Superficial femoral artery eversion endarterectomy: A useful adjunct for infrainguinal bypass in the presence of limited autogenous vein

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Purpose: **To evaluate, in a group of technically high-risk patients, the results of infrainguinal revascularization using a conduit constructed with endarterectomized superficial femoral artery (SFA) and available arm or saphenous vein.**

Methods: **Of 237 consecutive lower extremity vein graft bypass procedures performed in 195 patients from July 1992 through August 1996, 15 SFA eversion endarterectomies (in 10 men and five women; median age, 70 years) were performed and used as a composite bypass conduit with available autogenous vein for the treatment of limb-threatening ischemia. In each case, an occluded SFA was divided 8 to 15 cm distal to its origin, proximally endarterectomized, and sewn end-to-end to a segment of vein to provide adequate conduit length for bypass grafting. Indications for this technique were unavailability of vein as a result of failed previous bypass grafting (n = 10) or previous coronary artery bypass grafting (n = 5). Veins were sewn distally to a below-knee popliteal artery (n = 4; 27%) or tibial artery (n = 11; 73%).**

Results: **Primary patency, secondary patency, and limb salvage rates at 36 months by life table analyses for the 237 grafts were 62.3%, 81.0%, and 77.2%, respectively. The 15 composite SFA-vein bypass grafts had 36-month primary patency, secondary patency, and limb salvage rates of 60.0%, 72.0%, and 65.9%, respectively (mean follow-up, 15 months). Currently, eight of these patients (53%) have patent bypass grafts; two (13%) died at 4 and 18 months after the operation with patent grafts; two (13%) underwent amputations for progressive foot gangrene despite a patent bypass graft; and three (20%) had grafts that thrombosed at 4, 5, and 10 months. Typical hyperplastic intrinsic graft-threatening stenoses developed in two patients (13%) in the SFA segment at 4 and 8 months; they were discovered by routine duplex scan surveillance.**

Conclusion: **Composite SFA eversion endarterectomy/vein graft conduits yield acceptable results, behave similarly to other autogenous conduits used for technically high-risk infrainguinal revascularization, and are beneficial when autogenous vein is limited.** (J Vasc Surg 1997;26:439-46.)

Bypass grafting with greater saphenous vein has emerged as the most durable method of treatment for lower extremity ischemia in patients who have femoropopliteal arterial occlusive disease. Problems, therefore, arise when greater saphenous vein is unavailable, especially when the bypass graft is to an infrageniculate artery. Methods of attaining adequate bypass length include originating the graft from an alternative arterial inflow source, specifically, a nondiseased superficial femoral, deep femoral, or popliteal artery, and harvesting an alternative conduit. Alternative conduits to the ipsilateral greater saphenous vein include contralateral greater saphenous vein, lesser saphenous vein, basilic and cephalic arm vein, composite grafts using segments of prosthetic material attached to available vein, and expanded polytetrafluoroethylene (ePTFE) grafts with or without a distal anastomotic vein patch or arterio-

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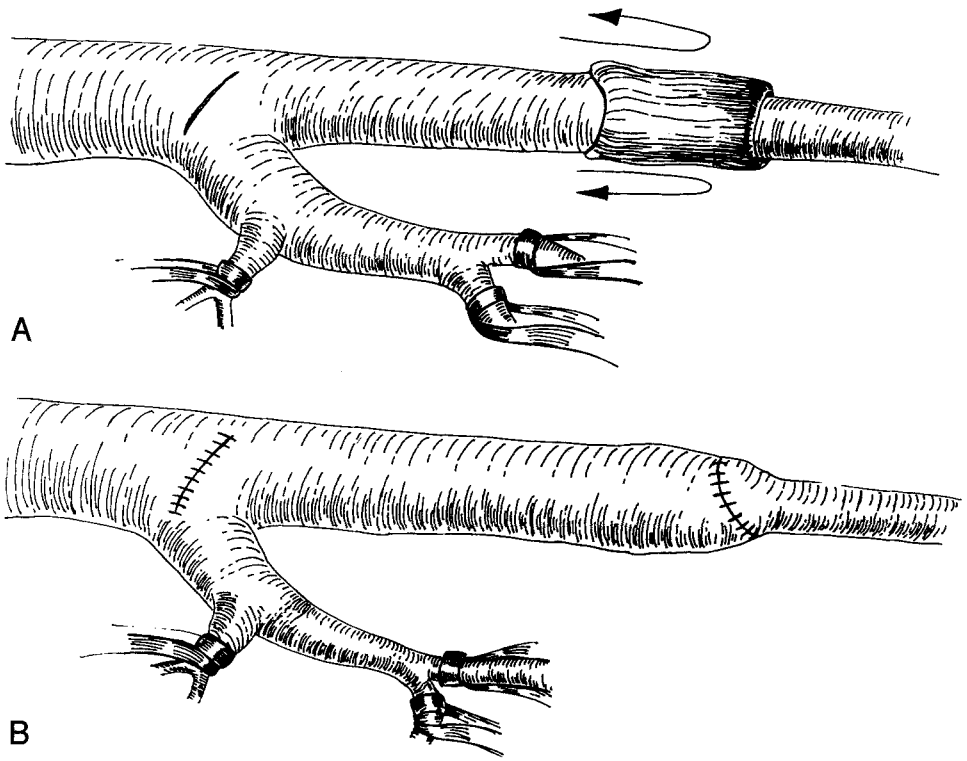

Fig. 1. A, Superficial femoral artery divided distally, with eversion endarterectomy in progress. **B,** Endarterectomized femoral artery is then sewn to a segment of autogenous vein, end-to-end, to construct a conduit for distal bypass.

venous fistula. Although some controversy remains, the limitations of prosthetic material and infrainguinal revascularization are well documented,[1] prompting many to advocate an all-autogenous bypass conduit policy whenever possible.[2]

To this end, we have used a composite conduit constructed with available autogenous vein sewn to a segment of endarterectomized superficial femoral artery, prepared by the eversion endarterectomy method, in situations in which most autogenous vein has previously been harvested. Although this procedure has been reported anecdotally,[3] few objective data exist on these conduits used as bypass grafts. This report therefore reviews our experience in a group of high-risk patients with superficial femoral artery eversion endarterectomy used as a composite graft with autogenous vein for infrainguinal revascularization.

METHODS

From July 1992 until September 1996, 253 consecutive infrainguinal revascularization procedures were performed in 212 patients and were managed on the vascular surgery service at Greenville Memorial Hospital. In an effort to maintain the policy of autogenous vascular reconstruction whenever possible, 237 of the 253 grafts were constructed with autogenous venous conduits, and 16 were constructed with ePTFE. Of these 237 grafts, 229 were reversed vein bypass grafts, and eight were performed using the in situ technique. Two hundred twenty (92%) were performed because of severe limb-threatening ischemic rest pain or tissue loss. One hundred fifty grafts (63%) were anastomosed distally to a tibial or pedal vessel, whereas 87 (37%) were anastomosed to the popliteal artery.

In 15 patients in whom autogenous vein was extremely limited, a bypass conduit was constructed using available greater saphenous, lesser saphenous, or arm vein sewn to a proximal segment of endarterectomized superficial femoral artery prepared by eversion endarterectomy, as shown in Fig. 1. In each patient, a segment of chronically occluded superficial femoral artery was mobilized, depending on the total length of conduit needed and the length of the available vein harvested. The artery was divided distally, endarterectomized, and sewn end-to-end to the vein. Any size discrepancy between a larger fem-

oral artery and a smaller vein segment was corrected by bevelling the ends before anastomosis. The anastomosis also incorporated an adjacent venous side branch, when possible, to minimize an abrupt diameter difference in the composite conduit. The conduit was then tunneled and anastomosed to the appropriate distal outflow artery. The superficial femoral endarterectomy was performed using the eversion endarterectomy technique described by Inahara,[4] with care in removing all intimal as well as circular medial muscular fibers from the vessel wall. The length of the superficial femoral artery, mobilized and everted, ranged from 8 to 15 cm (median, 12 cm; mean, 11.6 cm), depending on the length of the available vein. In seven instances (46%) a proximal arteriotomy was made at the common femoral artery near its bifurcation to assist with the proximal intimal dissection and to make sure that the profunda femoris artery orifice remained patent. These arteriotomies were either closed primarily (two patients) or patched (Dacron, four patients; vein, one patient) before performance of the bypass procedure. Patch angioplasty was usually used when concomitant profundoplasty or common femoral endarterectomy was necessary.

These superficial femoral artery/vein graft conduits were placed in 10 men and five women, with a median age of 70 years (range, 46 to 79 years). Fourteen of the 15 patients were cigarette smokers (present or former), and eight had diabetes.

The indication for bypass grafting was limb-threatening ischemia in all 15 patients, with tissue loss present in four patients. Ten patients (66%) had undergone previous infrainguinal vascular reconstruction, and four of these patients had undergone two prior reconstruction procedures. Five (33%) had undergone previous coronary artery bypass grafting. Thus in all 15 cases autogenous vein was limited. In addition, proximal or diffuse atherosclerosis prohibited the use of an alternative arterial inflow source, such as the deep femoral artery, to provide the needed length for the bypass graft. As well, in most of the 15 cases, the conduit length discrepancy was greater than what could be achieved by originating the graft from the distal profunda. In general, therefore, the constructed superficial femoral endarterectomy–vein graft conduit was considered a "last-ditch" autogenous effort. In no instance was the procedure attempted and abandoned.

All bypass grafts were sewn distally below the knee, with four grafts (26%) anastomosed to the below-knee popliteal artery and 11 grafts (73%) anastomosed to a tibial or pedal vessel. The only available

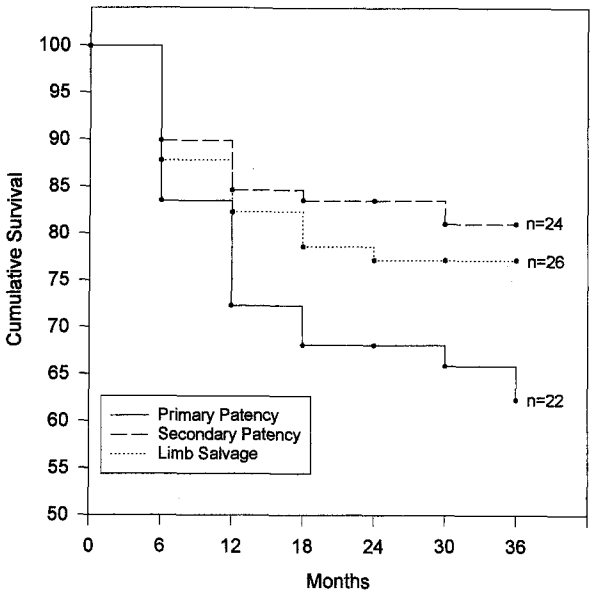

Fig. 2. Life table analysis of primary and secondary patency data and limb salvage data for the entire series (237 procedures).

vein for bypass grafting was a short piece of greater saphenous vein (11 patients, 73%), composite spliced basilic vein (one patient, 6%), composite spliced cephalic vein (one patient, 6%), lesser saphenous vein (one patient, 6%), or composite spliced lesser saphenous and greater saphenous vein (one patient, 6%). All of these venous grafts were reversed before attachment to the distal superficial femoral artery.

Our general operative technique for infrainguinal revascularization and prospective follow-up protocols have been previously described.[5] Each patient with a bypass graft underwent comprehensive duplex scan surveillance and ankle-brachial index (ABI) measurement every 3 months for the first 18 months and then every 6 months thereafter. Abnormalities that suggested a failing graft were investigated further by arteriography.

Primary and secondary graft patency rates and limb salvage rates were calculated using standard life table analysis.

RESULTS

Follow-up (evaluation within 3 months of the study period) was complete for all patients in the series. Life table analyses for primary and secondary patency data, as well as limb salvage data, are shown graphically in Fig. 2. The early operative (30-day) mortality rate was 5.1%. At 36 months, the primary patency rate was 62.3%, the secondary patency rate

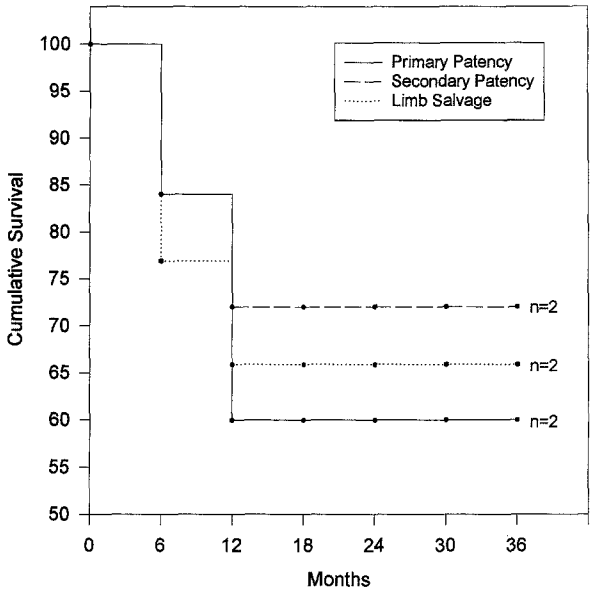

Fig. 3. Life table analysis of primary and secondary patency data and limb salvage data for composite superficial femoral artery eversion endarterectomy/vein conduit bypass grafts (15 patients).

was 81.0%, and the limb salvage rate was 77.2%. A total of 27 grafts (11.3%) were revised after duplex scan surveillance detected graft-threatening problems.

Primary patency, secondary patency, and limb salvage rates for the 15 composite superficial femoral artery/vein conduit bypass grafts are shown in Fig. 3. There were no operative deaths in this group of patients. Likewise, there were no early (30-day) cardiac or pulmonary complications. There were two minor wound infections that responded to antibiotics and one lymph leak in another patient that led to longer hospitalization but resolved with bed rest. Postoperative edema was present in varying degrees in all patients, but it was not thought to be unusually excessive in any and eventually resolved in all healed extremities.

Before the operation, ABIs in the 15 threatened extremities ranged from 0 to 0.47 (median, 0.37; mean, 0.24). Three extremities had no Doppler signal on presentation, and two had medial calcific vascular disease on presentation; in the latter, no ABI was obtainable. These two patients had toe pressures of 0 and 20 mm Hg. After the operation, ABIs ranged from 0.63 to 1.08 (median, 0.87; mean, 0.72). Improvement in ABI occurred in each patient and ranged from 0.2 to 0.93 (median, 0.56; mean, 0.53). In the two patients from whom ABIs could not be obtained, toe pressures improved from 0 mm Hg to 70 mm Hg and from 20 mm Hg to 70 mm Hg.

Follow-up for the 15 study patients ranged from 1 to 42 months (mean, 14.5 months). Eight patients (53%) are still alive with patent grafts and healed extremities. Two patients (13%) died with patent bypass grafts at 4 months (intracerebral hemorrhage) and 18 months (congestive heart failure). Despite functioning, patent bypass grafts with improved hemodynamics, two patients had distal foot ulceration that did not heal This failure to heal was probably a result of infection and poor distal runoff in the foot, which eventually necessitated major limb amputation at 1 and 4 months after the operation.

Three grafts thrombosed at 4 months, 5 months, and 10 months. The cause of graft thrombosis was uncertain in one patient. A review of his last graft flow velocity obtained at 3 months showed a diffusely large conduit (including the superficial femoral arterial segment) with a flow of 40 cm/sec and a distal anastomotic flow of 239 cm/sec. Despite systemic anticoagulation, this graft thrombosed at 5 months. The patient underwent repeat bypass grafting with spliced arm vein; the limb was salvaged. The other two patients had known, severe, unreconstructable distal tibial and pedal disease that, despite anticoagulation, was thought to be the cause of graft failure. Both patients required through-knee and above-knee amputations.

Intrinsic stenoses developed in two patients' endarterectomized superficial femoral artery segments (13.3%) at 3 months and 8 months after surgery. A focal stenosis in one artery lowered the distal graft flow velocities to less than 45 cm/sec. This lesion was confirmed with arteriography and was treated with percutaneous transluminal angioplasty. The lesion recurred at 4 months and eventually required patch angioplasty. The patient with the second arterial intrinsic stenosis had a diffuse narrowing along the entire endarterectomized arterial segment and was treated with patch angioplasty. Both lesions appeared hyperplastic in nature. One patient's bypass graft is secondarily patent 12 months after his original surgery, and the other patient eventually lost her leg, despite a patent bypass graft, 4 months after her original surgery. In each case, the superficial femoral diameter was of adequate size. One of the artery segments was 14 cm in length (focal stenosis), and the other was 12 cm (diffuse stenosis).

At least two graft flow velocities were obtained (1 and 3 months after operation) in each of the 15 study patients with grafts. In four patients (27%) an in-

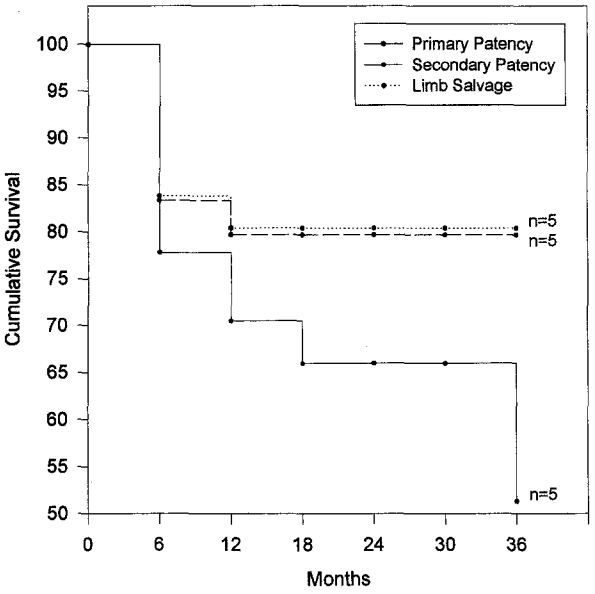

Fig. 4. Life table analysis of primary and secondary patency data and limb salvage data for redo bypass grafts (n = 40).

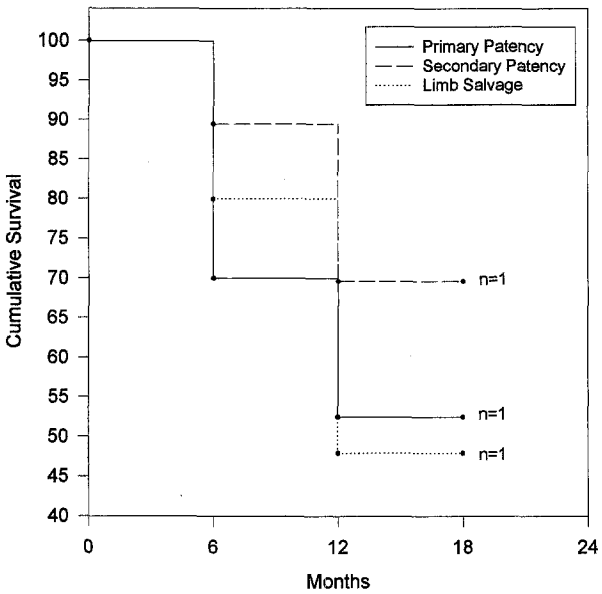

Fig. 5. Life table analysis of primary and secondary patency data and limb salvage data for arm vein bypass grafts (n = 11).

creased-diameter superficial femoral artery segment could be identified with focally low (<45 cm/sec) graft flow velocities. Flow velocities normalized in the smaller-diameter veins attached below the arterial segments in each case. Interestingly, a normal flow velocity developed in one of these low-flow arterial segments over the time between the two scans. A hyperplastic stenosis occurred in one of the arterial segments with this arterial-venous flow mismatch. Ten of the remaining conduits had normal graft flow velocities, making the transition from artery to vein difficult to discern. The remaining conduit had diffuse low flow and eventually failed despite anticoagulation.

Eleven extremities were salvaged in these 15 patients during the study period. Thus, for the conduits constructed with a segment of endarterectomized superficial femoral artery spliced to a piece of autogenous vein, the 36-month primary patency rate was 60.0%, the secondary patency rate was 72.0%, and the limb salvage rate was 65.9%.

As a comparison, two other high-risk bypass groups were analyzed from our data. Figs. 4 and 5 show life table graphs of these two groups—bypass grafts that were constructed after an initial bypass procedure had failed (redo bypass grafts) and all bypass grafts that were constructed with autogenous arm vein. The patency and limb salvage rates in these groups were comparable with those in the superficial femoral artery/vein conduit group. Log-rank statistical analysis for the comparison of two survival curves indicated no statistically significant difference in the secondary patency rate between the endarterectomized superficial femoral/vein conduit group and either the arm vein group (72.0% vs 69.6%; $p = 0.95$), the redo group (72.0% vs 79.7%; $p = 0.74$), or the entire group (72.0% vs 81.0%; $p = 0.37$) of bypass grafts.

DISCUSSION

The technique of eversion endarterectomy for the treatment of lower extremity ischemia is not new. Probably first performed on the iliac artery and reported in 1965 by Inahara,[6] eversion endarterectomy quickly became a useful tool in the vascular surgeon's armamentarium. Superficial femoral artery eversion endarterectomy was first described in 1967 by Harrison et al.[3] as "a procedure patterned after the old-time rural method of preparing sausage casings from hog intestines." Despite early enthusiasm for the operation, its limitations as a definitive procedure surfaced as unacceptably high restenosis rates developed. It was believed at the time that the superficial femoral arterial diameter might be too small for long-term patency when treated by eversion endarterectomy alone and that the eversion technique itself might damage the vessel wall.[7]

Interest in superficial femoral endarterectomy as a

definitive procedure to treat chronic lower extremity ischemia was rekindled in the 1980s by Ouriel et al.,[8] when they reported a 66% 3-year patency rate in selected patients with segmental stenoses of the superficial femoral artery at the adductor canal. This interest waned, however, in the late 1980s with the emergence of the superior results reported for infrainguinal bypass grafting coupled with close duplex scan surveillance. Our report, however, reemphasizes the importance of superficial femoral artery endarterectomy and suggests it may play a new, adjunctive role with current bypass grafting techniques. Our choice of using the eversion method as opposed to the open or semiclosed method was arbitrary. The eversion method is easy and can produce a tubular conduit that can be tunneled like a standard vein graft after one end-to-end anastomosis to a vein.

Currently, few data exist regarding the performance of this conduit when it is used as an infrainguinal bypass graft. Through the use of this technique, this series of high-risk patients, two-thirds of whom were undergoing their second or third bypass procedure, attained an acceptable secondary graft patency rate of 72.0% and a limb salvage rate of 65.9% at 3 years. In fact, there was actually no statistically significant difference in cumulative secondary patency rates among grafts constructed with endarterectomized superficial femoral artery/vein conduits and in those of the entire series. However, small numbers of patients mean that only relatively large differences would be detectable between the two groups.

This study raises the provocative question of when one should use a superficial femoral eversion endarterectomy in conjunction with a vein graft for infrainguinal revascularization. We have enthusiastically adopted the philosophy of using alternative arterial inflow sources when adequate venous length is a problem. We have published our experience with the use of the deep femoral artery as an inflow source and advocate its use when it is free of disease and is of good quality.[9] Likewise, 44 of the 237 grafts (19%) in this series originated from a popliteal or tibial artery and have performed well (36-month secondary patency rate of 89% by life table analysis). We continue to use these methods preferentially to superficial femoral eversion endarterectomy when possible. In contrast, we have been disappointed with ePTFE when it is used as a bypass graft to a tibial or pedal vessel. Although our experience is limited, during the study period we constructed six bypass grafts with ePTFE from the femoral artery to a tibial vessel for limb salvage—two with distal anastomotic vein patches and two with distal arteriovenous fistulas. Five grafts have thrombosed from 1 to 10 months after surgery, and only one remains patent at 1 month. Disappointingly, only two limbs have been salvaged by this technique. We believe, therefore, that the superficial femoral eversion endarterectomy–vein graft conduit provides an additional autogenous option for infrainguinal bypass grafting and advocate its use over that of ePTFE—especially when grafting to a tibial artery.

One final observation from these data stresses the continued importance of routine graft surveillance by duplex scanning—even at the portion of endarterectomized superficial femoral artery. For the entire series of bypass grafts, the incidence of intrinsic graft stenosis that required operative intervention was 11.3%. The incidence of hyperplastic stenotic lesions occurring in the arterial portion of our 15 superficial femoral artery/vein bypass conduits was a similar 13.3%, suggesting a congruent propensity of these arterial segments to develop graft-threatening lesions. On the basis of these findings, we recommend routine duplex scan surveillance of the endarterectomized artery, as well as of the vein. Development of intrinsic graft-threatening lesions appeared to be independent of artery diameter or length of superficial femoral artery segment endarterectomized. Until the cause of neointimal hyperplasia can be elucidated and prevented, routine surveillance remains the best defense against graft thrombosis.

CONCLUSION

Composite superficial femoral artery eversion endarterectomy/vein graft conduits yield results similar to those with other autogenous conduits, may develop intrinsic graft stenoses at rates similar to those of other conduits, and are a beneficial alternative when adequate autogenous vein is unavailable.

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DISCUSSION

Dr. James A. DeWeese (Rochester, N.Y.). I have enjoyed Dr. Taylor's presentation and I also appreciated having the opportunity to read the paper. Before or during the performance of 237 lower extremity vein bypass grafting procedures, Dr. Taylor and his associates discovered on 15 occasions that there was not an adequate vein of sufficient length to perform the proposed operation. On these patients, they performed an eversion endarterectomy of 10 to 12 cm length, and then performed bypass grafting distally. Primary patency rates of 62% and secondary patency rates of 81% at 3 years were achieved. I would very much like to compliment them on their persistence in using autogenous materials for their arterial reconstructions in these 15 patients. As they have stated, the use of a proximal femoral endarterectomy to accomplish this is not new. Actually, in 1964 we reported the use of a semiclosed or open thromboendarterectomy as an inflow for a distal vein bypass graft in five extremities. Inahara and I am sure many other of the older surgeons here at least have used this through the years. In 1967, Harrison reported performing 25 eversion lower extremity endarterectomy procedures, of which three were performed for this specific reason. Dr. Taylor's favorable experience with the combined operation should again alert all vascular surgeons that there is an alternative to the use of a long prosthetic graft in some patients with a limited amount of vein. There may be some question about the best technique for performing the femoral endarterectomy. When Dr. Harrison reported his 25 eversion endarterectomy cases in 1967, Wylie Barker in his discussion expressed concern that the added trauma of doing it as an eversion might contribute to atheromatous scarring and earlier graft occlusions. Indeed, Dr. Harrison, in 1968, while discussing a paper of John Connolly's concerning eversion endarterectomy reported the early development of a thickened endoluminal lining in seven of 25 eversion endarterectomy procedures that he had performed. Now, in addition, the patency rate of short thromboendarterectomy less than 15 cm using either open or semiclosed techniques reported by Dr. Inahara and also ourselves is similar to that reported by Dr. Taylor, raising the question of whether the eversion method really has any advantages over standard methods. My only question of Dr. Taylor would be whether he noticed that the femoral endarterectomy segment of the reconstruction actually did show stenosis during follow-up.

Once again, I would like to thank Dr. Taylor for bringing to our attention the advantages of endarterectomy and vein graft when the available veins are of limited length.

Dr. Spence M. Taylor. Thank you, Dr. DeWeese, for those comments. We have very little experience with any other method of endarterectomy used in this particular way. We prefer the eversion method simply because you can make a nice conduit and you can tunnel it similarly as a vein graft. They basically function just like a femoropopliteal bypass graft without having to do the proximal anastomosis, if you will. So, it tunnels well, and these are our results. We have no other comparison in terms of different types of techniques of endarterectomy to compare it with.

Dr. J. Harold Harrison (Atlanta, Ga.). I reported the eversion endarterectomy of iliac and femoral arteries as has been said in 1967, some 25 cases. From the late 1950s up until the early 1970s, we used endarterectomy as a primary treatment of occlusive disease almost exclusively. The eversion endarterectomy was by and far the best-looking operation that I had ever seen. We were very excited about presenting it, but then Wylie Barker got up and made the profound statement that accelerated atherogenesis from the extra trauma probably was going to get us in trouble, which it did. Other folks thought that this was going to be a world-shaking operation, and before the water got warm, by the next year, another series had been reported and I had to get up and tell them what was happening. Wylie Barker was very accurate. We were getting into more trouble apparently from the accelerated atherogenesis. We obviously slowed down the use of this procedure. I have continued, however, to use it in short segments of arteries along the way, and we are encouraged that someone is taking it back, because as we learn more about the methods of preventing the disease, and with some of the other techniques, it may come back to the point where it will function. Until that point, we are basically in trouble.

One thing that we pointed out at the time—I went back and read the papers—a great deal of tissue reaction occurs around an endarterectomized artery with eversion. This makes going back in for further procedures very difficult. We are leery of using vein in association with an endarterectomy. If you are going to use an endarterec-

tomy, use the endarterectomy all the way and save your vein for what you have for later use.

Dr. Taylor. I appreciate your comments, and I hope we don't have to come back and rebut next year with these all failed. We will continue to prospectively observe them, obviously. We are 36 months out and we will keep an eye on them for sure.

Dr. Robert W. Barnes (Gainesville, Fla.). I would just like to suggest a technical modification that facilitates removal of all of the medical fibers that, as in the carotid system, may reduce the incidence of recurrent stenosis. The eversion method of endarterectomy provides good visualization of only the distal portion of the conduit that is turned inside out. Instead of doing an eversion, why not perform an "inversion" endarterectomy through a proximal longitudinal incision over the distal common femoral artery extending over the orifice of the superficial femoral artery? After developing the endarterectomy plane around the proximal end of the plaque, the entire superficial femoral artery can be inverted by traction of the plaque. You can then remove completely those medial fibers under direct vision. In my own experience, this has reduced the incidence of recurrent stenosis, although I perform endarterectomy very selectively in patients, just as you do.

Dr. Taylor. I appreciate the comments.

Dr. John A. Mannick (Boston, Mass.). Just a final word about the durability of these procedures. As many other surgeons have done, we have used endarterectomy, in our case open and under direct vision, without eversion, as a way of getting down the leg to start a bypass vein graft. We have found this to be quite a satisfactory procedure. One of the things that has been most gratifying about it in our hands is that, as opposed to plastic prostheses, endarterectomy stenoses, like vein graft stenoses, occur early. If the endarterectomized segment is in a good shape at about 12 months, you can be quite confident that it is going to stay that way for a very long period of time. I do think that is a signal advantage. I wonder whether your observations have been the same. I was not quite sure about that from your presentation.

Dr. Taylor. Our observations were exactly the same. They tend to function and look just like vein grafts, in terms of intrinsic vein graft stenoses. The two areas that stenosis occurred, one at 3 months and one at 5 months, were early hyperplastic lesions, and all this suggests that duplex scan surveillance should be carried through to these segments as well.

Dr. Michael D. Kropilak (Knoxville, Tenn.). If you have a good profunda, would you prefer the profunda for inflow over endarterectomized superficial femoral artery? It seems like you are not gaining that much length with an endarterectomized superficial femoral artery, if they are 10 to 12 cm.

Dr. Taylor. Joe Mills and I reported using the profunda as an inflow source and have been very pleased with this, but you can get even a longer segment of superficial femoral artery. We have gone as far as 15 cm, which is longer than one could achieve with the profunda.