic, normocarbic, and hypercarbic. You will see that there were 78 patients in the hypocarbic group, 95 in the normocarbic, and 159 in the hypercarbic group. The number of shunts employed was roughly one in ten, and this varied little from group to group.

The mean stump pressure varied inversely with the PCO_2 . You will note that the mean pressure in the hypocarbic group was 63, versus 56 in the normocarbic group, and 45 in the hypercarbic group. These results are not statistically significant because of the small number of cases in each group.

As a result of these observations, we have switched from hypercarbia and now employ a PCO_2 level of between 30 to 40 mm Hg. (Slide) We did not find a correlation between the PCO_2 level and the stump pressure in those individuals experiencing a neurologic deficit. You will notice that roughly one half of those patients who experienced a stroke had a stump pressure of 50 mm Hg or greater.

We have concluded, as have Dr. Connolly and his group, that carotid stump pressure does not always identify those patients who are at high risk for developing a neurologic complication during operation, and that should have intraoperative shunting.

The use of local anesthesia, as described this morning, offers promise of being a more accurate indicator of the need for intraoperative shunting.

DR. EDWIN J. WYLIE (San Francisco, California): I agree that carotid reconstruction is easier to accomplish without the troublesome interference that an inlying shunt provides. Those surgeons who share this view have continued to search for a reliable means for identifying the patients who do not require shunting.

We have used the method described here early in our experience but abandoned it over 15 years ago. Carotid operations under local anesthesia are distressing to both the patient and the surgeon. In addition, the value of general anesthesia in reducing cerebral metabolic demand is sacrificed. In our subsequent experience we have found that stump pressure determination is a completely reliable technic. I think there are two fallacies in the conclusion from this paper.

The first is the assumption that the strokes reported in this series were the result of clamp ischemia. There are other causes of post-operative stroke, the most common being embolization from excessive manipulation of the carotid bulb. No evidence was presented to rule out one of these other causes in the two patients who developed postoperative stroke in the presence of high stump pressures.

The second fallacy concerns the selection of the level of stump pressure that indicates adequacy of collateral hemispheric blood flow. In an earlier published report we had settled upon a level of 50 mm Hg mean, a higher level than the one used by Dr. Connolly's group. We recently reviewed our current data on post-operative stroke and stump pressure. In the past two years, 423 carotid operations were performed. There were 350 patients whose stump pressures exceeded 50 mm Hg and none of these were shunted. In this group two patients (0.6%) developed hemiparesis postoperatively. One was the result of avulsion of the distal internal carotid artery and the other occurred in a patient with crescendo TIA and an existing neurologic deficit which worsened post-operatively.

The results suggest that the stump pressures continue to be the most reliable index for determining the need for intraoperative shunting.

DR. MAX R. GASPAR (Long Beach, California): Twenty years ago we used local anesthesia, and it was often a harrowing experience because patients became restless. This was the tipoff that cerebral ischemia was developing. I don't quite know how Dr. Connolly can avoid getting into trouble when a patient starts to get restless.

If his group can use shunts so successfully in 20% of patients, they must be doing it very well. But if only 20 shunts were used in three years, it hardly seems enough volume to train a group of residents to use shunts properly, and I am rather worried that he is sending residents out who don't really know how to put in a shunt when they need one. It's like taking off in a twin-engine airplane and having one engine quit. You have to know what to do instantly when that happens. I think that residents who are being taught to do carotid surgery should be taught to use a shunt on a routine basis. They should not be put into the position of having to try flying on one engine.

I agree with Dr. Thompson that it really is easier to do a leisurely operation on the carotid with a shunt in place. We use them routinely. In our last 100 patients there was one death due to myocardial infarction, there were two transient neurological deficits lasting less than two hours and one that lasted several days and then cleared completely. Obviously, this operation can be done several different ways, but everybody eventually uses a shunt at least some of the time, and I think we all should be able to use it very well all of the time.

DR. JOHN E. CONNOLLY (Closing Discussion): Dr. Thompson, I agree wholeheartedly that manipulation is very important, and I should have mentioned that. I must admit that our residents still have itchy fingers, and I don't think that the residents in the early series were much different than the residents now.

I seriously question in our manuscript (and time does not permit me to go into the details here) some postulations made by Wells and associates some years back about the advantages of general anesthesia for carotid surgery. Their paper has been quoted subsequently in many carotid articles. I can tell you that Innovar and Sublimaze have made it possible to operate under local anesthesia safely and conveniently with a sedated but conscious patient.

We first performed carotid endarterectomy under local anesthesia

but we gave it up because the patient was often uncomfortable and moving on the table. It was unpleasant both for the surgeon and the patient. But this is not true if these new drugs are employed. With their use we find very few patients who do not tolerate the operation very well under local.

Dr. Edwards, I feel that our results are not large enough to be sure that our next 100 patients will do as well as the reported group. We were, perhaps, lucky with that second group but I do feel that our change to the use of local anesthesia has given us an absolutely safe method of determining when a shunt is required.

Dr. Nemir, I agree that ulcerative plaques are extremely important. Regarding the question about concurrent coronary disease, we have not seen that relationship. My guess is that you are dealing with a group of patients who have both coronary artery disease and carotid artery disease, and in our hands these patients would be getting a total-body arteriogram, and we would be identifying the coronary disease, I think, before we do the carotid operation.

Dr. Smith, thank you for your concurrences.

Dr. Wylie, I'm quite aware of your writings on stump pressure, and in our paper I have listed 50 mmHg as your cutoff for stump pressure. However, one of your pupils, Dr. Wesley Moore, has written several widely quoted papers suggesting that 25 mmHg is the critical stump pressure, and that's why I wanted to be sure that those who use the 25 figure be aware that they can not depend on it entirely. And if you look over the literature, you will find that there are other authors who have thought they were safe with a stump pressure of even 70 mmHg and who have had postoperative neurological defect develop under general anesthesia without a shunt. It's not common; it's rare. So 50 mmHg in most cases is probably safe, but not invariably so.

If no unconsciousness or motor changes are noted during the trial carotid crossclamping but occur during the endarterectomy procedure, we can always insert a shunt at that time. This is possible because we continue to talk to the patient and assess the neurological status during the operation. Thus, it doesn't mean that we make one final decision right at the beginning of the operation as to whether we are going to use a shunt or not.

Dr. Gaspar, I think the use of a shunt in 20% of our patients gives our vascular fellows plenty of opportunity to learn how to use a shunt. We are hopefully training them to treat the patient as they will do after finishing their training.

(Slide) I want to point out something that Dr. Wiley Barker and I have been interested in. Normally, when you take the stump pressure, you have the external carotid crossclamped. We think that right after you have taken the stump pressure in this conventional manner, you should remove the clamp from the common carotid and see what contribution an open external carotid will make on the stump pressure. We find it often will elevate the stump pressure 10 to 15 mmHg. If so, you may choose to shunt from the common to the external carotid so that the shunt is not in the way of the endarterectomy at the upper end of the internal carotid.

(Slide) And this just shows that during the operation you can insert a shunt into the external carotid in that type of patient and have it well out of the way. Here is the upper end of the disease, where you are operating, the most important end, where the plaque may extend high in the internal carotid and it is not encumbered by a shunt. Thus, I would like to call to your attention even when you choose to use a shunt from the beginning, to think about the option of shunting from the common carotid to the external carotid and not always from the common carotid to the internal carotid artery.

Finally, what we're all trying to do is to lower the morbidity and mortality of carotid endarterectomy to the very lowest common denominator.