

# Vascular Access for Hemodialysis

## Patency Rates and Results of Revision

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Over a 4-year interval, 324 arteriovenous conduits were created in 256 patients with end-stage renal disease as access for chronic hemodialysis. These included 154 Cimino fistulae, 163 polytetrafluoroethylene (PTFE) grafts, and seven miscellaneous grafts. Satisfactory patency rates were demonstrated for as long as 4 years for both Cimino fistulae and PTFE grafts by life-table analysis. Failures of Cimino fistulae usually occurred early in the postoperative period, secondary to attempts to use inadequate veins. Thrombosis caused the majority of PTFE graft failures and was generally the result of venous stenosis. Correction of such venous stenosis is mandatory to restore graft patency and can result in prolonged graft survival.

THE INTRODUCTION OF extracorporeal dialysis of blood by Kolff et al. in 1943 provided a means whereby patients with end-stage renal failure, a hitherto fatal condition, could be sustained for prolonged periods.<sup>1</sup> The full potential for this remarkable means of patient salvage was not realized, however, until the introduction of the external arteriovenous shunt by Quinton, Scribner et al. in 1960,<sup>2</sup> and of the endogenous fistula by Brescia, Cimino et al. in 1966,<sup>3</sup> approaches which permitted repeated and routine access to the circulation. More recently, the introduction of synthetic vascular prostheses has allowed greater choice of procedure, especially for use in long-term patients who have exhausted peripheral venous sites. Thus, if the distal arm vessels of an individual being initiated on hemodialysis are satisfactory, an endogenous arteriovenous (Cimino) fistula may be created at the wrist or elbow; if unsatisfactory, or in persons needing an additional procedure following a failed fistula, a synthetic prosthesis may be used.

This report summarizes our experience with vascular access procedures performed over the past 4 years at the Brigham and Women's Hospital in patients with end-

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stage renal disease. The natural history of each type of access, the causes of failure, and the results of revisions performed on failed accesses are examined.

### Materials and Methods

Between June 1979 and October 1983, 324 arteriovenous conduits were created in 256 patients with end-stage renal disease maintained on chronic hemodialysis. These 256 people included 34 patients with nephropathy secondary to juvenile onset diabetes mellitus. The procedures included establishment of 154 Cimino fistulae, 163 grafts of expanded polytetrafluoroethylene (PTFE, including 93 Gore-Tex® and 70 Impra®), five of Dacron®, one saphenous vein loop, and one Thomas femoral shunt. Of the PTFE grafts, 80 were included in a randomized trial comparing Gore-Tex and Impra (unpublished). There were 246 revisions to prolong the patency of 96 accesses; these involved 16 Cimino fistulae and 80 PTFE grafts. There were 127 men and 129 women, aged 17 to 82 years (mean = 52.5 ± 15 years). Use of particular graft materials or techniques of placement were independent of patient age or presence of diabetes mellitus.

All vascular access procedures were performed by one of three staff surgeons, either primarily or assisting a surgical resident. The techniques used and the philosophy of placement (distal insertion in the arm for as long as possible in the most accessible and comfortable location for the patient) were relatively standard and similar in all cases.<sup>4</sup> In general, Cimino fistulae were created at the wrist under local anesthesia; synthetic grafts were placed, under axillary block, at more proximal levels, usually at the antecubital fossa in a forearm loop configuration.

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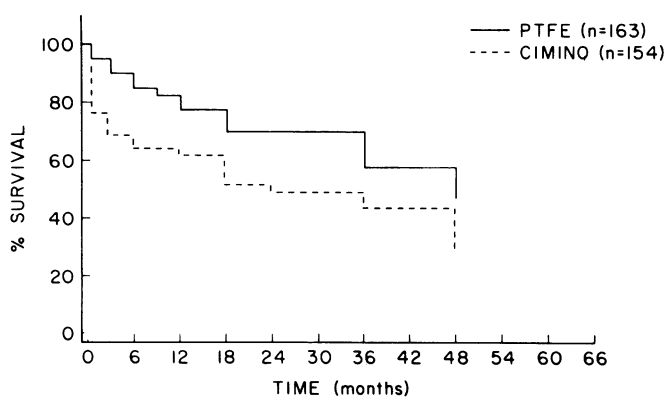


FIG. 1. PTFE grafts' cumulative patency rates are compared to Cimino fistulae. The lower survival of the native vein fistulas is a result of early failures.

General anesthesia was necessary in 15% of cases because of failure to achieve adequate sensory loss with local or regional anesthesia. The nondominant upper extremity was used preferentially. The lower extremity was avoided because of concern over infection, effects of peripheral vascular disease, and patient inconvenience.

Patency rates for all vascular accesses were analyzed by life-table analysis. Access failure was defined as replacement of a failed access by a new one. Thirty-three patients in the series received renal transplants, and five individuals were switched electively from chronic hemodialysis to continuous ambulatory peritoneal dialysis. Forty-three patients died. Each of these previously mentioned 81 individuals had a functioning access and was considered withdrawn from the study at that time. An additional eight patients died with nonfunctioning accesses and were regarded as graft failures. Statistical significance was established using either the Wilcoxon-Breslow or Mantel-Cox tests. Statistical significance among groups of data was established using a nonpaired Student's t-test.

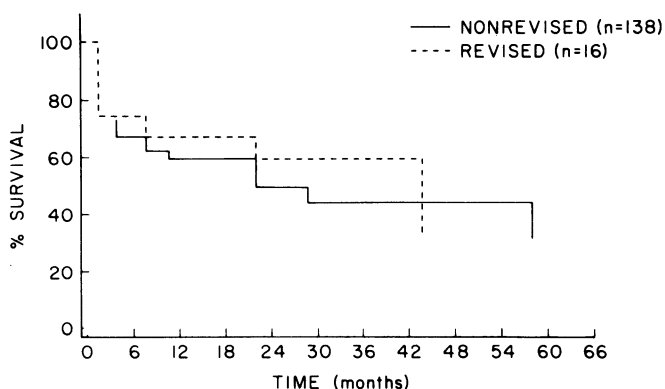


FIG. 2. Cimino fistula with and without revisions are compared. Successfully revised fistula show survival equivalent to unrevised fistulas.

## Results

### *Cimino Fistulae*

The cumulative patency rates for 154 Cimino fistulae are shown in Figure 1. There was no difference between patency of 99 endogenous fistulae placed at the wrist and 55 placed in the antecubital fossa when followed as long as 45 months. Most failures (24%) occurred in the first month following placement. Generally, it was necessary to replace a failed Cimino fistula either with a new fistula at a more proximal location or with a synthetic graft. However, 16 fistulae, which had clotted spontaneously, successfully underwent thrombectomies; two, twice (12%). In 12 of these latter cases, no cause for thrombosis could be identified; discrete areas of venous stenosis accounted for access failure in four instances and postdialysis hypotension and low flow caused thrombosis in two. Simple thrombectomy using a Fogarty balloon catheter introduced through a small venotomy was usually sufficient in these instances. Venous aneurysms or discrete areas of stenosis usually required more proximal placement of the fistula. Similarly, if an aneurysm of a Cimino fistula became bothersome because of enlargement, size, or incipient skin breakdown from pressure necrosis, the aneurysm was ligated and the fistula moved proximal. Infection of Cimino fistulae was rare, localized to a needle site, and was treated effectively by antibiotics and local care. The cumulative patency of Cimino fistulae that had successfully undergone thrombectomy or revision was equal to that of unrevised Cimino fistulae (Fig. 2).

### *PTFE Grafts*

The patency rate of PTFE grafts was significantly ( $p < 0.01$ ) better than that for endogenous fistulae (Figure 1). However, the difference results entirely from early failure of the Cimino fistulae and reflects efforts to establish them using veins of marginal quality. When the early failures are not considered, PTFE grafts and endogenous fistulae have equivalent survival (data not shown). In addition, the cumulative patency for Impra grafts was superior ( $p < 0.05$ ) to that of Gore-Tex, both at 1 and 2 years (Fig. 3), although it should be stressed that only half of these procedures were performed as part of a randomized trial.

When PTFE grafts were considered by location, those placed in a loop configuration in the forearm, with both ends anastomosed to vessels in the antecubital fossa, appeared to show better rates of patency compared to those placed in the upper arm. However, patients in this latter category invariably represented a group in which several accesses had been created previously and had failed. The more proximal grafts were usually placed

between the brachial artery near the antecubital space and the proximal brachial or cephalic vein. The body of the graft ran along the lateral aspect of the biceps muscle for patient comfort during dialysis. Occasionally, the subclavian vein below the clavicle was used, with the body of the graft lying as described above.

### Complications of PTFE Grafts

**Thrombosis.** There were 208 instances of complications occurring in 80 of the 163 PTFE grafts implanted (49%). Graft thrombosis was responsible for 91% of the episodes ( $N = 189$ ). Spontaneous thrombosis occurring primarily and without obvious anatomic cause accounted for 44% of all thromboses ( $N = 83$ ), and developed a mean of  $209 \pm 42$  days after graft implantation. Patency was reestablished, at least temporarily, in 87% of these cases by simple thrombectomy using a Fogarty balloon catheter. The remainder needed a patch graft or jump graft placed at the initial operation.

Recurrent thrombosis was common, accounting for 56% of all thromboses ( $N = 106$ ) and occurring a mean of  $218 \pm 33$  days after implantation; 2.6 thromboses occurred per involved graft. The most common identifiable cause was venous outflow stenosis, most often due to localized intimal hyperplasia of the vein immediately proximal to the graft-venous anastomosis. The treatment of recurrent thrombosis was by one of three procedures. In 55% of these cases ( $N = 58$ ), temporary graft patency could be reestablished by simple thrombectomy. The thrombectomy incision was always placed near the graft-venous junction, as the stenosis can occasionally be dilated directly with coronary artery dilators to a diameter of 3.0 or 3.5 mm. In 31% of instances ( $N = 33$ ), when the stenosis involved a long portion of the proximal vein, the stenotic area was bypassed with a short piece of PTFE. In the remaining 14% with discrete areas of stenosis (15 cases), the stenotic anastomosis was widened with a patch graft.

When thrombosis caused recurrent graft failure, the type of salvage procedure performed affected the subsequent patency of the graft. A significantly ( $p < 0.05$ ) longer cumulative patency was noted in those grafts repaired with a bypass of the outflow stenosis compared either to simple thrombectomy or to the use of a patch (Fig. 4). In addition, the average length of time between the initial correction of recurrent thrombosis and subsequent salvage procedures was significantly ( $p < 0.05$ ) greater when a bypass graft was performed (data not shown). Although almost 60% of the revised grafts required more than one secondary salvage procedure, the cumulative patency among the 80 revised PTFE grafts was equivalent to that of the unrevised PTFE grafts (Fig. 5).

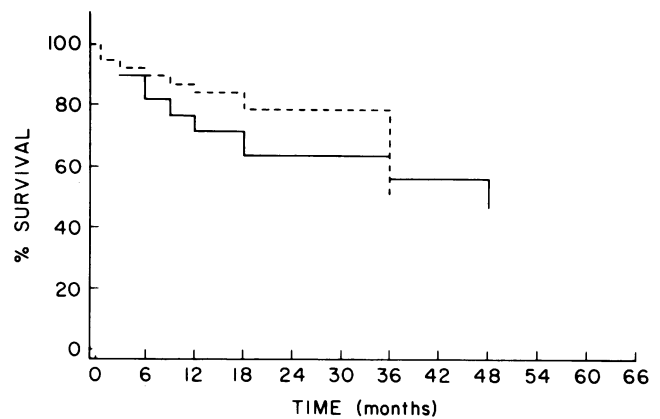


FIG. 3. Impra versus Gore-Tex PTFE grafts. The patency of Impra grafts was superior at both 1 and 2 years ( $p < 0.05$ ) [—Gore-Tex ( $N = 70$ ); ---Impra ( $N = 93$ )].

**Infection.** Graft sepsis accounted for 19% of PTFE graft complications ( $N = 40$ ). As some of these also had thrombosis, they have been counted under both complications. Infection was a relatively solitary event, with 1.26 infectious episodes per involved graft occurring  $318 \pm 48$  days after implantation. The sporadic nature of this complication probably implicates breaks in sterile technique during a hemodialysis treatment, although in six patients sepsis followed direct injection of street drugs ("mainlining") into the access. In 22 instances (55%), where the infected portion of the graft was small and relatively discrete, it was possible to bypass the area with a short piece of PTFE, close the new incisions, then excise and drain the involved portion. When the infectious process was more generalized or involved an anastomosis (18 grafts, 45%), total excision of the graft was necessary. In all secondary salvage procedures for graft sepsis, the infected wounds were packed open with povidine-iodine gauze for ample drainage. Systemic antibiotics were administered before and after operation.

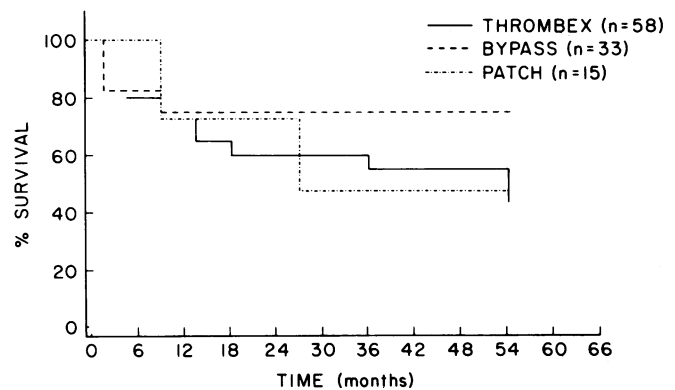


FIG. 4. PTFE graft survival following revision. A bypass graft to a new venous site was the most successful form of revision. Thrombex = thrombectomy.

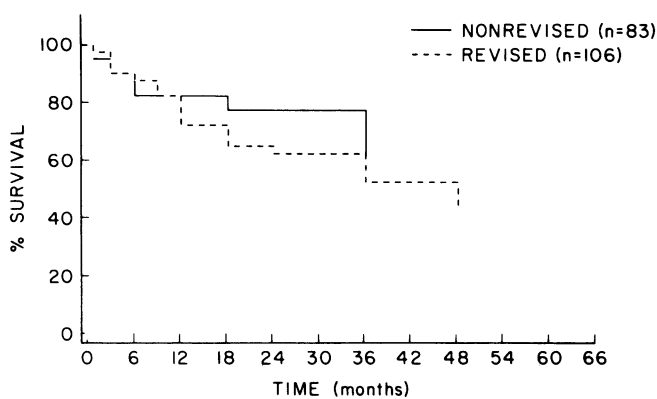


FIG. 5. Cumulative patency rates of PTFE grafts with and without revision are noted. Revised grafts have a survival equivalent to unrevised grafts.

The cumulative patency for infected grafts was obviously less than that for uninfected grafts because so many of the former group needed removal (Fig. 6).

**Pseudoaneurysm.** This complication occurred infrequently, accounting for two per cent of PTFE graft malfunctions ( $N = 4$ ), and becoming apparent  $504 \pm 90$  days after graft implantation. A relatively isolated event in the life of the graft, it occurred 1.33 times per involved graft. Treatment consisted of excision of the pseudoaneurysm and involved portion of the graft, followed by restoration of continuity with an interposition graft of PTFE.

**Arterial stenosis.** This occurred infrequently,  $159 \pm 79$  days after graft implantation, and accounted for less than two per cent ( $N = 3$ ) of graft malfunctions. In all cases, the condition seemed to result directly from initial technical compromise of the arterial anastomosis. Treatment consisted of direct dilation in two cases and bypass of the stenotic area in one.

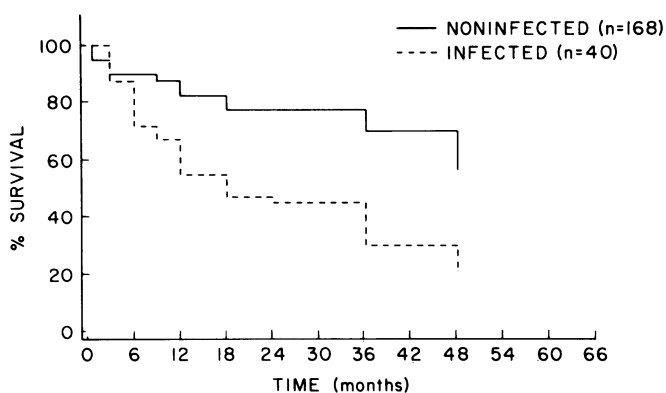


FIG. 6. Cumulative rates of PTFE grafts with and without infection. Infection results in significant graft loss, although a surprising number of infected grafts can be salvaged.

### Vascular Access in Diabetic Patients

Twenty-two Cimino fistulae and 27 PTFE grafts were placed in 34 diabetic patients. When compared to similar grafts in nondiabetic individuals, there was no difference in patency at 12 months. Small sample size among diabetic patients precluded statistical analysis after this period.

### Discussion

The number of patients with end-stage renal disease maintained on chronic hemodialysis is increasing progressively. Not only are more persons at high risk being accepted into treatment programs, but there is wider availability of improved and refined dialytic care. One obvious mandate for surgeons caring for these individuals is to ensure that they maintain a patent and functioning access to the circulation. Thus, a philosophy of placement has evolved in our unit which has remained satisfactory for some years. Using the upper extremities almost exclusively, we attempt to stay as distal as possible for as long as possible, sometimes using the same forearm site more than once. Either endogenous Cimino fistulae or PTFE grafts are placed almost exclusively.

Our experience with Cimino fistulae is similar to that reported by others and shows a high early (<30 days) failure rate.<sup>5,6</sup> These failures are usually due to inadequate venous size or run-off. Once the fistula is established and used successfully for hemodialysis, late failure (>30 days) is rare, and is most often the result of thrombosis. Clotted fistulae can usually be salvaged. However, if thrombophlebitis causes clotting, the fistula must be replaced, as inflamed veins invariably rethrombose regardless of flow. Late physiologic complications including palmar arch steal syndrome, hand swelling, and high cardiac output failure have been reported, although these difficulties occur very infrequently in our experience.<sup>7,8</sup>

Despite the fact that the results with Cimino fistulae, at least in this series, equal those of PTFE, the endogenous access still remains the procedure of choice. It can be placed distally at the wrist, leaving proximal sites alone for eventual use. Performed under local anesthesia, hospitalization can be avoided. The infection rate is lower than among synthetic grafts and can be more successfully treated. Generally, we place a Cimino fistula several months prior to anticipated use to ensure adequate maturation. Venous dilatation can be enhanced by intermittent use of a proximal tourniquet during this period. Early access failures, including those which continue to flow but do not dilate to a size adequate for convenient cannulation, require a new access, usually with PTFE.

Although several graft materials, including bovine carotid artery,<sup>9-11</sup> human umbilical vein,<sup>12</sup> autogenous saphenous vein,<sup>13,14</sup> and synthetic Dacron,<sup>15</sup> have been used for vascular access, expanded polytetrafluoroethylene polymers are now probably the most popular. We place these preferentially in a U-shaped configuration in the forearm, anastomosed to vessels in the antecubital space. Straight grafts between radial artery at the wrist and antecubital veins have been less successful in our experience. Our overall results with PTFE grafts are consistent with those reported by others.<sup>16-19</sup> It should be stressed that although revisions and thrombectomies are needed more frequently, the long-term results with this prosthetic material are about as good as with endogenous vein. This finding is probably influenced by patient selection, particularly as younger patients whose veins are often eminently suitable for a Cimino fistula are transplanted relatively quickly. Although Gore-Tex and Impra grafts have both been used, Impra grafts have become our access of choice, as results of a randomized comparison of 40 Impra and 40 Gore-Tex grafts show some superiority of Impra (unpublished data). In addition, the rate of complications was significantly ( $p < 0.05$ ) greater among Gore-Tex as compared to Impra grafts. Seventy-one per cent of Gore-Tex grafts required revision as compared to 46% of Impra grafts. However, these relatively preliminary results must be interpreted with caution.

Failure of prosthetic access devices is usually the result of thrombosis. Although it is not always possible to determine the precise cause, venous stenosis secondary to neointimal hyperplasia has been a major factor. It is important to repair such mechanical deficits to prevent recurrent thrombosis, by using either a patch graft at the graft-venous anastomosis or a jump graft to an uninvolved proximal segment of vein. Although the latter procedure has been more successful over the long term, it still may be best to begin with simpler, more limited procedures, usually accomplished under local anesthesia, before involving proximal vein. However, surgical persistence pays dividends, as revised grafts do as well in terms of long-term patency as those not needing revision. In addition, the hospital time required for revision is considerably less than that needed for recovery from placement of a new graft. The revised graft can be used immediately, but we prefer not to use a new graft for several weeks after its insertion to allow adequate in-growth of tissue around the conduit.

Although infection of prosthetic grafts is not rare, it is intriguing how relatively infrequently such an event occurs, considering the access is cannulated for every dialysis treatment, three times a week. Our rate of infection among PTFE grafts, regardless of the presence

of diabetes mellitus, confirms that reported in the literature.<sup>16,19</sup> It is gratifying, however, that one-half of all infected grafts can be salvaged by local bypass operation, saving the patient both the use of additional vessels and a prolonged hospitalization.

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