Is completion arteriography mandatory after reversed-vein bypass grafting?

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Many surgeons advocate uniform performance of operative completion arteriography after leg bypass surgery to ensure technical success and to optimize short- and intermediate-term graft patency. To determine the impact of this practice on the outcome of reversed-vein bypass surgery and associated patient charges, we reviewed our series of consecutive nonemergent leg bypass procedures. Ninety-three infrainguinal bypass procedures were performed in 80 patients (76 men and 4 women) from September 1991 to August 1994. The patients' average age was 67 years (range, 30 to 92 years). Follow-up (mean, 13.1 months; range, 1 to 36 months) was available on 91 grafts (97%). Indications for surgery included limb salvage in 75 cases, claudication in 12 cases, and popliteal aneurysm exclusion in 6 cases. All patients survived surgery. Primary graft patency rates as determined by life-table analysis were 87%, 81%, 78%, and 78% at 6 months and at 1, 2, and 3 years, respectively. Limb-salvage rates were 95%, 91%, 87%, and 87% at the same intervals. Bypass procedures were divided into two groups. The 25 grafts in group 1 were evaluated with inspection, continuous-wave Doppler insonation, and routine completion arteriography. The 68 grafts in group 2 were evaluated by inspection and insonation alone. Fourteen grafts occluded after surgery (average, 5 months; range, 1 to 12 months), five in group 1 and nine in group 2. The likelihood of graft occlusion was similar in both groups (p = 0.42). The optimal method of confirming technical adequacy after bypass surgery in the clinically satisfactory graft remains uncertain. Charges for completion arteriography at our institution average $700, including 15 minutes of additional operative time. In our experience, these charges do not appear to be justified by improved short- or intermediate-term graft patency rates in reversed-vein grafts when completion arteriography is performed. (J VASC SURG 1996;23:637-44.)

The current emphasis on cost containment has caused us to reexamine all aspects of our patient-care practices. Of particular interest are operative procedures that we believe are redundant or of limited value in relationship to their associated patient charge and impact on treatment outcome. Completion arteriography until recently has been considered an obligatory component of leg arterial bypass/revascularization surgery. Noting the risk and expense involved with operative arteriography, investigators have recently suggested Doppler flowmetry, transcutaneous oxygen sampling, and intraoperative duplex scanning as potential alternative methods of confirming technical success.

These investigations are predicated on the assumption that significant technical abnormalities are present after reversed-vein bypass grafting that require additional investigations beyond operative inspection, palpation, and insonation with continuous-wave Doppler ultrasound. The consequences of an abnormal completion arteriogram often are not well understood. No recent investigation has questioned the value of routine intraoperative arteriography during reversed-vein bypass grafting, as opposed to clinical graft assessment and selective graft imaging. If found to be redundant, or a useful but selective adjunct to clinical graft assessment, operative arteriography and other forms of extraordinary intraoperative graft assessment may be used less frequently, at a reduced patient charge, without adversely affecting short- and intermediate-term graft patency rates. We decided to review our experience with infrainguinal...
bypass to determine whether the performance of completion arteriography after reversed-vein bypass surgery is necessary to ensure acceptable graft patency and limb-salvage rates.

METHODS

We retrospectively reviewed all patients who underwent nonemergent infrainguinal revascularization bypass procedures by two authors (RLD and EJH) at the Palo Alto Veterans Affairs Medical Center and the Stanford University Medical Center between September 1991 and August 1994. During this time, only reversed-vein or prosthetic bypass procedures were performed for leg revascularization. No intraoperative prebypass imaging was performed to obtain additional information about bypass source, target vessels, or distal runoff.

Veins were harvested and prepared by the senior surgeon (RLD or EJH) through a continuous or discontinuous incision. At a second table, away from the operative field, the vein was gently distended and examined. Side branches were ligated with 5-0 silk suture. Areas of injury, stenosis, or valvular fibrosis were excised and primarily repaired, or additional veins were harvested. Easy perfusion of the graft with minimal resistance was uniformly required.

Grafts were tunneled anatomically or subcutaneously. Anastomoses were performed under direct vision with loupé magnification. One or two 6-0, 7-0, or 8-0 monofilament nonabsorbable sutures were used, often placed in a continuous fashion so that the first half of the anastomosis could be visualized while completing the second. The proximal anastomoses were constructed first, which distended the graft with pulsatile flow. The distal anastomoses were then completed. The target vessels were controlled by applying gentle tension on silicone elastic slings. If incompressible, tibial vessels were controlled with intraluminal balloon occlusion.

Grafts were assessed by continuous-wave handheld Doppler instruments (Parks Model 811B; Aloha, Ore.). The proximal and distal exposed portions of the graft were examined, with particular attention paid to pulsatility (triphasic, biphasic, or monophasic flow); signal frequency in the graft, distal anastomosis, and native vessel; change in signal noted by occlusion of the graft; and the amount of diastolic flow noted. The transition in signal frequency from graft to artery was evaluated to assess the size difference between the respective vessels and the presence and severity of distal anastomotic stenosis. Intraarterial papaverine (30 mg) was frequently used to help distinguish target vessel spasm from stricture at the distal anastomosis based on increased diastolic flow after injection. If questions remained regarding the distal anastomosis, a #2 catheter (Fogarty; Baxter International; Deerfield, Ill.) was occasionally passed through a small venotomy in the distal graft or graft hood through the distal anastomosis to demonstrate a patent and adequate lumen. No attempt was made to perform angioplasty in either the native artery or vein graft. The techniques of graft assessment are listed in Table I.

Bypasses were revised when significant abnormalities were noted. If additional information was needed or if the surgeon chose to perform postprocedural imaging, a completion arteriogram was performed by injecting 15 to 50 ml of radiopaque contrast through a 20-gauge catheter into the graft near the proximal anastomosis with inflow occlusion. A single exposure of a chest radiograph plate placed under the leg usually provided an adequate image; occasionally more views were required.

For purposes of comparison, bypass procedures were divided into two groups. The 25 procedures in group 1 included completion arteriography; the 68 procedures in group 2 did not. Additional patient and procedural characterization included patient age and sex, operative indications, complications and deaths, site of distal anastomosis, type of bypass conduit, method of postoperative graft surveillance, adequacy of preoperative anatomic rendering obtained by arteriography, and number of previous ipsilateral bypass procedures. Graft patency and limb-salvage rates were determined by life-table analysis, and \( \chi^2 \) comparisons between groups 1 and 2 were performed. The number and dates of subsequent amputations were also recorded. The charge for completion arteriography was determined from the procedures performed at Stanford University Medical Center on the basis of patient billings for materials, technician and professional fees, and 15 minutes of operative time (Table II).

RESULTS

Ninety-three infrainguinal bypass procedures were performed in 80 patients during the study period. Four were women; 76 were men. The patients' average age was 67 years (range, 30 to 92 years). Indications for surgery included gangrene or rest pain in 75 procedures (80%), claudication in 12 (14%), and exclusion of a popliteal aneurysm in 6 (6%). Bypass targets were the above-knee popliteal artery in 4 procedures, below-knee popliteal artery in 37, posterior or anterior tibial or peroneal artery in
were 95%, 91%, 87%, and 87% at the same intervals in patients with failed grafts. Three were performed at completion arteriograms: two at 120 days, one at 300 days, and one at 360 days. Fifteen procedures (16%) were followed by complications: wound infection and seroma in seven, myocardial infarction in four, graft hemorrhage in one, gastrointestinal hemorrhage in one, temporary acute tubular necrosis in one, and deep venous thrombosis in one. All patients survived at least 30 days after surgery.

Three procedures that involved completion arteriograms were revised. Two grafts were believed to be compromised on the basis of an abnormal Doppler signal, but the exact problem could not be determined. One arteriogram confirmed suspicion that the distal anastomosis included the wrong target vessel. The second arteriogram confirmed a vein-conduit abnormality, the resolution of which ultimately required a second venous conduit. Twenty-three arteriograms were performed without a specific clinical indication that could be determined from the operative record. Pedal grafts were more likely to be studied by completion arteriography (5 of 13; 38%) than tibial (12 of 38; 32%) or popliteal (6 in 40; 15%) grafts.

Completion arteriographic irregularities that were not considered significant for graft revision are listed in Table V. Fourteen grafts became occluded after surgery (average, 5 months; range, 0 to 12); five in group 1 and nine in group 2. The likelihood of graft occlusion was similar in both groups (p = 0.42; Tables VI and VII, Figs. 3 and 4). The average time to failure was 6.4 months (range, 5 to 8 months) in group 1, and 4.1 months (range, 1 to 12 months) in group 2 (p = 0.16, analysis of variance).

A review of the records of the patients with the 14 failed grafts revealed five broad categories for graft failure: severe postoperative wound infections in four diabetic patients, suboptimal autogenous vein graft conduit in two patients, external compression of subcutaneous pedal grafts by ankle restraints or footwear in two patients, technical error in graft tunneling in one patient, and composite autogenous conduit extension of failing infrageniculate polytetrafluoro-
ethylene bypass in one patient. Of the failed grafts, 11 were ipsilateral GSV, and three were alternative autogenous conduit. The remaining four grafts occluded without apparent cause. All four were found to be patent at the initial clinical follow-up, and became occluded between 3 and 4 months after surgery. All four were in group 2 (without completion arteriogram). Similarly, none of the four underwent graft flow-velocity analysis in the vascular laboratory before graft occlusion.

Charges for completion arteriography averaged $700 (Table II). Operative time required for completion arteriography varied with the type and difficulty of the case, but was never more than 15 minutes (the smallest increment of operative time available) for the patients studied.

**DISCUSSION**

The optimal method of confirming technical adequacy in the clinically satisfactory reversed-vein graft remains uncertain. In our series, completion arteriography alone prompted one revision in the 25 procedures in which it was used. It was also useful in evaluating two other grafts requiring revision, but the necessity of arteriography during these revisions was difficult to determine in this review. The patient charge per procedural change in this series was $5800 (3 of 25 arteriograms). If uniformly performed during all 93 procedures, completion arteriography would have increased charges for these patients by $47,600. One graft in the series became occluded within 30 days. No completion arteriog-
graphy was performed in this patient. The patient, however, had a serious postoperative wound infection that required extended hospitalization and may have contributed to graft failure. In comparing the results of the two groups studied (arteriogram and no arteriogram), no short- or intermediate-term benefits in patency or limb-salvage rates were apparent that could be attributed to completion arteriography alone.

Overall patency in this series compares favorably with several larger series of autogenous vein leg bypass procedures. In a recent comprehensive review, primary graft patency rates for reversed autogenous vein below-knee popliteal bypass were found to be 90%, 84%, 79%, and 78% at 6, 12, 24, and 36 months, respectively. Tibial bypass grafts achieved patency rates of 81%, 77%, 70%, and 66% at the same intervals; in-situ bypass primary patency rates were 87%, 80%, 76%, and 73% for below-knee popliteal bypasses and 84%, 82%, 76%, and 74% for tibial bypasses. In our series, 89 of 93 bypasses (96%) were performed to below-knee popliteal arteries or more distal arteries. The patency rates we report are well within the range expected for this mix of below-knee popliteal and tibial bypass grafts. This comparison supports our conclusion that acceptable graft patency rates after nonemergent reversed autogenous-vein bypass procedures may be achieved with the selective use of completion arteriography.

The significance of the comparison between groups 1 and 2 is limited by the lack of randomization and control inherent in this review. In addition, the results are susceptible to a type II statistical error because of the limited sample size. On the basis of existing standards of limb bypass procedures, however, it is very unlikely that a policy of mandatory completion arteriography would have significantly improved overall bypass patency rates in group 2 patients regardless of the number of patients included in the study.

In-situ bypass procedures were not performed during this time period. The reversed harvested vein graft is circumferentially inspected, distended, and flushed by hand during harvesting, which allows a degree of external observation not possible with the GSV in situ. Technical considerations that are relevant to the in-situ graft, such as residual vein valve leaflets or arteriovenous fistulae, pose potential postprocedural considerations that are generally not relevant to reversed-vein grafts, and a procedure that omits routine completion arteriography may not be appropriate during in-situ bypass grafting. The possibility that the in-situ graft may be more prone to technical error is indirectly acknowledged by the growing interest in angioscopically assisted valve lysis, sidebranch occlusion, and other forms of intraproperative in-situ graft assessment and intervention currently being proposed.

### Table V. Frequently encountered arteriographic abnormalities of unknown significance

| 1. Spasm of distal native artery at or near graft anastomosis |
| 2. Failure of complete anastomotic opacification |
| 3. Unequal retrograde/prograde target artery opacification |
| 4. Contrast dilution with nonopacified blood in target vessels |
| 5. Apparent nonanastomotic graft/target artery stenosis <50% of lumenal diameter, not associated with increased Doppler frequency |

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Fig. 2. Overall limb-salvage rates.
Significant graft abnormalities may occur more frequently in alternative autogenous vein grafts. Of the 14 grafts that failed, however, 11 were ipsilateral GSV and 3 were alternative autogenous conduit. This ratio is similar to the ratio of GSV and alternate veins used in the study (19 of 73; \( p = 0.94 \)). Within the limitations of the study, therefore, we cannot conclude that alternate-vein conduits are more likely candidates for mandatory completion arteriography, although selective graft imaging guided by surgical observation during these procedures is often useful and important.

Our decision to perform completion arteriography after a bypass procedure has evolved over time. Early in our operative experience, completion arteriography was used more frequently. More recently, we find that standard techniques for graft evaluation short of graft imaging are sufficient to detect significant technical errors during performance of reversed-vein grafts. Operative experience undoubtedly played a role in this evolution. Some bias toward the increased use of arteriography in more distal grafts is apparent from the data. This bias did not significantly influence graft patency rates based on the small number of graft revisions that resulted.

When standard graft evaluation techniques, such as those listed in Table I, suggest a significant flow disturbance or technical abnormality, and the cause of or solution to this abnormality is not apparent, selective use of graft and anastomotic imaging with
arteriography or duplex ultrasound may play a significant role in optimizing graft function. We have found arteriography useful in this regard, and we continue to use it primarily for this purpose. We have no significant experience with intraoperative duplex imaging. In addition, the data indicate that the one technical error apparent during operative arteriography may not have been detected without graft imaging. The experience in aggregate again suggests, however, that the practice of selective intraoperative graft imaging has not adversely affected our overall results in a significant way and may provide considerable cost savings when compared with mandatory completion arteriography.

Many abnormalities that were noted during completion arteriography apparently have no long-term significance (Table V), and operative interventions directed at supposedly significant arteriographic abnormalities often do not confirm the presence of a technical error. Marin et al. recently expressed concern about the significance of many abnormalities noted during completion arteriographic studies performed after 78 consecutive infrapopliteal bypasses. Arteriograms were categorized as showing no visible abnormality (grade 1; 50%) or mild (grade 2; 8%), moderate (grade 3; 23%), or severe (grade 4; 19%) potential technical errors. No patients with grade 2 or 3 defects had further surgical intervention, although all patients with grade 3 defects had at least one additional arteriogram or urokinase infusion. Despite surgical correction, the grafts with grade 4 defects demonstrated substandard patency rates at 1 month and 1 year (30 and 20%, respectively). Although the authors concluded that these results confirm the value of completion arteriography, an alternative interpretation of the same data suggests that many arteriograms may be unnecessary, and that grafts may fail regardless of the results of completion arteriography or subsequent surgical intervention directed by such studies. Most relevant to the cost-effectiveness question, in the Marin study defects noted on completion arteriography most commonly prompted yet another completion arteriogram without subsequent surgical intervention.

Four of 14 graft occlusions were unexplained; they occurred in otherwise uncomplicated grafts that were not studied by completion arteriography. All four grafts were patent at the initial follow-up examination but were occluded at subsequent evaluation at 3 or 4 months. None of the four was examined in the vascular laboratory for baseline flow velocities before occlusion. It is possible that technical defects that were present when the graft was implanted were subsequently responsible for graft failure. A growing body of evidence, however, suggests that intrinsic graft lesions not present in the vein before harvesting are responsible for many early graft failures, and that these lesions develop within the graft in the first few weeks after implantation.

Mills et al. recently reported early significant flow disturbances in 33 of 135 consecutive vein grafts studied, 45% of which progressed during an interval of 5 months and required intervention. Although either absent or present but not significant at the completion of the procedure, 73% percent of these lesions were detected by 6 weeks, and 91% were detected within 3 months of graft implantation. All four grafts in our series that occluded early with no apparent explanation remained patent for at least 30 days. If significant abnormalities in the conduit, anastomosis,
or run-off were present at the time of implantation, patency at even 30 days would have been unlikely. As noted by Marin et al., if subcritical vein graft lesions had been imaged by completion arteriography, these abnormalities may not have been sufficient to warrant revision at that time. In the recent series described by Mills et al., 24 of 44 early vein graft lesions either resolved during subsequent surveillance or remained stable and did not require further intervention. Therefore, the early identification of the presence of an abnormality does not necessarily determine whether intervention is necessary.

On the basis of our own experience and that of Mills and others, we believe many if not most intrinsic graft lesions develop within the first few weeks or months after implantation, and that these lesions represent the primary cause of short- and intermediate-term vein graft occlusion. Although much remains to be learned about the natural history of graft lesions and graft failure, graft surveillance may be more important to reversed-vein graft patency than completion-imaging studies performed at the end of the revascularization procedure. Only 62% of the grafts in our series underwent graft flow-velocity determination in the vascular laboratory. This low percentage was in part because of limited patient access to laboratory facilities during the first years of the study, wide geographic referral patterns that precluded return visits after successful bypass, and institutional awareness of the importance of graft surveillance in maintaining limb salvage. We currently study patients within 6 weeks and again within 3, 6, and 9 months to maximize secondary patency.

CONCLUSION

When performed on a perfunctory basis, the completion arteriogram often adds little additional information to that already available from standard evaluation techniques. This is especially true when preoperative arteriography provides sufficient anatomic detail to allow careful and accurate preoperative planning and when the bypass conduit used is reversed autogenous vein. Other recent proponents of mandatory completion arteriography also are re-evaluating their position because of similar considerations. On the basis of our experience, we believe that a policy of selective completion arteriography after reversed-vein bypass grafting is warranted by outcome and patient charge considerations.

REFERENCES


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