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review

Interventional radiology in haemodialysis fistulae and grafts

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Background. *The aim of the paper is to review the role of interventional radiology in the management of haemodialysis vascular access. The evaluation of patients with haemodialysis vascular access is complex. It includes the radiology/ultrasound evaluation of the peripheral veins of the upper extremities with venous mapping and the evaluation of the central vein prior to the access placement and radiological detection and treatment of the stenosis and thrombosis in misfunctional dialysis fistulas. Preoperative screening enables the identification of a suitable vessel to create a haemodynamically-sound dialysis fistula. Clinical and radiological detection of the haemodynamically significant stenosis or occlusion demands fistulography and endovascular treatment. Endovascular prophylactic dilatation of stenosis greater than 50% with associated clinical abnormalities such as flow-rate reduction is warranted to prolong access patency. The technical success rates are over 90% for dilatation. One-year primary patency rate in forearm fistula is 51%, versus graft 40%. Stents are placed only in selected cases; routinely in central vein after dilatation, in ruptured vein and elastic recoil.*

Conclusions. *Thrombosed fistula and grafts can be declotted by purely mechanical methods or in combination with a lytic drug. The success rate of the technique is 89-90%. Primary patency rate is 8% to 26% per year and secondary 75% per year.*

Key words: kidney failure, chronic; hemodialysis; catheters, indwelling; radiology, interventional

Introduction

Renal failure is treated by dialysis or renal transplantation. About 63% of patients are treated with haemodialysis, 9% with peritoneal dialysis and 28% with renal transplantation.[1] Haemodialysis can be performed through central venous catheters (internal jugular, subclavian and femoral vein) or through a permanent arteriovenous access. Long-term patency of central catheters is low, because they are prone to infection and thrombosis.[2] Chronic haemodialysis is performed by the autogenous arteriovenous fistula and the synthetic bridge graft. Native fistulas are the most durable type of vascular access and least prone to complications.[3] A recent American article reported 54% primary patency for grafts at one year, compared with 75-91% for native fistulas.[4] Peritoneal dialysis

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is performed after placement of an abdominal catheter and uses the peritoneum as the exchange membrane. Renal transplantation has become the treatment of choice for end-stage renal disease (ESRD) because of long-term survival and improved life quality in cases when transplantation is performed instead of haemodialysis. Because of the limited long-term patency of haemodialysis grafts or fistulas, repeated surgical or percutaneous radiological repair is necessary to preserve the long-term patency of the dialysis access, and preservation or improvement of the renal function. Percutaneous radiological treatment provides the least invasive procedure, intended to prolong life of the dialysis grafts or fistulas.

Radiological management and endovascular treatment haemodialysis fistulas and grafts

The first indications for interventional radiology were stenoses, which were difficult to treat surgically because of their location (central veins) or because of their propensity to early recurrence. The first radiological reports in 1980s were disappointing due to inadequate armamentarium and the inexperience of radiologists.[5] In the last decade, a decisive turning point came with the availability of high-pressure balloons, hydrophilic guidewires, stents, declotting techniques such as the pulse-spray and thromboaspiration, which helped radiologist to improve success rates.[3,6] The advantages of the endovascular approach-minimal invasiveness, better imaging and better venous preservation - rapidly became very clear. The publication of the American DOQI guidelines in 1997 gave the first official recognition to the value of interventional radiology for the treatment of both stenoses and thrombosis.[7]

Radiological patient evaluation prior to access placement

The role of preoperative screening is twofold: first, to identify usable vessel to create autogenous fistulas or a synthetic bridge graft, and second to detect occult central venous stenosis. Radiological screening is performed by ultrasound, venography, and in future it will also be done by MRI.[8-10] This helps surgeons to create native or good synthetic grafts fistulas. Native fistulas, which are never used and early graft failures, are associated with the common problem of inadequate vessel (artery or vein) selection. Patients with ESRD often have multiple venepunctures and numerous intravenous accesses inserted and thus increased likelihood of venous stenosis or occlusion. Robbin found that 77% [40 of 52] of patients had a history of previous central catheter placement or major surgery in which a central catheter may have been placed.[10] Thirteen patients [25%] had a history of catheter placement on the same side as the planned haemodialysis access.

A patient who has had prior central venous catheterisation (jugular or subclavian) should be screened with venography and ultrasound to exclude occult central venous stenosis. Surratt *et al*. found a 40% prevalence of subclavian vein stenosis in patients who had previously had dialysis catheterisation in this venographic study.[11] Occult central venous stenosis is nearly always asymptomatic, and becomes unmasked only when high venous flow occurs due to the ipsilateral fistula or graft. Patients may develop marked arm swelling, which can impair wound healing as well as impede the use of the vascular access. Therefore, if central venous stenosis is detected, serious consideration should be given to placing access in the opposite extremity.

With ultrasound, vessels can be assessed for size, stenosis, and occlusion.[9-13] Although ultrasound can be used to evaluate the venographic anatomy of the arm, venography can provide the access surgeon with a »road map«

of the entire arm. It also excludes central venous stenosis.[8,9] Venography is performed by puncturing the dorsal vein of the hand. Opacification of the forearm veins is obtained after placement of a tourniquet in the upper arm in order to create congestion. The venous status (presence, absence, mean diameter, stenosis, and occlusion) of the cephalic and basilic vein in the forearm, at the elbow and in the upper arm can be evaluated as well as the patency of the central veins. Care should be taken to image the axillary vein with the arm in abducted position to avoid pseudostenosis. In cases of contraindications to iodine injection (for example allergy or previously non-dialysed patients), carbon dioxide gas or gadolinium can be used as contrast agents.[13]

Radiological stenosis detection and indication for treatment

The underlying stenosis is predominantly present at the venous anastomosis of the graft, in the revealed area of the forearm native fistulas and in the venous outflow far from the anastomosis of upper arm fistulas.[14] The underlying stenosis is unmasked in more then 85% of cases thrombosis the grafts and in almost all cases for native fistulas.[14,15] Thrombosis occurs roughly 10 times more frequently on prosthetic grafts then in native fistulas.[15]

Among the numerous methods described for stenosis screening, radiologists can use ultrasound and MRI examinations.[7,16] Ultrasound provides both anatomic and physiologic information that can be useful in screening and problem-solving.[17] The typical ultrasound findings in access stenosis include areas of locally increased velocity (greater than 400 cm/sec) and/or turbulence and the detection of hypoechogenic material consisting of intimal hyperplasia forming an anatomically visible stenosis. Duplex ultrasound is able to diagnose efferent vein stenoses with an accuracy of 96%, synthetic graft stenoses with an accuracy of 86%, and anastomotic stenoses in native fistulas with an accuracy of 81%.[16,18] Doppler measurement of velocity is then multiplied by the cross-sectional area of the graft to give volume flows in millilitres per minute. Normal graft usually has volume flows well in excess of 1300 ml/minute, and it has been shown that volume flow less than 300 ml/minute or 450 ml/min is correlated with impending graft failure.[19] Ultrasound evaluation can be performed on abnormalities on puncture sites including pseudoaneurysms, aneurysm dilatations of cephalic vein (which usually are not clinically significant) and aneurismal dilatation in PTFE grafts, which can be very significant. Patients with non-invasively established haemodynamic significant stenosis or occlusion require fistulography and endovascular treatment (Figures 1, 2, 3).[4,20,21]

Dialysis fistulography is the least invasive method. Fistulography can be performed with the dialysis needles in place. The only, if any, risks involved in the procedure are the risk of contrast allergy and further reduction in residual renal function,[21] The latter consideration can be obviated with carbon dioxide or gadoliniums fistulography in selected cases.[13] A well-performed fistulogram is the foundation of all percutaneous interventions in haemodialysis access (Figures 1a, 2a, 4a). The technique of fistulography has been well-described.[5] A complete fistulogram must show the entire ingraft or fistulas from the arterial side all the way through to the venous circulation, with evaluation of the venous outflow, and the central veins (Figure 1a).

DOQI guidelines 10 and 17 recommend treating stenoses greater than 50% only when there are concomitant clinical abnormalities and flow-rate reduction or pressure changes.[7] Dilatation of asymptomatic stenosis detected by systematic colour flow duplex ultrasonography was beneficial only for »virgin« grafts (those that had never been previously dilated

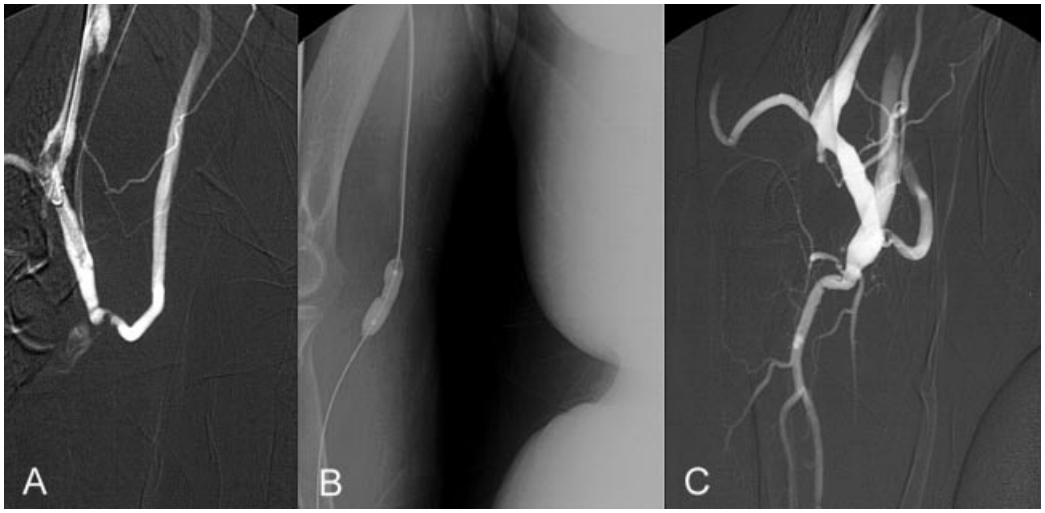

Figure 1. Fistulography. a. Stenosis in the anastomosis fistulae between brahial artery and cephalic vein, due to neointimal hyperplasia. b. PTA with 8 mm balloon; c. the result is a good anastomosis patency

or revised). The treatment of haemodynamically significant stenosis reduces the rate of thrombosis and prolongs the average use-life of the access.[8, 22-26]

Nevertheless, clinical examination should remain the key detection method. Clinical abnormalities include direct palpation of the stenosis under the skin and localised loss or reinforcement of the thrill. Stenosis of the arterial inflow or stenoses located in the anastomotic area can be responsible for a fistula, which is too flat, or for vacuum phenomena during dialysis. Stenosis in the cannulation areas can make routine needling difficult. Venous stenosis located far from the anastomosis causes congested fistula with loss of thrill, increased compression times after dialysis with formation of aneurysms and the development of collaterals. Finally, limb oedema indicates central venous obstruction (Figures2a, 4a). However, once haemodynamically significant stenosis is detected, the optimal timing of treatment for the prevention of thrombosis remains to be determined for both fistula and graft.

Dialysis-access thrombosis is usually detected clinically. A graft that no longer has a palpable pulse or thrill is clearly thrombosed and does not need any further evaluation for the diagnosis of access failure. Native fistulas, on the other hand, characteristically develop only thrombosis of segments of their venous outflow, and ultrasound and/or fistulography can be extremely helpful in delineating the length of thrombosis, as well as the character of venous reconstruction above the thrombosis site. Fistulography is usually done in anticipation of the percutaneous treatment of thrombosis and is extremely useful in planning revascularisation.

Endovascular treatment, haemodialysis access, native fistulas and grafts

Treatment of venous stenosis is important clinically because it preserves the access sites for future use.

Percutaneous angioplasty

Percutaneous transluminal angioplasty, which is an outpatient procedure, successfully treats over 80% of stenosis in both native and synthetic fistulas and in both venous and arterial outflow tracts.[4,6,14,20,21] Angioplasty

can be performed on both anastomotic and more proximal lesions including central stenoses (Figures 1a, 1c, 2b, 2c). Prospective angioplasty of all venous stenoses that narrow the lumen by more than 50% improves fistula function and prolongs access survival. Angioplasty therapy is safe, effective, and easily performed, and has become a standard therapy for the management of venous stenosis affecting dialysis-access fistulas and graft.[6,20,21]

Direct fluoroscopy observation is necessary to perform angioplasty, with digital capability being very advantageous. Heparinisation is unnecessary. During dilatation, flow is occluded for only short intermittent periods, and clotting of the access therefore rarely occurs. Because the procedure is potentially very painful, the patient requires adequate sedation.[21] Patients must be monitored very closely during this process. Since the requirements for adequate sedation varies considerably, the dosage must be carefully titrated.

Before angioplasty fistulography was performed to evaluate the anatomy and pathology of the fistulas or graft and its draining veins up through the superior vena cava (Figures 1a, 2a, 4a). The needle is inserted anterograde into the shunt-leading vein or graft. A hydrophilic-coated, steerable, 0.035-inch Terumo guidewire is passed up through the stenoses to the level of central veins. In cases where the vein is tortuous or occluded in a short segment, guidewire manipulation is also required with diagnostic catheter support, which can be a considerable challenge. A balloon catheter is passed over the guidewire and advanced to the most central lesion. It is important for the balloon to be slightly larger than the affected vein and that a high-pressure balloon is used.[4,21] The basic technique of angioplasty as applied to the access graft and associated venous range is dependent upon the use of a large diameter, high-pressure balloon catheter. Unless the veins are unusually small, a 6-8 mm balloon is used in both graft and peripheral veins and a 12 mm balloon is used centrally. A pressure of 10 atmospheres is routinely utilized. If this is not effective in breaking the lesion, pressures of 15 and 20 atmospheres are sequentially applied. The balloon is allowed to remain expanded for one to two minutes, with each in-

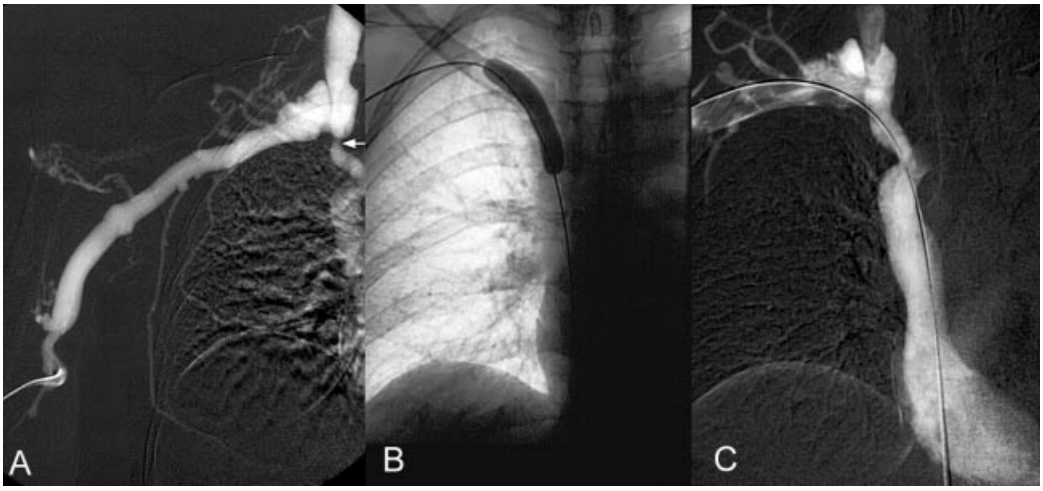

Figure 2. A patient with malfunctional forearm dialysis fistulas and oedema of the arm. Fistulography. a. High grade stenosis of the right brachiocephalic vein (arrow); b. PTA with the high pressure balloon; c. the result is a good patency.

flation. Multiple dilatations are used for resistant lesions. Post-procedural fistulography is performed to assess and document the results of the therapy (Figures 1c, 2c, 4d). The ability to measure intra-access blood flow immediately after the procedure may also prove beneficial.[18] Haemostasis is obtained following the removal of the vascular sheath by manual compression. Using a bandage is relatively inexpensive and very effective in most cases.

Patency rates with angioplasty vary according to the follow-up period and the types of access and vessel treated. Unfortunately stenoses do recur relatively rapidly. The largest series of angioplasty grafts have high success rates ranging from 94 to 98% in unassisted (or primary) patency rates, ranging from 17 to 40% at one year.[4-6,21] Over the period of a year, secondary patency rates of 82% and 85% were obtained in the forearm and in the upper arm respectively, but with more frequent reintervention in the upper arm (11 vs. 18 months). The initial success rate generally ranges from 80-94%.[14,21] The unassisted patency rate for angioplasty generally ranges from 31-45% per year. The only two large series for forearm native fistulas reported a success rate ranging from 91-95% and one-year primary patency rates from 44-51%.[4,5,21] This article also presents the positive influence of the age of the vascular access on the outcome dilatation of fistulas. Manninen reports a significantly poorer outcome when stenoses were located near the anastomosis and when the feeding artery was »small«.[22] When the outcomes of each of the lesions were compared to that of the anastomosis group, long venous, midgraft and subclavian groups had statistically inferior unassisted patency rates.[4,21] The poorest results e to be found in the literature are those associated with simple dilatation of the central vein (23 to 29% primary patency rate at 6 months).[26] Angioplasty treatment of venous stenosis based on prospective monitoring for increasing stenosis is effective. It results in a decreased incidence of thrombosis and extended usability of the dialysis vascular accesses.[4-6,21]

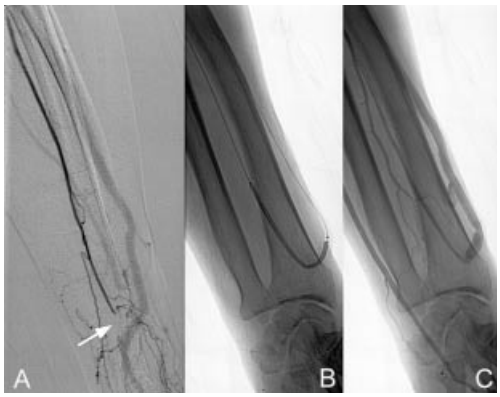

Figure 3. Reduced blood flow through the left forearm fistulas. a. Arteriography shows the occlusion of the radial artery above the fistulas (arrow), which functions through the collaterals of the palmar arch. b. Transarterial recanalisation and dilation of the occlusion. C: Higher blood flow through the fistulas.

Complications associated with venous angioplasty include severe allergy to iodine, infection, thrombosis and vein ruptures. Loss of vascular access following vessel rupture or thrombosis has become extremely rare, since stents and catheter thrombectomy are available. After a seemingly effective dilatation, some lesions recoil, which may occur immediately or over a period of days after the procedure.[4,20,21] Deaths related to procedures are extremely rare.[4]

Use of stents for venous stenosis associated with dialysis vascular access

The role of the endoluminal stent in the management of venous stenosis of dialysis access is unclear. Although stents can help manage some access difficulties, they are not permanent solutions. There is a consensus concerning the value of stent placement for the rupture of an outflow vein after balloon angioplasty, when prolonged balloon inflation fails[23] and for treatment of stenosis recoil. Elastic lesion may first completely dilate with the angioplasty balloon; significant residual

stenosis occasionally remains, suggesting an elastic lesion. The use of stent is suggested in cases of the rapid recurrence of stenotic lesion following angioplasty (Figure 4). Are stents significant for delaying restenosis? Same authors report intervals between interventions that double in length after stent placement, others disagree.[4,24-26] The presence of residual stenosis or developed thrombosis after stent placement might indicate insufficient pre-dilatation, and placement of stent during incomplete declotting procedures. In general, a 50% post-angioplasty stenosis may be used as a threshold for further intervention with stent. However, all authors of recent literature agree that only self-expandable stents should be placed in dialysis access and that indication must be selected. The diameter of the stent must be at least 1 or 2 mm larger than the diameter of the largest balloon used to dilate the stenosis. Its length should be as short as possible, to cover the lesion only. The stent must not be placed in stenotic lesions that cannot be dilated or a stenotic lesion at a venous anastomosis. At the venous anastomosis, a forearm fistula or graft stent can overlap the basilic vein and prevent the future creation of transposed brachiobasilic fistulas, or protruded stents into the subclavian vein from the final arch of the cephalic vein in which it could induce stenosis, which would preclude the future use of the basilic and axillary veins for direct fistula drainage of an upper arm graft. A stent placed in the subclavian vein must not overlap the ostium of a patent internal jugular vein. This vein is essential for placing the central catheter or for bypassing a subclavian stenosis. In order to avoid inducting stenosis on the contra-lateral trunk, a stent placed in the right or left brachiocephalic vein must not protrude into the superior vena cava. The stent must be placed in the brachiocephalic trunk only, without overlapping either the subclavian or internal jugular ostium. This means, however, that future access

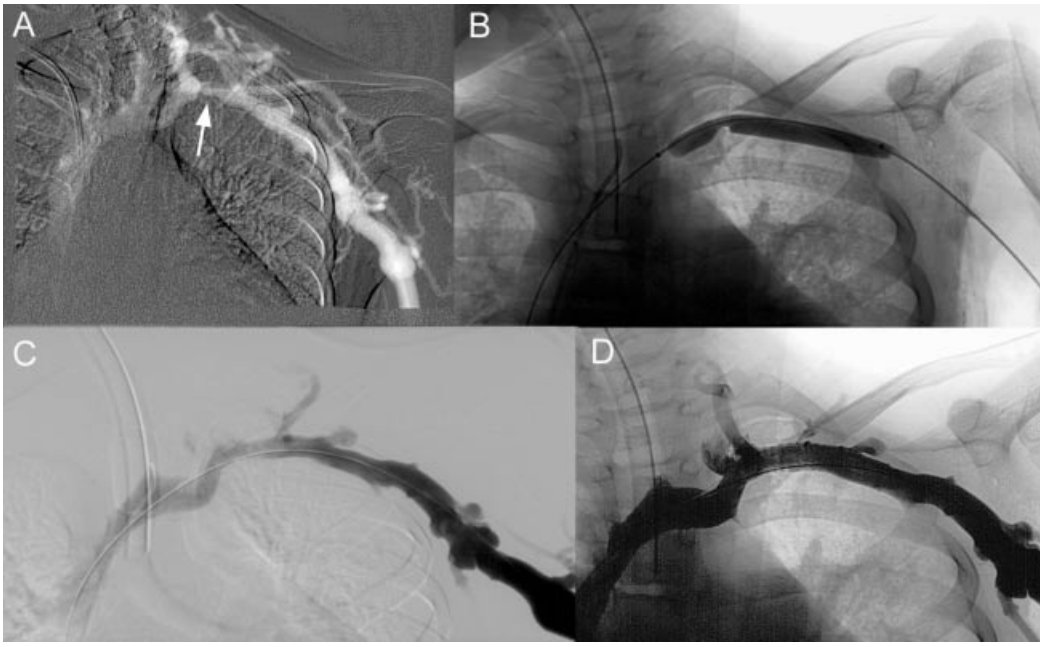

Figure 4. A patient with malfunctional dialysis fistulas and oedema of the arm. Fistulography. a. High grade stenosis of the subclavian vein with collateral flow (arrow). b. PTA with high pressure balloon of 12 mm diameter. c. Relatively good result after the PTA; d. better result after the placement of the stent.

sites must be anticipated before placing the stents. Authors recommend primary stent placement due to poor results after simple central vein dilatation (Figures 4b, 4c, 4d).[24,25]

Primary patency rate following the venous use of stents is relative poor, being approximately 20% per year. However, with aggressive re-intervention, the cumulative patency rate is roughly around 70% per year. Modalities that have been used for stent maintenance include thrombolysis, stent angioplasty, new stent, and the use of the Simpson or Redha atherectomy device. As previously mentioned, the principal difficulty underlying the inability to maintain patency is the development of neointimal hyperplasia.

The six-month and one-year stent primary patency rate in central veins was only 42% and 20%. Haage (84% and 54% respectively) and Mickely (90% and 70% respectively) obtained better results.[24,25]

The most typical complication is inaccurate placement or migration of stents.[24,25] Only two casualties have been reported linked to stent placement, by infection and presumed right atrium perforation.[4]

Endovascular treatment of dialysis fistula thrombosis

The most common complication of permanent vascular access are thromboses which, when not mended, account for 80 to 85% of access loss. The major predisposing factor is stenosis on vein side anastomosis of the vascular access, responsible for 85% of thrombosis.[2,4,6,14,20,21] Other causes of fistula thrombosis include arterial stenosis, post-dialysis fistula compression, hypotension, increased haematocrit levels, hypovolemia, or hypercoagulable states.[4,6,27] The therapeutic options of fistula thrombosis include surgical thrombectomy, thrombolysis with thrombolytic agents, thromboaspiration and mechanical dissolution. If these modalities are successful, a fistulogram can then be performed and detected stenoses treated with angioplasty or surgical revision.[4-6,14,20]

Surgical thrombectomy is a quick, outpatient procedure, has a very low complication rate, and is initially successful in 90% of cases.[4,21] However, failure to correct the underlying outflow stenosis leads to rapid rethrombosis.

The endovascular declotting techniques published to date can be divided into pharmaco-mechanical and purely mechanical methods. The earliest attempts to treat fistula thrombosis with thrombolytic agents, such as urokinase and streptokinase, originally yielded disappointing results.[27] However, recent dosing adjustments and technical advances have improved the success rate and reduced the incidence of bleeding in patients for whom there is no contraindication to thrombolytic therapy.[28] For example, the use of the pulse-spray technique, which combines thrombolytic therapy with hydromechanical clot disruption, rapidly established access patency in over 90% of cases with minimal complications. The pulse-spray method consists of placing two multi-sideholed catheters with tip-occluding wires in a criss-cross fashion in the thrombosed graft. The forceful and rapid injection of 0.2-0.3 ml aliquots of a 10 ml mixture combining 250,000 units of urokinase and 5000 units of heparin are than applied every 30 sec. to each catheter with a tuberculin syringe. The successful administration of tissue plasminogen activator has also been reported.

Pharmaco-mechanical methods include thrombolytics at low or high dose, infused locally through regular needles or specific catheters for some minutes or hours before detachment or the crushing of residual thrombus with a balloon, more rarely with an aspiration catheter. These were previously described as the Bookstein »pulse-spray« method, the Cynamon »lyse and wait« method, the Goodwin and Craggbrush infusion technique.[28-30] The commonly occurring

venous stenosis should be corrected.

Purely mechanical methods include clot extraction or disruption methods with the Trerotola and Sharaffuddin balloon-based methods, the Beathard spray-spray with saline method, the manual catheter-directed thromboaspiration, the Schmitz-rode rotating pigtail and all kinds of declotting devices. The major concern regarding these techniques is the possibility of clinically significant pulmonary emboli developing. To reduce the possibility of large pulmonary emboli, a device has been developed which consists of a high speed rotating camp tip which pulverizes the clot into tiny particles such as: Arrow-Trerotola PTD, Hydrolyser, Amplatz Thrombectomy device and many others that are likely to appear.

The technical success rates for pharmacomechanical and mechanical methods are 89-95%. Long-term primary patency rates are relatively poor in all reports, ranging from 8 to 26% per year.[4,21] However, secondary patency rates of 75% have been reported.[4] Treatment results of native fistula are better.[4,21,31]

The rates of significant complications range from 0-9%.[4,21] Complications include thrombus migration and vessel rupture, regarded as a significant complication, as well as infection, ischemic hand, remote or local bleeding, requiring transfusion or surgery, pseudoaneurysms and fluid overload.[4,5,31-33]

The mortality rate is low. Literature reports data on just six casualties linked to the declotting procedure. The causes of death were pulmonary or septic embolism and hemiplegia due to paradoxical embolism in patients with a patent foramen ovale and a right-to-left shunt.[4]

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