Prospective randomized comparison of surgical versus endovascular management of thrombosed dialysis access grafts

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Purpose: **Salvage of thrombosed prosthetic dialysis shunts can be performed using surgical or endovascular techniques. A prospective randomized trial was designed to compare the efficacy of these two methods in restoring dialysis access function.**
Methods: **One hundred fifteen patients with thrombosed dialysis shunts were randomized prospectively to surgical (n = 56) or endovascular (n = 59) therapy. In the surgical group, salvage was attempted with thrombectomy alone in 22% and with thrombectomy plus graft revision in 78%. In the endovascular group, graft function was restored with mechanical (82%) or thrombolytic (18%) graft thrombectomy followed by percutaneous angioplasty.**
Results: **Stenosis limited to the venous anastomotic area was the cause of shunt thrombosis in 55% of patients, and long-segment venous outflow stenosis or occlusion was the cause in 30%. In 83% of the surgical group and in 72% of the endovascular group, graft function was immediately restored (p = NS). The postoperative graft function rate was significantly better in the surgical group ($p < 0.05$). Thirty-six percent of grafts managed surgically remained functional at 6 months and 25% at 12 months. In the endovascular group, 11% were functional at 6 months and 9% by 12 months. Patients with long-segment venous outflow stenosis or occlusion had a significantly worse patency rate than those with venous anastomotic stenosis ($p < 0.05$).**
Conclusions: **Neither surgical nor endovascular management resulted in long-term function for the majority of shunts after thrombosis. However, surgical management resulted in significantly longer primary patency in this patient population, supporting its use as the primary method of management in most patients in whom shunt thrombosis develops. (J Vasc Surg 1997;26:373-81.)**

The maintenance of functional vascular access for patients on hemodialysis remains an important but difficult problem for surgeons involved in the care of these patients. The average primary patency of hemodialysis shunts ranges from 1 to 3 years in numerous reports.[1-4] Although the patency rates for primary fistulae are better, fewer than 50% of patients in most dialysis populations in the United States have veins of sufficient size to construct a functional fistula. The average hemodialysis patient can expect an episode of shunt thrombosis every 12 to 15 months, and access problems are the most common reason of admission for dialysis patients, accounting for more than $500 million per year in health care costs.[5,6]

An optimal protocol of management of clotted hemodialysis shunts has not been clearly defined. Some authors have reported that thrombosed shunts should be abandoned in favor of a new access site.[7] However, an increasing number of patients with renal failure are requiring long-term dialysis for 5 to 10 years or longer.[8] If the clotted shunt is routinely abandoned, there will be a large number of patients in most dialysis populations who will exhaust the more desirable upper extremity shunt sites and require alternate sites such as the leg or chest wall. In a few patients, all available sites may eventually be used, prohibiting further hemodialysis. For this rea-

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son, most authors propose that each dialysis site should be preserved for use as long as possible.[9,10]

To salvage thrombosed dialysis shunts, surgical thrombectomy with or without revision has been routinely performed. The results have been underreported, but it appears that a minority of shunts are functional for more than 6 months after salvage without repeated revision.[7] Recently, percutaneous techniques for dialysis shunt thrombectomy and angioplasty have been developed.[11] These are now widely used to open shunts and preserve function as an alternate to surgical therapy. The results with endovascular shunt salvage have been reported to be as good as or better than surgical salvage techniques, but there is a lack of comparative data on the two techniques.[12,13]

We developed a prospective randomized study to compare the results after surgical and endovascular salvage of thrombosed hemodialysis shunts. Our specific questions were: Does the shunt patency after thrombectomy differ between surgical and percutaneous endovascular techniques of management? What is the expected length of graft function after salvage? Can we select some shunts that will have a better outcome with salvage to use these techniques on, and others that would not benefit from salvage and should be abandoned?

METHODS

Between January 1995 and September 1996, 123 episodes of polytetrafluoroethylene (PTFE) shunt thrombosis in 95 patients were identified. Prosthetic shunts that were evaluated within 1 week of thrombosis were included and were treated within 48 hours of diagnosis. We attempted to treat all patients rapidly enough to eliminate the need for temporary central venous catheters. Patients with thrombosed autogenous arteriovenous fistulae were excluded from randomization. Shunts previously subjected to thrombectomy or revision more than twice or that had initially been constructed less than 6 weeks before thrombosis were also excluded. Patients were evaluated by both vascular surgery and interventional radiology staff and were required to be satisfactory candidates for both methods of treatment (no contrast allergy, no medical exclusion from operation). Informed consent was obtained after a full discussion of the study and the treatment options before randomization. Patients who agreed to participate were then randomized to receive either surgical salvage in the operating room or endovascular salvage in the interventional radiology suite.

Endovascular methods. Grafts were accessed in two places percutaneously using the cross-wire technique. Pulse-spray urokinase was administered using an initial dose of 250,000 units in 12 patients as previously described.[11] Subsequent doses of urokinase were given as needed after clot maceration to completely clear the shunt. Mechanical thrombectomy using a percutaneously placed Fogarty catheter was performed to clear thrombus from the catheter in 47 patients, pushing the clot into the venous circulation.[12] A shunt arteriogram was performed to evaluate the arterial and venous anastomoses and the venous outflow tract. Venous anastomotic stenosis was defined as a stenosis beginning at or within 2 cm of the venous anastomosis and extending less than 4 cm in total length. Diffuse outflow stenosis was defined as any stenosis in the outflow tract measuring 4 cm or longer. Central venous obstruction was defined as a physiologic obstruction of the axillary, subclavian, or innominate veins that did not dilate during forcible injection of contrast. Balloon angioplasty of stenotic segments was performed as needed. Stents were used only in the central venous system when a stenosis was resistant to balloon angioplasty. Patients were routinely discharged immediately after endovascular salvage unless admission was required for another reason.

Surgical methods. Surgical shunt salvage was performed with the patient under either local (n = 22) or regional (n = 34) anesthesia at the discretion of the surgeon and the anesthesiologist. Grafts were accessed by a short incision over the venous limb of the graft or by reopening the incision used to place the shunt. The venous limb was exposed and controlled. The graft was then opened and thrombectomy was performed using Fogarty thrombectomy catheters. A shunt angiogram was performed using fluoroscopy to identify the cause of graft thrombosis using the same criteria as outlined above. The contrast was followed through the outflow veins into the central circulation whenever possible to evaluate the central venous system. The graft was revised on the basis of the findings of the shunt angiogram and the attending surgeon's judgement. Jump grafts to a more proximal vein using PTFE or patch angioplasty across the stenotic segment were both used. When a venous outflow stenosis remote from the anastomosis was detected, balloon angioplasty was used to dilate the lesion after thrombectomy was performed. This was to prevent a long jump graft from interfering with the placement of a more proximal new shunt if this became necessary. When a long-segment venous outflow segment was found, all efforts were made to locate an alternate vein to pro-

Table I. Patient characteristics in 115 patients with shunt thrombosis by treatment group

Category	*Surgery group n = 56*	*Endovascular group n = 59*	*p*
Age	55.5 ± 6.4	56.2 ± 7.8	NS
Sex	49.7% female	55.1% female	NS
Diabetes	48.9%	51.1%	NS
Hypertension	62.2%	56.4%	NS
Shunt site	64.4% forearm loop 33.3% upper arm	71.4% forearm loop 27.1% upper arm	NS
Average shunt age at time of procedure	8.5 ± 7.4 months	8.5 ± 8.8 months	NS
Number of shunts revised for 2nd or 3rd time	25.0%	28.8%	NS
Central venous stenosis	13.1%	18.3%	NS

vide venous outflow and a PTFE jump graft was placed to this vein. Thrombectomy alone was performed if no cause of graft thrombosis was found or if the cause was not correctable. If the shunt was not able to be salvaged, a new shunt was placed during the same anesthetic whenever possible.

Patch angioplasty or short-segment jump grafts with PTFE to a more proximal vein were considered graft revisions. If more than half of the existing graft or a completely new graft was required, the patient was considered a salvage failure. After surgical salvage, patients were admitted if they required admission for another reason or if the procedure was performed in the evening hours and the patient did not live in close proximity to the hospital.

Shunt salvage by either endovascular or surgical means was considered a technical success if the graft functioned adequately to allow hemodialysis. This was performed as soon as necessary after graft salvage to eliminate the need for temporary central venous access catheters. All patients were followed-up through monthly contact with their dialysis center and review of dialysis flow rates and pressures. Graft failure was defined as recurrent thrombosis or increased dialysis pressures that prevented effective dialysis. Graft infection that required graft removal and a new access site was also considered a failure. If recurrent thrombosis occurred, the patients were reentered into the study if they satisfied the above exclusion criteria.

Cost data. Fifteen patients were randomly selected from each group to examine the charges associated with shunt thrombectomy. For these patients, all professional fees, including anesthesiology, surgery, radiology, and others were obtained, as were all hospital charges. These data provide only a comparison of billed amounts and may not reflect the actual reimbursed amounts or cost to Medicare or other providers. The typical reimbursement for dialysis shunt professional fees at our institution is less than 50% of the billed amount. Likewise, hospital charges significantly exceed the actual cost to the hospital as a result of the hospital markup on billed items.

Data analysis. Data were analyzed in accordance with the suggested standards on reporting results for bypass grafts.[14] Comparisons of proportions between two groups were performed with χ^2 analysis. Primary patency intervals for each graft were recorded, and the graft patency rates in each group were calculated using the life-table method according to standard models. Comparisons of patency rates between two groups were performed using the log-rank test.[15]

RESULTS

Of the 123 cases of shunt thrombosis evaluated, eight were excluded by the above defined criteria, leaving 115 episodes in 91 patients that were randomized. Fifty-nine were randomized to endovascular salvage and 56 to surgical salvage. Ninety-two percent of patients were followed-up at least 6 months or until graft thrombosis. The clinical characteristics of the two groups were similar in all categories and are listed in Table I. The causes of shunt thrombosis identified by shunt angiography for each group are listed in Table II. Stenosis at the venous anastomosis was the leading abnormality identified, but 30% of patients were found to have a segment of outflow vein disease longer than 4 cm or venous outflow occlusion. In 15% of patients, central venous obstruction was identified as the sole cause (7%) or a contributing factor (8%) in graft thrombosis.

The initial success rate in restoring graft function was 82% in the surgical group and 71% in the endovascular group ($p > 0.10$). The surgical and endovascular techniques used and their frequency are detailed in Table III. Thrombectomy alone was performed in 21% of the surgical group, and thrombectomy with graft revision was performed in 70%. In the remaining 9%, the grafts were not judged to be

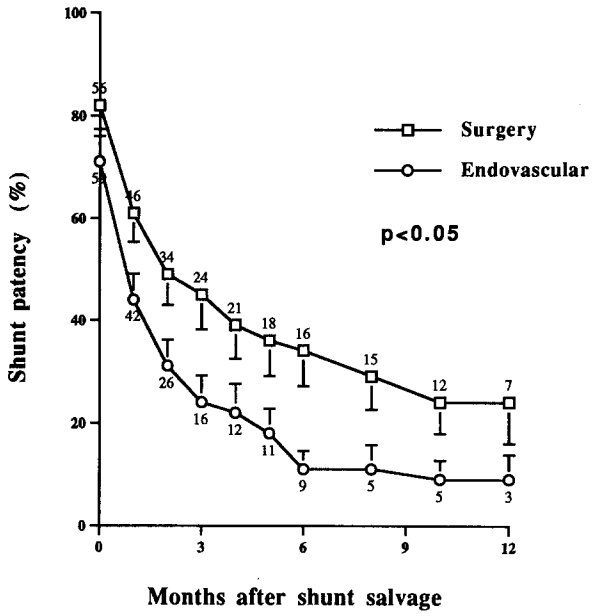

Fig. 1. Primary graft patency rate after salvage of thrombosed shunts treated with surgical compared with endovascular techniques. Patency rates are significantly different by log-rank test ($p < 0.05$).

salvageable after thrombectomy and shunt arteriography. In the endovascular group, 68% were treated with mechanical thrombectomy and balloon angioplasty, 19% were treated with thrombolysis and angioplasty, and in 13% endovascular salvage was not possible because of the extent of venous outflow disease that could not be crossed with a guidewire. There were no significant differences in the rate of initial success or primary patency for the two forms of endovascular treatment.

The primary graft patency rate after salvage, illustrated in Fig. 1, was significantly better in the surgical group (Table IV) than in the endovascular group (Table V; $p < 0.05$). In 34% of patients managed surgically, graft function was extended by 6 months and in 24% by 12 months. In the endovascular group, only 11% were extended by 6 months and 9% by 12 months. Patients who were found to have stenosis limited to the venous anastomotic area had a significantly better patency rate than those with other causes of graft thrombosis (Fig. 2; $p < 0.05$). This was in part a result of the poor results in patients with long-segment outflow stenosis or occlusion who were randomized to the endovascular group. Of 18 patients managed this way, guidewire passage was not possible in eight, and of the 10 in which patency was reestablished only one remained functional 2 months after salvage. In patients with long-segment

Table II. Cause of shunt thrombosis by treatment group

Cause of shunt thrombosis	*All patients*	*Surgery group*	*Endovascular group*
Venous anastomotic stenosis	63 (55%)	50%	59%
Long-segment outflow stenosis	23 (20%)	16%	24%
Venous outflow occlusion	11 (10%)	13%	7%
Arterial anastomotic stenosis	7 (6%)	9%	3%
Central venous stenosis	17 (15%)	15%	14%
Intragraft stenosis	6 (5%)	5%	5%
Other	4 (3%)	5%	2%
None identified	4 (3%)	7%	0%

No significant difference in any category between surgery group and endovascular group.

Table III. Methods used for salvage of thrombosed arteriovenous shunts

	No. of patients
Surgical group	
Thrombectomy only	12
Open thrombectomy and	
PTFE jump graft	24
PTFE patch angioplasty	9
Remote venous angioplasty	6
Salvage not possible	5
Endovascular group	
Urokinase and PTA	11
Mechanical thrombectomy and PTA	40
Salvage not possible	8

stenosis or occlusion managed surgically where an alternate outflow could be used, four of 12 patients had functional grafts at 6 months and two remained patent at 12 months. Graft patency rates after salvage separated by cause of thrombosis and type of management are illustrated in Fig. 3. In patients with venous anastomotic stenosis managed surgically, 44% were patent at 6 months and 31% were patent at 12 months.

There were only three complications noted in this series, two in the surgical group and one in the endovascular group. In the surgical group, there was one case of superficial wound infection that required prolonged healing and one episode of contrast hypersensitivity with dyspnea that required short-term (6 hours) intubation but no prolonged disability. In the endovascular group there was one case of contrast extravasation that resulted in transient painful swelling of the limb that resolved over 2 weeks without permanent sequelae. In two cases in the surgical group, grafts exposed for thrombectomy were found to be surrounded by purulent fluid. These were considered salvage failures, and the infected portion of graft was removed.

Table IV. Primary patency data of grafts after surgical revision

Interval (mo)	*No. of grafts at risk*	*No. of grafts thrombosed*	*No. withdrawn patent due to:*			*Patency rate*	*SE*
			Duration	*Lost to follow-up*	*Death*		
0	56	10	0	0	0	82%	4.6%
0-1	46	12	0	0	0	61%	5.6%
1-2	34	6	2	1	1	49%	6.0%
2-3	24	2	1	0	0	45%	6.8%
3-4	21	3	0	0	0	39%	6.6%
4-5	18	1	0	1	0	36%	6.9%
5-6	16	1	0	0	0	34%	6.9%
6-8	15	2	1	0	0	29%	6.4%
10-12	12	2	2	1	0	24%	6.0%
12-15	7	0	1	0	0	24%	7.9%

Table V. Primary patency data of grafts after endovascular revision

Interval (mo)	*No. of grafts at risk*	*No. of grafts thrombosed*	*No. withdrawn patent due to:*			*Patency rate*	*SE*
			Duration	*Lost to follow-up*	*Death*		
0	59	17	0	0	0	71%	5.0%
0-1	42	16	0	0	0	44%	5.1%
1-2	26	7	1	1	1	31%	5.1%
2-3	16	4	0	0	0	24%	5.2%
3-4	12	1	0	0	0	22%	5.5%
4-5	11	2	0	0	0	18%	4.8%
5-6	9	3	1	0	0	11%	3.6%
6-8	5	0	0	0	0	11%	4.8%
8-10	5	1	1	0	0	9%	3.8%
10-12	3	0	0	0	0	9%	4.9%

Central venous catheters for temporary hemodialysis were required in 16 patients (29%) in the surgical group. Ten were used in patients after unsuccessful surgical salvage, two were used in patients with concurrent medical problems that prohibited immediate shunt salvage, and four were used in patients who had a 24- to 48-hour delay in reaching operation as a result of scheduling conflicts. In the endovascular group, 18 patients (31%) required central venous catheters, 17 as a result of unsuccessful salvage and one as a result of concurrent myocardial ischemia that prevented immediate shunt salvage.

In the surgical group, 16% of patients were in the hospital for other reasons at the time of their shunt thrombosis. In 23% of cases patients were discharged after surgical revision, and in 61% they were admitted after surgery. Ninety-three percent of those admitted were discharged the following day. In the endovascular group, 21% of patients were in the hospital at the time of shunt thrombosis and 68% of patients were discharged after endovascular shunt salvage. Eleven percent were admitted after the procedure, resulting in significantly fewer admissions in the endovascular group than in the surgical group ($p < 0.05$).

In Table VI, the mean charges associated with surgical and endovascular shunt salvage are listed. There was no significant difference in the total charges associated with either technique. In the endovascular group there was a higher range of charges, ranging from a low of $3104 in a patient in whom the lesion was unable to be crossed with a guidewire to $11,646 in a patient who required several angioplasties and urokinase. The range in the surgical group was from $6711 to $11,430. The average increased charge associated with hospital admission after surgical salvage was $884.

DISCUSSION

The thrombosed dialysis shunt is and will likely remain a common problem for physicians involved in the care of dialysis patients. Significant resources are required to maintain adequate access for this lifesaving procedure. It is incumbent on surgeons and interventionalists to optimize the use of resources to maintain dialysis access in the most cost-effective manner. The goal of this study was to compare two techniques of management of thrombosed shunts to help determine the best use of each technique in increasing the efficacy and reducing the cost of dialysis access.

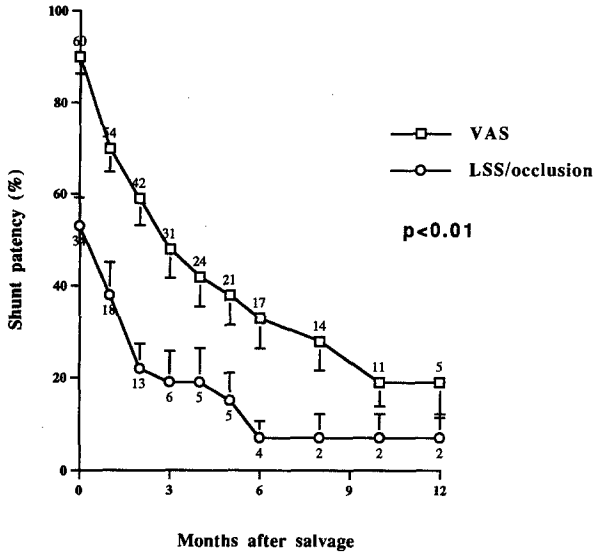

Fig. 2. Primary shunt patency rate after salvage of shunts that thrombosed as a result of venous anastomotic stenosis *(VAS)* compared with shunts with long-segment venous outflow stenosis or occlusion *(LSS/occlusion)*. Patency rates are significantly different by log-rank test ($p < 0.01$).

Table VI. Hospital and professional fees by treatment group in subset of 30 patients

Group	*Hospital*	*Professional*	*Total*
Surgical (n = 15 patients)	5344 ± 341	3128 ± 129	8472 ± 453
Endosvascular (n = 15 patients)	4977 ± 647	3029 ± 442	8006 ± 979

Retrospective studies have reported success rates of 70% to 90% using a variety of percutaneous techniques to clear thrombus from dialysis shunts and restore a functional shunt. These have included techniques using thrombolysis with urokinase,[11,16] mechanical clot maceration and embolization,[12,17] hydrodynamic thrombectomy,[18] and others. These techniques are reported to be equally capable of reopening dialysis shunts with a low risk of complications. All of these use the same techniques for percutaneously treating the cause of dialysis thrombosis: balloon angioplasty with or without stenting. The reported primary patency rates for these techniques vary greatly, in part from inadequate length of follow-up and the use of varied methods to calculate and compare patency data. Reported 6-month graft function rates have ranged from of 10% to 45%.[11,12,17,19] Multiple repeat procedures are often

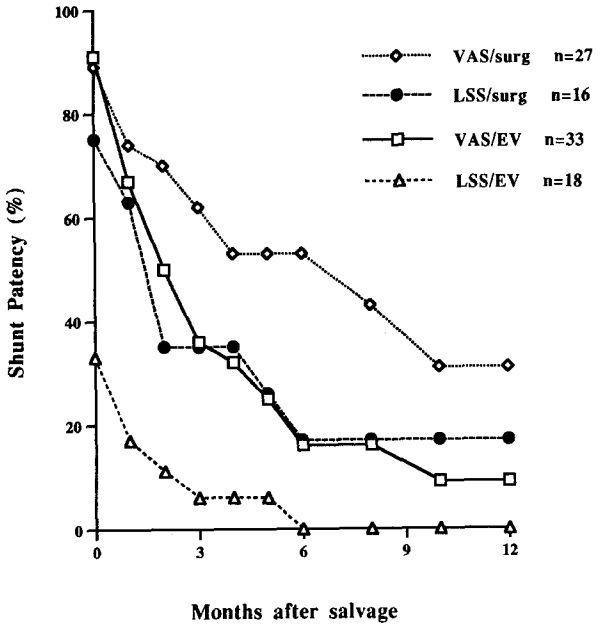

Fig. 3. Comparison of primary patency rates after shunt salvage in the following groups: *VAS/surg,* shunts with venous anastomotic stenosis treated surgically; *LSS/surg,* shunts with long-segment outflow stenosis or occlusion treated surgically; *VAS/EV,* shunts with venous anastomotic stenosis treated with endovascular salvage; and *LSS/EV,* shunts with long-segment outflow stenosis treated with endovascular salvage. Numbers are insufficient for statistical comparison.

recommended to provide meaningful extension of access function, but the cost of continued access function is increased significantly by each procedure required. Cohen et al.[11] reported a secondary patency rate of 69% at 12 months for 26 patients after initially successful thrombolysis and angioplasty, requiring an average of 2.9 procedures per patient. The prospective studies that compared percutaneous and surgical management to date have been inconclusive because of inadequate numbers or inadequate length of follow-up.[19,20]

In this prospective randomized trial, we compared the results of percutaneous endovascular management of dialysis shunt thrombosis with surgical management in 115 patients. Ninety-seven percent of patients were followed-up at least 3 months or until graft thrombosis after salvage, and 92% were followed-up at least 6 months. All patency in both groups was reported on an intent-to-treat basis to allow equal comparison.

The data demonstrate that the primary patency rate after graft salvage was significantly better in the surgical group than in the endovascular group. The

high failure rate after endovascular salvage may be caused by the resistance of venous hyperplastic lesions to dilation and the frequency of long-segment venous stenosis or venous occlusion. Venous hyperplastic lesions recoil significantly after dilation and do not crack or undergo remodeling similar to arterial atherosclerotic lesions. This may result in early recurrence after dilation and poor long-term patency unless multiple repeated dilations are performed.

Long-segment venous outflow stenosis or occlusion was found to be a frequent cause (30%) of shunt thrombosis in our patient population. In comparison, Valji et al.[21] reported only 9% of cases to involve long-segment venous outflow stenosis. Patients with stenosis limited to the venous anastomosis had a significantly better primary patency rate. Long-segment stenotic lesions or venous occlusions are more resistant to angioplasty, which rarely resulted in a functional dialysis shunt 30 days after revision. The only shunts with this cause of thrombosis that remained patent at 3 months after salvage were those treated surgically by revision to an alternate outflow vein. This suggests that shunts with long-segment outflow stenosis or occlusion that cannot be revised to an alternate vein to provide outflow should be abandoned, as the only effective method of providing lasting access would be a new shunt at a site with good venous outflow.

In this study, patients were admitted to the hospital less frequently after endovascular salvage procedures than after surgical salvage procedures. This is in part a result of the need to perform these procedures in the evening hours after completion of the elective schedule in our hospital. Many patients can be discharged after surgical salvage as well, but we did not elect to do so for social reasons in those patients in whom the procedure was completed late in the evening. The charges associated with surgical and endovascular salvage did not differ significantly in the subsets evaluated. However, both techniques were costly, with an average total charge of over $8000 per salvage attempt. We must continue to look for ways to reduce the cost of maintaining hemodialysis access.

The technique of surgical graft salvage is important because of the varied causes of shunt thrombosis that may require different procedures to maximize salvage rates. Thrombectomy should be performed in an operating suite with the capability for intraoperative fluoroscopy to define the cause of graft thrombosis and to determine the appropriate revision. The capability to image the central veins is important given the incidence of central venous obstruction found in this and other studies.[22] Also, access to operating suites should be streamlined so that graft salvage may be performed rapidly, precluding the need for temporary central venous catheters. Grafts can be accessed for dialysis immediately after surgical or endovascular revision, using normal doses of heparin.

Surveillance of dialysis grafts has been described using criteria to identify grafts at risk of thrombosis, which may allow prophylactic repair.[23] Endovascular techniques to improve patent but failing grafts have been reported to provide good long-term graft function rates.[23-25] Endovascular techniques have also been reported to result in extended secondary patency rates of thrombosed dialysis grafts by use of multiple sequential salvage procedures. However, the results of this prospective trial indicate that the primary patency rate after a single procedure for shunt thrombosis is significantly better after surgical salvage than after endovascular management using percutaneous mechanical thrombectomy and balloon angioplasty. A complimentary role for surgical and endovascular management of dialysis grafts may include both, with patent but failing grafts undergoing endovascular salvage and thrombosed shunts undergoing surgical salvage, but such an approach must also be carefully tested in prospective studies to validate its efficacy.

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DISCUSSION

Dr. Richard L. McCann (Durham, N.C.). To my knowledge, this study by Dr. Marston and colleagues is the largest prospective randomized study to compare two approaches for the management of patients with thrombosed dialysis access grafts. Similar, though nonrandomized, data were presented by our nephrologists at the American Society of Nephrologists meeting last fall. We also found a statistically significant better patency rate with surgical thrombectomy and revision compared with mechanical or pharmacologic thrombolysis and angioplasty. I have attributed this difference to the limited efficacy of balloon angioplasty to treat the predominantly elastic stenoses that typically occur at the venous anastomosis, and I would ask the authors whether they agree with that assessment.

The advocates of the endovascular approach cite reduced cost and preservation of the maximum number of distal sites as advantages of that technique. My second question is, have you looked at the relative costs of the two approaches? One small study cited in your manuscript surprisingly demonstrated a lower cost for surgery compared with the endovascular approach, and I would like you to comment on your experience with respect to increasingly important financial implications.

The third question has to do with revisions. We prefer the upper-arm configuration, with the arterial anastomosis above the elbow and the venous anastomosis in the axilla. We often make two and even sometimes three venous extensions sequentially to prolong the life of a graft in the upper arm. Would you comment on the location of your grafts and the strategy for venous limb extensions, addressing the criticism that the surgical approach limits potential sites for new graft placement? This is an excellent manuscript on a very common but still controversial topic. It was well presented, and I predict it will be frequently quoted in the future.

Dr. William A. Marston. Thank you, Dr. McCann, for your thoughtful comments. We agree that angioplasty balloons do not dilate venous lesions very well because there is no plaque to crack. The lesions have a lot of recoil, and we think this is the reason that endovascular techniques do not work well. It does not have anything to do with clearing thrombus. They can clear the thrombus from the graft quite well, but they do not treat the problem very well.

Second, in terms of cost, it is a rather difficult issue to get at because these patients may be in the hospital at the time of their thrombosis, as that occurred in 20% of our patients, and they may stay in the hospital afterwards for other reasons. We looked at a small subset, 15 procedures in each group, and there was no difference in the cost in that group. If we can perform the procedure surgically with the patient as an outpatient, which we are trying to work on in our hospital, I think the cost will not be significantly different, and possibly less.

Third, what are our sites? Two thirds of these patients had forearm shunts, and a third had upper-arm shunts, and we use at least one jump graft or patch angioplasty and usually two or three before we quit on a given graft.

Dr. Mitchell Goldman (Knoxville, Tenn.). I just have a question about your patients who were treated by endovascular means. I was wondering whether you had any measurement of pulmonary vascular resistance or function before and after you pushed the clot in there.

Dr. Marston. We do not have that, and I agree with you. We were quite surprised to find out about this technique. There have been a number of papers, and the incidence of clinical or symptomatic pulmonary embolism is very low, less than 1%.

Dr. Goldman. Well, if you are going to keep doing this over and over again, sooner or later it may catch up with you.

Dr. Marston. We agree.

Dr. S. Edwin Duncan (Tyler, Tex.). I enjoyed your presentation, Dr. Marston. In Tyler, Tex., the nephrologists and access surgeons performed a similar study with the emphasis on evaluating the costs of the endovascular versus the surgical management of thrombosed access grafts. It was a retrospective study in reviewing the uses of the different types of therapy for these thrombosed grafts. Interestingly, there was nearly a 2:1 difference in terms of surgery expenses versus radiographic endovascular therapy. As you pointed out, radiographically, the grafts could be declotted using thrombolysis therapy and angioplasty techniques, but a significant number of these treated grafts then returned thrombosed in a very short period of time, then requiring surgical revision. The cost of the thrombolysis, the angiographic suite, the angioplasty devices, as well as the radiographic fees versus surgical revision costs initially were quite significant.

Our conclusion was that in terms of cost and time efficiency plus the early return of patients with thrombosed grafts back to dialysis, that surgery was the most desirable form of therapy for these patients. Presently, it is our practice that when we see a thrombosed graft in a dialysis patient, unless this is a very recently placed graft, that the patient goes directly to surgery without the inappropriate delay from radiographic intervention.

Dr. Marston. I would agree with you, and a number of the reports of good results with endovascular salvage have to do with repeated dilation, monthly or every other month, and the cost of that must be very high.

Dr. Mark Friedell (Orlando, Fla.). I cannot help but ask about your experience with the use of stents at the venous outflow.

Dr. Marston. We have not done that, and our radiologists do not believe that they will limit the problem because, if you place stents in the central veins, they stenose right through the stent there. I do not know why they would do any better in a smaller vein.

Dr. Friedell. Just to say a word about it, we had a rash of stents being put in by a few cardiologists in town. Of course, they were usually not on call the weekend that the graft rethrombosed. We would inherit the case and manage it surgically. It is an absolute nightmare to be cutting through a stented vein trying to patch it open. Stenting a graft almost precludes further surgical management.

Dr. Marston. I agree.

Dr. Clifford Buckley (Temple, Tex.). I join Ed Duncan in saying that we also looked at the difference in cost between the endovascular management of these lesions and the direct surgical approach. At our institution it is approximately $800 to $1000 cheaper to repair a thrombosed fistula surgically than to do it using thrombolysis and endovascular treatment. We do use endovascular techniques for those fistulae that occlude within 3 to 6 months of placement because the occlusion is usually not caused by hyperplastic tissue at the outflow anastomosis but is frequently a technical problem or related to inadequate venous run-off. In these circumstances, it is better to have the fistula thrombolysed and a fistulogram obtained to evaluate the problem. Many times an angioplasty of a outflow stenosis from a misplaced stitch will salvage the fistula for a long time. In addition, if inadequate venous outflow or run-off is identified, the fistula can be revised to a more appropriate venous outflow anatomic situation. In our practice, most of the early graft occlusions are treated with thrombolysis. Those that have been functioning for at least 6 months are managed surgically.

Dr. Marston. I think there may be some role in situations like this for endovascular techniques, but we need good prospective data to determine that.