Eur J Vasc Endovasc Surg **32**, 84–89 (2006)
doi:10.1016/j.ejvs.2005.10.004, available online at http://www.sciencedirect.com on SCIENCE DIRECT

Radiological Intervention to Maintain Vascular Access

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Stenoses and thromboses of dialysis grafts and fistulae are common problems in patients with end stage renal disease (ESRD). Timely recognition and treatment of access-related complications are essential to achieve long-term access function. Minimally invasive percutaneous interventions are techniques of growing importance for the interventional community. While stenoses can typically be treated by balloon angioplasty (PTA), thrombotic lesions may necessitate the combination of mechanical devices and/or thrombolytic agents with ancillary PTA. In this article, interventional treatments for the failing arteriovenous (AV) access are presented and reviewed.

Keywords: Hemodialysis access; Stenosis; Thrombosis; Percutaneous treatment; Transluminal angioplasty; Stents and prostheses; Thrombolysis; Fistula; Graft; Vascular access.

Introduction

Dysfunction of arteriovenous fistulae and grafts occurs frequently in haemodialysis patients and contributes significantly to morbidity and hospitalization in the dialysis population.[1] The number of patients with end-stage renal disease has risen steadily to reach over 420,000 in the United States alone,[2] so that the choice of a suitable method to preserve vascular access is of increasing significance for the patients and their physicians. Over the last decade vascular access complications have been increasingly approached on a multidisciplinary basis. It must be emphasized that early diagnosis and treatment of access-related complications are vital to achieve long-term access function. Nowadays, dialysis centres often request percutaneous interventions in the management of AV-access-related problems. Existing percutaneous treatment indications and algorithms for stenosed and/or thrombosed dialysis grafts and fistulae are described in this article.

AV Fistula Stenosis

A reduction of vessel diameter >50% associated with a reduction in access flow, measured dialysis dose or previous thrombosis, indicates the need for intervention. In radiocephalic AV fistulas, 55–75% of stenoses are located close to the AV anastomosis and ∼25% in the outflow tract.[3,4] In brachiocephalic and/or basilic AV fistulas the typical location (55%) is at the junction of the cephalic with the subclavian vein and the basilic with the axillary vein, respectively.[3] An arterial inflow stenosis >2 cm from the anastomosis is uncommon, but may endanger flow into the AV fistula.

To visualize a stenosis, angiography is performed by either retrograde puncture of the brachial artery for anastomotic problems, or by direct antegrade puncture of the postanastomotic vein if an outflow problem has occurred.[5]

Primary interventional treatment by PTA is indicated in stenoses of the anastomotic area located in the upper forearm and in the upper arm. PTA is also possible in stenoses of the anastomotic area located in the lower forearm as an alternative to surgical treatment (Fig. 1). Success rates are greater than 90% with 1-year primary patency rates of up to 51%.[4,6]

Steal syndrome and hand ischaemia are rare potential complications after treatment of anastomotic stenoses in upper arm fistulas.

In the case of stenosis of the outflow tract or at the junction of the superficial vein with the deep venous system PTA again is the first treatment option.[7]

In general, the stenosis is negotiated with a hydrophilic coated, 0.035-in. guidewire, followed by the balloon catheter passed over the guidewire.

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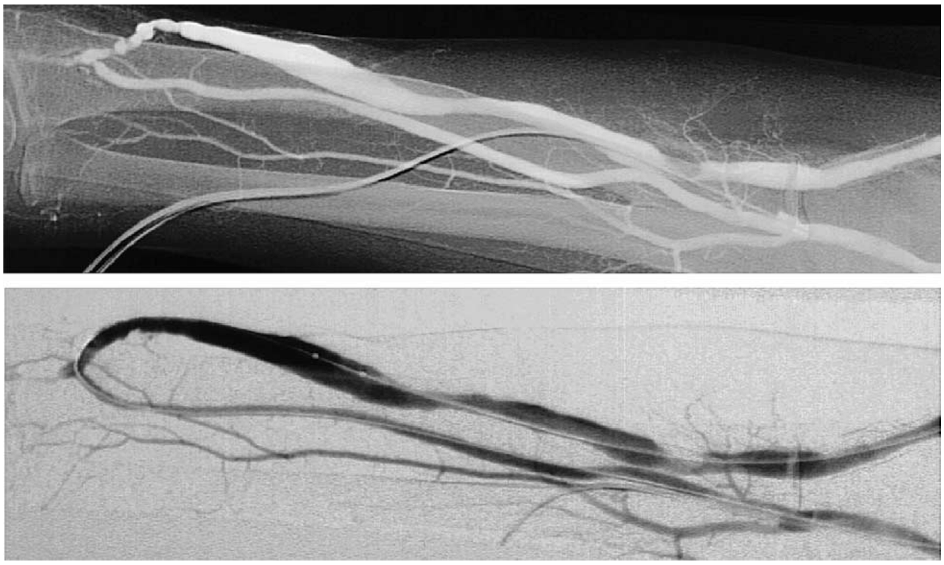

Fig. 1. Angiogram demonstrates postanastomotic stenoses with pearl-string appearance (a). Notice the distinct morphologic and haemodynamic improvement after balloon angioplasty (b).

Sometimes the use of a diagnostic, preferably hydrophilic, catheter may be necessary to overcome tortuous vessel segments.

Careful dilatation with a pressure of about 10 atm for up to 1–2 min is recommended, which may be repeated.

Some stenoses cannot be dilated sufficiently by conventional balloon angioplasty. These stenoses can be treated with cutting balloons.[8] In our experience even stenoses longer than 5 cm can be approached radiologically, although graft interposition[9] is an option.

A restenosis can be treated radiologically, with or without a stent, or surgically[5] depending upon the individual situation and the potential invasiveness of the surgical treatment.

Despite the complete expansion of the PTA balloon (without a waist) of sufficient diameter, the dilated vessel wall may collapse immediately after removal of the balloon. This elastic recoil can be treated with stent implantation, especially in central veins.[10] Stent placement in the needling areas of forearm fistulas should be reserved for acute PTA-induced ruptures not controllable by prolonged balloon inflation.

AV Fistula Thrombosis

The duration, location and extent of AV fistula thrombosis as well as the type of access are important determinants of treatment outcome. Fistula thrombosis should be treated within 48 h whenever possible. Timely declotting allows immediate use without need for central venous access. Although comparative studies are lacking, the available literature strongly suggests that thrombosed autogenous AV fistulas should preferably be treated by interventional radiology. The only exception may be forearm AV fistulas that have thrombosed due to anastomotic stenosis. It is likely that in such cases, creation of a new proximal anastomosis will provide good results although no surgical series has demonstrated this thus far.

Interventional thrombolysis can be performed mechanically or pharmacomechanically. A short-segment thrombosis can be simply treated with balloon angioplasty alone; however, an extensive thrombosis requires the combination of mechanical devices and/or thrombolytic agents with consecutive balloon angioplasty.

Poulain *et al.* combined a local low dose infusion of urokinase with PTA and thromboaspiration to achieve a 12-month overall patency in 14 native fistulas of approximately 90%.[11] Zaleski *et al.* reported on 17 patients with complete thrombosis of their Brescia–Cimino fistulas, which were treated by angioplasty and urokinase infusion.[12] Procedural success was 82% with primary, primary assisted, and secondary patency rates at 12 months of 71, 93, and 100%, respectively.

Twenty of 24 patients (83%) with occluded Brescia–Cimino fistulas were successfully recanalized by Overbosch *et al.* using the Hydrolyser catheter.[13] Median assisted patency was 34 weeks and was significantly shorter in fistulas than in PTFE grafts ($p = 0.002$).

Turmel-Rodrigues *et al.* described an 81% initial success rate using thromboaspiration and PTA in 16

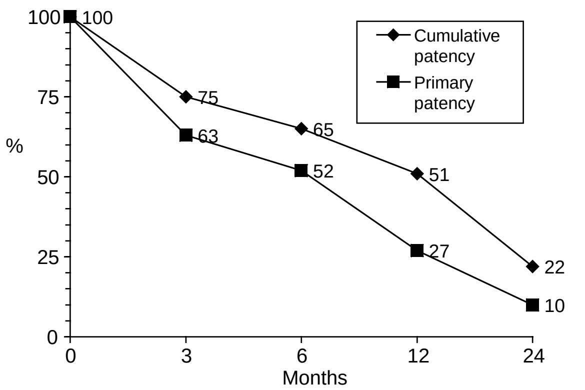

Fig. 2. AV fistula thrombosis treatment ($n = 81$). Graph of life-table analysis depicting Aachen University Hospital primary and cumulative patency rates.

patients.[14] An 81% secondary patency at 1 year was reported.

Liang *et al.* reported a success rate of 93% and a primary patency rate at 1 year of 70%.[15]

In our department, we have had a technical success rate of almost 90% in 81 native fistula procedures with a combination of PTA and mechanical thrombectomy devices (amplatz mechanical thrombectomy device and hydrolyser catheter). The primary and overall fistula patency was 27 and 51% at 1 year, respectively, pinpointing the efficacy of percutaneous thrombosis treatment strategies[16] (Fig. 2).

These results show that initial percutaneous interventions in occluded native arteriovenous fistulas are very effective in the early treatment of the recently occluded dialysis access with good success rates and satisfactory primary and long-term patency rates comparable to those of surgical thrombectomy. However when percutaneous thrombolysis is feasible, surgical revision should be reserved for failures of percutaneous techniques. The choice of the appropriate percutaneous approach will depend on the size and location of the thrombus detected by angiography, while the choice of device depends on the experience of the centre with the respective modality.

Graft Stenosis

A reduction of >50% of the lumen diameter together with significant flow decline is a recommended indication for treatment in graft stenosis.[17] As in AV fistulas, most arterial inflow stenoses can be effectively treated by PTA.[18] Success rates of 98% have been observed by some groups.[19] The procedural approach is essentially similar to the management of fistula stenosis. A stenosis of the arterial anastomosis itself can be dilated, provided only the afferent artery and the graft is affected but the efferent artery is not stenosed. If there is an additional stenosis of the efferent artery, angioplasty of the anastomosis alone will enhance graft flow with the risk of peripheral ischemia due to reduced peripheral arterial perfusion. In these patients, percutaneous dilatation of the efferent artery may solve the problem.

Intra-graft (or mid-graft) stenoses are found in the cannulation segment of access grafts. They result from excessive in-growth of fibrous tissue through puncture holes. These stenoses can be treated by PTA,[20] or alternatively by graft curettage[21] and segmental graft replacement.

The most common cause for access graft dysfunction is venous anastomotic stenosis.[22] Since access grafts should be reserved for patients with exhausted peripheral veins, vessel saving procedures like PTA should be preferred to graft extensions to more central vein segments, although the latter may have superior patency rates.

When PTA repeatedly fails, additional stent implantation should be considered.[23]

When recurrent stent obstruction occurs, graft extension is still possible.

Graft Thrombosis

As with AV fistula occlusion, graft thrombosis should be treated without delay and within 48 h, at least before the next dialysis session. A compact 'arterial plug' is invariably seen. Mature thrombi older than 5 days are often fixed to the vessel wall beyond the venous anastomosis, rendering surgical extraction more difficult. In grafts, this is less of a problem for the interventional radiologist.

PTFE graft thrombosis can be approached using a wide array of percutaneous techniques including combinations of thromboaspiration, thrombolytic agents such as tissue plasminogen activator (tPA), mechanical thrombectomy and mechanical thrombectomy devices. Turmel-Rodrigues *et al.* found higher patency rates after radiological intervention with a 6 month primary patency rate of 32% in thrombosed grafts.[3] The results of the treatment of thrombosis and associated stenosis in synthetic grafts have been summarized by Aruny *et al.*[24] Clinical success rates for thrombolysis or mechanical thrombectomy range from 75 to 94% with primary patencies of 18–39% at 6 months. Reported 6- and 12-month secondary patencies for thrombolysis range from 62 to 80 and 57 to 69%, respectively.

Trerotola *et al.* demonstrated a 95% technical success with a 3-month primary patency of 39% using the Arrow-Trerotola percutaneous thrombolytic device.[25]

Comparing different mechanical devices for percutaneous thrombolysis, Smits *et al.* concluded, that 'the treatment of the underlying stenoses was the only predictive value for graft patency'.[26] Each centre should therefore choose the technique according to their expertise. Whichever technique is used, it is important to perform thrombolysis rapidly to avoid the need for a temporary catheter and as an outpatient procedure to decrease costs, whenever possible.

The involvement of large veins, e.g. the brachial vein, to a large extent complicates management in fistula and graft patients and is an additional important feature determining technical success. Durable access function depends on various factors such as cannulation trauma, tendency for restenosis, hypercoagulability, and the frequency of reobstruction.[27]

AV access aneurysm

In long segment fistula aneurysms percutaneous interventional treatment with implantation of a covered stent is possible as an alternative to surgery, however, deployment at the needling area must be avoided.[28] Anastomotic aneurysms and large aneurysms with a significant thrombus-load should preferably be treated surgically.[29] False aneurysms may be treated by thrombin injection under ultrasound guidance. Since aneurysm expansion is due to increased intra-access pressure usually as a result of venous outflow obstruction, local treatment always should go along with outflow repair by PTA and/or thrombectomy/thrombolysis.

Central venous obstruction

Swelling of the access arm is the most significant clinical symptom of central venous obstruction.[30] The superficial veins may become prominent due to collateral flow, and pain and paraesthesia may result. Central venous lesions have to be treated, when they are severe and disabling such in impairing upper extremity swelling, wearisome pain or if they lead to inadequate haemodialysis.[31] If there is an underlying cause (e.g. lymphoma, goiter, thoracic aortic aneurysm, mediastinal fibrosis, pacemakers), which cannot be treated, or where treatment fails to resolve arm swelling, PTA with stent insertion is indicated.[23]

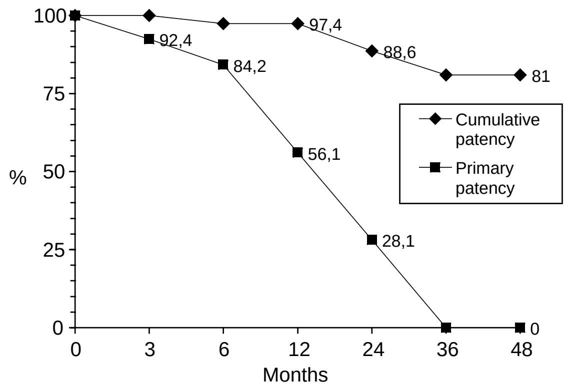

Fig. 3. Aachen University Hospital primary and cumulative central venous stent patency rates ($n = 50$).

In the last decade, several studies of patients treated with PTA alone have been published. Primary patency rates of 10% or less at 1 year and numerous restenoses were reported.[32,33] Stent implantation has been shown to improve primary 1-year patency rates to 56% or more[30,34,35] (Fig. 3). Regular follow-up and reinterventions are required to maintain patency and accomplish long-term clinical success.[34] These figures do not differ significantly from those of surgical intervention.[30,35] Nonetheless, due to the relative invasiveness of surgery for central venous obstructions the less invasive interventional therapy is recommended as first-line treatment.[34] Reports show that symptomatic central venous obstruction in dialysis patients can be treated with a high success rate through radiological intervention.[36] Stent placement should avoid overlapping the ostium of a patent internal jugular vein to achieve a safe and sufficient result, since this latter vein is essential for future placement of central catheters. Similarly, a stent placed in the brachiocephalic vein if at all possible should not overlap the ostium of the contralateral vein, otherwise contralateral stenosis may occur and preclude future use of the contralateral limb for access creation.

An appropriate endoprosthesis for central veins should be flexible enough to be used in curved and tortuous vessels. To evade stent dislocation and proximal embolization, a self-expanding stent should be preferred, because venous occlusions may undergo progressive luminal enlargement after stent placement. Mechanical thrombectomy should not be regularly used as a primary therapy for dialysis-related central venous occlusions, mostly because of the sharp angles and slim vessel walls observed in this region. On the other hand, thrombectomy devices are effective tools in debulking neointimal tissue in case of stent reocclusion. The use of thrombolytic agents in central vein obstruction is not recommended as a primary treatment.

Central and peripheral reocclusion is a commonly observed complication and is more likely to take place after thrombosis has occurred for the first time.[37] The interventionalist should be ready for repeat interventions, occasionally multiple, over the months and years after the primary recanalization procedure.

Put briefly, in case of central venous occlusion related to dialysis access, initial stent deployment is very effective with improved long-term patency rates compared with other therapeutic modalities such as percutaneous balloon angioplasty alone. When interventional treatment of central venous obstruction is impossible or fails, reassessment of patient history and data is necessary to define the most effective surgical method to guarantee long-term vascular access for hemodialysis.

Summary

- Adequate treatment of AV access dysfunction is a complex undertaking in which the interventional radiologist, vascular surgeon and nephrologist should cooperate with each other on a conjoint basis.
- Whilst further studies are required to determine the most favourable and long-lasting treatment strategy, a primary percutaneous treatment approach is a cost-reducing, attractive alternative to more invasive procedures. As long as less-invasive equivalent therapeutic alternatives to preserve the access are at hand and possible, the existing vascular access should be maintained.
- In stenotic lesions and short segment thromboses percutaneous transluminal angioplasty is the first treatment option.
- In access thrombosis percutaneous thrombectomy is equally successful in native fistulae and grafts. The declotting method, whether pharmacomechanical or purely mechanical, has no major effect on short- or long-term patency. To date, either type of method for access recanalization is suitable and should be based on the familiarity of the interventionalist with the particular therapeutic modality.
- Thrombosed giant aneurysms should preferably be treated surgically.
- In case of central venous obstruction, treatment should be performed percutaneously by PTA with additional stent implantation, whenever possible.

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Accepted 7 October 2005
Available online 16 November 2005