Technical Options in Venous Valve Reconstruction

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PURPOSE: Several modifications and details of techniques that were found useful in venous valve reconstruction are described. Related technical outcome data are also presented.

METHODS: Five hundred eighty-two valve segments were reconstructed in 347 limbs using a variety of different techniques.

RESULTS: Intraoperative valve competence was achieved in 86% of 347 limbs. The incidence of technical stenosis was 4%, thrombosis of repair <1%, loss due to hematoma/infection <1%, and operative mortality 0%. Postoperative duplex competence was achieved fully in 78% and partially in 16%; 6% remained refluxive. Rapid postoperative healing of stasis ulcer occurred in 93%.

CONCLUSIONS: The expanded variety of technical options in valve reconstruction allows optimization for the individual patient. Regardless of pathology, a functional venous valve can be reconstructed in most patients utilizing one of the described techniques. ***Am J Surg.*** **1997;173:301–307.**

Venous valve reconstruction for "primary" reflux was pioneered by Kistner in 1968.[1] Since then, valve reconstruction has evolved into a wider variety of techniques[2] and has been extended to address postthrombotic reflux as well. Certain modifications and details of techniques that proved useful in our experience are reported below.

MATERIAL AND METHODS

A total of 582 valve segments were reconstructed in 347 limbs at the University of Mississippi Medical Center over a period of 15 years (1979 to August 1994). Surgery was undertaken when conservative therapy failed or when recurrent complications developed during conservative therapy. The primary indication for valve reconstructive surgery was as follows: stasis ulceration or stasis dermatitis 71%, pain 17%, swelling 6%, recurrent calf vein thrombosis 3%, and recurrent cellulitis 4%. The pathology in 582 reconstructed valves was primary valve reflux in 55%, postthrombotic reflux in 39%, and congenital dysplasia in 6% (refluxive duplication conduits 5%; refluxive valvular dysplasia 1%).

Hemodynamic assessment consisted of detailed pressure studies,[2] including air plethysmography, duplex, ultrasonography and contrast (ascending and descending) venography. The laboratory studies were repeated at periodic intervals during postoperative follow-up. Technical outcome of the procedure was assessed on the following factors: (1) restoration of valve competence, (2) maintenance of patency without hemodynamic stenosis, (3) healing without loss of repair due to hematoma or infection, and (4) rapid resolution of stasis ulceration after surgery. In this report, we focus on technical aspects of the procedures described and short-term early outcome (<90 days). Long-term clinical results and venous functional assessment are not included here, but will be reported separately elsewhere.

Pathological classification was based on surgical findings and gross appearance of the operated venous segment. The valve was classified as postthrombotic if an inflammatory reaction was present, wall thickening was evident, or the valve structure and venous lumen were obviously involved in the process.

Technique

Internal valvuloplasty. We have preferred a transverse venotomy for exposure of the valve.[2] A technical difficulty commonly encountered during the procedure is the appropriate placement of the venotomy and identification of the valve cusps. A high venotomy may render valve exposure difficult and low incision may violate the valve structure. Descending venography is not always reliable in preoperative mapping of the valves because intact valve cusps may be obscured by massive reflux, and postthrombotic trabeculae sometimes erroneously suggest the presence of valve cusps.

We have found that the clear identification of the valve attachment lines by initial adventitial dissection avoids many of these difficulties (**Figure 1**). The uppermost superficial femoral valve is constantly present unless destroyed by advanced thrombotic sequelae. In primary valve reflux, valve attachment lines may be clearly visible without the need for adventitial dissection. Thick adventitial covering may obscure whole or part of the valve attachment lines even in primary valves and when postthrombotic changes are present. In the latter instance, even the normally present valve "bulge" may be absent. Repairable intact cusps may sometimes be present in these cases, however, rendering an initial exploratory adventitial dissection worthwhile. The profunda orifice should be used as the landmark for initial adventitial dissection to identify a valve station obscured by sclerosis or postthrombotic wall thickening. Valve cusps were present without exception when uninterrupted valve attachment lines could be identified on external in-

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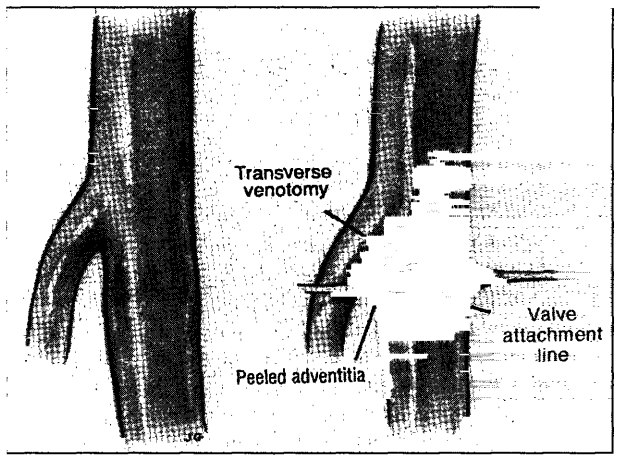


Figure 1. Exposure of valve attachment lines by adventitial dissection is an important initial step in most valve reconstruction techniques. Careful peeling/excision of the adventitial covering with loop magnification will expose portions of the valve attachment lines, which then should be followed to expose the lines in their entirety.

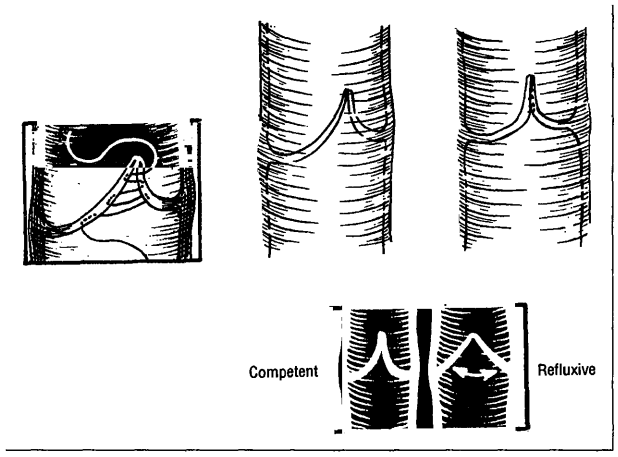


Figure 2. External valvuloplasty: the commissural valve angle is normally acute in competent valves. The valve angle is widened when the valve is refluxive (inset, **bottom**). The object of external valvuloplasty is to close the valve angle by transmural sutures, bringing the two valve attachment lines together. The horizontal mattress suture technique allows coaptation of unequal valve attachment lines (inset, **top**).

spection. With a commissural apex clearly identified on either side, a transverse or longitudinal venotomy[1] can be placed accurately, forestalling the need for a "T" type of exposure.[3] Absence of the valve attachment lines despite adequate adventitial dissection denotes postthrombotic dissolution of the valve cusps. One should proceed forthwith to alternate methods of reconstruction, eg, axillary vein valve transfer, without wasting further time in attempting to identify nonexistent valve cusps. If repair of the first superficial femoral vein valve is not feasible, the second superficial femoral vein valve can be sought and repaired. In this series the first superficial femoral valve was repaired in 302 cases and the second valve in 28 (9%) cases through the same groin incision. The second valve is located 2 to 5 centimeters distal to the uppermost valve, but its presence and location are less constant.

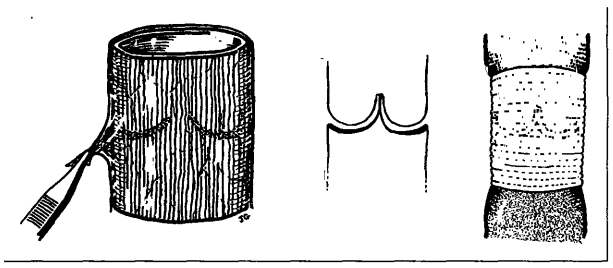


Figure 3. Prosthetic sleeve in situ: Surgical manipulation of a refluxive valve may result in rendering the valve competent. The phenomenon is more often seen in smaller caliber veins. A prosthetic jacket may be applied to the valve station in such cases to maintain valve competency. Further constriction of the valve station in an effort to correct reflux that persists even after normally encountered mild venospasm may result in iatrogenic stenosis and is not recommended.

TABLE I
Valve Competence Induced by Surgical Manipulation

Valve	n	Incidence Percent*
Superficial femoral first valve	47/287	16%
Superficial femoral second valve	5/28	18%
Profunda femoral	55/121	45%
Posterior tibial	17/32	53%
Peroneal	2/3	67%

** Percentage of total repairs for the segment.*

External valvuloplasty. The initial step in external valvuloplasty[4] is to identify the valve attachment lines clearly as described above. The valve sinus walls may be extremely thin and should be handled with delicacy. If inadvertent perforation should occur, repair by placement of a superficial pursestring suture of 7-0 Prolene is preferable to a through-and-through suture technique, which may further extend the tear. If the perforation occurs between the valve attachment lines, external valvuloplasty repair as described below should be carried out to cover the perforation without direct repair. The commissural valve angle of refluxive valves is widened (mean 20°, n = 49; normal 8°, n = 14).[5] The external valvuloplasty technique closes the wide angle between the valve attachment lines (**Figure 2**).

In 7% of external repairs only one commissural valve angle was wide, the other was less than 11°. Although repair along the wide commissural side alone restored valve competency in these cases, coaptation of the opposite commissural side was carried out to avoid future widening of the valve angle and recurrence of reflux. As the valve station is usually dilated and larger than the adjoining venous lumen, suture line stenosis is generally not a concern. If a competent repair would result in stenosis, the external technique should be abandoned in favor of another technique.

Prosthetic sleeve in situ. Initially refluxive valves may become competent intraoperatively (strip test) due to venoconstriction, which commonly occurs with surgical manipulation (**Figure 3**). The commissural valve angle in such cases is not widened.[5] This phenomenon was seen in 16% of proximal femoral valve reconstructions and more commonly in smaller caliber veins (**Table I**). A Dacron or poly-

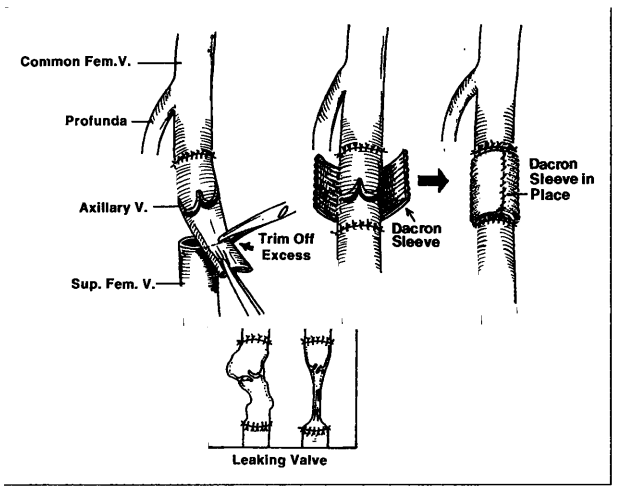


Figure 4. Technique of axillary vein transfer: The valve should be inserted under optimal tension without torsion. The shallow axillary valves are easily susceptible to malcoaptation and reflux due to technical deficiencies such as torsion or excessive or inadequate tension (inset).

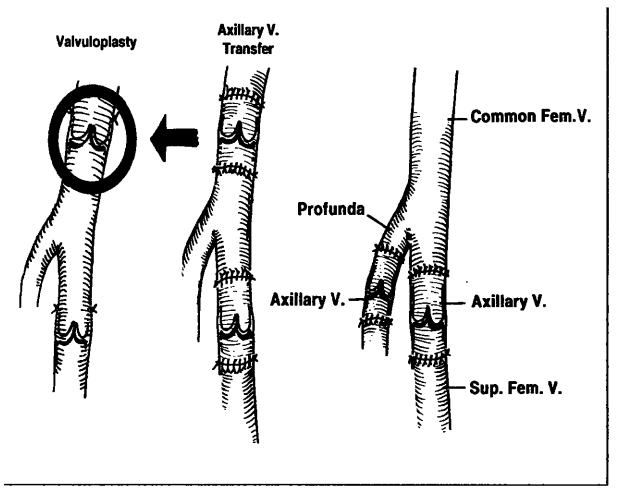


Figure 5. Valvuloplasty or axillary vein transfer to the common femoral vein (left) may be performed in lieu of the technically more difficult direct profunda valve reconstruction, especially when there is axial transformation of the profunda femoral vein. When this technique is employed, the superficial femoral vein should be reconstructed concomitantly.

tetrafluoroethylene (PTFE) sleeve may be fitted around the valve in such cases to maintain the valve annulus at a slightly constricted state to assure competency. The prosthetic sleeve can be appropriately "tailored" to allow for the entry of a large tributary (ie, profunda) at or near the valve station.[6] We have not utilized the sleeve technique for further constriction of valve stations that are still overtly refluxive even after surgically induced venoconstruction for fear of substituting obstruction for reflux. The prosthetic jacket may be anchored in place by one or two sutures attaching the jacket to the adventitia.

Axillary vein transfer. Preoperative venography or duplex scan has been neither useful nor reliable in localization and assessment of competence of axillary vein valves. The axillary vein is approached through a transverse incision along the skin lines in the axilla. One or more valves are usually present along the proximal portion of the vein near the first rib. Forty-four percent of the explored valves, however, were found to be incompetent in situ.[2] Even when one valve is incompetent, an adjoining valve may be competent. The opposite axilla may yield a competent valve when no valves or only incompetent valves are encountered on one side (5% of axillary explorations). In 14% of axillary explorations, even bilateral exposure revealed no usable competent valves. "Bench" repair of an incompetent axillary valve by the external valvuloplasty technique in an effort to restore competency before transfer was successful in only 3 of 8 instances when it was attempted. Bench repair by the recently introduced transcommissural technique (see later) was more successful; all of 15 such repairs attempted since 1993 restored competency to the transferred axillary valve.

The axillary vein is usually a good match in size for the superficial femoral vein. When the axillary vein contracts down from surgical manipulation, spasm may be relieved by local irrigation with a dilute solution of nitroglycerine (1 mg/10 mL). Interrupted suture technique should be used because even the most carefully done continuous suture technique was found to result in at least some suture line stenosis, after intraoperative venospasm is relieved after surgery. Insertion of the axillary vein graft under proper tension and without torsion is crucial. The length of recipient vein resected should be approximately 50% of the length of the axillary vein graft because the cut ends of the mobilized recipient vein retract. The upper suture line is completed first, and the tension and torsional axis of the vein graft are adjusted, monitoring for reflux through the open distal end with the proximal clamps off (**Figure 4**). The distal suture line is then completed and a Dacron jacket applied to the axillary vein valve graft to prevent later dilatation from compliance mismatch. The axillary vein valves are shallow, and failure of coaptation appears to be easily induced by technical imperfections. Despite careful attention to detail, 16% of axillary vein transfers were still mildly leaky by the strip test at surgery.

Reconstruction of the profunda valve. Repair of a refluxive profunda valve may be important, especially when it effectively functions as the axial vein through a large profunda-popliteal connection[7] in the presence of thrombotic obstruction of the superficial femoral vein. Such axial transformation of the profunda femoral vein was noted in 21 postthrombotic patients (16%) in this experience. Less obvious, but significant, profunda reflux is probably present in most postthrombotic patients because of collateralization (see later discussion). The profunda femoral vein has a variable anatomy, and a proximal valve was present in 84% of cases explored. A large circumflex femoral vein that takes off in a more transverse direction near the profunda origin should not be confused with the profunda vein. The profunda artery, which joins the companion vein 1 or 2 cm distally, is a good marker for proper identification. Profunda exposure and reconstruction can be technically difficult, especially in obese individuals. A common femoral venous valve is infrequently present. Repair of this valve when present may be attempted in lieu of direct profunda reconstruction (**Figure 5**). This was accomplished in 9% of profunda reconstructions.[2]

Transcommissural repair with optional angioscopic control. The valve attachment lines and commissural apices

are defined and should be clearly visualized in the form of an inverted "V." The repair should be performed with the vein distended and without clamping the vein. Through-and-through transluminal sutures are placed across the inverted "V" traversing the valve cusps "blindly" near their attachment to the venous wall (**Figure 6**). The sutures are placed externally using the exposed valve attachment lines as a cue to traverse the valve cusps internally near their wall attachments. The sutures are placed transluminally rather than transmurally as in the external valvuloplasty technique. Three or four interrupted sutures are generally required; the last suture is placed at the point where additional sutures would result in luminal stenosis. The procedure is then repeated on the opposite commissure.

This type of transcommissural repair was described by Gloviczki et al[8] and popularized by O'Donnell and Rodriguez[9] under angioscopic visualization. We have found that angioscopic visualization during actual placement of sutures is not necessary and, indeed, may be cumbersome. Valve attachment lines become obscured under angioscopic saline irrigation and are better visualized when the valve station is distended with blood. Excellent competency can be obtained routinely without the aid of the instrument. However, the use of an angioscope before and after the repair adds a useful dimension to the procedure: The pathology of the valve can be observed prior to repair and proper placement of sutures confirmed or corrected afterwards; furthermore, the degree of valve tightening and reflux during the repair can be progressively ascertained by angioscopic irrigation. Additional sutures may be placed to achieve the optimal tightening of the valve cusp desired. We prefer direct introduction of the angioscope through a 3-mm venotomy placed close to the valve station and controlled by a pursestring suture of 5-0 Prolene. This technique was found to result in a smaller incision, more limited dissection and clearance of tributaries, and shorter operative times than the saphenous venous stump approach for angioscopy.[8,9] After withdrawal of the scope, the pursestring is simply tied to close the small venotomy.

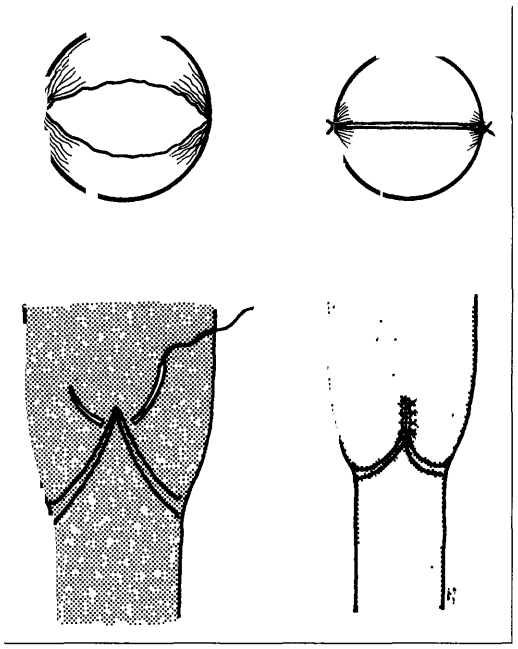


Figure 6. Transcommissural repair utilizes transluminal sutures to close the commissural valve angle while simultaneously tightening the valve cusp. The use of angioscope is optional. This type of repair is preferred over external valvuloplasty, which closes the valve angle by transmural sutures *without* tightening the valve cusps.

Denovo valve reconstruction. In a patient with a totally destroyed postthrombotic valve, axillary vein transfer remains the first line treatment of choice. In some patients, however, the axillary vein valves may be incompetent (even after bench repair), or absent or unavailable for some other reason, eg, Erb's palsy or previous mastectomy. A denovo valve reconstruction may be considered in such patients. The superficial femoral vein either in the femoral area or most distally in the adductor canal can be used as the host site. A longitudinal venotomy of about 3 cm is required. The valve cusps can be fashioned out of the harvested saphenous vein, as originally described by Durango.[10] We prefer a thinner-walled donor vein such as a large adjacent tributary or preferably the axillary vein when already exposed for valve transfer. The latter yields denovo valves that are thinner and more supple than the saphenous vein. After trimming the adventitia and part of the media, aided by injection of intramural balanced salt solution, elongated semilunar cusps are fashioned to fit the recipient vein (**Figure 7**). The cusps have both an intimal and a nonintimal surface. We prefer to orient the nonintimal surface inward rather than outward as originally described.[10] The risk of thrombosis on the nonintimal surface may be less facing the more rapid luminal flow than if exposed to the sluggish sinus flow. The "U"-shaped cusps are anchored initially by 3 or 4 strategically placed through-and-through mattress sutures that are tied outside the vein wall. The suture line is completed by a running horizontal mattress suture of 7-0 Prolene placed in an overlapping manner with knots placed outside the vein wall. Denovo valve function is ascertained when the venotomy is partially closed in its upper portion and the valve cusps are allowed to function with the proximal clamp off.

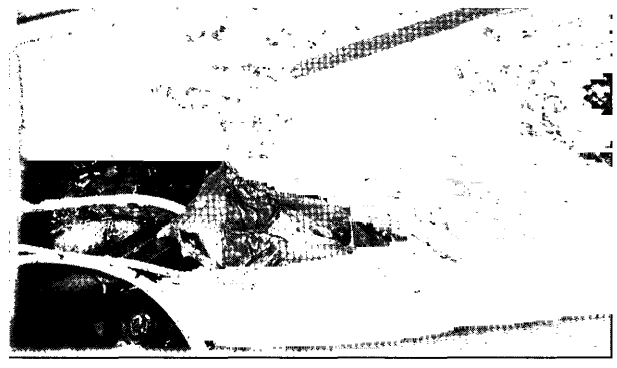


Figure 7. Denovo valve reconstruction: The axillary vein is the preferred donor site as it yields more supple and thinner cusps than the saphenous vein. The nonintimal surface of the "U"-shaped cusps are oriented toward the lumen of the recipient vein.

Venoplastic procedures. A Y-V venoplasty and transverse-longitudinal venoplasty (**Figure 8**) are useful alter-

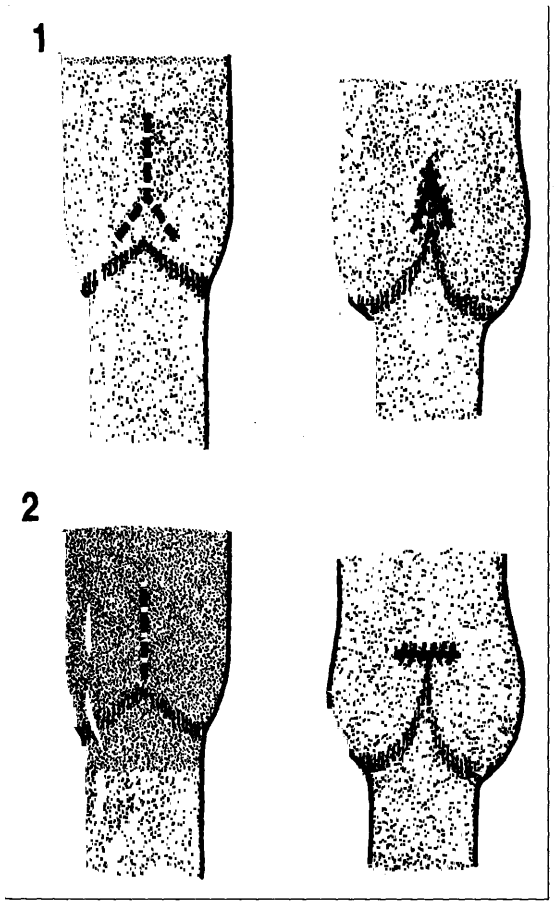


Figure 8. Venoplastic techniques: Y-V venoplasty or a longitudinal-transverse venoplasty tightens valve cusps and enlarges the valve sinuses without direct suturing of the valve cusps themselves. The techniques are useful in select instances when other techniques are technically difficult.

native techniques that can be applied in special circumstances. Both venoplastic techniques pull up and tighten the valve cusps without direct placement of sutures on the cusps themselves. In addition, the valve sinuses are enlarged and deepened. These are useful fall-back techniques when intraluminal valve exposure for routine internal valvuloplasty is difficult owing to small vein size or obesity or when the commissural valve angle is extremely wide, raising concerns of excessive inversion of tissue by external valvuloplasty. We have utilized the techniques for successful salvage when an inadvertent perforation has occurred near the valve attachment lines, jeopardizing the performance of the other standard valvuloplasty procedures.

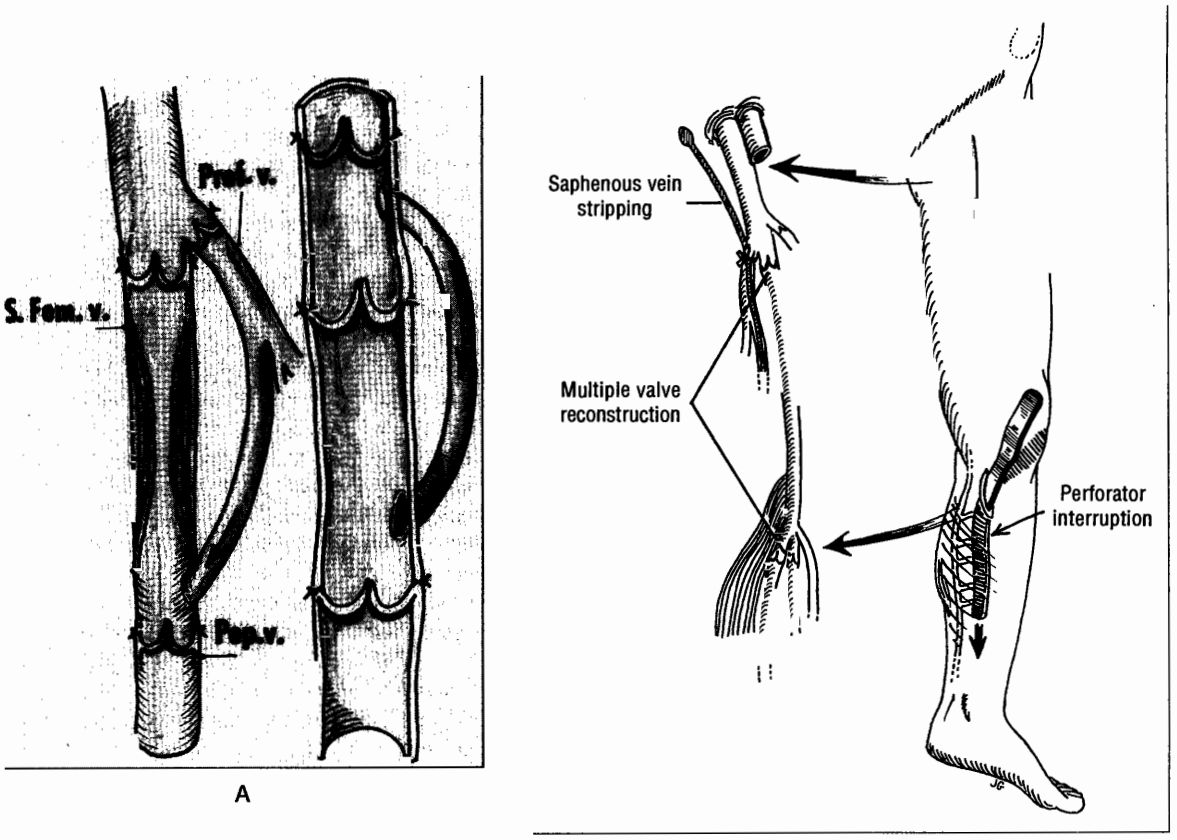
Valve reconstruction below an obstruction. Some patients with postthrombotic reflux with severe stasis skin changes have coexisting iliac vein obstruction from previous thrombosis. Such patients may benefit from an antireflux procedure *below* the obstructed iliac vein. A valve reconstruction may be undertaken at the femoral level or distally at the adductor canal. Such repairs appear to remain patent and durable.

Technique of multiple valve reconstruction. Multiple valve reconstruction[5,11] may be indicated for postthrombotic reflux and arguably for primary reflux with multisegment, multilevel disease. An oblique groin incision along the skin crease, with appropriate elevation of flaps, allows adequate exposure of proximal portions of the superficial and profunda femoral veins. Exposure to the distal popliteal and posterior tibial veins is obtained through an oblique incision along the skin crease below the knee. If the saphenous vein is refluxive, a proximal strip of the saphenous vein intervening between the groin and leg incisions is carried concurrently without making additional incisions. When indicated, a modified Linton procedure disrupting the medial perforators in the subfascial plane with a malleable retractor blade may also be accomplished through the same limited leg incision (**Figure 9**). Apart from abolishing perforator reflux when present, disruption of large perforators may help to increase venous refilling time by eliminating noncritical inflow into the calf venous pump. Such comprehensive repairs to correct multiple refluxive segments in the superficial, perforator, and deep systems have been carried out in 49 cases (**Table II**) with acceptable operative times (2½ to 3 hours).

Reoperative valve reconstruction. When there is recurrence of stasis ulcer after valve repair, the etiology may be due to new or missed reflux in a venous segment that was not corrected at the initial procedure. Primary failure of the initially repaired valve also occurs with passage of time. A "redo" valve reconstruction due to failure of initial valve repair after time was carried out in 14 limbs (4%). Reexposure of the femoral vein through the old incision may be difficult if not impossible (6 cases) owing to cicatrix formation. If not previously repaired, the second superficial femoral valve can be approached and repaired (2 cases) by slightly extending the old incision. A superior approach is to expose and repair a valve segment through a fresh incision some distance removed from the original scar. The preferred site is the distal femoral vein at the adductor-canal where a valve is commonly present (5 cases). The popliteal vein is less satisfactory (1 case) because its adventitial coat is quite thick, probably from knee flexion, and identification of valve station is difficult. In 7 of 20 popliteal explorations (35%), the valve station could not be localized despite the presence of a valve on venography. When valvuloplasty is not feasible, an axillary vein transfer may be executed to a fresh area of the femoral vein.

Perioperative Care

All patients receive a variable amount of heparin during surgery: 2,000 units for external techniques and 5,000 to 10,000 units when a venotomy is performed. Postoperatively, low-dose heparin is administered as a continuous infusion (400 to 700 U/hour) for 2 to 3 days after surgery. Low-dose warfarin sodium[12] (2.5 mg/PO daily) is started the day after surgery and continued indefinitely thereafter. Coagulation parameters are seldom prolonged with this regimen and frequent Protime determinations are not necessary. This regimen appears to have eliminated the serious bleeding complications associated with previous high-dose chronic warfarin therapy (5 bleeds in 113 cases with the high-dose regimen versus 0 bleeds in 234 cases with the low-dose regimen). Full anticoagulation is maintained for 8 weeks postsurgery for denovo valve reconstruction at present, after which a low-dose regimen is substituted.



A

B

Figure 9. Multiple valve reconstruction: A. Repair at multiple levels of the axial vein (axial-axial collaterals) or at the origin of the major tributary vein and distally in axial vein (tributary collaterals) may control collateral reflux. B. Such multiple valve reconstructions encompassing the superficial femoral, deep femoral, or crural veins can be combined with proximal saphenous vein stripping and disruption of medial perforators through limited groin and crural incisions.

RESULTS

Our total valve reconstruction experience with individual techniques is listed in Table II. Operative mortality was zero.

Of 582 valve segments undergoing attempted repair, total intraoperative competence (strip test or angioscopic irrigation) was achieved in 86%. In an additional 10% the repaired valve still leaked slightly, although less refluxive than before; and in the remaining 4% the repair was considered a failure in that the valve remained refluxive after the repair. Postoperative duplex examination showed 78% of repairs were competent, 16% were partially competent, and 6% were still refluxive.

There is potential for creation of iatrogenic venous obstruction of the operative site due to misapplication of technique, such as suture line stenosis, overzealous tightening of the valve in the internal technique, constriction of the valve station by the external technique, and the hemodynamically significant application of a stenosing prosthetic sleeve. The incidence of such technical stenosis (4%) was determined by postoperative duplex examination and arm/foot venous pressure differential/reactive hyperemia techniques.[7]

Postoperative thrombosis of the actual valve repair occurred in 4 cases, or less than 1% of valve reconstructions. In 12 other patients (3.5%), deep venous thrombus in the distal venous tree not involving the repair (3%) or in the opposite unoperated limb (0.5%) was detected. Six patients were symptomatic and the other 6 were clinically silent.

Only one repair was lost, even though hematoma/seroma requiring drainage or aspirations occurred in 5%. Wound infection occurred in 2% of operated cases. Among 210 prosthetic sleeves employed in the various techniques, only 2 had to be removed because of infection. The above statistics are noteworthy since 71% of patients were operated

TABLE II
Technique of Venous Valve Reconstruction in 550* Venous Segments in 347 Cases†

	n
Internal valvuloplasty	91
External valvuloplasty	151
Prosthetic sleeve in situ	130
Axillary vein transfer	101
Transcommissural repair with angioscopy	31
Other‡	46

* *Includes 23 failed repairs not listed.*
† *Multiple valves were repaired in 131 cases, double valves repaired in 98, and three or more valves each in 33. In 49 cases saphenous stripping and perforator disruption was performed in addition to multiple valve repairs.*
‡ *Includes segment transfers, ligation of refluxive duplication conduits or collaterals, and venoplastic procedures.*

on for stasis ulceration/dermatitis, and in 31% an active ulcer was present.

Among 267 stasis ulcers in the series, rapid healing occurred in 93% (6 giant ulcers were skin grafted) within 90 days after surgery and 7% never healed (primary nonhealing).

Fifteen valve reconstructions were undertaken distal to an occluded iliac vein (13 in the femoral portion, 2 in the popliteal). One patient was lost to follow-up, and 14 others have been followed up for a mean period of 4 years (range 1 to 8 y). All repairs were competent and have remained patent without thrombosis. Thirteen were operated for stasis ulceration, and all 13 ulcers healed rapidly after valve reconstruction surgery. Both popliteal reconstructions failed with recurrence of ulcer within a year of the repair. Among the 11 femoral repairs, only 2 have failed (1 at <1 year and another at 7 years) with the other 82% remaining free of ulcers.

Seven denovo valve reconstructions have been undertaken. All have remained patent without thrombosis 15 to 24 months (minimum follow-up) after surgery. Five of the 7 patients have healed their ulcers rapidly (<4 months), 1 after 1 year and another with a subsequent skin graft. All remain healed to date.

COMMENTS

The choice of optimal technique for an individual patient must be determined by the existing pathophysiology as well as by technical and time considerations. A wide choice of techniques is now available, and it should be rare that valve reconstruction is not feasible in a given patient regardless of pathology. If a single valve is to be repaired in a large vein, the internal valvuloplasty is an established technique with good long-term results that are durable.[13] However, like other open techniques (eg, axillary vein transfer) it is time-consuming and thus not expedient in multiple valve reconstructions; it also cannot be used in small-caliber veins. For the latter, a closed technique is preferable. Although these procedures are rapid, they are less precise than the internal valvuloplasty. The transcommissural technique is increasingly our first choice in a variety of situations, as it combines the best elements of open and closed techniques and the commissural valve angle is closed and valve cusps are tightened as well. Because of its recent vintage our experience with this technique has been less than with other more well-established techniques. Long-term results of this promising technique are as yet unavailable to establish its utility. When the valve apparatus is completely destroyed, technical options become limited to axillary vein transfer or, as a last resort, denovo valve reconstruction. Irrespective of the particular technique employed, however, it is clear that competence can be restored to the valve stations with a high degree of success and with minimal postoperative complications.

Primary reflux typically involves multilevel, multisegment disease in severely symptomatic patients. Repair of the single valve at the femoral level in primary valve reflux yields roughly a 60% success rate at 5 years.[1,2] It is an open question whether correction of additional segments of reflux, ie, multiple valve reconstruction, would not further improve on these results.

The situation in postthrombotic syndrome is more complex.[6,14] Collateral reflux is a prominent feature and substantial axial reflux may also be present due to postthrombotic valve destruction. Coexisting obstructive lesions are commonly present. In some instances, the profunda vein is transformed into the axial vein and the superficial femoral vein is totally occluded or poorly recanalized. In addition, abnormalities of the calf venous pump are present owing to capacitance reduction from organized thrombus and postthrombotic compliance wall changes resulting in reduced ejection volume. Little can be done to correct these abnormalities of the calf venous pump itself but axial and collateral venous reflux can be corrected. Collaterals may be axio-axial or tributary-axial in their origin and destinations.[14] Direct valve repair in collaterals is technically impossible. Ligation of collaterals instead of repair may lead to outflow obstruction when the axial vein is inadequately recanalized.[5] A strategy to abolish axial and collateral reflux is to perform multiple valve reconstructions at multiple levels in the axial vein and at the origin of major tributary trunks from which collaterals originate (**Figure 9**). Entry and exit points of collateral reflux can thus be controlled.

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