PTFE Grafts for Hemodialysis Access

Techniques for Insertion and Management of Complications

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In a series of 602 procedures, over 90% of primary forearm insertions of PTFE grafts between the radial artery and a cubital vein were possible. Thrombosis of the graft, which was invariably due to venous outflow obstruction, was the most common complication encountered. Revision of the venous anastomosis was not necessary in about one-third of the thrombosed grafts if a size 3 coronary dilator could be passed and the augmentation test was satisfactory. For revisions, creation of a new venous anastomosis using a jump graft was preferred over patch angioplasty or venous endarterectomy. Crossing the elbow for this purpose did not adversely affect graft patency. The incidence of aneurysm formation and infection was 16% and 35%, respectively. Infections involving the graft were managed by drainage, antibiotics, and bypass of the infected portion. Immediate bypass and delayed bypass were equally effective. About one-half of the infected grafts were salvaged by these techniques. The most common organism was *Staphylococcus aureus.* With a combination of the techniques outlined above, the service life of individual PTFE grafts can be extended. Two-year access patency in this series was 77%.

WITH THE INCREASING NUMBER of patients sustained on chronic hemodialysis, access related surgery forms a significant proportion of vascular surgical practice today. A cursory review of current procedures reveals a considerable variety in techniques of insertion and in the management of complications. For example, some centers prefer the upper arm straight graft[1,2] while some others advocate the forearm loop.[3,4] Considerable differences exist in the choice of artery or vein and the location for access insertion. In this report, we present our experience with over 600 dialysis access grafts, emphasizing insertion technique and management of complications.

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Materials and Methods

A total of 602 PTFE hemodialysis access grafts were inserted in 532 patients at the University of Mississippi Medical Center during the period 1976–1986. Other types of access fistulae, such as Cimino AV fistula, Scribner shunt, etc., were excluded from this review. A substantial number of patients were lost to follow-up because of transfer to other chronic dialysis facilities and other reasons (Table 1). Adequate follow-up data were available on 312 grafts.

Insertion Technique

A straight graft in the forearm of the nondominant hand was preferred. Local anesthesia (1% Xylocaine® infiltration) was used, except in the occasional instance in which a general anesthetic was required for poor pain tolerance, uncooperativeness, extreme apprehension, or other reasons. Patients subjected to local anesthetic were not kept NPO as a general rule, thus ensuring uninterrupted continuation of scheduled medications (*e.g.*, antihypertensives) and allowing flexible scheduling without extended fasting. Patients were premedicated with oral Valium® given on call. A second generation cephalosporine was administered intramuscularly at the same time.

The radial artery was exposed near the wrist with a 1-inch longitudinal incision. The antecubital vein exposed through a transverse incision was the preferred outflow. When this vein was unavailable due to inadequate size or thombosis from previous venipuncture, the cephalic or basilic vein was chosen. Tunneling and placement of the graft between the two incisions was

TABLE 1. *PTFE Grafts for Dialysis Access*

602 grafts in 532 patients
↓
Transfer, transplant, peritoneal dialysis, death, or inadequate follow-up
↓
312 grafts with 1–10-year follow-up

carried out before heparin (5000 U) was given. The technique of tunneling was considered important. The tunneling instrument should be somewhat smaller than the 6-mm size access graft. This ensures tamponade of the tunnel by the distended graft, which helps to secure hemostasis and prevent tunnel hematoma and subsequent infection. The long "disposable" metal trocar that is often supplied with chest tubes was particularly suitable for this purpose. A hole drilled through the end allows easy fixation of the graft to this tunneling device. The metal trocar is easily bent into any shape required for tunneling. The graft should be placed as subcutaneously as possible (Fig. 1). Counter pressure applied against the tip of the tunneling device with a sponge helps to achieve this placement. Deeper placement of the graft results in difficult access puncture, frequently leading to multiple holes, tears, and perigraft hematoma resulting in compartmental syndromes, or infection. The tunnel should be deeper near the incisions (Fig. 1A, offset) to provide for thick flaps at those points to ensure prompt primary healing. Beveled anastomoses are made to the artery and vein with continuous 6-0 Prolene using loop magnification. Heparin may be left unreversed if hemostasis is satisfactory after completion of the anastomoses.

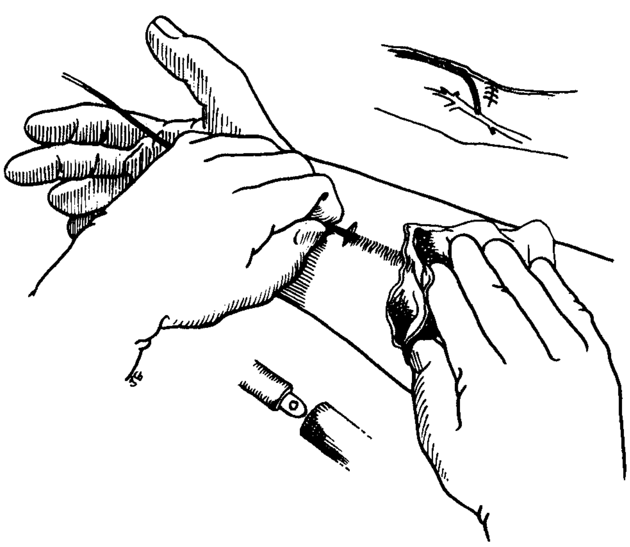

FIG. 1A. Tunneling techniques. Counter pressure against the instrument assures a superficially located tunnel. The tunneling instrument should be somewhat smaller in size than the graft diameter to ensure tamponade of the tunnel by the distended graft (offset below).

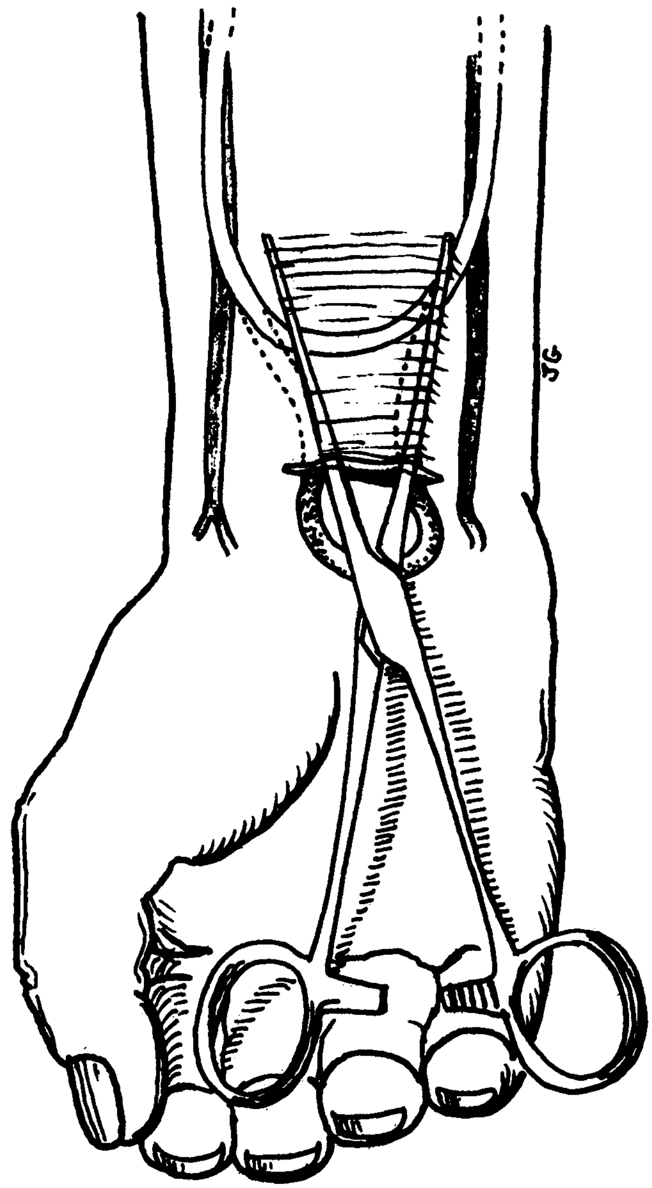

FIG. 1B. In looped grafts, counter incision for tunneling should not be located over the loop to avoid erosion by the graft. The maneuver depicted allows dislocation of the loop away from the incision.

After the procedure, the pulsatility of the graft should be monitored with and without clamp occlusion of the outflow end of the graft. A palpable increase in pulsatility with this maneuver confirms satisfactory outflow. In our experience, this maneuver has been more reliable than palpating "thrill" for this purpose. Since the most common cause of early graft thrombosis is inadequate outflow, this step is particularly important. Orally administered antibiotic with antistaphylococcal activity, usually cephalosporine or other, is continued for 3 to 5 days after surgery. The patient is instructed to avoid

FIG. 2. Augmentation test to ensure adequate venous outflow to the graft. A palpable increase in pulsatility on occlusion of the outflow end confirms satisfactory outflow.

sleeping with the elbow bent acutely and to keep the arm elevated on a pillow for a few days after surgery.

Management of Complications

Thrombosis of the graft. A thrombosed access graft should be examined for palpable pulsations near the arterial end. These are invariably present, suggesting a problem at the venous end. Absence of pulsations at the arterial end of the graft may indicate poor inflow or propagation of thrombus into the arterial tree. Thrombosed grafts should be approached through the old antecubital incision used for construction of the venous anastomosis. A newer incision, creating a bridge of skin between two incisions with tenuous blood supply, is considered unnecessary. Circumferential control of the graft is likewise unnecessary and may lead to injuring the deep surface of the graft while attempting to pass an instrument around it. An incision is made over the "cobra head" in the prosthesis and the venous side thrombectomized with a Fogarty catheter. Heparin (5000 U) is immediately instilled into the open vein *via* a catheter. A Fogarty catheter (number 3 or 4) should be used next to declot the graft from the arterial end. Retrieval of the bullet-shaped clot from the arterial end with establishment of satisfactory inflow denotes a successful effort. A separate incision over the arterial end of the graft may occasionally be necessary to establish complete and satisfactory thrombectomy.

In approximately one-third of cases, the revision of the venous end is unnecessary as the venous anastomosis easily admits a 3-mm or larger coronary dilator. A positive augmentation test for pulsatility as previously described denotes satisfactory outflow (Fig. 2). Absence of satisfactory augmentation indicates the need for revision of the venous end. Revision may be carried out by a jump graft with a new venous anastomosis to an adjoining vein (basilic or cephalic) or to the same vein in a more cephalad location. The jump graft can cross the elbow crease if necessary to achieve this purpose. Venous endarterectomy and patch venoplasty are less preferred alternative procedures for revising the venous anastomosis. Venous endarterectomy is carried out by scraping the hyperplastic new intima at the venous orifice with a #5 blade that is carefully swirled circumferentially through the anastomosis (Fig. 3). Forceful dilation of venous stenoses with coronary dilators is unsatisfactory and often leads to injury and rupture of the venous segment.

Revision of the arterial end. Stenosis of the arterial anastomosis can be enlarged satisfactorily by incising the stoma with a Pott's micro scissors, introduced through an incision in the access graft placed directly over the anastomosis (Fig. 4). The enlarged stoma should be secured by a few sutures of fine Prolene to prevent extravasation and false aneurysm formation. However, this is usually not a problem because the graft is generally adherent to the artery for some distance beyond the anastomosis. Arterial control for this procedure is preferably obtained by a tourniquet (see below), thus avoiding tedious circumferential dissection around the arterial anastomosis for vascular control.

False aneurysm. Tourniquet control with systemic heparinization provides satisfactory vascular control and minimizes the extent of dissection around the false aneurysm. With tourniquet control, the aneurysm is boldly incised and the clot evacuated. The destroyed access graft is trimmed until a healthy graft is encountered. The missing segment is replaced by introducing a new piece of PTFE graft within the bed of the false aneurysm and anastomosis to the ends of the old graft for continuity. More extensive destruction of the PTFE graft by extensive aneurysm formation from repeated needle punctures is more appropriately treated by defunctionalizing the entire segment and bypassing the damaged length with a fresh graft routed through a separate adjoining tunnel and anastomosed to the undamaged ends of the old graft. At least 3–5 cm of the old graft should be preserved at each end for dialysis puncture until the fresh graft matures. Stenotic lesions in the access graft from intimal build-up or partial destruction may be similarly treated by segmental bypass.

Infection. Extensive infection of the graft with cellulitis and involvement of the suture lines will usually require complete excision of the graft and drainage for satisfactory control of the infection and sepsis. More limited infections may be successfully managed by incision and drainage with adequate antibiotic coverage. Superficial infections and, occasionally, a deep infection of the graft may heal with this approach. More frequently, the infected segment of the graft must be excised and bypassed for salvage of the access device. The bypass may be done immediately prior to the incision and drainage, or as a staged procedure a few days later when the inflammatory reaction has subsided following incision and drainage (Fig. 5). Occasionally we have succeeded in salvaging a prosthesis involved with a very localized chronic infection, presenting as a chronic sinus, without a bypass. The sinus and the infected tissue are completely excised; the graft itself is scraped clean of tissue and covered by adjoining healthy tissue by primary closure. Systemic antibiotics are necessary for successful salvage.

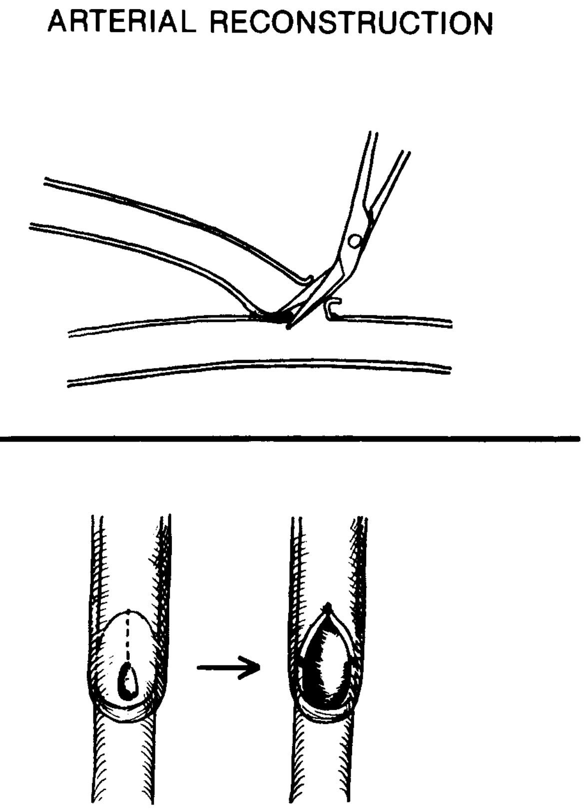

FIG. 4. Technique of arterial anastomotic revision. Because the graft is adherent to the artery for some distance, the common septum may be divided without fear of extravasation. A few sutures placed from inside ensure integrity of the stoma.

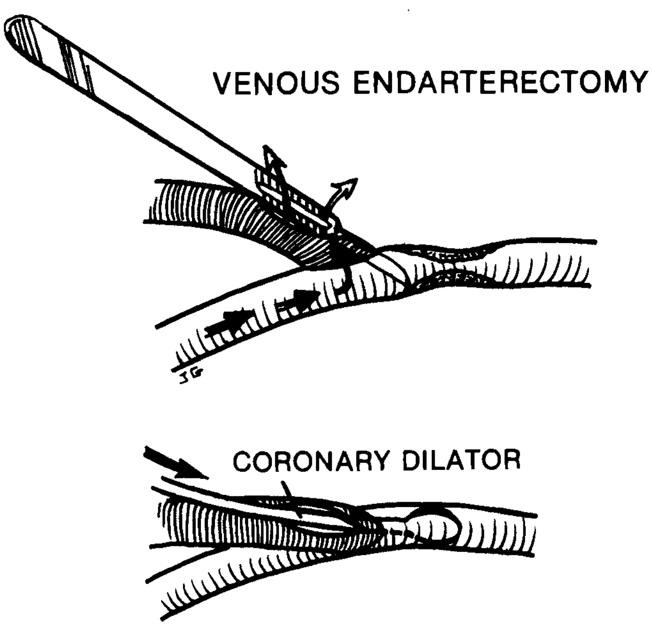

FIG. 3. Technique of venous endarterectomy. The coronary "dilator" should be used for sizing and minimal dilatation only. Ambitious dilatation usually results in false passage. Note "backbleeding" from distal vein.

Results

Among the 602 forearm grafts inserted, only 28 loop grafts used the brachial artery. In all others a straight graft originating from the radial artery was used. Of the 28 loop grafts, the brachial artery was electively used in 15. In 13 others the radial artery was initially examined and found to be unsuitable to carry inflow into the access. Only then was the brachial artery chosen for access inflow. Among the 312 grafts with adquate follow-up, the straight graft was converted into a loop with inflow

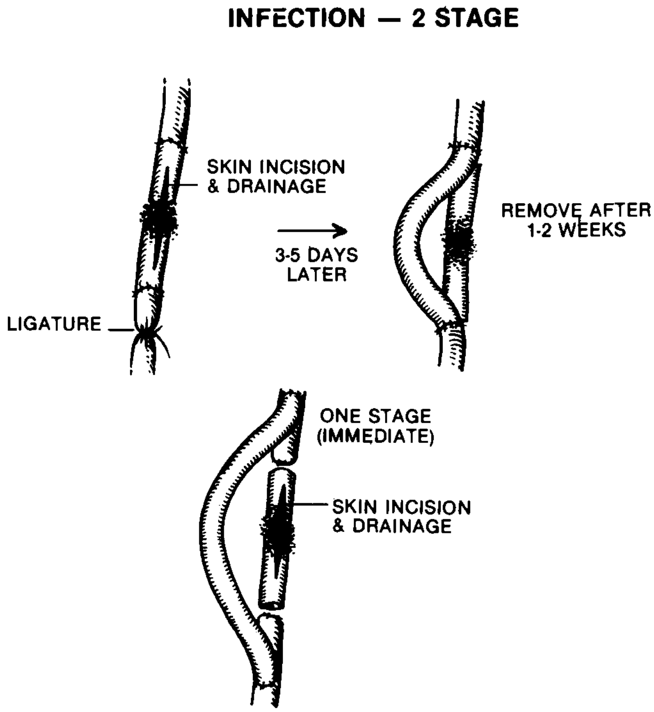

FIG. 5. Infections can be treated in two stages (top) with incision and drainage followed by a secondary bypass, or in one stage with a primary bypass (bottom).

from the brachial artery in a total of 17 grafts. Conversion was dictated by infection (5 grafts), inadequate radial artery inflow (8 grafts), or other technical reasons (2 grafts). Among the 312 grafts followed for a year or more, no further complications presented in 117. Complications were encountered in 195 grafts (64%). The mean interval between insertion and onset of first complication was 330 days for these 195 grafts. Of these 195 grafts, 124 suffered a recurrent complication, with a mean time interval of 182 days. A third complication was encountered in 62 grafts with a mean time interval of 178 days (*i.e.*, complication-free interval was stable for grafts suffering from recurrent complications).

The variety and incidence of complications are listed in Table 2. There were 372 primary and recurrent complication events in these 312 PTFE grafts. Thrombosis was the most frequently encountered complication, occurring in two thirds of the access grafts. Approximately one third of the complications were infection-related. Fifty false aneurysms were encountered in this series, usually due to repeated needle puncture at the same graft site. There were six instances of steal and three of gangrene in this series. Two of the three patients with gangrene were diabetic and carrying loop grafts from the brachial artery. There were no instances of access-induced cardiac failure in this group.

TABLE 2. *312 PTFE Grafts for Dialysis: Complications (1–10-Year Follow-up)*

	N	Per Cent of Incidence
Thrombosis	203	(64)
Infection	110	(35)
False aneurysm (repeated needle puncture)	50	(16)
Steal/gangrene	6/3	(3)
Heart failure	0	(0)

TABLE 3. *Access Thrombosis*

203 Initial Episodes		282 Total Episodes	
Early (<2 wks)	8%*	"Simple"	37%
Late	76%†	2° to stenosis	63%
Access Stenosis			
Venous	67%	2/3 of stenoses at venous end	
Arterial	15%		
Graft	18%		

* Calculated for 602 insertions.
† Calculated for 312 grafts with adequate follow-up.

Access Thrombosis. There were 203 initial episodes of graft thrombosis and 282 total episodes including recurrent thrombosis. Twenty-four per cent of initial episodes (49 in 602 insertions for 8% incidence) were early, occurring within 2 weeks of graft insertion, while 76% occurred later. Over one-third (37%) of all thrombotic episodes were classified as simple (*i.e.*, no technical basis such as stenosis or poor inflow could account for the thrombosis). In the remaining two-thirds, a structural basis required surgical revision of the graft. Two-thirds of the revisions were needed at the venous end (Table 3). Arterial revision was required in 15% and replacement of a segment of stenosed or destroyed graft was necessary in 15%. In approximately one-third of the episodes requiring graft and/or arterial anastomotic revision, a concomitant venous revision was also necessary (Table 4). Jump graft with the new venous anastomosis was the preferred method of revision. Venous endarterectomy (Fig. 3) was resorted to in 13% of venous revisions. Patch venoplasty was used in 8%, often in association with venous endarterectomy (Table 4). Crossing the elbow crease for segmental revision did not adversely affect graft patency or recurrent thrombosis.

Graft infection. There were 110 episodes of infection in these 312 grafts. Staphylococcus was the most common infection (54%). Other organisms were encountered in 10%. In a surprisingly large number (36%) with clinical infection, there was no growth on bacteriological culture. This is possibly related to antibiotic coverage prior to culture or the presence of a responsible anaerobic organism, as anaerobic culture was not routinely done in these instances. Ninety grafts required surgical intervention for control of infection. Six of these 90 were nonfunctional old grafts and were simply excised. The infection was serious enough to warrant excision and abandonment of 24 functioning grafts. Simple incision, drainage, and systemic antibiotics was the mode of treatment in nine grafts. Six of these were subsequently salvaged with elimination of infection. The three grafts that did not respond to this treatment regimen were abandoned. Localized infection was excised and the graft covered over by fresh tissue in seven grafts. This maneuver eliminated infection in three, while the remaining four required subsequent excision of the graft and abandonment.

A local bypass around the area of infection was performed in 44 grafts. Thirty-nine (90%) had successful salvage of the graft with this maneuver. In 28 instances, the bypass was classified as primary (*i.e.*, the bypass was performed at the same sitting as the incision and drainage). In 16 others, the bypass was performed a few days after initial incision and drainage of the abscess with ligation of the graft to stall flow through the infected area. There was no difference in the salvage rate between primary and secondary bypass methods (Table 5).

The modified patency rate of the 312 grafts studied was 93% at 1 year and 77% at 2 years. The term "modified patency" denotes inclusion in survival statistics of those grafts salvaged by appropriate surgical intervention for management of the aforementioned complications.

TABLE 4. *Dialysis Access: Thrombectomy/Revision (282 Procedures)*

	Per Cent
Simple thrombectomy (103)	37
Thrombectomy with revision (179) *(approximately 2/3 require revision)*	63
Segmental replacement (156/179)	87
Venous endarterectomy (23/179) (8% with patch venoplasty)	13

Discussion

Certain principles of technique in dialysis access surgery using PTFE grafts merit emphasis. When possible, the graft should be placed in an accessible location (forearm) of the nondominant limb. The graft should be placed as superficially as feasible beneath the skin so that access puncture is easy, thus helping to minimize injury to the graft from multiple punctures, tangential punctures, etc. In our experience, the radial artery is preferred for the takeoff of the PTFE graft. Because of the natural size limitations of inflow, cardiac failure is virtually absent when this vessel is used. Since thrombotic and infectious complications are quite common in this group of patients, the choice of radial artery for initial insertion allows the option of moving up the arm to other arterial locations if the primary graft should be abandoned from complications. With infectious complications involving the suture line, the potential threat to limb or life is also much less when the radial artery is used rather than brachial or more proximal arterial points of takeoff. Most of the published reports[3,5] have used upper arm or loop grafts for PTFE dialysis grafts. The incidence of thrombotic and infectious complications reported in these more proximally located grafts, with a larger inflow artery, is in many respects quite similar to our experience with straight grafts reported herein.

The most common complication in our and other series[6,7] continues to be thrombosis of the graft. In about one-third of these complications, the thrombosis is cryptogenic (*i.e.*, no structural basis for thombosis could be found). In the other two-thirds, however, a stenosis was usually found at the venous end. For this reason, the venous anastomosis must be constructed meticulously with assurance of an excellent runoff at the time of primary insertion. This could help to reduce the incidence of early thrombosis of the grafts even though late thrombosis from intimal hyperplasia appears insensitive to good insertion technique. In our experience, the augmentation maneuver described in Figure 2 has been more useful to gauge adequate outflow than is monitoring for a thrill at the venous end. It is important to make the venous anastomosis to one of the named veins in the antecubital region. Unnamed subcutaneous veins, however large, have been disappointing in providing lasting runoff. The reason for this may be kinking of subcutane-

TABLE 5. *Salvage* Procedures for Access Infection*

	N	Success	Failure
Bypass (total)	44	39	5
Primary	28	26	2
Secondary	16	13	3
Incision and drainage antibiotics	9	6	3
Excision of sinus, primary closure	7	3	4
Total	60	48	12

* Thirty grafts were abandoned for extensive infection and required excision.

ous veins with elbow flexion, which does not appear to be a problem with the named veins situated beneath the fascia. Systemic heparinization is routinely used to prevent intraoperative vascular thrombosis.

Despite ensuring adequate runoff, some PTFE grafts repeatedly thrombose in the early period after insertion. The precise cause for this is not clear. Flexion of the elbow, creating kinking of the graft at the venous outflow, dehydration and low perfusion state, prolonged compression of the relatively immature graft for hemostasis at the needle puncture site, or clotting of the dialysis lines and apparatus are possible explanations. Appropriate measures, including an arm pad to keep the upper limb extended, hydration, maintenance of adequate perfusion pressure, and careful technique during dialysis, should be exercised. Despite all these precautions, every dialysis center has seen the occasional patient in whom the PTFE graft must be abandoned because of recurrent unremittent thrombosis in favor of some other dialysis technique.

Few PTFE dialysis grafts escape thrombosis at some point during their dialysis life. The problem can be localized to the venous end when arterial pulsations are present at the arterial end of the graft. When these are absent, an inflow problem, along or combined with an outflow stenosis, should be expected. In any event, thrombectomy of the graft should be approached through the old skin incision used for the venous anastomosis. A separate skin incision some distance away creates a skin bridge with compromised blood supply and moves away from the point of anastomosis at which the stenotic problem usually resides. If satisfactory declotting is achieved and the venous anastomosis admits a 3-mm or larger coronary dilator, anastomotic revision is usually unnecessary.

While venous endarterectomy and vein patch angioplasty can be used to correct discrete stenosis at the venous takeoff, we have come to rely increasingly on a jump graft to bypass the stenosed area altogether. The jump graft can be anastomosed to the same or other adjoining vein in a virgin area. This is usually accomplished through the same skin incision, especially when the anastomosis can switch from the cephalic to the basilic vein and vice versa. A large antecubital vein also provides a suitable outflow for primary insertion and subsequent revisions. If necessary, there should be no hesitation to cross the elbow joint in search of a suitable outflow vein, as joint crossing does not seem to affect patency.[8] Others have noted inferior patency[3] with patch venoplasty compared to the jump graft with new venous anastomosis. On the relatively infrequent occasions of stenosis of the graft at the arterial anastomosis, revisional procedures are simple and easily effected. Most primary insertions and revisions are accomplished under local anesthesia as an outpatient procedure.

In our experience and that of others,[3,9] the incidence of infection in dialysis grafts appears distressingly high. Infection leads to graft abandonment in a significant number and apparently recurs in at least some patients. It is not clear whether inattention to proper technique or inherent immune deficiency is responsible for this individual predilection. Even infection of the prosthesis can be managed with successful salvage of the graft if the infective process is relatively localized and extensive tunnel infection is absent. In some renal dialysis patients, even extensive tunnel infection may present with little outward signs of inflammation or tenderness. Despite close physical examination, such grafts may appear completely normal. Because of this experience, we tend to explore aggressively and to ligate grafts when evidence for bacterial seeding is present. Even when a tunnel infection was not encountered, ligation of the graft has resulted in cessation of the bacteremia in a few instances, suggesting suture line seeding.

While ligation usually results in immediate improvement in the status of the patient, the focus of infection must usually be excised eventually. In an occasional patient, septicemia has persisted despite ligation of the graft and was relieved only when the graft was completely excised and removed. The surprisingly large number of access devices salvaged from localized infection by bypass was gratifying. Results appear to have been equally good whether the bypass was primary or secondary. The choice between these two techniques resides primarily on the status of the graft site during drainage. If significant cellulitis of surrounding tissue is present, a secondary bypass followed by initial incision and drainage is appropriate. Primary bypass is useful for a very localized inflammatory process or for chronic and indolent sinuses.

Pseudoaneurysms are a frequent complication of PTFE grafts. Many of these occur in long-standing grafts subjected to repeated puncture and injury. An element of venous obstruction from stenosis is present in many, potentiating the false aneurysm from high pressure in the graft.[10] Despite careful instruction to the contrary, some patients tend to stick the PTFE graft through the same needle tract, exacerbating this complication. Revision of the false aneurysm and replacement with a segment of fresh graft is relatively easy. It has been our experience that the technique is made considerably easier by using a tourniquet for vascular control, rather than circumferential dissection for clamp application. In fact, in most other revisional surgical procedures involving the PTFE graft, either tourniquet, digital, or Fogarty vascular control is used as necessary to avoid circumferential dissection. Circumferential dissection has a potential for injury to the deep aspect of the graft and vessels and should be avoided when possible.

When the lifetime of a PTFE graft is finally expended from repeated and recurrent complications, a site in the forearm on the same or opposite side for secondary insertion should be easily achieved. Even among patients who have been on dialysis for 10 years or more, loss of site for access insertion has seldom occurred in our experience.

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