Secondary Patency of Thrombosed Prosthetic Vascular Access Grafts with Aggressive Surveillance, Monitoring and Endovascular Management


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Abstract Background: To study the long-term patency of thrombosed prosthetic vascular access grafts treated with percutaneous mechanical thrombectomy (PMT) followed by aggressive surveillance and monitoring and repeated endovascular interventions.

Study design: Two hundred seven vascular access grafts presented with first-time thrombosis were treated with PMT using the AngioJet device (n = 185) or the Arrow-Trerotola percutaneous thrombolytic device (n = 22) followed by angioplasty (± stenting) of the anatomical lesion responsible for the thrombotic event. Clinical success was considered at least one successful subsequent hemodialysis session. Graft surveillance/monitoring included clinical and hemodialysis parameters to detect a failing or thrombosed graft.

Results: PMT was technically successful in 202 cases (97.6%) and clinically successful in 193 cases (93.2%). During follow-up, 149 got thrombosed and either abandoned (n = 33) or underwent at least once repeat thrombectomy (n = 116); finally 100 grafts were abandoned (n = 90), ligated (n = 5) or removed (n = 5). Endovascular management (0.54 procedures per 100 graft-days, thrombectomy, n = 307 sessions and angioplasty, n = 162 sessions) increased significantly functional assisted-primary patency rates from 29% and 14% at 1 and 2 years to a secondary patency of 62% and 47%, respectively. Secondary patency was worse in loop grafts (P = .02) and intermediate graft thrombosis (occurred between 31–182 days after graft placement, P < .001) and better when renal failure was due to hypertension or diabetes (compared to other or cryptogenic causes, P = .048) or isolated angioplasty for graft dysfunction during follow-up had been performed (P < .001). Multivariate analysis identified intermediate graft thrombosis and isolated angioplasty as independent predictors of secondary patency (P < .001, relative risk 2.77 and P < .001, relative risk 0.28, respectively).

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Introduction
The 2006 update of the KDOQI guidelines have recommended that endovascular techniques to restore function of thrombosed hemodialysis prosthetic grafts, should have a clinical success rate of at least 85% and that primary patency at three months should be at least 40%. Variable success and primary patency rates have been reported in the literature. However, there is paucity of data on the secondary patency of thrombosed prosthetic grafts that were successfully restored; endovascular interventions can be performed on an outpatient basis and repeated several times. We have previously published on the assisted primary patency of thrombosed prosthetic grafts and autogenous fistulae managed with percutaneous mechanical thrombectomy (PMT). The aim of this study was first to investigate the results of an aggressive protocol of surveillance, monitoring and repeated endovascular interventions on secondary patency rates of thrombosed prosthetic vascular access grafts that presented with first-time thrombosis and treated with PMT and second to identify prognostic factors associated with better outcome.

Material and Methods
During a 5-year period, 214 vascular access grafts (thigh grafts, n = 4 and upper arm grafts, n = 210) presented with first-time thrombosis. Two hundred and seven of them in 185 patients (85 men, mean age at presentation 61.9 years) were treated with PMT, while in the remaining 7 grafts in six additional patients, thrombectomy was aborted because the access had an occlusive lesion that could not be crossed with the hydrophilic wire (venous anastomosis, n = 2, draining veins, n = 3) or was deemed beyond endovascular management (n = 1) or this was attempted and aborted (n = 1). The hospital IRB approved the study. Patients that had the first episode of graft thrombosis treated at outside institutions were excluded from the study. The procedure was deferred in medically unstable patients, e.g. intubated etc, until patients recovered from the acute event. Time interval between thrombotic episode and patient presentation was not a contraindication to perform the procedure, if this was less than a month. Two thrombectomy procedures performed within the last month of a recurrent thrombosis was also a contraindication for a new attempt and these grafts were usually abandoned. Patient demographics are shown in Table 1. Interval between graft placement to the first thrombotic episode ranged from 13 days to 7.6 years. During the period between graft placement and first thrombosis, 45 grafts had 86 preemptive interventions (range 1–5). Median (interquartile range) time interval between the last preemptive and the index PMT procedure was 117 (52–262) days.

Table 1: Demographics of study patients in relation to the cause of renal failure

<table>
<thead>
<tr>
<th>Cause of chronic renal failure</th>
<th>Diabetes Mellitusa (n = 53)</th>
<th>Hypertension (n = 102)</th>
<th>Otherb (n = 23)</th>
<th>Unknown (n = 7)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>64 ± 10.9</td>
<td>63 ± 14.5</td>
<td>56 ± 11.9</td>
<td>48 ± 21.5</td>
<td>.002</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.94</td>
</tr>
<tr>
<td>Male</td>
<td>29 (55%)</td>
<td>56 (55%)</td>
<td>11 (48%)</td>
<td>4 (57%)</td>
<td>.62</td>
</tr>
<tr>
<td>Female</td>
<td>24 (45%)</td>
<td>46 (45%)</td>
<td>12 (52%)</td>
<td>3 (43%)</td>
<td></td>
</tr>
<tr>
<td>Graft configurationc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.62</td>
</tr>
<tr>
<td>Straight</td>
<td>38 (62%)</td>
<td>78 (68%)</td>
<td>14 (56%)</td>
<td>5 (71%)</td>
<td></td>
</tr>
<tr>
<td>Loop</td>
<td>23 (38%)</td>
<td>36 (32%)</td>
<td>11 (44%)</td>
<td>2 (29%)</td>
<td></td>
</tr>
<tr>
<td>Time from graft placement (months)d</td>
<td>5.6 (1.9–16.2)</td>
<td>7.6 (2–17.5)</td>
<td>8.5 (2–18.3)</td>
<td>3.7 (2.4–34.6)</td>
<td>.91</td>
</tr>
<tr>
<td>History of intervention for graft dysfunction</td>
<td>6 (12%)</td>
<td>35 (33%)</td>
<td>3 (16%)</td>
<td>1 (14%)</td>
<td>.02</td>
</tr>
<tr>
<td>Time from last intervention (days, median)</td>
<td>183</td>
<td>106</td>
<td>122</td>
<td>53</td>
<td>.49</td>
</tr>
</tbody>
</table>

a Co-existing hypertension in 42 cases.
b Included glomerulonephritis, polycystic kidney disease, nephrotic syndrome and other nephropathies.
c Some patients had more than one graft included in the study.
d Exact date of surgery not known in 5 grafts placed at outside institutions. Continuous data are shown as mean and standard deviation or median and interquartile range; categorical data are given as number of cases (percentages).
The AngioJet thrombectomy system (series 3000 and Ultra, more recently, Fig. 1) uses a rheolytic thrombectomy method. A detailed description can be found elsewhere.\textsuperscript{10} The Arrow-Trerotola percutaneous thrombolytic device uses a rotating basket that fragments the thrombus that is then removed from the sheath ports or flushed away by the blood flow. Details can be found elsewhere.\textsuperscript{3}

**Description of Percutaneous Thrombectomy Technique**

A detailed description of the technique can be found elsewhere.\textsuperscript{10–12} Briefly, our technique is a modification of Beathard’s “double sheath technique”\textsuperscript{2}; Arterial thrombectomy is usually performed first instead and compromised by the following steps:

1. **Venous and arterial access.**
2. **Arterial thrombectomy:** This is performed under fluoroscopy with an over-the-wire 4 Fr Fogarty thru-lumen embolectomy catheter.

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**Figure 1** This figure shows the device unit of the AngioJet Ultra Thrombectomy System, which generates the high pressure necessary to achieve isovolumetric balance between fluid delivery and removal (courtesy of Possis Medical, Inc, Minneapolis, MN, USA).

**Figure 2** A radiograph of a thrombosed upper arm prosthetic graft that underwent percutaneous mechanical thrombectomy with the AngioJet device. Subsequent angiogram revealed the presence of significant stenosis of the venous anastomosis (arrow) and the body of the graft (arrowhead).

**Figures 3** (a,b) The presence and severity of the lesions shown in Fig. 2 was confirmed during percutaneous balloon angioplasty, as shown by the balloon waist (3a: venous anastomosis, 3b: graft body) before they were fully dilated.
(Edwards Lifesciences, Irvine, CA) or a 6 mm balloon angioplasty catheter more recently, inflated with 50% contrast solution.

3. Mechanical thrombectomy of the venous side: This is performed with an AVX™ or DVX™ AngioJet catheter (Possis Medical, Inc) or Arrow-Trerotola percutaneous thrombolytic device (Arrow International, Inc.) under fluoroscopic guidance. 4. Angioplasty (arterial and/or venous) of hemodynamically significant (≥50%) stenoses (Figs 2-4).

5. Hemostasis.

Definition of Outcomes

Technical success was considered a patent graft at the conclusion of the procedure, based on a good thrill or fully patent on angiogram. Clinical success was considered at least one successful subsequent hemodialysis session. 1 Reporting Standards for Arterio-Venous Accesses of the Society for Vascular Surgery and the American Association for Vascular Surgery were used to define postintervention functional primary, functional assisted primary and functional secondary graft patency. 13 All grafts were followed up to the end of postintervention secondary patency (final thrombotic event), graft removal (because of infection), graft ligation, graft abandonment because of kidney transplantation or recovered renal function or patient death.

Graft surveillance and monitoring protocol

Details appear elsewhere. 10-12 This included clinical parameters (surveillance: graft pain during hemodialysis, prolonged bleeding time after hemodialysis and abnormal findings on physical examination) and hemodialysis parameters (monitoring: high venous pressures (>300 mm Hg), suboptimal blood flow (<400 ml/min) or recirculation on hemodialysis). 1

Statistics

All data were analyzed with SPSS 14.0 for Windows (SPSS Inc., Chicago, Ill, USA). Graft patency rates were calculated with the Kaplan-Meier method and compared with the Log-rank test. Cox regression was used for multivariate analysis. Normally distributed data were expressed as mean (±sd) and compared with t-test, otherwise they were expressed as median and interquartile (25th–75th percentile) range and Mann-Whitney or Kruskal-Wallis test was used. Categorical data were analyzed with the chi-square or Fisher’s

Table 2  Distribution of stenoses treated with angioplasty ± stenting during the initial thrombotic event in relation to graft type

<table>
<thead>
<tr>
<th>Location</th>
<th>PTFE (n = 105)</th>
<th>Vecta (n = 90)</th>
<th>All grafts (n = 205)</th>
<th>P value</th>
<th>Odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial anastomosis</td>
<td>44 (42%)</td>
<td>27 (30%)</td>
<td>76 (37%)</td>
<td>.09</td>
<td>1.68 (0.93–3.05)</td>
</tr>
<tr>
<td>Graft</td>
<td>70 (67%)</td>
<td>51 (57%)</td>
<td>128 (62%)</td>
<td>.15</td>
<td>1.53 (0.85–2.74)</td>
</tr>
<tr>
<td>Venous anastomosis</td>
<td>100 (95%)</td>
<td>87 (97%)</td>
<td>197 (96%)</td>
<td>.73</td>
<td>0.69 (0.16–2.97)</td>
</tr>
<tr>
<td>Draining veins</td>
<td>61 (58%)</td>
<td>58 (64%)</td>
<td>127 (62%)</td>
<td>.37</td>
<td>0.76 (0.43–1.37)</td>
</tr>
<tr>
<td>Central veins</td>
<td>27 (26%)</td>
<td>24 (27%)</td>
<td>55 (27%)</td>
<td>.88</td>
<td>0.95 (0.50–1.81)</td>
</tr>
<tr>
<td>Number of stenoses</td>
<td>3 (2–4)</td>
<td>3 (2–4)</td>
<td>3 (2–4)</td>
<td>.39</td>
<td>N/A</td>
</tr>
<tr>
<td>Stent placement</td>
<td>5 (5%)</td>
<td>2 (2%)</td>
<td>8 (4%)</td>
<td>.46</td>
<td>2.2 (0.42–11.6)</td>
</tr>
<tr>
<td>Graft age (months)</td>
<td>7 (2.2–18.4)</td>
<td>5.4 (1.6–16.3)</td>
<td>6.6 (2–17)</td>
<td>.14</td>
<td>N/A</td>
</tr>
</tbody>
</table>

a Not known in 12 grafts placed at outside institutions.

b Procedure abandoned in 2 additional grafts.

c Median and interquartile range.

Table 3  Distribution of stenoses treated with angioplasty ± stenting during the initial thrombotic event in relation to time since graft placement

<table>
<thead>
<tr>
<th>Location</th>
<th>Time since graft placement (months)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤1 (n = 20)</td>
<td>1–3 (n = 30)</td>
</tr>
<tr>
<td>Arterial anastomosis</td>
<td>5 (25%)</td>
<td>9 (30%)</td>
</tr>
<tr>
<td>Graft</td>
<td>6 (30%)</td>
<td>16 (53%)</td>
</tr>
<tr>
<td>Venous anastomosis</td>
<td>11 (55%)</td>
<td>29 (97%)</td>
</tr>
<tr>
<td>Draining veins</td>
<td>14 (70%)</td>
<td>12 (40%)</td>
</tr>
<tr>
<td>Central veins</td>
<td>3 (15%)</td>
<td>3 (10%)</td>
</tr>
<tr>
<td>Number of stenoses</td>
<td>2 (1–3)</td>
<td>2 (1.8–3)</td>
</tr>
</tbody>
</table>

a Exact date of surgery not known in 5 grafts placed at outside institutions.

b Two grafts not included in the analysis because the procedure was abandoned. In three additional grafts no stenosis was identified.

c Median and interquartile range.
exact test where appropriate. A $P$ value $\leq .05$ was considered as significant.

**Results**

All 7 aborted cases had Vectra (C. R. Bard, Inc., Murray Hill, N.J., USA) loop grafts and these were the only graft characteristics that were different between aborted and non-aborted cases ($P = .005$ and $P = .001$, respectively). Using a per-protocol approach, PMT was technically successful in 202 cases (97.6%, including 3 crossovers from the Arrow-Trerotola to the AngioJet device and vice versa) and clinically successful in 193 cases (93.2%); on an intention-to-treat approach these rates were 94.4% and 90.2%, respectively.

Six patients (3.2%) developed adverse events, including arterial embolism (successfully managed percutaneously), allergic reaction, vomiting (that necessitated the procedure to be aborted), a minor arm hematoma, resolved with conservative management, device tip entrapment into a vein side branch (necessitating surgery) and shortness of breath (requiring admission and work-up that excluded pulmonary embolism). Thirty-day mortality was 0%. Clinical success in grafts that presented with early thrombosis ($\leq$1 month since original surgery) was 75%, compared to 96% in the remainder ($P = .004$, odds ratio 7.3, 95% CI 2.1-24.9). There was also a trend for better clinical success rates in PTFE grafts (96%) compared to Vectra grafts (90%, $P = .085$). There was no association between clinical success and the remaining clinical parameters or the location and total number of the responsible stenotic lesions (arterial anastomosis, $n = 76$, graft, $n = 128$, venous anastomosis, $n = 197$, draining veins, $n = 127$ and central veins, $n = 55$). In 3 patients (1.4%) no stenosis was identified. There was a trend toward arterial anastomosis stenosis being more frequent in PTFE grafts (Table 2). A relationship between graft age and the total number and also the incidence of stenotic lesions at various locations was also seen, as shown in Table 3. Four of the patients in which PMT was not technically and/or clinically successful, were managed with surgical thrombectomy ($n = 3$) or repeat PMT ($n = 1$). Two of these grafts are still in use 2 ½ years later.

Two patients were lost to follow-up, which left 195 grafts in the study. During follow-up, 39 of them remained

<table>
<thead>
<tr>
<th>Postintervention functional patency</th>
<th>Time (months)</th>
<th>3</th>
<th>6</th>
<th>12</th>
<th>24</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td></td>
<td>46%</td>
<td>32%</td>
<td>17%</td>
<td>6%</td>
<td>—</td>
</tr>
<tr>
<td>Assisted primary</td>
<td></td>
<td>54%</td>
<td>44%</td>
<td>29%</td>
<td>14%</td>
<td>.003</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
<td>77%</td>
<td>71%</td>
<td>62%</td>
<td>47%</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Table 4: Long-term postintervention functional patency results. Endovascular management increased both primary and postintervention assisted primary patency to a postintervention secondary patency of 47% at 2 years.

Figure 4: Results of balloon angioplasty of the lesions shown in Figs. 2 and 3. The lesion at the venous anastomosis had a residual stenosis and underwent repeat angioplasty with further improvement, as shown in the right side of the image.

Figure 5: Kaplan-Meier curves of postintervention functional primary, assisted primary and secondary patency of all thrombosed grafts. Error bars on the survival curves represent the standard error; the number of patients at risk at each interval is shown below the graph.
patent (25 of them dysfunction-free at 296 ± 212 days follow-up), seven were either removed for infection (n = 3) or ligated (for steal syndrome, n = 1, venous hypertension, n = 1, graft pseudoaneurysm, n = 1, anastomotic pseudoaneurysm, n = 1) and 149 re-thrombosed and either abandoned (n = 33, one of them removed later for infection) or underwent redo thrombectomy (n = 116). Three of these 116 grafts were later removed (for infection, n = 2) or ligated (for dysfunction during placement of a new prosthetic graft, n = 1), 56 were still patent at last follow-up and 57 were finally abandoned (one of them removed later for infection). Six additional patent grafts were abandoned, because patients recovered renal function, spontaneously (n = 1) or after kidney transplant (n = 5). Lastly, 9 grafts (including the three grafts that were rescued after a failed PMT, as described above) had surgical reintervention (five surgical thrombectomies with intraoperative balloon angioplasty of the venous anastomosis in two of them, three anastomotic revisions with interposition grafting, n = 2 or patch angioplasty, n = 1 and one patch plasty for pseudoaneurysm) at a median of 170 days (range 8–854 days) after the first thrombectomy. The total number of repeat PMTs that was performed for graft thrombosis was 307 (median 2, range 1–10). Seventy-nine grafts developed at least once dysfunction (total number 162, median 1, range 1–8) and preemptive endovascular management was attempted. The total number of endovascular procedures that was performed for graft dysfunction or thrombosis was 469, which accounted for 0.54 procedures per 100 graft-days.

Long-term postintervention patency results are shown in Table 4 and Fig. 5. A moderate but statistically significant improvement of postintervention functional primary to functional assisted primary patency was seen. Endovascular management increased substantially postintervention functional assisted primary patency rates from 27% and 14% at 1 and 2 years to a secondary patency of 62% and 47%, respectively.

Postintervention functional primary patency was worse in patients younger than 62 years compared to older patients (12% vs 21% at 12 months, \( P < .04 \)) and those with graft thrombosis within 12 months of graft placement compared to the remainder (10% vs 29% at 12 months, \( P < .001 \)). On multivariate analysis, only graft side and patient age were significant (\( P = .048 \) and \( P = .001 \), respectively). The remaining patient demographics and graft characteristics had no effect on postintervention primary patency rates.

Postintervention functional assisted primary patency was better in the presence of an arterial anastomotic stenosis, compared to its absence (39% vs 24% at 12 months, \( P = .04 \)) or if re-intervention for graft dysfunction during follow-up had been performed, compared to those grafts this was not necessary (35% vs 25% at 12 months, \( P = .002 \)) and worse for grafts that thrombosis occurred within the first three months of graft placement compared to later (36% vs 12% at 12 months, \( P < .001 \)). Age, diabetes, graft thrombosis within the first three months and re-intervention for graft dysfunction during follow-up were independent predictors of postintervention functional

<p>| Table 5 Independent predictors of postintervention functional assisted primary patency |</p>
<table>
<thead>
<tr>
<th>B</th>
<th>SE</th>
<th>Wald statistic</th>
<th>P value</th>
<th>( \text{Exp}(B) ) (relative risk)</th>
<th>95% CI for ( \text{Exp}(B) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.015</td>
<td>0.006</td>
<td>6.222</td>
<td>.013</td>
<td>0.985</td>
</tr>
<tr>
<td>Diabetes</td>
<td>-0.38</td>
<td>0.181</td>
<td>4.432</td>
<td>.035</td>
<td>0.68</td>
</tr>
<tr>
<td>Graft thrombosis within 3 months of placement</td>
<td>0.85</td>
<td>0.17</td>
<td>23.76</td>
<td>&lt;.001</td>
<td>2.23</td>
</tr>
<tr>
<td>Re-intervention</td>
<td>-0.58</td>
<td>0.17</td>
<td>11.63</td>
<td>.001</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Figure 6 Kaplan-Meier curves of postintervention secondary patency of all thrombosed grafts in relation to time since graft placement; intermediate graft thrombosis (occurred between 31–182 days after graft placement) was associated with worse secondary patency. Error bars on the survival curves represent the standard error; the number of patients at risk at each interval is shown below the graph.
assisted primary patency on multivariate analysis (Table 5). The remaining patient demographics, graft characteristics, preemptive angioplasty for graft dysfunction before the first thrombotic episode and PMT device type we used had no effect on postintervention assisted primary patency rates.

Postintervention functional secondary patency rates were worse in loop grafts compared to straight configuration (54% vs 66%, at 12 months, \( P = .02 \)) and in those with intermediate graft thrombosis (occurred during the 2nd and up to the 6th month after graft placement) compared to the remainder (41% vs 75%, at 12 months, \( P < .001 \), Fig. 6) and better when renal failure was due to hypertension or diabetes (compared to other or cryptogenic causes, 63% vs 58%, at 12 months, \( P = .048 \)) or if re-intervention for graft dysfunction during follow-up had been performed compared to those grafts this was not necessary (84% vs 46%, at 12 months, \( P < .001 \), Fig. 7). Remaining patient demographics and graft characteristics, preemptive angioplasty for graft dysfunction before the first thrombotic episode and PMT device type had no effect on postintervention secondary patency rates. Multivariate analysis with Cox regression identified intermediate graft thrombosis and re-intervention as independent predictors of worse (\( P < .001 \), relative risk 2.77) and better (\( P < .001 \), relative risk 0.28) postintervention secondary patency (Table 6 and Fig. 8).

Discussion

Our study showed that aggressive management of thrombosed hemodialysis prosthetic grafts with PMT results not only in acceptable postintervention primary and assisted-primary patency, but also in very good secondary patency, through multiple re-interventions for dysfunction and recurrent thrombosis.

In the present study, we confirmed the excellent technical and clinical success rates of rheolytic thrombectomy.\(^ {10} \) Clinical success rates were significantly lower in patients who developed early/intermediate graft thrombosis. Thrombophilia is known to be associated with an increased risk of graft thrombosis.\(^ {14–16} \) Low inflow from coexisting proximal arterial stenosis,\(^ {17,18} \) and/or hypotensive episodes during hemodialysis might had also contributed. Our clinical success results far exceeded the recommended 85% target, set by the KDOQI guidelines, which we attribute to the aggressive use of angioplasty and early patient referral, since technical and clinical success are both significantly better in patients presenting for PMT less than 3 days after the thrombotic episode.\(^ {10} \)

A significant association between the total number and pattern of stenotic lesions diagnosed during the initial thrombectomy and graft age was observed in the current study. As grafts become older the total number of stenoses associated with graft thrombosis increases; with the exception of draining vein stenosis, this pattern was seen in all locations, including central veins. Although the increased incidence of stenoses in older grafts seems expected, we were surprised to find that central vein stenosis, traditionally attributed to previous catheter use, followed the same pattern; it is well known that central vein stenoses are not always the result of previous catheters\(^ {19,20} \); increased blood flow through the access causing turbulence and vibration can also stimulate intimal hyperplasia,\(^ {21} \) which could explain our findings. The incidence

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Independent predictors of postintervention functional secondary patency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td>Intermediate thrombosis</td>
<td>1.019</td>
</tr>
<tr>
<td>Re-intervention</td>
<td>–1.268</td>
</tr>
</tbody>
</table>

Figure 7 Kaplan-Meier curves of postintervention secondary patency of all thrombosed grafts in relation to the need for re-intervention (angioplasty for graft dysfunction) during follow-up. Error bars on the survival curves represent the standard error; the number of patients at risk at each interval is shown below the graph.
of midgraft stenosis, related to repeated graft puncture for hemodialysis, showed, as expected, a linear association with time, but on the other hand an increased incidence of venous anastomosis stenosis was observed very early.

A variable incidence of complications of percutaneous thrombectomy and thrombolysis of prosthetic grafts has been reported, this being between 3%-16%. Serious complications, like pulmonary embolism or death, were not observed in our series. The single episode of arterial embolism we encountered was managed promptly with rheolytic thrombectomy. Arterial emboli has been previously described to occur after open thrombectomy, and probably in our case it was the result of the balloon thrombectomy of the arterial anastomosis and proximal graft.

Like others, we favor an aggressive endovascular approach in treating failing or thrombosed accesses. Being minimally invasive, they are easily accepted by the patients. The high rate of clinical effectiveness and the fact that the access can be used immediately are additional factors that favor these methods. As shown in the current report, as grafts become older they tend to develop multiple and probably more virulent stenoses, resistant to angioplasty or prone to recur and this puts a limit on the number of attempts to treat recurrent graft thrombosis. Valji reported that shorter intervals between graft thromboses is a predictor of earlier subsequent graft failure. We have observed a similar pattern.

There has been considerable debate on the role of open versus percutaneous graft thrombectomy, especially in the past. Endovascular procedures do not burn the venous capital, i.e. the draining vein distal to the venous anastomosis is spared for future graft revision. This might be one of the reasons better results have been reported with revision surgery than percutaneous methods, however percutaneous interventions performed by experienced operators can yield equivalent results; endovascular techniques are also continuously evolving. A new anastomosis with a healthy vein might last longer than a diseased one that underwent angioplasty, however a recent large study that compared surgical thrombectomy alone with adjuvant angioplasty (on-table or sequential) and revision of the venous anastomosis with either patch angioplasty or jump graft, showed that the last three methods had the same patency results but consistently better than the first method. Surgery in our series had a very limited role in managing grafts with failed endovascular interventions or late complications.

Our postintervention primary patency results far exceeded the recommended target of 40% three-month primary unassisted patency set by the KDOQI guidelines, and what has been reported by most studies in the literature, which we attribute to the thorough use of angiography to identify the responsible stenotic lesion(s) and to angioplasty to treated those. We observed a steep decline in postintervention primary patency curve during the first few months, consistent with previous observations. The cause of early recurrent graft thrombosis is obviously associated with recurrence of the original stenotic lesions enhanced possibly by the presence of additional risk factors like hypercoagulopathy; this serious problem should be addressed by further research. Surveillance and monitoring coupled with endovascular interventions increased the postintervention primary patency by an absolute value of 12% at 6 and 12 months to the assisted primary patency rates shown in Table 4. Grafts in younger patients and those with early/intermediate thrombosis had worse primary and assisted primary patency, which indicates that the process responsible for graft thrombosis might have been more virulent, for example a higher incidence of thrombophilia and more aggressive myointimal hyperplasia. Compared to three previous studies (two of them from the 1990’s) that reported on one-year postintervention secondary patency rates of 53%, 51% and around 10%, following percutaneous thrombectomy or thrombolysis, our results of postintervention secondary patency (62% and 47% at one and two years, respectively) are significantly better and were maintained at 3 years. We attribute this to the aggressive use of balloon angioplasty during the...
initial and subsequent thrombectomies and repeat endovascular management of failing or thrombosed grafts; obviously the decision on when to abandon a graft is very crucial in determining secondary patency and this can be variable in different practices; we did not give up unless the patient had two recent thrombectomies performed or the patient was medically unstable. The KDQI guidelines have not proposed a particular target for postintervention secondary patency of thrombosed prosthetic grafts, probably because of the lack of data to support such a recommendation; based on the results of our contemporary protocol we believe that targets for secondary patency at 3, 6 and 12 months should be set at least to 70%, 60% and 50%, respectively.

Postintervention patency in this study was predicted by several parameters, with the most striking being graft age and re-intervention for graft failure; Valji and colleagues reported that graft age did not influence future graft patency, but they had a small number of grafts, especially grafts placed less than one year before the thrombectomy. This worse patency could simply be reflective of the cause that led to the initial graft thrombosis, irrespectively of its nature, i.e. technical, hypercoagulopathy or development of myointimal hyperplasia. The established role of graft surveillance/monitoring and appropriate preemptive angioplasty was shown, as expected, in our study to be significant, confirming previous studies. Future studies could be focused on these high-risk groups. Finally, we believe that better thrombectomy methods will not improve long-term patency and that future research should be focused in methods to prevent and treat more effectively arterial and venous anastomosis, intragraft and remote stenoses responsible for recurrent graft failure.

In conclusion, PMT of thrombosed prosthetic grafts is a highly successful procedure with acceptable long-term postintervention secondary patency, provided that an aggressive policy of endovascular management is established to manage subsequent episodes of thrombosis and/or dysfunction. Further research to identify the causes of intermediate graft thrombosis is justified.

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References


