Effect of Secondary Interventions on Patency of Vascular Access Sites for Hemodialysis

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Purpose. To determine the impact of secondary procedures performed to maintain arteriovenous fistula (AVF) and arteriovenous graft (AVG) patency.

Methods. There hundred and eighty six vascular access procedures were retrospectively evaluated. 156 (40.4%) patients required radiological interventions to treat acute thrombosis, swelling of the extremity with the access site, insufficient hemodialysis, or stenosis at an anastomotic site.

Results. The 386 cases comprised 106 AVGs and 280 AVFs. In 138 of the 156 cases, which required a radiological intervention, the treatment was successful and saved the vascular access site. The unassisted post-intervention patency time for these 138 successful cases was 13.1 ± 6.5 months (range, 1–65 months). Twenty-nine (63%) of the 46 access sites treated with surgical thrombectomy were saved.

Conclusions. Frequent, regular follow-up of hemodialysis patients with vascular access sites is the best way to diagnose problems early and allow the best chance of long-term function.

Keywords: Hemodialysis; Therapeutic thrombolysis; Thrombectomy; Arteriovenous fistula.

Introduction

Vascular access for hemodialysis is one of the definitive surgical solutions for patients with end-stage renal disease (ESRD) who are not suitable for peritoneal dialysis. Approximately 300 000 patients in the United States are currently on long-term hemodialysis.¹ In Turkey, roughly 25 000 patients are on a regular hemodialysis program and the cost of this care has significant economic impact.² Maintaining uninterrupted hemodialysis access is of paramount importance for reducing patient morbidity and minimizing treatment costs.

According to the 1997 National Kidney Foundation Dialysis Outcomes Quality Initiative Clinical Practice (DOQI) guidelines, 50% of patients on hemodialysis should receive this treatment via an arteriovenous fistula (AVF) rather than an arteriovenous graft (AVG) or a permanent central catheter.³ These guidelines also identify “increasing the placement of autogenous fistula” as the primary solution for improving quality of life and outcome for patients with ESRD. Most hemodialysis patients who have autogenous or prosthetic vascular access sites require secondary procedures to resolve problems that arise over time. Spontaneous thrombosis, development of flow-reducing stenosis in the afferent artery or efferent vein, central vein stenosis, and central vein occlusion are the most common reasons for re-intervention. In addition to surgical treatment, it is now routine for vascular access stenosis and thrombosis to be treated with interventional radiology techniques. These include dilatation of a stenotic segment via either angioplasty or stenting and many declotting methods.⁴

The aim of this study was to determine the impact of secondary procedures that were used to maintain AVF and AVG patency.

Methods

Between January 1996 and January 2005, 1315 procedures for creating hemodialysis access sites were
performed in Baskent University, Department of Surgery, Ankara, Turkey. We reviewed the findings for 482 of these AVFs and AVGs in 321 patients who continued to undergo hemodialysis in our units and were monitored with routine follow-up. Ninety-six of these 482 fistula and grafts never matured, so these were excluded and data for the remaining 386 AVF and AVG were retrospectively evaluated. A database was created from operative logs and radiology, nephrology, general surgery and dialysis center records. The demographic data collected were sex and age of patient, history of dialysis catheter placement, number of prior fistula created, cause of ESRD, preoperative venous imaging status and comorbid conditions (Table 1). In each case, preoperative assessment entailed either physical examination alone or physical examination plus duplex US scanning and venography. Physical examination was the only modality used to determine the type and site of vascular access until 1998. We subsequently used preoperative ultrasonography and venography in selected patients after considering their history of prior vascular access operations and central vein catheterizations. Since 2002, however, we have used Doppler ultrasonography and venography to evaluate all patients (except those without adequate insurance coverage). The most suitable vein was selected based on this assessment.

When insufficient AVF or AVG flow for hemodialysis was detected, the first investigative step in each case was fistulography. For this, the efferent vein of the fistula was cannulated and a sphygmomanometer cuff was placed around the arm and inflated to above systolic pressure. Then contrast medium was injected and the pressure in the cuff caused reflux of contrast medium back through the anastomosis site. If the clinical problem was high venous pressure during dialysis or swelling of the limb with the access site, conventional x-ray venography was done to obtain images of the more proximal veins. If stenosis (defined as >50% reduction in luminal diameter) without thrombosis was detected in the region of the venous anastomosis or anywhere along the draining vein or the central veins, then percutaneous transluminal angioplasty (PTA) was the treatment of choice. In such cases, the success of the procedure was always checked with control fistulography and pressure measurements. Stents were placed to prevent elastic recoil after PTA in cases of suboptimal angioplasty (defined as >50% narrowing with persistent filling of the venous collaterals), and in cases where stenosis recurred within 2 months of successful angioplasty. PTA or PTA/stent placement was considered technically successful if there was <30% residual stenosis and no filling of the venous collaterals.

In the initial years of our study period (before 2000), thrombosis affecting an AVF or AVG was treated with early surgical thrombectomy. This problem was suspected based on loss of thrill at the fistula site, and each diagnosis was confirmed with Doppler US prior to operating. Surgical thrombectomy was performed in the operating room under local anesthesia. If the thrill was restored during the operation and control Doppler US examination indicated sufficient flow, the procedure was considered successful.

In subsequent years, in cases where it was appropriate we corrected AVF or AVG thrombosis with pharmaco-mechanical thrombolysis (Fig. 1). In such instances, the diagnosis was confirmed with Doppler US and the exact location and extent of the thrombus was determined by fistulography. Then thrombectomy was performed using the Arrow-Trerotola mechanical thrombectomy device (Arrow International Inc, Middletown, PA, USA) and 2000–3000 IU heparin was administered during this procedure. In addition, pulse-spray streptokinase treatment (total dose 150 000–350 000 IU) was administered to every patient. In 5 cases, balloon mechanical thrombectomy was also performed. After each percutaneous thrombectomy procedure, the patency of the fistula was evaluated with control fistulography. As well, in each case where there was a stenotic segment at the level of the anastomosis, PTA was considered successful with a 5–8 mm diameter balloon catheter. In the 2 cases in which dilatation with high-atmospheric-pressure balloon catheters (Blue Max, Boston Scientific Corporation, Watertown, MA, USA) failed (pressure gradient still higher than 10 mmHg or still >50% stenosis after the procedure), metallic stents (Palmaz stent, Cordis Corporation, a Johnson & Johnson company;

Table 1. Demographic data and comorbid conditions in 386 hemodialysis cases

<table>
<thead>
<tr>
<th>Condition</th>
<th>Number of AVFs</th>
<th>Number of AVGs</th>
<th>Sex (M/F)</th>
<th>Age (mean years)</th>
<th>Etiology of ESRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes (n) (%)</td>
<td>280</td>
<td>106</td>
<td>214/172</td>
<td>49.6 ± 15.2</td>
<td>Diabetes (n) (%)</td>
</tr>
<tr>
<td>Hypertension (n) (%)</td>
<td>128 (33.1%)</td>
<td></td>
<td></td>
<td></td>
<td>Hypertension (n)</td>
</tr>
<tr>
<td>Glomerulonephritis (n) (%)</td>
<td>68 (17.6%)</td>
<td></td>
<td></td>
<td></td>
<td>Glomerulonephritis (n)</td>
</tr>
<tr>
<td>Infection (n) (%)</td>
<td>55 (14.2%)</td>
<td></td>
<td></td>
<td></td>
<td>Infection (n)</td>
</tr>
<tr>
<td>Polycystic kidney disease (n) (%)</td>
<td>33 (8.5%)</td>
<td></td>
<td></td>
<td></td>
<td>Polycystic kidney disease (n)</td>
</tr>
<tr>
<td>Postrenal obstruction (n) (%)</td>
<td>21 (5.4%)</td>
<td></td>
<td></td>
<td></td>
<td>Postrenal obstruction (n)</td>
</tr>
<tr>
<td>Amyloidosis (n) (%)</td>
<td>14 (3.6%)</td>
<td></td>
<td></td>
<td></td>
<td>Amyloidosis (n)</td>
</tr>
<tr>
<td>Unknown (n) (%)</td>
<td>36 (9.4%)</td>
<td></td>
<td></td>
<td></td>
<td>Unknown (n)</td>
</tr>
<tr>
<td>Mean duration of ESRD (months)</td>
<td>34.5 ± 38.3</td>
<td></td>
<td></td>
<td></td>
<td>Mean duration of ESRD (months)</td>
</tr>
<tr>
<td>Number of prior dialysis catheters placed</td>
<td>2.9 ± 2.8</td>
<td></td>
<td></td>
<td></td>
<td>Number of prior dialysis catheters placed</td>
</tr>
<tr>
<td>Number of previous dialysis access sites</td>
<td>2.7 ± 1.9</td>
<td></td>
<td></td>
<td></td>
<td>Number of previous dialysis access sites</td>
</tr>
<tr>
<td>Number of patients with PVI</td>
<td>234</td>
<td></td>
<td></td>
<td></td>
<td>Number of patients with PVI</td>
</tr>
</tbody>
</table>

PVI: preoperative vascular imaging.
Warren, NJ, USA) were placed in the segments thought to be the main origin of the thrombus.

In cases where acute central vein thrombosis was impairing AVF or AVG function, catheter-directed thrombolysis with streptokinase (total dose 150,000–350,000 IU) was performed. Once percutaneous thrombolysis was carried out, fistulography was performed to assess for residual thrombosis and stenosis at the access site. Residual stenosis was corrected by PTA. If there was elastic (post-procedure) stenosis in the central vein, and if this blockage was >50% and/or the pressure gradient was still high, then a stent (Wallstent, Boston Scientific, Natick, MA, USA) was placed to address these problems (Fig. 2).

In all cases where an AVF or AVG problem arose, a central jugular catheter (or a subclavian or femoral catheter if appropriate) was also inserted for hemodialysis and the patient completed at least 2 hemodialysis sessions with this double-lumen catheter in place. Radiological or surgical interventions were deemed successful if the access site was sufficient for at least 4 hemodialysis sessions.

Unassisted post-intervention patency time was defined as the interval from a surgical or endovascular intervention to 1) the time of subsequent access site thrombosis or 2) the time of final patency assessment for the study.

**Statistical analysis**

Mean (±SD) was the descriptive statistic used to express results for quantitative variables. Kaplan-Meier survival analysis and log-rank statistics were performed according to unassisted post-intervention patency in different groupings of patients, and rates for the different patency categories were calculated at 6 and 12 months after AVF/AVG creation. Differences between groups for a given parameter were assessed using the Fisher’s exact test or Chi-square test.
with Yates correction, as appropriate. All statistical analyses were performed using the statistical software package SPSS for Windows, version 11.0.

Results

Demographic data

The 386 patients in the study were 57% men and 43% women. The mean age was 49.6 ± 15.2 years (range, 19–80 years), the mean duration of ESRD was 34.5 ± 38.3 months (range, 1–170 months), the mean number of previous central vein dialysis catheter placements was 2.9 ± 2.8 (range, 0–14), and the mean number of previous hemodialysis access sites was 2.7 ± 1.9 (range, 1–11). The causes of ESRD were diabetes (128 cases, 33.2%), hypertension (68 cases, 17.6%), glomerulonephritis (55 cases, 14.2%), infection (33 cases, 8.5%), postrenal obstruction (31 cases, 8%), polycystic kidney disease (21 cases, 5.4%), amyloidosis (14 cases, 3.6%), and unknown (36 cases, 9.3%) (Table 1).

The 386 cases comprised 106 (27.5%) AVGs and 280 (72.5%) AVFs. The different types of vascular accesses created were snuffbox (43 cases), radiocephalic (Brescia-Cimino, 86 cases), antecubital brachiocephalic (103 cases), brachioaxillary (51 AVGs), brachiobasilic (31 AVGs), femorofemoral (24 AVGs), basilic vein transpositions (45 cases), femoral vein superficializations (2 cases), and brachial vein superficialization (1 case).

Postoperative radiological interventions

During follow-up, 156 (40.4%) of the 386 cases required radiological interventions due to acute thrombosis, swelling of the extremity with the access site, insufficient hemodialysis, or stenosis at an anastomosis site. Of the 156 cases with complications that required radiological intervention, 47 were acute thrombosis (treated with pharmaco-mechanical thrombolysis) and 109 were stenosis (treated with other percutaneous
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Surgical thrombectomy

In addition to the 47 acute thrombosis cases that were treated with pharmaco-mechanical thrombolysis, another 46 cases of acute thrombosis (17 AVGs and 29 AVFs) were managed with surgical thrombectomy. The demographic characteristics of patients with acute thrombosis were similar in both thrombolysis and thrombectomy groups. Twenty-nine of these 46 access sites (14 AVGs, 15 AVFs) were saved by surgical thrombectomy. For these 29 cases, the rates of unassisted post-intervention patency at 6 and 12 months were 34% and 7%, respectively. The corresponding rates for the 31 cases of AVF or AVG thrombosis that were successfully treated with percutaneous pharmaco-mechanical thrombolysis were 52% and 15%. Although both rates were higher in the percutaneously treated group, the differences were not statistically significant (p > 0.05 for both) (Table 2).

The abovementioned 29 cases rescued with surgical thrombectomy were further analyzed according to access type. The rates of unassisted post-intervention patency for the AVFs in this subgroup at 6 and 12 months were 52% and 15%, respectively. The corresponding values for the AVFs successfully treated with percutaneous pharmaco-mechanical thrombolysis were 22% and 13%. The differences between these corresponding rates were not statistically significant (p > 0.05 for both) (Table 2). For the AVGs successfully treated with surgical thrombectomy, the rates of unassisted post-intervention patency at 6 and 12 months were 43% and 7%, respectively. The corresponding values for the AVGs successfully treated with percutaneous pharmaco-mechanical thrombolysis were 63% and 16%. The differences between these corresponding rates were not statistically significant (p > 0.05 for both) (Table 2) (Fig. 3).

Discussion

Turkish Nephrology Society data from 2003 indicate that, in 72.5% of the cases of AVF or AVG thrombosis in that year, the solution was to create a new access site.2 However, when such a problem develops, many of these sites can be saved with closer patient follow-up and prompt surgical or radiological intervention. This interventional approach also maintains patients’ quality of life and reduces morbidity and treatment costs.

Aside from surgical methods, today it is routine to use interventional radiology techniques to treat stenosis and thrombosis of hemodialysis vascular access sites or central veins. These alternatives include dilation of stenotic segments with or without stent placement, and many declotting techniques. In series published on percutaneous treatment of thrombosed AVF and AVGs, stenosis was the underlying cause in almost 85% of cases.5,6 Stenosis of vascular access for hemodialysis is usually caused by proliferation of intimal smooth muscle cells in the region of the venous anastomosis. However, this problem can occur anywhere along the draining vein.5 Four of the patients in our series had efferent vein stenosis in axillary and cephalic veins, and we were able to rescue all 4 of these access sites with PTA.
DOQI guidelines recommend that AVFs should be created in at least 50% of all patients who are newly diagnosed with ESRD. However, data from the Turkish Nephrology Society Registry reveal that, in our country, double-lumen central venous catheters are preferred for initial vascular access in 62.2% of all hemodialysis patients. In most cases, evaluation for a permanent access site is done after initial access has been secured. Complications with vascular access are also common indications for temporary central venous catheterization. Unfortunately, the subclavian vein is the preferred site for central venous catheter insertion, and stenosis or thrombosis of this vessel develops in 42% to 50% of these cases. Such problems may not become clinically apparent until venous flow is increased, resulting in swelling of the upper limb. Similarly, internal jugular catheter placement can cause damage to the brachiocephalic vein and femoral catheterization can damage the iliac vein. In some cases, stenosis or occlusion of the venous outflow of an AVF occurs in the absence of previous catheterization. Such problems may not become clinically apparent until venous flow is increased, resulting in swelling of the upper limb. Similarly, internal jugular catheter placement can cause damage to the brachiocephalic vein and femoral catheterization can damage the iliac vein. In some cases, stenosis or occlusion of the venous outflow of an AVF occurs in the absence of previous catheterization. Such problems may not become clinically apparent until venous flow is increased, resulting in swelling of the upper limb. Similarly, internal jugular catheter placement can cause damage to the brachiocephalic vein and femoral catheterization can damage the iliac vein.

Table 2. Comparison of 6- and 12-month unassisted post-interventional patency rates for surgical and percutaneous treatment of thrombosis, with patients categorized according to fistula type

<table>
<thead>
<tr>
<th>Surgical treatment</th>
<th>6 mo (upip)</th>
<th>12 mo (upip)</th>
<th>Percutaneous treatment</th>
<th>6 mo (upip)</th>
<th>12 mo (upip)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVF + AVG n:29</td>
<td>34%</td>
<td>7%</td>
<td>AVF + AVG n:31</td>
<td>52%</td>
<td>15%</td>
<td>p &gt; 0.05 for both</td>
</tr>
<tr>
<td>AVF n:15</td>
<td>52%</td>
<td>15%</td>
<td>AVF n:8</td>
<td>22%</td>
<td>13%</td>
<td>p &gt; 0.05 for both</td>
</tr>
<tr>
<td>AVG n:14</td>
<td>43%</td>
<td>7%</td>
<td>AVG n:23</td>
<td>63%</td>
<td>16%</td>
<td>p &gt; 0.05 for both</td>
</tr>
</tbody>
</table>

upip: unassisted post-intervention patency.
AVG: arteriovenous graft.
AVF: arteriovenous fistula.

Fig. 3. Kaplan-Meyer analysis and log-rank statistics for 6-month unassisted post-interventional patency rates for surgical and percutaneous treatment of AVF (a) and AVG (b) thrombosis.
with stent placement. After stent placement, multiple re-interventions are often needed to prolong patency. Re-stenosis can be treated with angioplasty alone in most cases, but sometimes additional stent placement is required. Reported rates of assisted primary patency at 1 year range from 33% to 97%. In our series, 84 of the 109 cases of venous stenosis were in central veins. In other words, 84 (22%) of the 386 total access sites in the study developed central vein stenosis. This high rate may be a reflection of the high frequency of dialysis catheter placement for securing initial access, as noted in the registry information above. Each of our 84 patients with central vein stenosis exhibited insufficient flow for hemodialysis and/or venous hypertension. All these cases were treated with percutaneous interventions, and stents were placed when necessary. The success rate was 95%.

In most patients who develop acute thrombosis of a central vein, the underlying pathology is venous stasis. When there is acute central vein occlusion related to dialysis access, stent deployment is very effective as a first step. This method has long been recommended as the primary treatment tool, and offers better long-term patency than other therapeutic modalities, such as percutaneous balloon angioplasty alone. Mechanical thrombectomy is not recommended as routine primary treatment for dialysis-related central vein occlusion because of sharp angles in the vasculature and thin vessel walls. On the other hand, thrombectomy devices are effective tools for debulking neointimal tissue in cases of stent recoclusion. Catheter-directed thrombolysis is associated with high rates of lysis because the thrombolytic agent is delivered directly to the site in high concentrations. Some authors have reported good results with a combination of thrombolytic agents, angioplasty and stent placement. In all patients our protocol for treating acute thrombosis in a central vein is percutaneous thrombolytic treatment with additional PTA and stenting when necessary. In some of our hemodialysis patients, central vein stenosis developed but treatment was not attempted because there was less than 50% blockage. In 15 of these cases, thrombosis developed in addition to (and likely due to) the stenosis. All these patients were successfully managed with a combination of thrombolytic therapy and PTA, and some required additional stent placement. When a vascular access provides inadequate flow for dialysis, the problem is usually stenosis of the vein adjacent to the anastomosis site in an AVF, or stenosis of the venous anastomosis region in an AVG. Although balloon angioplasty can widen the lumen and restore flow at least temporarily, elastic recoil is common and the stenotic segment may resist even high-pressure dilatation. Excellent technical success has been documented with PTA for dysfunctional AVGs and AVFs. Repeat angioplasty can be performed if stenosis of an AVF or AVG recurs, and the success rates are similar to the first angioplasty attempt. It has been claimed that, in cases of recurrent venous stenosis at an access site, angioplasty plus stent placement results in longer intervals between interventions than angioplasty alone. Recently, Beatard studied patients who had stenosis at the venous anastomosis of AVGs and compared results with PTA alone to results with PTA combined with placement of self-expanding stents. The data indicated that stenting provided no additional benefit. In our series, 21 patients had stenosis in the anastomosis region of an AVF or AVG. Percutaneous radiological interventions were successful in 15 of these cases (71% success rate). Five of these stenotic segments were at the venous anastomosis site of an AVG and were managed with PTA and stent placement. The other 10 were AVFs, and PTA alone was sufficient for dilatation in these cases.

We also determined the unassisted post-interventional patency time for each case of occlusion/stenosis of a central vein, AVF or AVG that was treated with percutaneous radiological interventions. For these cases, the rates of unassisted post-interventional patency at 6 and 12 months were 78% and 45%, respectively. These figures are both higher than the targets recommended by the DOQI (50% and 40%, respectively).

Thrombosis of an AVF or AVG is a frequent problem that leads to significant morbidity and longer hospital stays for the dialysis patient. In the past, thrombosis of a dialysis shunt was almost always corrected with surgical thrombectomy. Today, there are also numerous percutaneous treatment alternatives for thrombosed AVFs and AVGs. These include mechanical thrombectomy, pharmaco-mechanical thrombolysis, and percutaneous infusion of pharmacological agents for thrombolysis. The National Kidney Foundation’s clinical practice guidelines for vascular access state that each institution should choose the most appropriate approach for resolving access-site thrombosis based on the expertise at that particular center. In general, treatment of AVG thrombosis is thought to be more successful than treatment of AVF thrombosis. In our study, there was only 1 unsuccessful pharmaco-mechanical thrombolysis attempt in AVFs (success rate 87.5%) and we had 100% success with this technique in AVGs. The corresponding success rates with surgical thrombectomy were 51.7% for AVFs and 82.3% for AVGs. DOQI guideline No. 21 states that immediate patency rate
with both these techniques should be at least 85%,” but we were only able to reach this target in the group that underwent percutaneous treatment. In addition to higher success rates for percutaneous treatment of AVFs and AVGs, we found that the chance of rescue with surgical thrombectomy was higher if the vascular access was an AVG. The overall rescue rate with percutaneous pharmaco-mechanical thrombolytic treatment was 88.5%, whereas the corresponding rate for the surgical procedures was 63%. Overbosch et al. examined the cases of 24 patients with occluded Brescia-Cimino AVFs, and noted that 20 (83%) were successfully declotted with a Hydrolyser thrombectomy catheter (Cordis Corporation, USA). The median assisted patency time for these AVFs was 34 weeks, which was significantly shorter than that for the occluded AVGs in the study.

Sands et al. observed no significant differences between surgical and percutaneous treatment of AVG thrombosis with respect to success rates, primary patency times, or complication rates in a retrospective study.25 Beathard described equal initial success rates when mechanical thrombolysis was compared with surgical thrombectomy in AVGs.26

Green et al. reported higher rate of patency in favor of the surgical treatment group in a multicenter trial.27 In our series, the 6- and 12-month rates of unassisted primary patency were higher for the AVGs that were treated percutaneously than for the AVGs that were treated surgically. DOQI guideline No. 21 recommends that, for AVGs treated with percutaneous thrombolysis and PTA combined, the unassisted patency rate at 3 months should be 40% or higher. The same guideline notes that, for AVGs treated with surgical thrombectomy, this rate should be 50% at 6 months and 40% at 12 months. According to our data, we reached the abovementioned target unassisted patency rate for percutaneous treatment of AVG thrombosis (our rate: 63% at 6 months). Our unassisted patency rate for AVGs at 6 months after surgical thrombectomy was relatively close to the recommended level (our rate: 43%); but our rate at 12 months (7%) was significantly below target. Green et al.27 reported a significantly higher technical failure rate in their endovascular treatment group, they also found that the failure rate for surgically treated AVFs was particularly high. Trerotola et al. used the Arrow-Trerotola percutaneous device to treat thrombosed AVGs and recorded 95% technical success and 39% primary patency at 3 months.28

AVF thrombosis is a less frequent clinical problem than AVG thrombosis. In general, the percutaneous declotting techniques that have recently been validated in AVGs are more difficult to perform in AVFs. As well, few published articles have dealt with this issue and the patient numbers presented are relatively small. The findings in many reports suggest that percutaneous interventions for occluded AVFs are at least as effective as surgical treatment with respect to technical success and patency times. In our series, the technical failure rate for pharmaco-mechanical thrombolytic treatment plus PTA (2 failed cases, 20%) was lower than the failure rate for surgical thrombectomy (51%). However, the rate of unassisted primary patency at 6 months was more than 2 times higher in the surgical thrombectomy group (52%). We found that, for both the AVFs and AVGs, in the long term the surgical procedures extended mean patency times to a somewhat greater extent than the percutaneous techniques. However, the differences were not statistically significant because the patient numbers were small. Over the long term, neither the percutaneous nor the surgical techniques yielded optimal outcomes.

Frequent follow-up of hemodialysis patients with vascular access sites is the best way to diagnose problems early. This allows the best chance of rescuing a site rather than creating a new one. The rescue approach reduces morbidity and decreases the cost of hemodialysis treatment.

References


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