Axillary vein transfer in trabeculated postthrombotic veins

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Purpose: **This study assessed whether axillary vein transfer can be successfully performed in trabeculated veins and whether patients with this severe form of postthrombotic syndrome can be helped by an aggressive approach.**

Methods: **A total of 102 axillary vein transfer procedures were carried out in 83 limbs with trabeculated veins. More than one venous segment was repaired in 38 limbs with a second axillary valve in 19, and a different technique was used in the remainder. The superficial and deep femoral veins were the most common target sites. "Bench repair" of leaky axillary valves was performed before the transfer in 32 cases. Venous stasis dermatitis or ulceration was present in 90% of the limbs. The operability rate and chance of successful valve reconstruction was high, even in the presence of severe venographic appearance.**

Results: **The actuarial transplant patency rate was 83% at 10 years. The actuarial freedom from recurrent ulceration rate was more than 60% at 10 years, similar to the results obtained in a matched group of axillary vein transfers to nontrabeculated veins. Severe preoperative ambulatory venous hypertension (venous filling time [VFT] of less than 5 seconds), which was present in 67% of patients, did not adversely affect outcome, but short VFTs that persisted after surgery did. VFT and VFI90 (venous filling index, air plethysmography) improved after valve transfer. Swelling disappeared or was significantly reduced in 55% of patients (11 of 20 patients) who had moderate or severe preoperative swelling. In 82% of patients (31 of 37 patients) who had mild or no preoperative swelling, the swelling remained stable after surgery, and in 18% of patients (6 of 37 patients), it became worse. Pain was significantly diminished in 70% of patients; 23% of patients with severe pain had complete resolution.**

Conclusion: **Axillary vein transfer, in combination with other antirefluxive procedures when indicated, is safe, effective, and durable in patients with trabeculated veins and severe forms of postthrombotic syndrome. It may be considered as an option when conservative therapy or other types of surgery fail. (J Vasc Surg 1999;29:1050-64.)**

Venous stasis ulceration resulting from advanced postthrombotic syndrome is a difficult clinical problem, which is often recalcitrant to conservative therapy. Although precise figures are unavailable, we estimate from annual deep venous thrombosis (DVT) incidence data that this patient population numbers a million or more in the United States. The phlebographic appearance in this group of patients can be quite daunting, with trabeculated irregular recanalization, segmental obstructions, and variable collateralization. Few simple surgical options exist for amelioration of symptoms. The modified Linton procedure has a high recurrence rate in this group.[1] Most vascular surgeons believe that this class of patient is inoperable, and valve reconstruction in particular is contraindicated. We have, however, successfully used axillary vein transfer in this cohort patient since 1979. Early concerns relating to short-term patency and valve function of the transferred axillary vein segment because of the advanced postthrombotic changes in the recipient deep veins were quickly resolved, and the initial clinical results were satisfactory. Concerns regarding long-term patency and usefulness of the procedure, however, have persisted. Our results appear to offer some reassurance about the use of this procedure.

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MATERIALS AND METHODS

From 1979 to 1997, 259 patients with postthrombotic reflux underwent valve reconstruction

Table I. Case material

Group	*Trabeculated veins*	*Nontrabeculated veins*
Number of patients	81	82
Number of limbs	83	82
Mean age of patients	55	51
Male : female	1:1	1:1
Right : left	4:6	4:6
Axillary vein segments transferred	102	94
Multiple valve repairs, number of limbs	38	34
Multiple axillary valve transfers	19	12
Ancillary procedures		
Long saphenous ligation	14	14
Long saphenous stripping	32	26
Short saphenous ligation	9	15
Modified Linton procedure	24	28
Mean reflux scores	2.4	1.8
CEAP classification		
C	C3—10%, C4—12%, C5—16%, C6—62%	C3—12%, C4—10%, C5—18%, C6—60%
E	P—0, S—100%	P—15%, S—85%
A	S = 55%, P = 29%*, D = 100%	S = 67%, P = 34%*, D = 100%
P	R = 0, O = 0, R & O = 100%	R = 15%, O = 0, R & O = 85%
Valve site reconstructed		
Common femoral	10	4
Proximal superficial femoral	46	47
Distal superficial femoral	3	6
Profunda femoris	26	21
Popliteal	14	16
Tibial	3	0

*Perforators more than 5 mm diameter on phlebography.
CEAP, clinical, etiologic, anatomic, pathophysiologic.

surgery at our institution. Of these, 106 were found to have trabeculated veins with synechiae at surgical exploration. Axillary vein transfer was the technique used in 83 of the 106 limbs. The presence of trabeculae at the valve transfer site was confirmed by visual inspection in all cases. The analysis pertains to this subset of patients.

Patient selection and indication for surgery. All patients were referred because initial therapy administered elsewhere had failed. Since 1985 (74 of 83 patients), no patient was excluded from valve reconstruction because of severity of clinical features or venographic appearance. The indication for surgery was recurrent stasis dermatitis or ulceration in 90% of patients who underwent surgery (see CEAP [clinical, etiologic, anatomic, pathophysiologic] classification, Table I). Pain or painful swelling was the indication for surgery in the remaining 10% of patients. Sixty-two percent of the limbs had active ulcers (clinical class 6) at time of surgery, 16% were in remission (class 5), and 12% had stasis dermatitis.

A total of 102 axillary vein transfer procedures to trabeculated venous segments were carried out in 83 limbs in 81 patients at the University of Mississippi Medical Center and River Oaks Hospital. Staged bilateral procedures were performed in two patients. In 38 of the 83 limbs, two or more refluxive major venous segments (eg, superficial femoral, profunda femoris, or popliteal) in the same limb were reconstructed as part of a multiple valve reconstruction procedure. A second axillary valve was used in 19 of these limbs (16 to another trabeculated segment in the same limb) for the additional reconstruction (a total of 102 axillary valve segments transferred), and in the other 19 limbs, an alternative technique such as direct valvuloplasty or other antirefluxive procedures (eg, external valvuloplasty, division of poorly recanalized superficial femoral vein) was used. In 11 patients (13%), the axillary vein transfer was carried out as a 'redo' procedure after the previous valve reconstruction (earlier axillary vein transfer, 7; other type, 4) had failed. Eighteen other patients (22%) in this group had previous superficial venous or perforator surgery that failed.

Ancillary procedures. When present, superficial or perforator incompetence was addressed concomitantly with axillary vein transfer to the deep veins (Table I). Saphenous ligation or stripping was carried out in 55 limbs, and perforator ligation was carried out in 24 limbs. Combined saphenous and perforator surgery was performed on four limbs.

Nontrabeculated group. Comparing the outcome of axillary vein transfer in trabeculated veins with the outcome of this technique in nontrabeculated veins was useful. A total of 82 limbs underwent such axillary valve transfers to nontrabeculated vein segments (confirmed by means of venotomy at surgery) during the same interval. They were well matched to the previous group in demographics, location of valve transfer, additional valve segments repaired, ancillary procedures performed, CEAP classification,[2] and venous segments that were refluxive preoperatively (Table I). In 77 of these 82 limbs, the valve structure was found to be partially or totally destroyed, requiring the use of the axillary valve transfer, because direct valve repair was not feasible. In the remaining five cases, axillary valve transfer was used after initial valvuloplasty attempt failed because of technical reasons. Among the 82 limbs, 85% were considered to be postthrombotic in etiology.

PREOPERATIVE WORKUP

Patients were screened for hypercoagulability factors that might have etiological relevance and provide a guide to the intensity and duration of postoperative anticoagulation. Venous laboratory investigation included arm-foot venous pressure differential with reactive hyperemia,[3] ambulatory venous pressure measurement, air plethysmography,[4] and Duplex examination in the recumbent and erect positions (the latter with quick inflation and deflation cuffs[5]). Preoperative ascending and descending venography was also performed.

FOLLOW-UP EXAMINATIONS

We were able to perform follow-up examinations in 77 of the 83 limbs in the trabeculated group and 69 of the 82 limbs in the nontrabeculated group. Patients were seen at 4- to 6-month intervals during the first year after surgery and at less frequent intervals thereafter. The venous laboratory examinations performed preoperatively, including duplex examination, were repeated[1] 3 to 6 months after surgery, at 1 year, and at less frequent intervals thereafter. Patency and competence of the transferred axillary vein segment were routinely assessed by means of duplex examination. Most of the gray scale scans obtained in the earlier period have been reconfirmed by means of color duplex scans in the follow-up period. Contrast venography was repeated on a selective basis in cases of nonhealing of stasis ulceration or development of complications that indicated compromise of repair.

TECHNIQUE

Because simultaneous access to the superficial and deep femoral veins is provided, the groin incision remains our primary choice for valve reconstruction. In addition to the superficial femoral vein, the profunda femoris may also be involved in postthrombotic changes of varying degree or may be enlarged in compensatory fashion (axial transformation)[6] in response to compromise of superficial femoral outflow. In either case, significant reflux is present in this vessel, and valve reconstruction of the profunda femoris is desirable. A variety of techniques can be used to simultaneously reconstruct the superficial femoral and profunda femoris veins through the groin incision.[6] In our experience, the proximal femoral veins near their junction at the common femoral vein invariably remain open, even in advanced cases, and a valve reconstruction procedure is usually feasible despite poor contrast filling seen by means of preoperative ascending phlebography; poor visualization or nonvisualization of deep veins in the groin is often a venographic artifact caused by multiple levels of venous obstruction in the limb and resulting in abnormal contrast flow patterns. For this reason, a policy of routine exploration of the proximal femoral veins, regardless of the severity of preoperative phlebographic appearance, has prevailed. In the last 60 explorations in postthrombotic patients in whom trabeculated veins were encountered, a femoral valve reconstruction (axillary vein transfer, less commonly other types of valve repair) was feasible in 54 cases. In contrast, such "blind" explorations, even when the vein does not opacify on contrast venography, have been less rewarding with popliteal vein explorations. A valve reconstruction was feasible in only two of nine such explorations in which severe postthrombotic changes were indicated by means of preoperative venography. Apparently, venography artifacts leading to poor visualization or nonvisualization are much less common in the popliteal vein than the femoral vein. We no longer carry out popliteal explorations unless some hope of successful valve repair is provided by means of preoperative venography.

More distal segments of the superficial femoral vein can be accessed in the subsartorial canal or at the adductor hiatus.[7] Approaches to distal segments of the superficial femoral vein and the popliteal vein are particularly useful for 'redo' procedures, when initial proximal valve reconstruction has failed. We also use the popliteal site as part of a staged multiple valve reconstruction procedure. In some patients, the popliteal vein may be the initial choice for valve

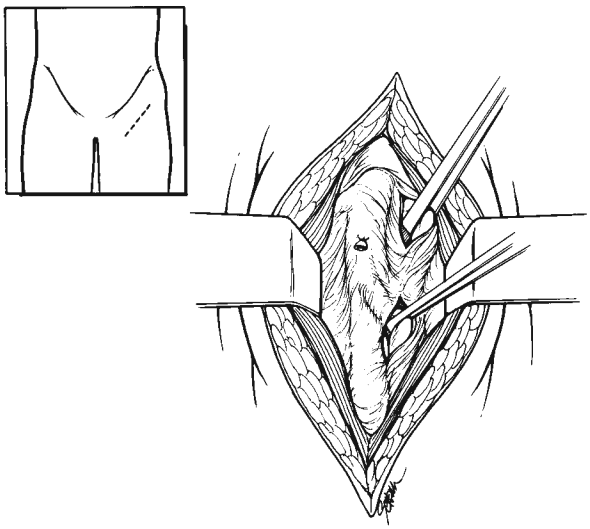

Fig 1. Axillary vein transfer. Exposure of the femoral vein confluence in the groin area. Sharp dissection through postthrombotic fibrous encasement is necessary so that the artery may be carefully separated from the vein. Dense encasement was present in 40% of the cases in this series. A 3- to 4-cm segment of vein should be cleared of small branches and collaterals, carefully preserving the profunda femoris vein.

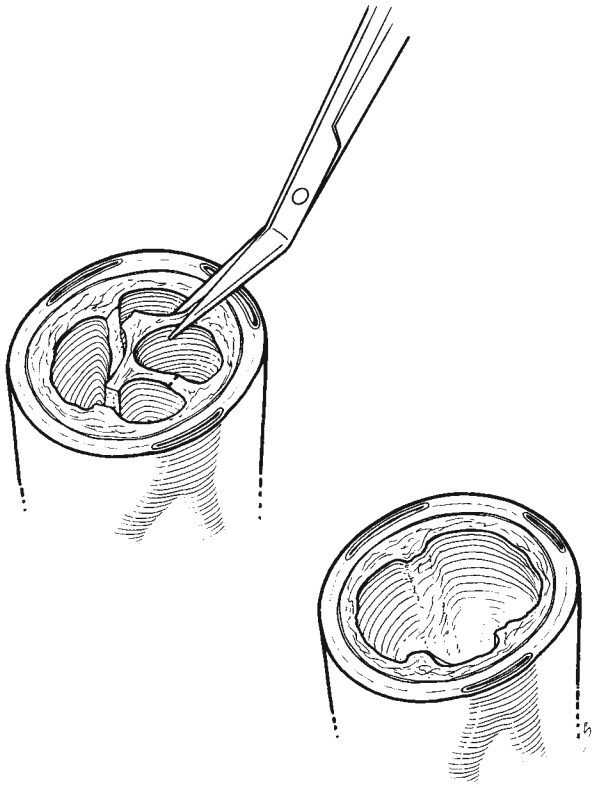

Fig 2. Intraluminal synechiae are excised to create a single lumen for the anastomoses. Thin-walled collaterals developing from vasa vasorum in the wall of the vein may be present. Excision of intramural vasa vasorum collaterals to direct their flow into the lumen is not recommended to avoid dangerous weakening of the wall resulting in suture line tears. These flimsy collaterals should be incorporated into the suture line.

reconstruction because it is relatively disease-free compared to the femoral veins. The tibiopopliteal venous segment is approached through a medial incision. Taking down the medial head of the gastrocnemius from its femoral attachment provides adequate exposure, even in obese limbs; reattachment is not necessary and is without sequelae. The short saphenous and gastrocnemius veins are ligated and divided to clear a venous segment of adequate length to effect the vein transfer procedure. A prominent profunda popliteal connection, which should be carefully preserved when the profunda femoris carries significant outflow from the leg, is invariably present. In such cases, the axillary valve transfer is performed caudal to the entry of this collateral.

Examination of the valve station before valve transfer. In many cases, the presence of trabeculated postthrombotic changes with destruction of native valves is readily apparent on inspection and palpation. Not uncommonly, however, a valve station bulge is present, suggesting the preservation of native valves. A vigorous adventitial dissection to expose valve attachment lines should be carried out in such cases. Delineation of valve attachment lines in their entirety denotes the presence of underlying valve cusps,[8] and they can be repaired primarily with a much simpler and less extensive direct-repair technique than axillary valve transfer. This is a surprisingly frequent occurrence in postthrombotic cases.[6] Absence of valve attachment lines indicates thrombotic dissolution, and a segment of vein about 1 to 2 cm long is then excised in preparation for valve transfer. The technique of axillary vein transfer has been described in detail elsewhere.[8] The essential steps are shown in Figs 1 through 5. In brief, the axillary vein is approached through an incision along the skin crease. A good size-match is usually present, but disparities in size can be minimized by harvesting a more proximal or distal valve as needed. Valved tributaries can sometimes be joined together (n = 8, in both groups in this series) to address size disparities (Fig 6). An axillary vein with valved branches can also be used to reconstruct the femoral confluence (n = 6; Fig 6). Two sequential valves in the axillary vein con-

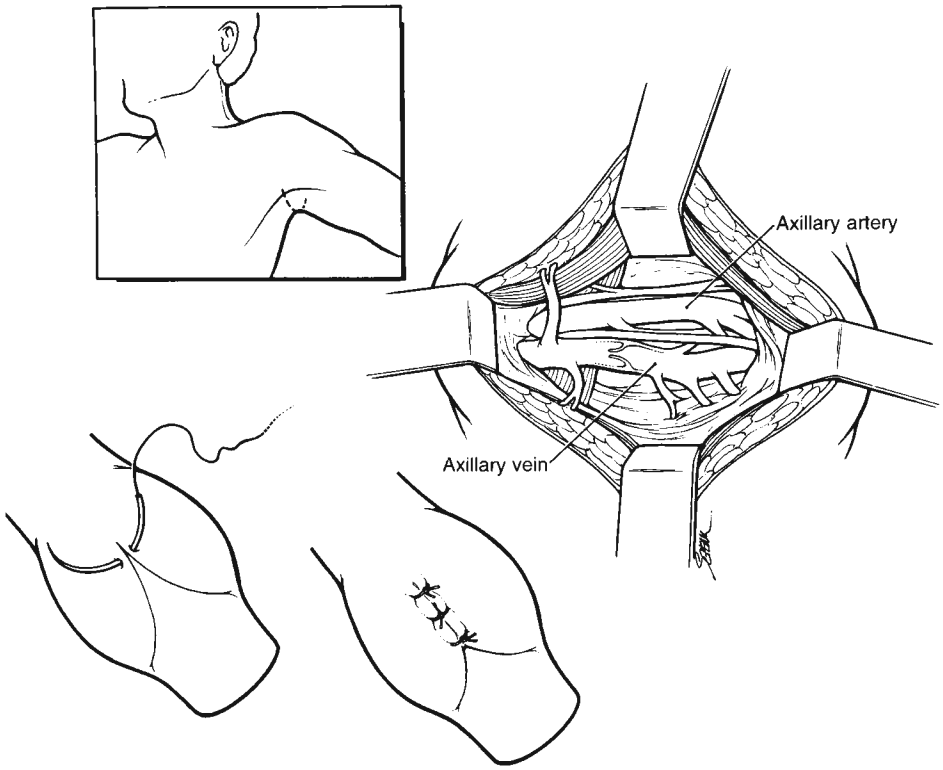

Fig 3. Exposure of the axillary vein and bench repair. Bench repair by means of the transcommissural technique is shown. Because the valve station needs to be distended during bench repair, it is easier to perform the procedure in situ or after transfer. In situ repair in the axilla avoids unnecessary harvest in the occasional instances in which the repair is unsuccessful.

duit can also be used to reconstruct the confluence by implanting the profunda femoris between the two valves (n = 4).[6] Segmental obstruction of the iliac vein or vena cava with pelvic collaterals is no impediment to femoral valve reconstructions.[8] Eighteen such reconstructions in both groups were undertaken in this series. Vena cava filters, all patent at the time of surgery, were present in three patients.

Reconstruction of the axillary vein after the valve is excised is not necessary, because no permanent impairment has been noted; transient mild swelling occurred in less than 2%.[8] The valve-bearing segment should be inserted under optimal tension with no hint of torsion. The upper suture line is performed first, and the valve is tested by removing the clamps (Fig 4) and, if possible, stripping the blood in the segment above against the valve (positive strip test). The transferred valve segment is enclosed in a ringed polytetrafluoroethylene sleeve to avoid late dilatation.[9]

Bench repair of axillary vein valve. Approximately 40% of axillary valves are incompetent in situ.[10] An adjoining competent valve is usually present and should be sought. Failing this, a "bench repair" of the leaky valve should be carried out. In about 10% of axillary valve transfers (n = 10 in this series), competent axillary valves become incompetent de novo[11] intraoperatively after transfer, despite careful technique. These valves are also candidates for bench repair. This series encompassed some early cases (n = 8, trabeculated and nontrabeculated) in which leaky axillary transfers were accepted, because bench repair techniques had not been developed. Attempts to repair the leaky valve with an external valvuloplasty technique[12] were only occasionally successful (two of nine attempts). Bench repair with the prosthetic sleeve technique[10] was also unsatisfactory (three of six failed). More recently, the transcommissural technique[8] has been successfully used (Fig 3) for bench repairs. Of 38 bench repairs made with this technique, competence, confirmed by means of the strip test, was restored to 35 previously incompetent axillary valves. Because this maneuver is executed rapidly, there is little reason to tolerate a leaky axillary valve transfer. Thirty-two

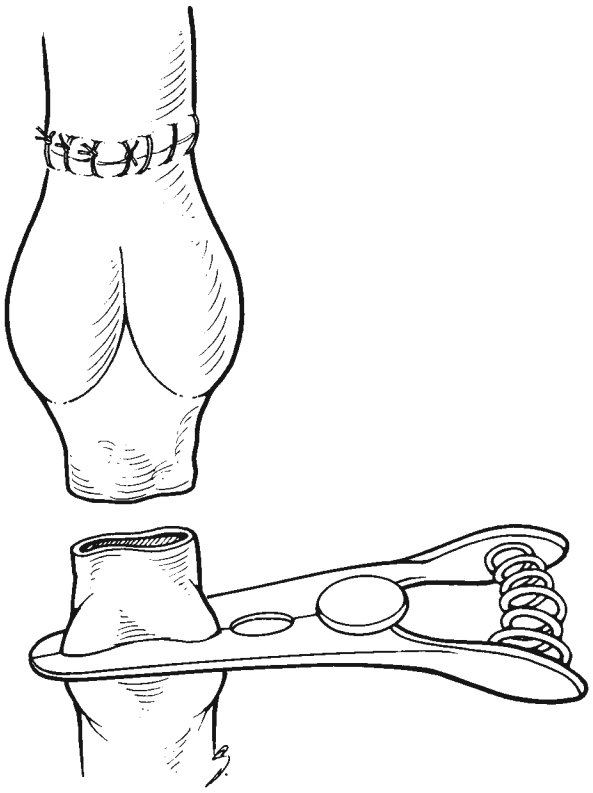

Fig 4. Axillary vein transfer. The proximal anastomosis has been completed. Interrupted sutures should be used for at least half the circumference of the anastomosis. Note the absence of valve leak with the proximal clamp off. Standard vascular clamps provide effective vascular control, even in heavily trabeculated veins. Clamp injury has not been noticed.

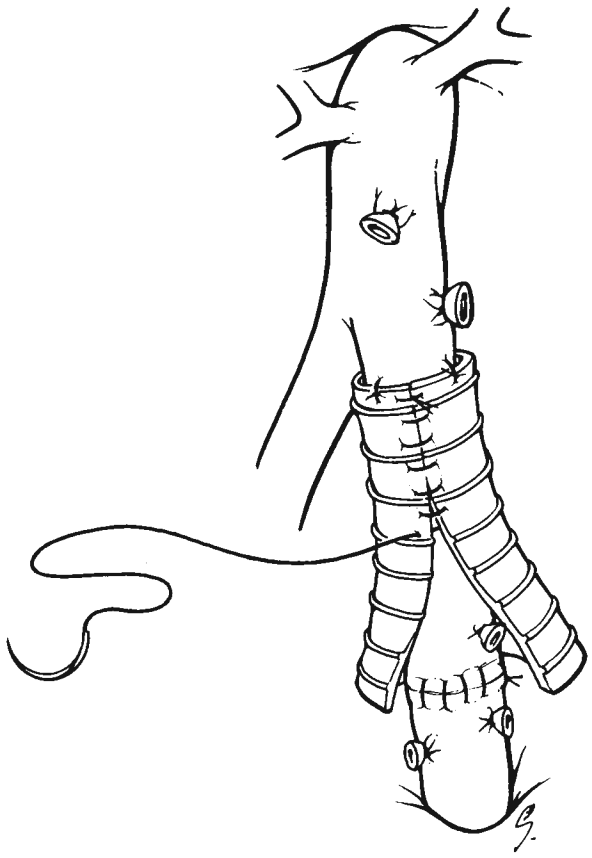

Fig 5. Axillary vein transfer. A ringed polytetrafluoroethylene sleeve is being applied around the transferred valve to prevent late dilatation.

bench repairs in the trabeculated series and 14 in the nontrabeculated series (38 with the transcommissural technique, two with the external technique, six with the prosthetic sleeve technique) are included in this report.

POSTOPERATIVE CARE

Patients received 5,000 to 12,000 units of heparin intravenously during surgery. Intravenous heparin was continued at 500 to 1,000 units per hour for 4 to 6 days after surgery on a prophylactic (not therapeutic) protocol. In the last year, dalteparin sodium (2,500 units twice daily) administered subcutaneously has been substituted for intravenous heparin. Patients were started on warfarin sodium the day after surgery and were discharged when a target international normalized ratio (INR) of 2.0 to 2.5 was maintained for 6 to 8 weeks, after which the target range was lowered to 1.7 to 2.0. Patients with hypercoagulability abnormalities were maintained on this regimen indefinitely. In other patients, warfarin sodium was reduced to a low-dose regimen,[13] typically 1 to 2.5 mg daily. Routine protime determinations were not required on this regimen.

After initial recovery from surgery, patients were rapidly returned to primary care by the local physician. Patients were encouraged to resume full activity and exercise after discharge and return to work after the first month. Patients were discharged home with a semirigid leg support to control postoperative swelling. After 4 to 8 weeks of using the leg support, patients were encouraged to choose the level of use of this compression device on their own or to abandon it if they so desired.

OUTCOME ASSESSMENT

Complete epithelialization of the ulcer was necessary to consider the ulcer healed[14]; epithelial breakdown to any extent after initial healing, even when transient, was considered a recurrence. Most

Table II. Venous functional parameters before and after surgery.

Parameter	*n*	*Preoperative: mean ± SD*	*Postoperative: mean ± SD*	*P*
Postexercise pressure (mm Hg)	53	71 ± 19	75 ± 14	NS
Percentage drop (%)	53	29 ± 14	26 ± 11	NS
VFT (seconds)	53	6 ± 4	12 ± 12	< .03
Valsalva pr (seconds)	51	8 ± 8	7 ± 8	NS
VFI90 (mL/second) (APG)	41	6 ± 4	4 ± 2	< .01

VFT, venous filling time; *VFI90,* venous filling index.
[1] *Because some laboratory techniques were introduced later than others in this long experience, the n value for various test results may vary. Also, the n value for invasive hemodynamic testing is generally less than that for noninvasive techniques because of technical or access problems and because both preoperative and postoperative data need to be available (Table II; Figs 7 and 8).

ulcers healed within 4 months after surgery; in the construction of actuarial curves, ulcers that healed were considered healed at the beginning of the curve (ie, the initial grace period of 4 months for ulcer healing was ignored in constructing the curves). Ulcers that never healed after the procedure were counted as recurrences at the first follow-up visit after the grace period for calculation of actuarial data.

Swelling. Leg swelling was graded as grade 0 (absent), grade 1 (pitting, not gross), grade 2 (visible ankle edema), or grade 3 (massive, encompassing the entire leg).

Pain. Patients were asked to indicate their level of pain on a visual analogue scale,[15] ranging from 0 to 10.

Data analysis and statistics. Data were contemporaneously entered at each patient visit into a commercially available database. Because only prospective data were analyzed, the n value for some parameters that were added to the database later during the course of this experience is less than the total number of cases in this series. Actuarial survival curves were subjected to logistic regression to analyze variables. The paired *t* test was used to compare outcome regarding venous laboratory parameters.

RESULTS

There was no operative mortality. Ten (10%) axillary vein transfers in the trabeculated group were slightly incompetent intraoperatively after the transfer procedure. Complications included hematoma/seroma (6%); superficial wound infection (6%) in five limbs, related to the saphenous strip in two; deep wound infections (2%) in two cases (both resulted in loss of repair, one at 10 days and the other at 26 months); postoperative (less than 6 weeks) DVT (4%); and miscellaneous complications (2%). There was no pulmonary embolus in this patient cohort.

The cumulative incidence of adverse events inherent to the postthrombotic extremity and not directly related to surgery recorded during long-term follow-up included cellulitis/lymphangitis (5%) and recurrent DVT (6%).

Axillary vein transplant patency and competence. The early (less than 3 months) patency rate was 96%. Three repairs were lost, one each to DVT, technical error, and infection. There was a late loss (more than 3 months) of an additional five transplants (6%), one caused by infection and four related to recurrent DVT. The cumulative patency rate of axillary vein transplants in the trabeculated group was higher than 80% at 10 years, as shown in Fig 7. Actuarial survival curves for the transferred axillary valves in the trabeculated group based on valve closure times (1 second or less, 2 seconds or less, and 3 seconds or less) are shown in Fig 8. The cumulative percent probability of a transferred axillary valve to maintain a valve closure time of 1 second or less was 38% at 4 years; the percent probability of a valve closure time of 2 seconds or less was 53% at 4 years.

Hemodynamic outcome. Despite severe phlebographic appearance, most patients were well compensated preoperatively for outflow function. By means of the arm/foot venous pressure technique, 86% (n = 55) were obstruction grades 1 or 2 (compensated), and 14% were grades 3 or 4 (decompensated). After surgery, four patients showed an increase from the compensated to the decompensated category, but this change proved transient in two patients. The other patients remained unchanged, within one grade of their preoperative status. None of the patients exhibited clinical signs of acute outflow embarrassment (phlegmasia).

In contrast to the relatively benign outflow parameters, most patients exhibited marked calf pump dysfunction, with grossly abnormal reflux-related parameters and severe ambulatory venous hypertension preoperatively (Table II). Sixty-seven percent of patients showed a preoperative ambulatory venous

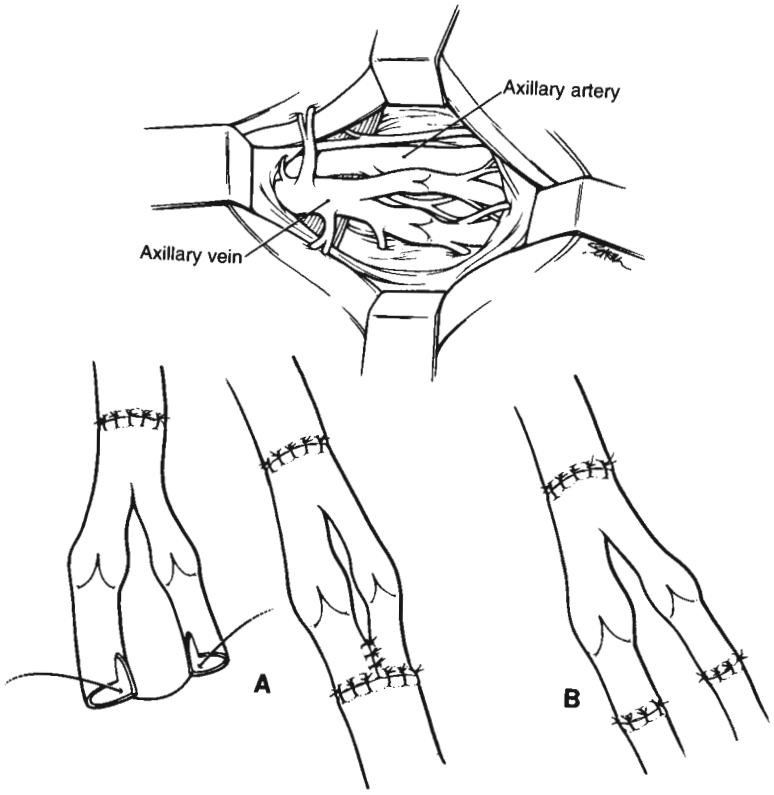

Fig 6. Axillary vein transfer, technical variations. **A,** A branched axillary vein has been used to construct a valved "double barrel" conduit. This technique may be used to address size disparities. **B,** A branched axillary vein can also be used to reconstruct the femoral confluence, restoring competency to both the superficial femoral and profunda femoris veins.

pressure of 70 mm Hg or higher, with 56% recording venous filling time (VFT) of 5 seconds or less. Preoperative VFI90 was elevated. Both VFT and VFI90 showed significant improvement after valve surgery. There was no change in postexercise pressure or percentage drop (Table II).

Clinical results. Actuarial outcome that was graded good or excellent according to current reporting standards[14] for the trabeculated group (n = 77, all clinical classes) was 62% at 5 years, 57% at 10 years, and 53% at 15 years. Actuarial freedom from recurrence in the large subset who had active or recurrent ulcers (classes 5 and 6) is shown in Fig 9. Comparative data for the nontrabeculated group are also shown. There was no statistical difference between the two groups. The recurrences level off at 3 to 5 years for both groups, after which there are very few recurrences.

Regression analysis indicated that ulcer recurrence was similar in single- and multiple-valve reconstructions and regardless of whether a concurrent saphenous vein procedure had been performed with axillary vein transfer. Similarly, a concurrent modified Linton procedure did not influence outcome. Bench-repaired axillary veins, including 25% that still leaked despite the repair, showed a higher (48% vs 25%), but statistically insignificant, recurrence rate compared with the group that did not require a bench repair. There was a trend toward higher recurrence (60% vs 32%) in axillary valves that were still somewhat leaky intraoperatively compared with fully competent repairs, but the difference did not reach statistical significance because of the small sample size. Severe preoperative ambulatory hypertension with a VFT less than 5 seconds was not an impediment to a successful outcome; this subset of patients (n = 45) had a nearly identical recurrence rate of 33%, compared with 38% for the group of patients (n = 16) whose preoperative VFT was longer than 5 seconds. Residual severe ambulatory venous hypertension (VFT less than 5 seconds) after surgery, however, adversely affected outcome (45% recur-

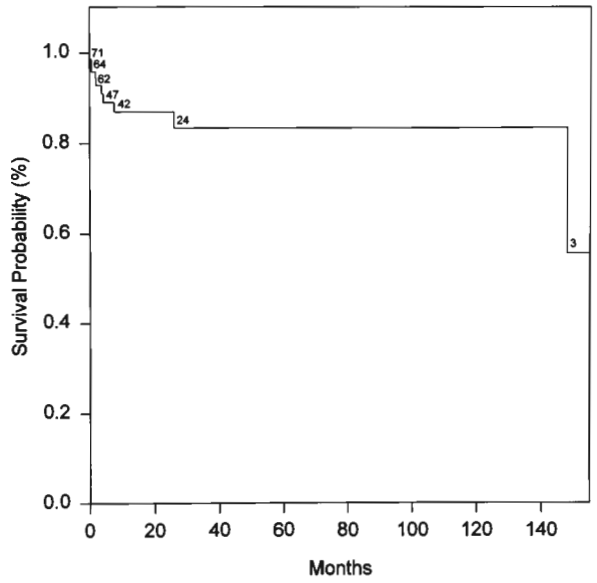

Fig 7. Cumulative patency rate of transferred axillary valves in the trabeculated group.

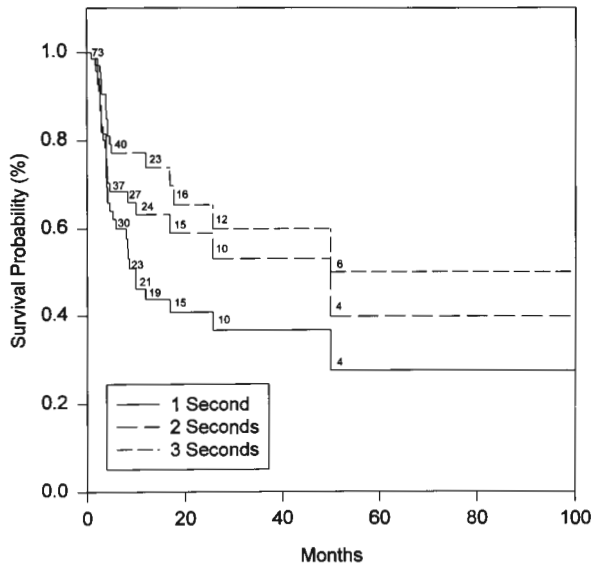

Fig 8. Valve closure times of transferred axillary valves; survival probability (actuarial) for valve closure times of 1 second or less, 2 seconds or less, and 3 seconds or less are shown. Number of valves at risk at selected intervals are shown above each curve.

rence vs 14%; $P < .02$). Twenty-two percent of patients (18 of 81 patients) had identifiable hypercoagulation abnormalities in the trabeculated groups; no adverse clinical outcome was noted in this subset compared with the rest.

Swelling. Among the 57 limbs for which this information was available, 37 limbs had grade 0 or grade 1 swelling preoperatively; 20 had grade 2 or grade 3 swelling before surgery. In eight of 12 limbs with preoperative grade 3 swelling and three of eight limbs with preoperative grade 2 swelling, the swelling disappeared altogether or regressed to pitting non-gross edema. Grade 3 edema developed after surgery in six of 37 limbs that had no or only mild edema preoperatively. In the remaining 31 of 37 limbs, swelling remained mild and stable after surgery.

Pain. Mean preoperative pain level was 6 of 10 on the visual analogue scale. Mean pain level after surgery was 2 of 10 ($P < .01$). Among 53 limbs for which this information was available, seven (13%) had neither preoperative or postoperative pain, 37 (70%) had significant relief of pain after surgery by at least 3 of 10 points on the visual analogue scale, in seven (13%) there was no change, and pain worsened after surgery in two (4%). In 12 of 39 limbs with a preoperative pain level of 5 of 10 or greater on the visual analogue scale, pain entirely disappeared (level 0) after surgery.

Stocking use. Preoperative stocking use was reported by 80% of patients (n = 55); 9% were intolerant of stockings, and relevant information was unavailable in 11%. Postoperatively, 27% of patients had abandoned stockings, 26% reported using them irregularly, and 47% reported using them on a regular basis.

DISCUSSION

This report focuses on our experience with perhaps the most difficult subset of postthrombotic patients, those with trabeculated postthrombotic veins, which are often associated with additional segmental venous obstructions and with clinical features of severe postthrombotic syndrome. They invariably fail compression therapy and are often consigned to lifelong episodic Unna boot regimens. Many of these patients (22% in this series) had had earlier multiple procedures, including skin grafts, limited superficial venous surgery, or perforator ligation, that failed. The pathophysiology of their veins is one of combined obstruction and reflux. Considering the grossly abnormal phlebographic appearance (Fig 10), most of the patients are surprisingly well compensated with regard to outflow, but appear poorly tolerant of the reflux component combined with calf pump dysfunction. Most of the patients have severe ambulatory venous hypertension with extremely short VFT. Multisegment, multisystem (superficial, deep, and perforator) reflux is typically present. Because the source of reflux

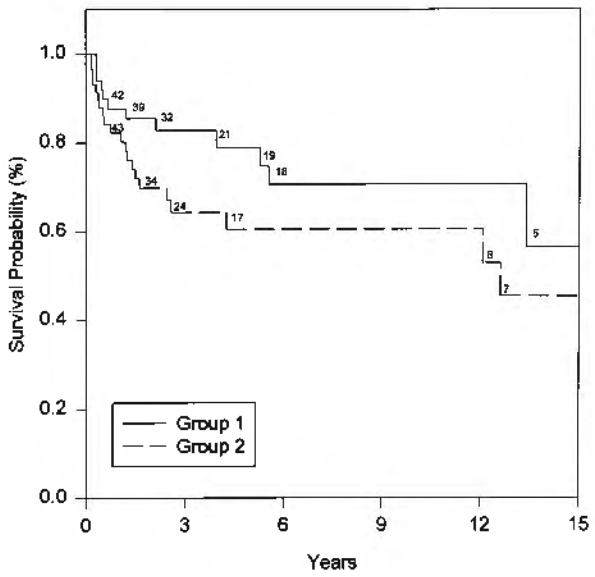

Fig 9. Actuarial recurrence-free ulcer healing in the subset of patients with stasis ulceration after axillary vein transfer to nontrabeculated (group 1, n = 51) and trabeculated veins (group 2, n = 59). Limbs at risk at selected intervals are shown above each curve.

Fig 10. Venographic appearance of trabeculated deep veins in a patient with severe postthrombotic syndrome. Despite venographic appearance, functional obstruction is typically well compensated in these patients.

is heterogenous, attempts to eliminate it necessarily require a combination of procedures directed toward the deep, perforator, and superficial systems. When a significant source of reflux in one or the other system is overlooked and left uncorrected, recurrence may result and symptoms of pain and swelling may persist. Although surgical elimination of reflux seldom normalizes laboratory parameters (Table II),[6,10,16-19] it does appear to afford sufficient hemodynamic improvement to result in substantial clinical improvement. Because we used a combination of procedures, we cannot prove from this experience that axillary vein transfer was solely responsible for the outcomes. We can, however, conclude that axillary vein transfer in combination with the other procedures described can be effective, safe, and durable in this surgically neglected group of patients who are devoid of other options. Actuarial ulcer healing rates as high as 60% sustained beyond 10 years, similar to our results in nontrabeculated veins, were noted in this experience. These results are also similar to those reported by us[16] and others[7,17-19] with valve reconstruction in primary valve reflux. Furthermore, other debilitating symptoms of severe postthrombotic syndrome, particularly pain, appear to be relieved to a significant extent with valve reconstruction. Patients in this series who were operated on after 1985 (74 of 83 patients) were unselected; ie, no patient was turned down because of severity of clinical presentation or venographic appearance. Clearly, the procedures described in this experience are applicable to a wide range of postthrombotic patients. There was a surprisingly high operability rate on the deep system, with an excellent chance of achieving a valve reconstruction procedure, particularly in the femoral area, despite the severity of phlebographic appearance (Fig 11). This fact, together with the advent of bench repair of leaky axillary valves, has increased the availability of this surgical option in this difficult group of patients.

To our knowledge, there are no published long-term (longer than 5 years) results of compression therapy or traditional surgical procedures, such as perforator interruption and vein stripping, in postthrombotic syndrome.

Analysis of the results offers some clues about how the results may be further improved. Every effort should be made to achieve a competent repair

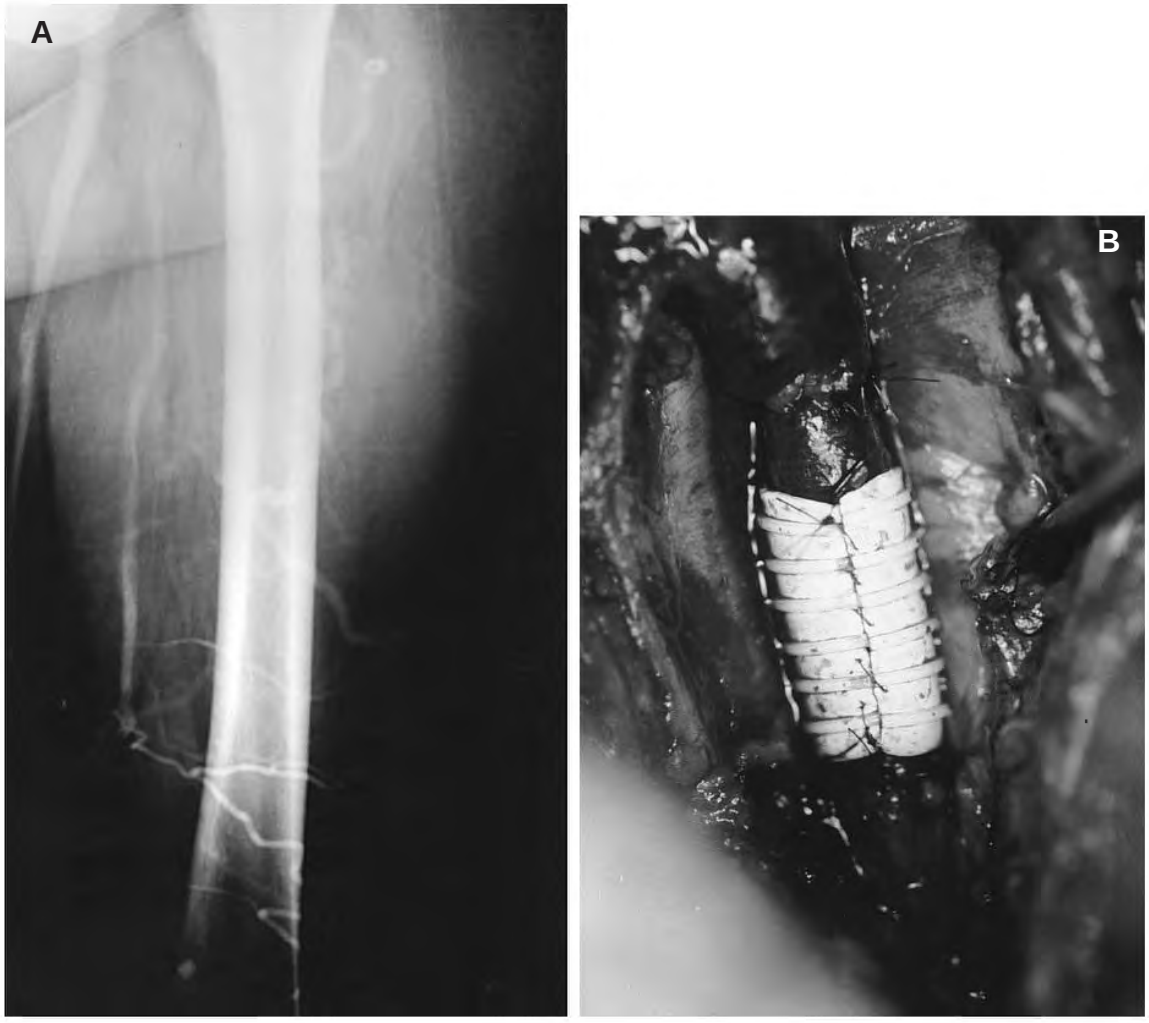

Fig 11. Venographic appearance in case of advanced postthrombotic syndrome. Note extensive network of superficial collaterals. Saphenous vein appears to function as main outflow tract, and proximal femoral veins are not visualized **(A)**. "Blind" exploration of groin (see Technique section) revealed enlarged trabeculated profunda femoris vein to which an axillary vein transfer was performed **(B)**. A poorly recanalized superficial femoral vein was divided, and the dilated saphenous vein was stripped, which was tolerated without any ill effects. Nonvisualization of profunda femoris on this venogram, therefore, proved to be a venographic artifact.

intraoperatively; even slightly leaky repairs apparently tend to have a higher recurrence rate. Because a postoperative VFT of less than 5 seconds was associated with a higher recurrence rate, additional sources of reflux, particularly long saphenous reflux, should be eliminated concurrently with deep valve reconstruction to achieve the maximum prolongation of VFT feasible in a given patient. A dilated saphenous vein that appears to act as a collateral (secondary varicosity) on ascending phlebography (Fig 11) is a significant source of reflux in this group of patients. It is commonly believed that saphenectomy should not be carried out in these circumstances, because the collateral pathway would be compromised. We have, however, shown that saphenectomy can be carried out safely in these patients, without sequelae and without compromising total limb outflow.[6] Saphenectomy improves VFT.[20,21] Similar ulcer healing rates in limbs, regardless of whether they underwent saphenous procedures or not, should not be misconstrued to indicate the futility of saphenous procedures in this context. Because the nonsaphenectomy group in this series did not have saphenous reflux to begin with, this statistic indicates instead that similar results can be achieved in limbs with additional

saphenous reflux by performing a saphenous procedure concurrently with deep valve reconstruction.

The situation with regard to concurrent or staged modified Linton procedure with deep valve reconstructions is less clear. Ambulatory venous pressure does not improve after perforator ligation.[22]

Our rationale for carrying out multiple valve reconstructions (concurrent or staged) is based on the hypothesis that elimination of all possible sources of reflux (superficial or deep), particularly collateral deep reflux, is desirable for a durable result in postthrombotic syndrome. Axio-axial and tributary-axial collateral reflux, particularly involving the profunda femoris, is a prominent feature of postthrombotic syndrome.[1,6,8,18] Multiple valve reconstructions at the superficial femoral, profunda, and popliteal levels may control the entry and/or the exit points of such collateral reflux.[8]

Uncorrected profunda femoris reflux is a well-known source of recurrence[18,19] and persistent ambulatory hypertension.[19] Failure of a reconstructed valve is the single most common cause of recurrence in this series and others.[19] In addition, multiple valve reconstructions may help diminish recurrence when one of the repairs fail, but the other(s) remain functional. Masuda and Kistner[19] reported 43% cumulative clinical success at 10 years with single valve reconstructions in 16 cases of postthrombotic syndrome.[19] Fourteen were segment transfer procedures, and two were valve transplants. Although that series is not comparable with ours (trabeculated veins were not specified), the difference in results may be caused by their choice of technique (segment transfer vs axillary vein transfer) and/or reconstruction of only one valve, as noted by these authors themselves.[19] Segment transfer has generally yielded inferior results at multiple centers when compared with axillary vein transfer.[19] Whether perforator interruption, either alone or in combination with saphenectomy, has a role as a primary procedure without deep valve reconstruction in postthrombotic syndrome remains an open question. High recurrence has been reported for this procedure in postthrombotic syndrome by some authors.[1,23]

Although valve closure times of normal competent valves is well defined,[24] attempts to apply the method to quantify and grade reflux and relate it to clinical severity have been disappointing. Therefore, definition of reflux based on valve closure times is necessarily arbitrary. Nevertheless, we have classified valve closure times of 1 second or less, 2 seconds or less, and 3 seconds or less to represent competent, mildly refluxive, and incompetent valve repairs, respectively, a slight modification of the scale proposed by Masuda and Kistner.[19]

Mechanisms responsible for the genesis of ambulatory venous hypertension are complex[25-28] and involve both reflux- and nonreflux-related factors. The latter may be particularly important in postthrombotic syndrome.[26] Thus, successful reduction or elimination of reflux by means of surgical valve repair may not improve or normalize ambulatory venous pressure parameters in some patients.

Although the clinical results in this difficult group of patients are encouraging, it must be acknowledged that support for several concepts espoused in our approach to the problem is empirical and not scientifically validated. This favorable clinical experience may, however, provide the justification and impetus for a further, more focused study.

REFERENCES

1. Raju S, Fredericks R. Venous obstruction: An analysis of 137 cases with hemodynamic, venographic, and clinical correlations. J Vasc Surg 1991;14:305-13.
2. Beebe HG, Bergan JJ, Bergqvist D, et al. Classification and grading of chronic venous disease in the lower limbs: A consensus statement. Phlebology 1995;10:45-52.
3. Raju S. New approaches to the diagnosis and treatment of venous obstruction. J Vasc Surg 1986;4:42-54.
4. Nicolaides AN, Sumner DS, editors. Investigation of patients with deep vein thrombosis and chronic venous insufficiency. Los Angeles: Med-Orion Publishing; 1991.
5. Neglén P, Raju S. A rational approach to detect significant reflux using duplex Doppler scan and air plethysmography. J Vasc Surg 1993;17:590-5.
6. Raju S, Fountain T, Neglén P, Devidas M. Axial transformation of the profunda femoris vein. J Vasc Surg 1998;27:651-9.
7. Sottiurai VS. Surgical correction of recurrent venous ulcer. J Cardiovasc Surg 1991;32:104-9.
8. Raju S, Hardy JD. Technical options in venous valve reconstruction. Am J Surg 1997;173:301-7.
9. Raju S. Venous insufficiency of the lower limb and stasis ulceration: Changing concepts and management. Ann Surg 1983;197:688-97.
10. Raju S, Fredericks R. Valve reconstruction procedures for nonobstructive venous insufficiency. J Vasc Surg 1988;7:301-10.
11. Sottiurai V. Valvuloplasty of incompetent transferred axillobrachial valves: indication and long-term results. San Diego: American Venous Forum Eighth Annual Meeting; 1996.
12. Kistner R. Surgical technique of external venous valve repair. Proc Straub Pacific Health Found 1990;55:15-6.
13. Poller L, McKernan A, Thomson JM, et al. Fixed minidose warfarin: A new approach to prophylaxis against venous thrombosis after major surgery. Br Med J 1987;295:1309-12.
14. Porter JM, Moneta GL, Beebe HG, et al. Reporting standards in venous disease: An update. J Vasc Surg 1995;21:635-45.
15. Scott J, Huskisson EC. Graphic presentation of pain. Pain 1976;175-84.
16. Raju S, Fredericks R, Neglén P, Bass JD. Durability of venous valve reconstruction techniques for "primary" and postthrombotic reflux. J Vasc Surg 1996;26:357-67.
17. Bry JD, Muto PA, O'Donnell TF Jr, Isaacson LA. The clini-

cal and hemodynamic results after axillary-to-popliteal vein valve transplantation. J Vasc Surg 1995;21:110-9.
18. Eriksson I, Almgren B. Influence of the profunda femoris vein on venous hemodynamics of the limb. Experience from thirty-one deep vein valve reconstructions. J Vasc Surg 1986;4:390-5.
19. Masuda EM, Kistner RL. Long-term results of venous valve reconstruction: A four-to twenty-one-year follow-up. J Vasc Surg 1994;19:391-403.
20. Bjordal RI. Pressure patterns in the saphenous system in patients with venous leg ulcers. Acta Chir Scand 1971;137: 495-501.
21. Raju S, Easterwood L, Fountain T, et al. Saphenectomy in the presence of chronic venous obstruction. Surgery 1998;126:634-44.
22. Burnand KG, O'Donnell TF Jr, Thomas ML, Browse NL. The relative importance of incompetent communicating veins in the production of varicose veins and venous ulcers. Surgery 1977;82:9-14.
23. Gloviczki P, Bergan JJ, Canton LG, et al. Mid-term results of endoscopic perforator vein interruption for chronic venous insufficiency: lessons learned from the North American Subfascial Endoscopic Perforator Surgery Registry. San Diego: Society for Vascular Surgery Fifty-second Meeting; 1998.
24. Van Bemmelen PS, Bedford G, Beach K, et al. Status of the valves in the superficial and deep venous system in chronic venous disease. Surgery 1990;109:730-4.
25. Raju S, Fredericks R, Lishman P, et al. Observations on the calf venous pump mechanism: Determinants of postexercise pressure. J Vasc Surg 1993;17:459-69.
26. Raju S, Neglén PN, Carr-White PA, et al. Ambulatory venous hypertension: Component analysis in 373 limbs. Vasc Surg. In press 1999.
27. Raju S, Hudson CA, Fredericks R, et al. Studies in calf venous pump function utilizing a two-valve experimental model. Eur J Vasc Endovasc Surg. In press 1999.
28. Raju S, Green AB, Fredericks RK, et al. Tube collapse and valve closure in ambulatory venous pressure regulation: Studies with a mechanical model. J Endovasc Surg 1998; 5:42-51.

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DISCUSSION

Dr Thomas F. O'Donnell, Jr (Boston, Mass). I certainly would like to compliment Dr Raju and his associates on their presentation of an 18-year experience with the surgical treatment of post-thrombotic deep venous reflux. This report gains particular relevance in light of the preceding paper from the North American Subfascial Endoscopic Perforator Surgery Registry, which reported a high ulcer recurrence rate with treatment of perforator and superficial venous disease. Particularly in the post-thrombotic cohort, there will be a need for deep venous reconstruction.

Dr Raju has analyzed a subset of his enormous Houston-like experience with 259 valve reconstructions—a number that exceeds the total procedures available from a compilation of all other series in the literature, which is about 223 limbs. The follow-up period was extensive, with half the patients followed for 5 years or more. All were well studied with phlebography for anatomy and multiple hemodynamic measurements. Several important conclusions can be drawn from this paper. There were no deaths, no pulmonary embolisms, a low 4% incidence rate of deep venous thrombosis, and a 96% early patency rate. This is a safe procedure.

Despite extensive recanalization changes suggesting near occlusion with phlebography, obstruction is judged objectively with hemodynamic measurements. Actually, Dr Raju's own measurement was unusual in 14%. This emphasizes the fact that reflux is the dominant pathology in post-thrombotic syndrome.

Next, valve function in the transplanted venous segment appears critical. One valve appears sufficient, but any reflux should be corrected by the Kistner transcommissural repair.

I would like to compliment them also on using log rank expression of ulcer recurrence, which I believe is the single most objective method for measuring a procedure's efficacy. Their 5-year ulcer-free survival rate of 65% was nearly identical to our own series of axillary to popliteal vein transplants reported in the Journal of Vascular Surgery in 1995.

I have several questions.

First, regarding the study conduct or design. Because this review spans 18 years, what major changes in evaluation techniques and postoperative management occurred that might have affected your results? Although this was a retrospective study with its inherent bias towards underestimating certain factors because of a chart review process like several presented at this meeting, what data were prospectively recorded in this study?

A little bit about technique. Recanalized veins, as you showed in your slide, usually have multiple channels. Did you sew the interposed segment to the circumference of the vein always or did you pick out dominant proximal distal channels? Intraoperatively, do you use continuous wave Doppler scanning or would duplex scanning be advantageous?

And finally, anticoagulation. Because recurrent deep venous thrombosis was the most common cause of graft loss, would you use low-dose anticoagulation in all patients, particularly the trabeculated group?

I enjoyed the manuscript, and I thank the Society for the privilege of commenting on this paper.

Dr Seshadri Raju. Dr O'Donnell, thank you for those comments. Data integrity has been a high priority item. Ever since 1982, we have maintained a prospective com-

puterized database on these patients. Core elements analyzed in this study, such as recurrence, complications, and so forth, were designed as data fields from the very beginning. All clinic visits including the initial and follow-up visits were actually conducted in this computerized format, and the information was contemporaneously entered. Similarly relevant data acquired during surgery have adhered to a prospective computerized format. Of course, we have added new fields to this database in recent years, such as analogue pain scale; these too are largely prospective data. For this reason, the n value for the newer fields is smaller than the number covered by the entire series. The other question had to do with evolution of technique over the 18-year period. This is inevitable. Although the basic technique has not changed over the years, I think there has been improved execution from largely intangible factors and incremental changes associated with increasing experience; these factors are difficult to identify in specific terms. Some aspects of technique, such as the method of bench repairs, have changed in major ways that they can be identified. Comparing the results of our early experience with contemporary results, we estimate that we have been able to improve the 5-year recurrence rate by about 15% to 20% because of increasing experience.

We try to create a single lumen at the anastomotic site by local excision of the intraluminal synechiae. An exception is the vasa vasorum collaterals in the wall of the recipient veins. It is better to incorporate these extremely thin-walled channels in the suture line to achieve a secure anastomoses rather than trying to make them a functional part of the anastomoses. We have not used duplex scanning during surgery. We have simply relied on careful technique and the strip test to ensure patency and competence of the transferred axillary valve segment.

Regarding anticoagulation, our practice in this area has changed over time. Our initial attempts at long-term anticoagulation at therapeutic levels in these patients were abandoned quite early in this experience because of the inevitable bleeding complications that occur with full therapeutic anticoagulation regimens. We currently target an INR of 2.5 to 3.0 for up to 6 to 8 weeks after surgery, after which the target is lowered to 1.7 to 2.0 in patients without hypercoagulability syndromes. At 6 months, there is a further reduction to "low dose" warfarin sodium of 1 to 2.5 mg a day without regard to protime. This regimen has essentially eliminated bleeding complications while reducing recurrent thrombosis to acceptably low levels.

Dr Frank T. Padberg, Jr (East Orange, NJ). I would like to congratulate you for your technical prowess in demonstrating the safety of this procedure over such a long period of time. I note, however, that in your log rank comparison you compared it to your own valve repairs without post-thrombotic causes and showed very little difference. Our last paper, as you know, showed that there was a significant difference with post-thrombotic disease in SEPS. My bias is that there should be one in deep vein valvular repair as well. My question is, could you compare that for us by log rank ulcer recurrence for those patients treated with only best medical therapy? As we know, the likelihood of achieving freedom from ulceration at 5 years in good hands should be about 70%.

Dr Raju. Dr Padberg, thank you for those comments. The control group that I used for comparison with the trabeculated group was largely postthrombotic also but without trabeculae as shown under CEAP classification in Table I. There is no difference in recurrence between the two groups. We have also documented in a presentation 3 years ago before the societies at New Orleans that the results of deep valve reconstruction between "primary" and postthrombotic patients are within a few points of each other. It appears that restoration of competency rather than the etiology is the relevant factor governing recurrence. In contrast, our experience with perforator interruption in postthrombotic patients has been dismal, similar to your experience with SEPS (J Vasc Surg 1991;3:305-13).

There are very few long-term studies of conservative management of postthrombotic ulceration. Most report a short-term recurrence of 50% to 70%, a figure consistent with our own clinical experience. Two other studies of which I am aware that have followed patients somewhat longer have excluded initial treatment failures and noncompliant patients from analysis to arrive at lower recurrence rates. Besides recurrence, outcome analysis should include other criteria, such as pain and functional parameters contributing to quality of life. It is our impression that surgery has an edge over conservative therapy in these outcome measures.

Dr E. John Harris (Stanford, Calif). This is truly an outstanding series, Dr Raju, but I did not catch the morbidity related to the harvest of the axillary valve. Is there any? And if it is significant, have you considered using a cryopreserved superficial femoral vein with a competent valve as an alternative?

Dr Raju. Those morbidity figures are included in the manuscript but were omitted from the oral presentation because of time considerations. Only two patients in the entire series have had any arm complaints, both with episodic arm swelling. Axillary vein harvest appears to be remarkably trouble free.

Dr William H. Baker (Maywood, Ill). Dr Raju, a very nice series. I rise with a little caution regarding blind exploration of veins. It may have been a necessity when you started this series, but I cannot imagine finding a patent vein when the duplex scan tells me that it is occluded. Could you perhaps elaborate on that?

Dr Raju. I agree that duplex scanning is more reliable and should be used before "blind" explorations. My comments were directed towards venography in general and the way they are interpreted and reported in other contexts as well. Nonvisualization does not necessarily indicate absence. We know, for example, that the deep system will not visualize in many normal individuals unless contrast is forced into the deep system by a tourniquet. Yet, opacification of the saphenous and nonopacification of the femoral veins in the thigh are frequently misinterpreted to assign an unwarranted critical collateral role to the saphe-

nous vein. We have shown that saphenectomy is safe and, in fact, may be beneficial in postthrombotic patients with this venographic presentation. Clearly, adequate intramuscular and other deep collaterals are present in these patients even though they do not visualize on venography because of variable centripetal flow patterns. Even duplex scanning with standard examination technique may miss these deep collaterals.

Dr Christopher K. Zarins (Stanford, Calif). Could you comment on excision of the trabeculae? I know you do it locally, but would it be of help to use an angioscope and to excise as completely as possible those trabeculae over a longer segment?

Dr Raju. I think it would be. I have not done it, but I know Dr Kistner has been carrying out trabeculectomies at the important junctional sites, like the femoral confluence. He has done several cases, and he tells me that it works very well.