Extrathoracic Arterial Grafts Performed for Carotid Artery Occlusive Disease Not Amenable to Endarterectomy

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Hypothesis: Extrathoracic cervical grafts are safe and provide long-lasting stroke prevention in patients with disease not amenable to standard carotid bifurcation endarterectomy.

Design: Review of a prospectively maintained vascular surgical registry.

Setting: Combined university and Department of Veterans Affairs vascular surgical service.


Interventions: Carotid interposition grafting, subclavian-carotid bypass, or carotid-carotid bypass.

Main Outcome Measures: Perioperative stroke and death, and life-table determination of freedom from stroke, stroke-free survival, and graft patency.

Results: Sixty patients (mean age, 65.8 years; range, 36-83) underwent cervically based carotid grafting. All had greater than 70% stenosis or occlusion of the innominate, common carotid, or internal carotid arteries, and 30 (50%) had undergone at least 1 previous ipsilateral carotid endarterectomy. Indication for operation was stroke or transient ischemic attack in 46 (77%) and asymptomatic high-grade stenosis in 14 (23%). Operative procedures included 31 (52%) carotid interposition grafts, 18 (30%) subclavian-carotid grafts, and 11 (18%) carotid-carotid grafts. Mean follow-up was 29 months (range, 1-117 months). Perioperative stroke rate was 5% (3/60) all in symptomatic patients, and there were no perioperative deaths. By life-table analysis, freedom from stroke was 92% at 1 and 5 years. Stroke-free survival was 90% at 1 year and 61% at 5 years. Primary graft patency was 94% at 1 year and 84% at 5 years, with assisted primary patency of 90% at 5 years.

Conclusion: Cervical carotid artery grafts for complicated or recurrent carotid atherosclerosis not amenable to endarterectomy are durable and provide excellent freedom from stroke with low perioperative morbidity and mortality.

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The role of carotid bifurcation endarterectomy (CEA) for symptomatic and asymptomatic atherosclerotic occlusive disease of the carotid bifurcation has been clarified over the past decade by the results of several randomized trials of CEA.1-4 The increase in performance of CEA that these studies have generated will likely lead to an increase in the prevalence of recurrent carotid artery stenosis.5 Recurrent carotid artery stenosis may not be amenable to standard techniques of endarterectomy so that other procedures such as carotid interposition grafting or carotid bypass may be required.

Greater awareness of the role of extracranial carotid disease in stroke has also increased identification of patients with occlusive disease proximal to the carotid bifurcation. Because of the rarity of these lesions, their natural history has been extrapolated from carotid bifurcation disease. Patients with these proximal lesions may be treated with direct repair via a sternotomy or with a cervically based bypass to the carotid artery (subclavian-carotid or carotid-carotid bypass).6-10

While carotid interposition grafting and cervically based carotid bypass are theoretically attractive alternatives to direct reconstruction using a median sternotomy, the safety and long-term stroke prevention of such procedures is unclear. The purpose of this study was to review our experience with carotid interposition and bypass grafting in terms of operative complications and durability of stroke prophylaxis.
PATIENTS AND METHODS

A review of the vascular registry at Oregon Health Sciences University and the Portland Veterans Affairs Medical Center, Portland, Ore, was performed covering the period January 1988 through March 1998. All patients who underwent surgery for occlusive disease of the innominate or carotid arteries not amenable to standard CEA were included. This included patients who had disease considered by the surgeon at operation to be unsuitable for endarterectomy, as well as all disease that would require sternotomy for direct surgical repair.

Patient demographics and atherosclerotic risk factors at the time of surgery (smoking, hypertension [need for antihypertensive medication], diabetes mellitus [oral hypoglycemic medications or insulin], and coronary artery disease [angina, abnormal electrocardiogram, congestive heart failure, coronary artery bypass graft or coronary angioplasty]) were documented. A specific history of cerebral vascular disease (stroke, transient ischemic attack, amaurosis fugax, or prior CEA) was recorded.

The indication for operation was classified as either symptomatic (stroke, transient ischemic attack, amaurosis fugax, global ischemia) or asymptomatic (high-grade stenosis). Operative details reviewed included the conduit used for grafting, the origin and termination of the grafts, the use of intraoperative shunts, and total operative time. Perioperative morbidity was documented. Clinical follow-up routinely included an early postoperative visit with a cervical duplex ultrasound examination followed every 6 months by clinical visits to assess for freedom from stroke and repeated cervical duplex ultrasound examination to document graft patency and development of graft stenosis.

Analysis of graft patency, freedom from stroke, and survival were performed by the life-table method. The influence of the type of operation performed (interposition or bypass), graft material (vein or prosthetic), and operative indication (symptomatic or asymptomatic) on perioperative stroke were determined by $\chi^2$ analysis. Long-term graft patency and freedom from stroke of the various operations and conduits were compared by the log-rank test. Data were analyzed by a statistical software program (JMP; SAS Institute, Cary, NC). All differences were considered statistically significant at $P<.05$.

RESULTS

During the 10-year study period, 60 patients underwent carotid interposition grafting or cervically based carotid bypass for occlusive cerebrovascular disease. Mean age at operation was 65.8 years (range, 36-83 years). There were 40 men and 20 women with the typical atherosclerotic risk factors. Other patient demographics are detailed in Table 1. One half of the patients had undergone at least 1 previous ipsilateral CEA, and 1 patient had undergone previous carotid angioplasty and stenting. Indication for operation was cerebral ischemia in 46 patients (77%) and asymptomatic high-grade lesions (80%-99% stenosis) in 14 patients (23%) (Table 2).

The 60 operations performed included 31 carotid interposition grafts and 29 cervically based bypass grafts. The types of operations are shown in Figure 1 and listed in Table 2. Carotid interposition grafts were performed for recurrent carotid bifurcation disease not amenable to endarterectomy in 21 patients, a combination of atherosclerotic stenosis and small internal carotid aneurysms in 4 patients, and disease not amenable to first-time endarterectomy owing to radiation in 3 patients, and complex extensive plaque (requiring a very long endarterectomy or extruding through the adventitia) in 3 patients.

Cervical bypass grafts were performed for proximal common carotid artery stenosis in 16 patients (including 5 occlusions), innominate stenosis in 4 patients (including 2 occlusions), and for combinations of common carotid and bifurcation stenosis in 9 patients. Cervical grafts were combined with recipient-side CEA in 8 patients and with donor-side CEA in 4 patients. Subcla-
interposition grafts were performed with a venous conduit in 11 patients. Average operative time was 170 minutes, with no difference between interposition and bypass grafting procedures (165 minutes vs 175 minutes; \( P = .34 \)).

Operative complications are listed in the tabulation below.

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%) of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>3 (5)</td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
</tr>
<tr>
<td>Transient ischemic attack</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Superficial wound infection</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Hematoma</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Cranial nerve palsy (temporary)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>1 (2)</td>
</tr>
</tbody>
</table>

There were 3 perioperative strokes for an operative stroke rate of 5%. All 3 strokes occurred in symptomatic patients. One patient underwent a venous left carotid interposition and awoke with a right hemiparesis. Upon reexploration, the graft was found to be thrombosed. This graft was revised and the patient had a minimal deficit at the time of hospital discharge. A second patient awoke with a neurologic deficit following a right carotid interposition. Upon reexploration, the graft was patent and intraoperative angiography revealed no technical problems. This patient was left with a moderate deficit at the time of discharge from the hospital. The third perioperative stroke occurred in a patient 3 days following a subclavian-carotid bypass. The bypass was patent on duplex scan and the patient recovered with minimal deficit.

There was no statistical difference in rate of perioperative strokes in symptomatic vs asymptomatic patients (3/46 [6.5%] vs. 0/14 [0%]) \(( P = .78)\). Similarly, the type of operation (interposition vs bypass) did not influence perioperative stroke rate (2/31 [6.5%] vs 1/29 [3.5%]; \( P = .95)\). The type of conduit (vein vs prosthetic) also had no effect on early stroke rate (2/38 [5.3%] vs 1/22 [4.5%]; \( P = .63)\).

Average follow-up was 29 months (range, 0-117 months). During follow-up there was 1 patient with late stroke in the ipsilateral cerebral distribution 11 months following a Dacron carotid interposition graft. The rates for 5-year freedom from stroke, survival, and stroke-free survival were 92%, 69%, and 61%, respectively (Figure 2).

Primary graft patency was 84% at 5 years and assisted primary patency was 90% at 5 years (Figure 2). There were 2 patients with late graft occlusions. A carotid interposition vein graft occluded 2 months postoperatively and resulted in a transient ischemic attack. A Dacron subclavian-carotid bypass occluded 39 months postoperatively and was asymptomatic. There were 2 patients with late graft revisions—1 at 12 months for a stenosis at the distal end of an interposition vein graft that was causing transient ischemic attacks, and 1 at 13 months for an asymptomatic stenosis at the distal end of a Dacron carotid-carotid bypass.

Life-table analysis revealed no difference in 5-year freedom from stroke when analyzed by the type of operation (interposition vs bypass, 93% vs 92%; \( P = .95)\) or the conduit used (vein vs prosthetic, 95% vs 89%; \( P = .30)\). There were also no differences in 5-year primary graft patency when interposition grafts were compared with bypass grafts (88% vs 83%; \( P = .54)\), and when vein grafts were compared with prosthetic grafts (90% vs 77%; \( P = .94)\).

**COMMENT**

Some patients with extracranial carotid artery occlusive disease cannot be treated with standard CEA. Depending on the location of the occlusive lesion, carotid interposition grafting and various configurations of cervically based carotid bypasses are conceptually attractive procedures for the treatment of such patients. However, there have been concerns regarding operative morbidity, optimal graft material, graft patency, and the long-term stroke prophylaxis associated with carotid grafting.

Our data suggest that these operations can be performed with acceptable morbidity and mortality. There were no operative deaths in this series and the operative stroke rate was 5%, with all strokes occurring in symptomatic patients. These results compare favorably with...
those of other reports. Fry et al reported a combined perioperative stroke and death rate of 5% in a group of 20 subclavian-carotid bypasses. A similar perioperative stroke and death rate (4.3%-6.3%) was reported by Berguer et al in 2 recent series of cervical bypasses. Salam et al described 31 patients undergoing carotid-carotid or subclavian-carotid bypass without a single perioperative stroke or death. Such cervically based procedures appear to offer lower morbidity and mortality than transthoracic repairs where the combined stroke and death rate has been reported in the range of 14% to 16%. In addition, both interposition grafting and cervically based carotid bypass appear quite durable, with an assisted primary patency in this series of 90% at 5 years. In our experience, only 2 grafts required revision to maintain patency and 2 other grafts occluded during follow-up with neither occlusion resulting in a stroke. The durability of these cervical grafts argues against the suggestion that cervical bypasses offer patency rates inferior to direct transthoracic repairs.

Some authors have suggested that prosthetic extrathoracic carotid grafts may provide superior durability over venous conduits. Recently, Rockman et al reported that in redo carotid surgery, the use of a vein interposition led to an increased risk of recurrent stenosis or occlusion compared with prosthetic grafts. Their series, however, contained only 9 vein interpositions in 82 redo carotid operations, and had an overall stroke rate of 8.6% with interposition grafting. Other authors have demonstrated no difference or even superior results with vein grafts. Synn et al concluded that vein is a better conduit than prosthetic material in longer bypasses from the subclavian artery to the carotid bifurcation. In our study, there appears to be no difference in the durability of prosthetic vs vein conduits in extrathoracic carotid grafting. Both conduits provided excellent long-term results. We conclude, therefore, that the choice of conduit is relatively unimportant in extrathoracic carotid grafting. While our preference is for autogenous conduits, we believe that a prosthetic conduit is superior to a poor-quality venous conduit. In addition, certain procedures such as carotid-carotid bypass appear best performed with a crimped or externally supported prosthetic conduit to avoid kinking in a curved configuration and we have found crimped 7-mm Dacron to be an excellent conduit in this setting.

Martin et al reported 75% long-term freedom from stroke in a small series of patients with cervical grafts, raising concerns regarding poor long-term stroke prophylaxis with extrathoracic carotid grafting. Despite the advanced degree of extracranial carotid occlusive disease present in the patients in our series, life-table analysis found 92% of surviving patients remained stroke-free 5 years following cervical grafting. These results compare very favorably with stroke prophylaxis following CEA for both symptomatic and asymptomatic carotid occlusive disease. Freedom from stroke at 5 years was 87% in the North American Symptomatic Carotid Endarterectomy Trial and 95% in the Asymptomatic Carotid Atherosclerosis Study.

Although the need for extracranial carotid grafts is relatively infrequent, the increased numbers of CEAs performed along with greater physician awareness of the relationship between carotid occlusive disease and stroke...
REFERENCES


DISCUSSION

Jeffrey L. Ballard, MD, Loma Linda, Calif: Dr Abou-Zamzam and colleagues from the Oregon Health Sciences Center have presented a 10-year review of 60 patients who underwent carotid interposition grafting or cervically based carotid artery bypass for occlusive disease of the innominate and carotid arteries. None of these vessels were amenable to standard endarterectomy techniques. In this group of typical vascular surgery patients, there were 31 carotid interposition grafts and 29 cervically based bypass grafts. Surgical results were excellent as one might expect from this group of highly talented vascular surgeons. Data were well analyzed and thoroughly support their conclusions.

There were no operative deaths in the series and the operative stroke rate was 3%. All of these strokes occurred in asymptomatic patients. Life-table analysis demonstrated that the post-operative stroke risk was not affected by the type of operation or the conduit used during the procedure. Additionally, there were no significant differences in 5-year cumulative graft patency when interposition grafts were compared to bypass grafts or when vein grafts were compared to prosthetic grafts.

Based upon these excellent results, the authors conclude that these extrathoracic arterial grafts performed for arterial occlusive disease not amenable to endarterectomy are safe, efficacious, and durable. Furthermore, they conclude that the choice of conduit is relatively unimportant for these cervically based carotid grafting procedures.

At Loma Linda University Medical Center, our results over the past 3 years parallel those of the Oregon group. We have performed 23 similar procedures with 1 perioperative stroke and no operative deaths. Most of the grafts were PTFE. Graft patency rate and stroke-free survival are similar to the results just presented.

Just to ensure that Dr Abou-Zamzam does not waltz off the podium unscathed, I have a few questions. (1) In the manuscript, it is stated that some of the carotid interposition grafts were performed for “recurrent carotid bifurcation disease not amenable to endarterectomy.” What criteria did you use to come to this conclusion? Was this an intraoperative assessment or was there something specific about your preoperative evaluation that led you to this conclusion prior to surgical intervention? Also, how did you know that the innominate artery was not amenable to endarterectomy? (2) One carotid interposition vein graft occluded 2 months postoperatively. Was this event possibly due to a technical error, and, if so, what is your intraoperative protocol for ensuring that there are no technical defects in these bypass grafts? That is, do you perform routine intraoperative duplex ultrasound or angiography following these vascular reconstructions? (3) What outpatient protocol do you use to follow these grafts after the initial procedure? (4) Does your group have any experience with ministernotomy. This technique utilizes a limited skin incision extending from the sternal notch down to the Angle of Louis. The manubrium and upper sternum are divided in the midline down to the third intercostal space and then the sternum is transected transversely, creating an upside down “T” incision. This facilitates direct exposure of the upper pericardium, which can then be divided vertically so that the base of the heart and arch vessels can be readily exposed. We have recently performed innominate and common carotid artery endarterectomy, patch angioplasty, and bypass with encouraging preliminary results. Are you familiar with this modification of median sternotomy, and when might you favor this direct approach for some innominate or other great vessel disease? (5) My last question revolves around your choice of conduit. I have favored synthetic conduits for these reconstructions because of the larger size of the subclavian and carotid arteries compared to a greater saphenous vein conduit. If you had a cervically based bypass procedure to do tomorrow, what would be your conduit of choice?

Clifford W. Deveny, MD, Portland, Ore: The authors have concluded that there is no relationship between previous stroke and stroke in this study. However, their numbers are relatively small and their stroke rate is so small (3%) that I think they would need a larger group to have the power to detect such a difference.

Stephen N. Etheredge, MD, Oakland, Calif: I rise to speak against the saphenous vein as a conduit of choice except in those cases where you are dealing with an infective process. Two significant problems are the inability to back flush from the brain...
down because of the valves that are present in the vein itself and the second one being that those same valve rings in a high-flow situation increase your risk of hyperplasia at those locations and may lead to further stenosis. If the prosthetic material is equally good, I would suggest that you stay away from the vein unless you have to use it for infective reasons.

Cornelius Olcott, MD, Stanford, Calif: There has been increasing interest in endovascular balloon dilatation for innominate lesions. What is your experience with endovascular techniques for brachiocephalic lesions?

Dr Moneta: Dr Ballard asked about the criteria for determining recurrent bifurcation lesions not amenable to endarterectomy. All of our patients having carotid operations for recurrent disease undergo angiography. If the lesion is a long lesion, or if this is a second recurrence following 2 previous bifurcation endarterectomies, or if it is a recurrence following radiation treatment, we will tend to treat those patients with grafting rather than attempt to try to do another endarterectomy. He also asked about criteria for not considering endarterectomy of the innominate artery. Ours are not much different from anyone else’s. If there is extensive calcification of the aortic arch, we won’t do an innominate endarterectomy because of dangers associated with clamping the arch. Also, if the orifices of the innominate and the left common carotid artery are close together such that placement of a clamp on the arch will compromise both lumens, we will not attempt endarterectomy of the innominate artery.

Also, if a patient has had a previous sternotomy, we don’t do endarterectomies on the innominate just because of the risk and difficulty of opening a previous sternotomy. And of course there are patients whom we judge to be too high a medical risk for that procedure.

Our intraoperative assessment of patients following extrathoracic cervical grafting is quite simple. In virtually all cases, only a continuous-wave Doppler examination is used. Angiography is rarely and selectively performed. We do not do routine intraoperative duplex scanning or angiography for any type of vascular reconstruction on our vascular surgical service.

The follow-up protocol for evaluation of these patients is a duplex scan shortly postoperatively, then every 3 months for the first year for patients with venous conduits, and then every 6 months indefinitely. Prosthetic conduits are followed every 6 months indefinitely.

I don’t have any experience with the mini sternotomy that Dr Ballard advocated. We have used a full sternotomy for direct reconstruction of the arch vessels.

About the conduit that is used, we prefer a prosthetic conduit for carotid to carotid bypasses because of the curve that is inherent in those grafts. I prefer a vein graft when the distal anastomosis is to the internal carotid artery. I find it is easier to sew a vein to the internal carotid artery and the size matches nicely. If the 2 ends are to the common carotid and subclavian vessels, then a prosthetic conduit is a nice size match and a technically easier procedure.

Dr Deveney indicated we need more numbers to really know the stroke rate. More numbers always help. We will keep track.

Steve Etheredge doesn’t like saphenous vein for these procedures. We do under the circumstances previously discussed. Our data suggest both vein and prosthetic work well. We have done a few innominate artery angioplasties. We feel these patients have to be without the contraindications to operation in case there is a problem.