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Endovascular Techniques for Dialysis Vascular Access

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Abstract: A nephrologist is well equipped to understand and manage the complexities involved in educating and preparing a patient with chronic kidney disease to embrace the challenges involved with renal replacement therapy. The importance of vascular access in providing adequate dialysis therapy cannot be overemphasized. Unfortunately, it remains a weak link in providing optimal care and a major cause of morbidity and mortality. The timely diagnosis of a dysfunctional vascular access involves implementing a good monitoring and surveillance program. A nephrologist of the millennium needs to be well equipped with skills to perform procedures such as fistulogram, percutaenous angioplasty, endovascular thrombectomy and occasionally placement of stents and coils for timely intervention of a dysfunctional access. The current review describes the basic procedures that can be easily performed by nephrologists to provide ideal care to dialysis patients.

Keywords: Interventional nephrology, dialysis access, endovascular procedures, angioplasty, angiography, vascular access, Thrombectomy.

INTRODUCTION

Vascular access dysfunction is a major cause of morbidity and mortality in dialysis patients [1]. With their unique perspective on dialysis patients and their problems, an increasing number of nephrologists are safely and effectively performing endovascular procedures to assist in the maintenance of hemodialysis accesses [2]. This article aims to describe the basic vascular access related procedures performed by interventional nephrologists such as angiography, angioplasty and endovascular thrombectomy.

ANGIOGRAPHY

A diagnostic angiogram is usually performed to evaluate a graft or a fistula in its entirety, with the purpose of identifying any stenotic lesions within the dialysis access. It must be kept in mind that the dialysis access is a circuit, which begins and ends in the heart [3] and the angiogram should include, at a bare minimum: the feeding artery and the anastomosis, the juxta-anastomosis, the body of the access, the venous outflow and the central veins. If a therapeutic intervention is indicated, an angioplasty is performed in combination with the angiogram.

DESCRIPTION OF AN ANGIOGRAM

To obtain initial venous access, the access is cannulated using an 18 gauge (for arterio-venous graft; AVG) or a 21 gauge (for arterio-venous fistula; AVF) thin-walled needle. A guidewire is then passed into the access, and the needle is exchanged for a vascular sheath, which is used to inject radiocontrast for imaging of the access. If the cannulation is in the downstream direction, a retrograde occlusive arteriogram is performed to evaluate the artery and the juxta-anastomotic region. Alternatively, and sometimes preferentially [4], the access may be cannulated in the antegrade direction and the arterial system is evaluated by direct visualization, with selective cannulation of the artery.

ANGIOPLASTY

Significant vascular access stenosis identified on an angiogram may be treated by percutaneous transluminal angioplasty (PTA). Stenoses are most common at the venous anastomotic site in an AVG, though they may occur both peripherally throughout the access including the arterial, juxta-anastomotic and intra-graft areas, as well as within the central venous system [5]. Neo-intimal hyperplasia at the graft-vein interface is believed to be a major factor in the underlying pathophysiology of venous access stenosis [6].

Percutaneous balloon angioplasty should be performed only in cases with functionally significant stenosis, as defined as a decrease of greater than 50% of normal vessel diameter, accompanied by hemodynamic or clinical abnormality, such as abnormal recirculation values, elevated venous pressures, decreased blood flow, swollen extremity, unexplained reduction in Kt/V, or elevated negative arterial prepump pressures, that prevent achieving the prescribed blood flow [7,8].

It should be noted that an angioplasty is not a benign procedure and can cause substantial trauma to the vascular endothelium. The vascular injury may heal without any significant sequelae, or it may incite the development of a new stenosis or accelerate the progression of a preexisting subclinical lesion [6,9,10].

Success is defined as less than 30% residual stenosis post-procedure and resolution of physical indicators of stenosis and 50% unassisted patency at 6 months. Though PTA is safe, effective, and can be easily performed in an outpatient setting with minimal discomfort to the patient,

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there are still unanswered questions regarding its long-term efficacy and whether it truly is an effective intervention for vascular access dysfunction [9].

DESCRIPTION OF AN ANGIOPLASTY

After cannulating the access, an initial angiogram is performed to identify any stenotic lesions within the access. A guidewire is then introduced through the vascular sheath and passed across the stenotic lesion. An angioplasty balloon catheter of appropriate size is then advanced over the guidewire to the identified stenotic lesions or the venous anastomosis at the graft-vein interface. The angioplasty balloon is inflated with dilute radiocontrast so that it may be visualized by using fluoroscopy, until there is full balloon effacement. (Figs. **1**, **2**). In general, an angioplasty balloon catheter is over-sized about 20% for a venous angioplasty. A residual stenosis of 30% or less is commonly used as the definition of success for all angioplasty procedures.

Fig. (1). Arteriovenous graft: venous anastomosis stenosis, prior to angioplasty.

OUTCOMES

K-DOQI recommends a minimum 50% unassisted patency at 6 months with PTA and a 50% 1-year unassisted patency after surgical revision. Surgical revision is held to a higher standard, as it usually extends the access farther up the extremity by the use of a jump graft and thus has the potential for loss of venous 'real-estate'. Most studies in the past have shown patency with endovascular techniques at least as good if not better, as detailed in Table **1**. Studies that have directly compared PTA versus surgical revision for venous stenoses show conflicting results [11, 12].

ENDOVASCULAR THROMBECTOMY:

Eighty-five to ninety percent of arteriovenous access thromboses are associated with venous outflow stenotic lesions [13, 14] caused by endothelial and fibromuscular hyperplasia. Thrombectomy procedures are routinely performed by nephrologists, using a combination of mechanical and pharmaco-mechanical techniques. Stenoses accompanied by thromboses are more difficult to treat than stenoses detected by prospective monitoring; treatment of stenoses associated with thrombosis is therefore associated with poorer outcomes for both surgical and percutaneous techniques. Endovascular techniques yield 3-month patencies ranging from 30% to 40% [15, 16]. K-DOQI recommends a minimum of 85% immediate patency for both percutaneous thrombolysis and surgically revised thrombectomies; 40% unassisted patency and functionality at 3 months for endovascular procedures, and 50% unassisted patency and functionality at 3 months for surgical procedures [17, 18]. As in angioplasty, surgical revision is held to a higher standard. Thrombosed arteriovenous fistulas were previously believed to be unsalvageable. Although the procedures are technically more challenging in fistulas, results are similar to graft interventions.

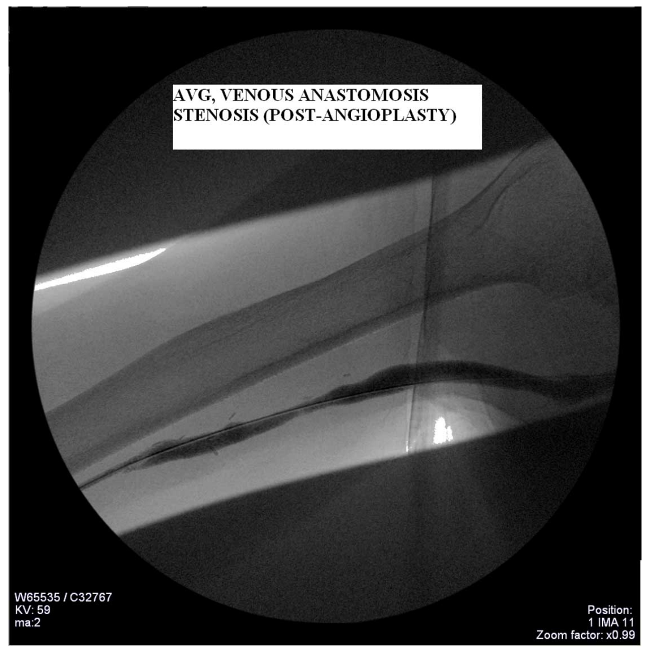

Fig. (2). Arteriovenous graft: venous anastomosis stenosis, post-angioplasty, with minimal residual stenosis

DESCRIPTION OF A THROMBECTOMY [19]

In accomplishing successful thrombectomy of a vascular access, 4 steps are required:

1. Diagnostic angiogram to evaluate the graft or fistula, along with the venous outflow and central veins
2. Removal of the thrombus from the vascular access
3. Treatment of stenosis by using angioplasty
4. Dislodgement of the arterial plug to reestablish flow

Although the order in which these 4 steps are performed is physician and patient dependent, all 4 steps must be performed for successful restoration of blood flow through the vascular access.

Endovascular thrombectomy is performed most commonly by using thromboaspiration, which combines angiography, thrombectomy by means of thrombus aspiration, and balloon angioplasty. This procedure requires

Table 1. Patency Rates with PTA in Dialysis Access

Investigator	Year	Immediate Patency	3-Month Patency	6-Month Patency	1-Year Patency
Beathard [5]	1992	94%	77.2%	66.4%	44.5%
Kanterman [23]	1995	Not reported	Not reported	63%	41%
Glanz [24]	1987	82%	Not reported	Not reported	45%
Mori [25]	1994	Not reported	68%	42%	25%
Turmel-Rodrigues L [26]	1993	95%	Not reported	Not reported	82%

accessing the vascular access through a vascular sheath, then selecting a guidewire and embolectomy catheter. Accessing the thrombosed vascular access often is the most difficult part of the thrombectomy procedure because usually there is no blood ‘flashback’ into the cannulation needle. Both the venous and arterial sides of the thrombosed access must be cannulated. It is preferable to first cannulate a straight section for insertion of the balloon catheter on the venous side of the access. The sites for cannulation should be chosen to ensure that there is enough space between the 2 vascular access sites to allow for sweeping the thrombus from the vascular lumen.

To obtain initial venous access, a graft is cannulated using an 18-G thin-walled needle in the downstream direction. A guidewire then is passed into the access, and the needle is exchanged for a 6- or 7-Fr vascular sheath. In the case of an autogenous fistula, a 21-G micropuncture needle is used first to gain access to the fistula. Ultrasound guidance may be required for cannulation. The vascular sheath facilitates aspiration of the thrombus, allows for easy introduction of the angioplasty balloon catheter or embolectomy catheter, and is used to inject radiocontrast for imaging of the access.

The guidewire then is passed up to the level of the central veins, and a straight catheter is advanced over the guidewire to the central veins to obtain a central venous angiogram. After the central venous angiogram is obtained, any necessary drugs may be administered through this catheter, including heparin and medications used for conscious sedation.

The straight catheter is pulled back toward the introduction site to obtain an angiogram of the peripheral veins. Contrast is injected while the catheter is pulled back to delineate and identify stenotic lesions with or without thrombi.

An angioplasty balloon catheter of appropriate size is then advanced over the guidewire to the identified stenotic lesions or the venous anastomosis at the graft-vein interface. The angioplasty balloon is inflated with dilute radiocontrast so that it may be visualized by using fluoroscopy, until there is complete balloon effacement. The entire venous side of the graft then is sequentially dilated. The angioplasty balloon is removed, leaving the wire in place to maintain access to the central circulation.

The graft is now cannulated with the needle pointed upstream toward the arterial anastomosis at a point approximately 4 cm from the venous anastomosis. A guidewire is advanced into the access through the needle, and the needle is exchanged for another vascular sheath. A 4-Fr embolectomy catheter is advanced arterially through the vascular sheath. Under fluoroscopic guidance, the embolectomy catheter is pulled across the arterial anastomosis while aspirating the thrombus through the sheath side port. It may be necessary to repeat this action several times until flow is restored, indicated by a good pulse in the graft. Flow can be confirmed by injecting a small amount of radiocontrast through the side port of the venous directed sheath. If there is rapid disappearance of the contrast, a digital subtraction angiogram is obtained.

At this point, the interventionist must determine whether there is either an inflow or outflow stenosis that will require additional angioplasty. If there is evidence of an inflow stenosis, an arterial angiogram may be indicated, in which case a guidewire is advanced into the artery. A vascular catheter then is advanced over the wire, and radiocontrast is injected to visualize the artery, arterial anastomosis, and juxta-anastomotic segment. Upon recognition of an arterial stenosis, an appropriate-sized angioplasty balloon is advanced over the guidewire and inflated. In similar fashion, if a stenosis is present in the juxta-anastomotic segment, dilation using the appropriate-sized angioplasty balloon catheter is performed. In general, an angioplasty balloon catheter is oversized by about 20% for venous angioplasty and the balloon is sized according to the arterial diameter for arterial angioplasty, though there are no controlled studies that have examined angioplasty balloon sizing on clinical outcomes. A comparison of ultra-high pressure balloons versus high-pressure balloons for venous anastomosis stenosis in arterio-venous grafts showed no significant improvement in patency on routine angioplasties [20]. Another study that evaluated the effect of prolonged inflation times (1 minute versus 3 minutes) found that although a 3-minute inflation time significantly improved the likelihood of technical success, there was no significant difference in postintervention access patency [21].

A repeat angiogram is obtained to evaluate results of the angioplasty and identify any complications. When satisfied that the procedure is complete, hemostasis is obtained by removing the vascular sheaths and applying manual pressure over the puncture sites. A suture may be used to temporarily close the puncture sites. The procedure is considered successful if unobstructed flow through the access is established to allow for one subsequent dialysis treatment.

OUTCOMES

Both endovascular and surgical techniques may be used to perform thrombectomies. The KDOQI guidelines indicate

Table 2. Comparison of Different Techniques for Thrombosed Access

Investigator	Year	Results
Beathard [27]	1995	Equivalent overall, though long-term patency of endovascular techniques was superior
Schuman [28]	1994	Surgical thrombectomy superior
Schwartz [18]	1995	Equivalent overall, though shorter hospital stay and lower anesthesia requirements noted with endovascular techniques
Tordoir [29] (meta-analysis)	2009	Equivalent overall in grafts, though surgery may be preferred in autogenous fistulae
Uflacker [30]	1999	Equivalent overall, no statistically significant differences in primary or secondary patency
Vesely [31]	1999	Surgical significantly better in long-term patency, though results of both inferior to published guidelines
Marston [32]	1997	Surgical significantly better in long-term patency
Dougherty [33]	1999	Equivalent overall, no statistically significant differences in primary or secondary patency
Green [34] (meta-analysis)	2002	Surgical approach superior

that percutaneous transluminal angioplasty of a thrombosed vascular access should result in 40% patency at 3 months [15, 16], with immediate patency of 85%, whereas the recommendation for surgical thrombectomy is 50% unassisted patency and functionality at 3 months [17, 18]. However, there are few randomized studies comparing the two procedures directly. Table **2** summarizes the results of some of those. It should be kept in mind that the older studies show better surgical outcomes, but with the improvement and standardization in endovascular techniques, the outcomes for both endovascular and surgical techniques are comparable.

COMPLICATIONS

A procedure related complication is defined as an unexpected adverse event that requires additional therapy. The American Society of Diagnostic and Interventional Nephrology (ASDIN- www.asdin.org) has recently released a Position Statement classifying complications associated with hemodialysis vascular access procedures. In this system, the "type" of complication refers to the procedure being performed or the involved vessel and the "grade" refers to the intensity of the medical care required to address the complication. 10 types and 4 grades of complications have been described in detail. Among these, those related to the endovascular techniques described above include access site hematoma, vascular rupture, arterial complications, medication reactions and systemic complications.

CONCLUSIONS

A major pre-requisite for adequate hemodialysis treatment in end-stage renal disease patients is a functioning vascular access. Endovascular therapy is an important addition to the interventionist's armamentarium and helps in maintaining and prolonging the longevity of each access [22]. Percutaneous procedures are safe and effective, and can be performed in an outpatient setting with minimal discomfort to the patient.

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Declared none.

CONFLICT OF INTEREST

Declared none.

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