ANNALS OF SURGERY
Vol. 219, No. 6, 673–678

Subclavian Revascularization

A Quarter Century Experience

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Objective
Twenty-five years of experience with subclavian revascularizations were reviewed to determine the long-term patency rates of different extrathoracic approaches.

Summary Background Data
Although it is generally agreed that proximal subclavian stenosis should be treated by an extrathoracic route whenever possible, the optimum procedure is debated. Alternatives include subclavian carotid bypass, subclavian-to-subclavian or axilloaxillary bypasses, and the authors' preferred technique of subclavian carotid transposition (SCT).

Methods
Records were researched for the past 25 years in a single specialty surgical clinic for extrathoracic subclavian revascularizations. One hundred ninety such procedures were identified, and hospital charts and office medical records were reviewed for procedure, preoperative symptoms, blood pressure differentials, and postoperative complications. Patency was determined by physical examination, differential blood pressures, Doppler spectral analysis, duplex examinations, and arteriography.

Results
Bypass procedures were used infrequently, and although the results are reported, they are excluded from any analysis. Subclavian carotid transposition was used in 178 procedures. All anastomoses were found to be patent at follow-up, except for one, which failed at 26 months. Mean follow-up was 46 months, with five patients lost to follow-up. Overall mortality rate was 2.2%, with the mortality falling to 1.1% if only subclavian carotid transposition patients are included.

Conclusions
Subclavian carotid transposition should be the treatment of choice for routine subclavian carotid occlusive disease because of its exceptional long-term patency and low morbidity.

Subclavian arterial occlusive disease may present as a multitude of cerebrovascular insufficiency symptoms or may be asymptomatic. In addition, stenosis of the subclavian artery can produce embolic phenomenon to the hand or arm claudication.

Contorni[1] described the hemodynamic changes that can occur in the cerebral circulation with proximal subclavian occlusion, and in 1961, the term "subclavian steal" was applied by Reivich to the reversal of flow in the vertebral artery.[2] In 1964, Parrot[3] described the technique of subclavian carotid transposition (SCT) for the treatment of proximal subclavian arterial occlusive disease. Since that time, the operation has not gained popularity; however, recent reports suggest that it has theoretical advantages and may have superior long-term patency.[4–6]

In 1971, Edwards and Wright[7] reported their first experience with the side-to-side anastomosis, forming the basis for the early patients entered into this study. Subsequently, the technique was modified to an end-to-side anastomosis because of more universal applicability and technical ease. This has been termed more recently subclavian carotid transposition, and although we also report our experience with subclavian carotid bypass, the groups are not entirely comparable because, in most cases, a bypass was used for more distal occlusive disease.

It is generally agreed that proximal subclavian stenosis should be treated by an extrathoracic route whenever possible; however, the optimal procedure is debated.[5,8] Although direct revascularization via median sternotomy or thoracotomy might be indicated occasionally, its higher morbidity and mortality have led to other procedures. Alternatives include subclavian carotid bypass (SCB) and subclavian-to-subclavian or axilloaxillary bypasses. Our preferred operative technique has been subclavian carotid transposition (SCT). This study examined our experience with subclavian revascularization and determined the long-term patency rates of the different extrathoracic approaches.

MATERIALS AND METHODS

Patients were identified by manual search of case cards kept on every vascular procedure. They were researched for extrathoracic subclavian revascularizations, yielding 190 such procedures in the past 25 years. Hospital charts and office medical records then were reviewed for procedure, preoperative symptoms, blood pressure differentials and postoperative complications. Patency was determined in follow-up by physical examination, differential blood pressures, Doppler spectral analysis, duplex examinations, and arteriography. Attempts were made to contact all patients by telephone to obtain bilateral blood pressures. If a blood pressure differential over 20 mm of mercury was noted, the patient underwent duplex examination.

From October 1967 until August 1993, 190 procedures were performed on 186 patients for extrathoracic subclavian revascularization. Women outnumbered men 103 to 83. Patient ages ranged from 22 to 86 years (mean = 61 years).

Bypass procedures were used infrequently for subclavian occlusive disease. Eleven patients were treated with 12 operative procedures during the study period. All but two patients received subclavian carotid bypass. One patient underwent subclavian/subclavian bypass with Dacron, which was removed subsequently 6 years later for infection and replaced with an axilloaxillary saphenous vein bypass graft. Another underwent carotid/brachial bypass. The primary indication for operation was upper extremity ischemic symptoms (> 90%), which, in some cases, were secondary to iatrogenic catheter-induced dissection. In follow-up of 1 to 132 months (mean = 31 months), there was a <50% patency rate at 48 months. Because these results are inferior to the majority of reports in the literature,[5] and because we perform SCT whenever possible, we assume that these patients were selected for a more severe occlusive disease process and, therefore, are not comparable to the SCT patients. In addition, because of small numbers in the bypass group, meaningful comparisons to the SCT patients cannot be made. Therefore, the subsequent data relates only to the subclavian carotid transposition.

Subclavian carotid transposition was used in 178 procedures on 175 patients. Women outnumbered men 97 to 78. The mean age was 61 years (range = 22–86 years). Analysis of the procedure distribution over time revealed that two thirds of the procedures were performed in the second half of the study period (Fig. 1). The indications for operations are detailed in Figure 2. Ninety-eight patients experienced dizziness; however, in 24% of the cases, this was their only symptom. In just over 50% of the cases, the patients experienced arm or hand ischemic symptoms. Six patients presented with embolic phenomenon and two others had rest pain. In 25 patients (14%), syncope was the primary complaint. Six patients underwent operations for symptomatic subclavian coro-

Presented at the Southern Surgical Association Annual Meeting, Hot Springs, Virginia, December 6–8, 1993.

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Accepted for publication January 24, 1994.

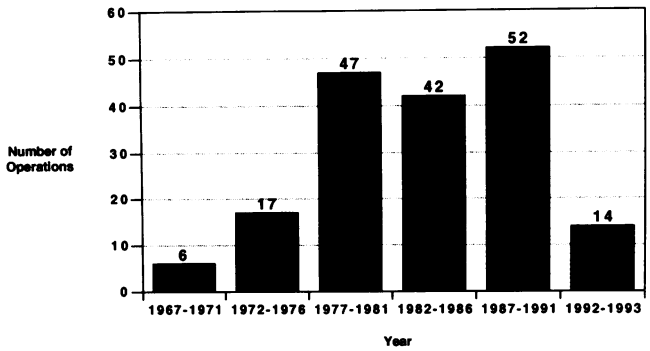

Figure 1. Distribution of operations over the years of the study.

nary steal from a patent internal mammary artery bypass graft and proximal subclavian stenosis. In five cases, diplopia was a presenting symptom, and in two cases, the patients underwent repair for asymptomatic occlusions. One procedure for asymptomatic stenosis was performed when, at the time of a vertebral-to-carotid transposition, the subclavian artery was injured and repair necessitated SCT. Another procedure was performed for an aberrant right subclavian artery and associated dysphagia.

All patients underwent preoperative arteriography, with 52% of the patients having complete occlusion. The mean stenosis was 91%. Average difference in preoperative systolic blood pressure in 96 patients for which these values were available was 40 mm of mercury.

The most frequently used operation was SCT in 145 procedures (81%). Eight patients were treated with side-to-side SCT early in the study. Six patients required endarterectomy to facilitate end-to-side transposition. In one patient, a simple subclavian/vertebral endarterectomy with patch graft was performed. Subclavian carotid transposition was combined with other procedures in 18 cases. Ten carotid endarterectomies and six vertebral carotid transpositions were performed simultaneous to the SCT. In one case, a coronary artery bypass was performed simultaneously and in another case a distal brachial artery bypass was performed. The left subclavian was involved in 87% of the cases.

Nonfatal complications occurred in 29 patients (17%). The most common complications were transient Horner's syndrome and transient hoarseness. Reoperation was required in eight patients, six for hemorrhage. In one patient, a thoracic duct lymph leak required reoperation, with satisfactory closure of the leak; in another patient with a combined SCT/carotid endarterectomy, reoperation was undertaken when the patient suffered a stroke in the immediate postoperative period. This was believed to be secondary to the carotid endarterectomy and not the subclavian revascularization. Two patients had deep venous thrombosis, whereas two patients experienced transient dysphagia. No patient suffered a myocardial infarction and no episodes of acute subclavian artery thrombosis were documented. (Fig. 3).

Postoperative deaths defined as occurring within 30 days of the operation occurred in four patients. The first patient died of a pulmonary embolus after a combined coronary artery bypass and SCT. One patient suffered a fatal arrhythmia on the first postoperative day and could not be resuscitated. Another patient returned to the hospital 18 days after discharge after a combined SCT and carotid endarterectomy. He suffered a stroke, which was fatal. The last patient died after multisystem organ failure secondary to widespread wound infection and necrotizing fasciitis. The overall mortality rate was 2.2%; however, if the death after coronary artery bypass and the death after the combined SCT/carotid endarterectomy are excluded, the mortality from SCT falls to 1.1%. No patient had a stroke that could be attributed to the temporary occlusion of the common carotid artery that is needed to perform the anastomosis.

Follow-up was obtained on 97% of the patients, with only five patients lost to follow-up. The mean follow-up was 46 months. Late death occurred in 22 patients. Objective determination of patency was made in 114 (78%) of the remaining 147 patients. (Fig. 4). Physical examination was used in the final 33 patients.

Follow-up blood pressures were recorded in 61 patients. The mean blood pressure differential between the arms was 3 mm of mercury higher on the revascularized side.

All anastomoses were patent at follow-up except one in which the patient was readmitted 26 months after surgery with a massive left hemispheric stroke and an absent left carotid pulse. It was presumed that the left carotid artery thrombosed proximally and was not affected by the SCT. The patient experienced no arm-ischemic

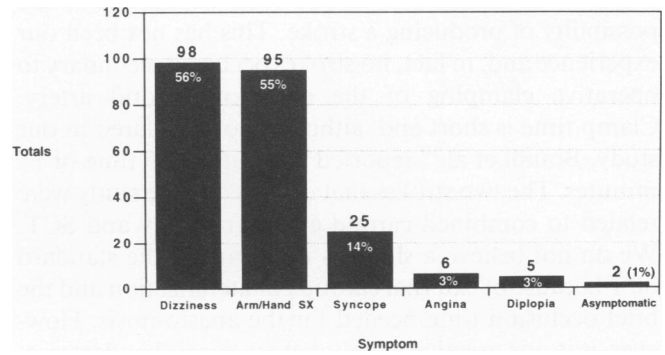

Figure 2. Symptoms of all transposition patients.

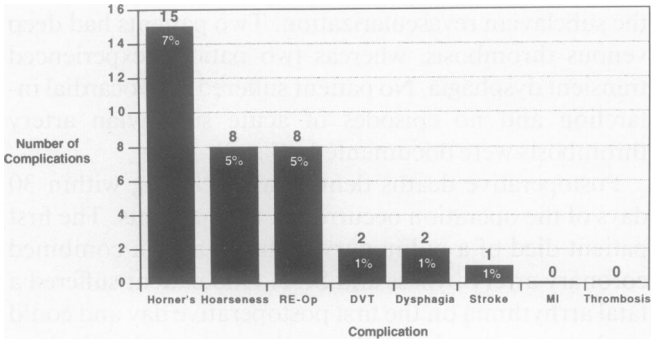

Figure 3. Complications after transposition.

symptoms. Thus, our overall cumulative patency rate is 100% at 2 years and >99% thereafter. Preoperative symptoms were relieved in 97% of the patients.

DISCUSSION

Patients with subclavian occlusive disease represent a small fraction of patients presenting with cerebrovascular insufficiency. In a previous study at our institution, this represented only 6% of the patients evaluated for cerebral symptoms.[9] Consequently, over a short period of time, no single surgeon will gain a large experience treating this problem. We that believe the present study encompasses the largest number of patients observed for the greatest length of time for SCT in the world literature. Since our earliest report in 1971,[7] this has been our procedure of choice for proximal subclavian occlusive disease.

Subclavian carotid transposition offers multiple advantages over carotid-to-subclavian bypass and extra-anatomic subclavian/subclavian or axilloaxillary bypasses. Because a direct anastomosis can be performed, no prosthetic materials are needed, and pseudointimal hyperplasia related to compliance mismatch is not a problem. Some surgeons have been reluctant to perform SCT because of the necessity of carotid cross-clamping and the possibility of producing a stroke. This has not been our experience and, in fact, no strokes occurred secondary to operative clamping of the common carotid artery. Clamp time is short and, although not measured in our study, Brandl et al.[10] reported a mean clamp time of 17 minutes. The two strokes that occurred in the study were related to combined carotid endarterectomy and SCT. We do not believe a shunt is necessary in the standard SCT because of external carotid collateralization and the brief occlusion time needed for the anastomosis. However, it is our practice to shunt every carotid endarterectomy and, therefore, when a combined carotid endarterectomy/SCT is performed, a shunt is used. In addition, because only one anastomosis is required, Sterpetti et al. found a significantly shorter operative time was required for SCT (75 minutes) when compared to a carotid/subclavian bypass (134 minutes).[4] Other advantages of the transposition technique *versus* bypass include the removal of the stenotic lesion from the circulation if it is an embolic source and the ability to gain access to the vertebral orifice if endarterectomy is necessary.

The early procedures were done by performing a side-to-side anastomosis between the subclavian artery and the common carotid artery. This was used initially because of reluctance to transect the subclavian artery low in the neck; however, with experience, the end-to-side anastomosis became the procedure of choice. This approach is superior because of the lack of anastomotic tension and is technically easier. Unusual distributions of disease and arterial injury from catheters and dissections may prevent the use of this technique. We were able to perform a SCT in 96% of patients presenting with subclavian artery occlusive disease while Mingoli et al.[11] reported only 50% of patients were amenable to SCT. Modification of the technique to include partial proximal subclavian endarterectomy with transposition allows more universal application of this method.

If transposition is not an option, a bypass with synthetic or autogenous tissue may be performed. In the present study, the patients who underwent bypasses were not compared to the transposition patients because we believed that these patients represent a completely different disease process. Because our experience with bypass is limited, no meaningful statistical analysis could be performed. Our cumulative patency rate of <50% at follow-up is inferior to those reported in the literature,[4–6,12] which support the argument that these patients constitute a different cohort in our study.

The possibility of proximal common carotid or innominate artery stenosis must be eliminated before un-

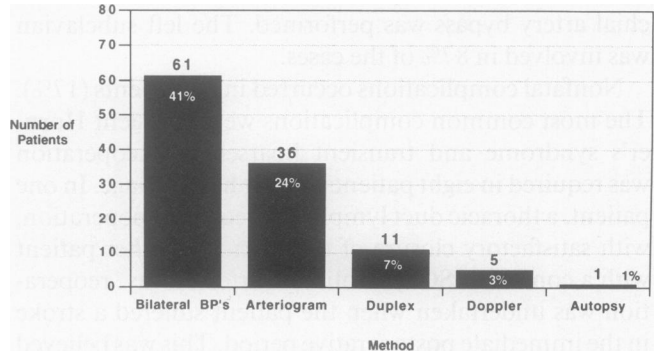

Figure 4. Methods of patency determination.

dertaking SCT. Although this is a theoretical problem, in practice it occurs infrequently. If a proximal common carotid stenosis occurs after SCT, theoretically, a subclavian carotid steal can occur, leading to cerebrovascular symptoms.[5] In our series, three patients were treated in follow-up with this problem. One patient presented 2 years after left SCT with a large left hemispheric stroke because of an occluded common carotid artery. No pulse could be palpated in the left arm at that time, and it was presumed that the bypass had occluded. To our knowledge, this is the only occlusion in the entire study group. Another patient with proximal carotid stenosis experienced angina with a patent internal mammary artery coronary graft (subclavian coronary steal) 18 months after SCT. He was treated with staged right SCT for proximal stenosis and subsequent subclavian-to-subclavian Dacron bypass. The patient again presented 6 years postoperatively with an infected graft, necessitating removal and revascularization with an autogenous axilloaxillary bypass. Most recently, a patient presented with recurrent vertebral basilar insufficiency symptoms after left SCT and was found to have a proximal left common carotid stenosis. This was treated successfully with open balloon angioplasty from the common carotid artery. At 1-year follow-up, there is no recurrence of symptoms and no differential blood pressures.

Although subclavian carotid steal can occur from SCT in the presence of proximal common carotid stenosis, subclavian coronary steal can occur when there is proximal subclavian stenosis and a patent internal mammary artery coronary graft. Eight patients in the study were treated for this problem by either SCT or bypass, with complete resolution of their cardiac symptoms and no postoperative myocardial infarction. Subclavian carotid transposition provides an excellent long-term solution to this problem.

The proof that this procedure is superior lies in its universally high patency rate. Although Kretschmer et al.[6] found a statistically significant greater patency rate with transposition over bypass, the universal experience in the small series of reported transpositions in the literature indicates that patency is almost always 100%. In the recent literature, with the current series added, there are 453 cases of SCT.[4–6,10,12–15] In only two other series has an SCT procedure failed in follow-up.[13,15] This leads to an overall patency rate of greater than 99%—quite a feat for any vascular operation. Although the longest previous follow-up was over 8 years,[10] we report a mean follow-up of 46 months with 53 patients observed for more than 5 years, 16 patients for more than 10 years, 5 patients for more than 15 years, and one (the longest) patient observed for more than 19 years. A 7% significant complication rate and a mortality rate of just over 1% indicate that this procedure is safe.

Because subclavian carotid transposition has been found to be safe and efficacious in the short term and, with this study, found to have exceptional long-term patency, we conclude that it should be the treatment of choice for routine subclavian occlusive disease. As surgeons gain more experience and confidence with this approach, it will become practiced more universally.

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Discussion

DR. ROBERT B. SMITH III (Tucker, Georgia): Dr. Edwards and his associates have reported a wealth of experience with subclavian to carotid transpositions for symptomatic subclavian artery occlusion. Their low operative morbidity and superior late patency rates have set the standards for which other