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Percutaneous Transluminal Angioplasty in Arteriovenous Fistulas: Current Practice and Future Developments CE

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A B S T R A C T

End-stage renal disease leads to dependency on hemodialysis. Although the native arteriovenous fistula (AVF) is the preferred access, AVF dysfunction is a common problem. This article discusses the access circuit, diagnosis of AVF problems, and common percutaneous transluminal angioplasty techniques. Future advances to improve primary patency rates are also discussed. Knowledge of this information will aid the radiology nurse in providing quality care to this patient population.

Introduction

End-stage renal disease is a common condition causing significant morbidity and mortality. In the Annual Report from the UK Renal Registry, there were almost 60,000 patients receiving renal replacement therapy in the United Kingdom in 2014 (Caskey et al., 2016). In the United States, this figure is higher at more than 400,000 (Roy-Chaudhury, 2016).

There are three methods of long-term hemodialysis most commonly used; arteriovenous fistulas (AVFs), arteriovenous grafts (AVGs), and tunneled dialysis catheters. A well-functioning AVF provides good quality dialysis and is a lifeline for the patient. National and international guidelines recommend the native AVF as the preferred hemodialysis access owing to its lower morbidity and mortality rates when compared with synthetic AVGs and catheter dialysis access (Allon, 2007; NKF-K/DOQI, 2006; Tonnessen et al., 2005).

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AVF dysfunction is most commonly secondary to a failure of fistula maturation and or venous outflow stenosis. A hemodynamically significant stenoses leading to dialysis fistula dysfunction is associated with an increased rate of fistula thrombosis along with significant morbidity (KDOQI, 2006).

Percutaneous transluminal angioplasty (PTA) is a safe effective treatment of dialysis fistula stenoses and dysfunction, which prolongs the life of the fistula or graft. However, there is a high rate of restenosis and thus relatively low primary patency rates after PTA.

In this article, we will explore the patient pathway to the angiography suite, including the diagnosis of dialysis fistula dysfunction, describe the access circuit, common PTA techniques, and how future advances in technology may improve primary patency rates.

Diagnosis of dialysis fistula dysfunction

A diagnosis of dialysis fistula dysfunction is based on clinical assessment of the fistula, quality of dialysis, and measurements of recirculation and volume flow. Depending on the clinical

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assessment, the patient will be referred for ultrasound (US) duplex assessment of the fistula, directly for PTA, or for assessment in vascular access clinic. Pathways for referral will depend on local resources available.

What matters most to the patient is that the fistula can be cannulated using two needles with ease without multiple painful attempts. When the needles are withdrawn, the bleeding stops relatively quickly without prolonged compression, and they achieve good quality dialysis.

Recirculation is an indicator of dialysis access dysfunction where venous blood exiting the dialysis machine is drawn back by the arterial access needle and recirculated in the machine. Recirculation should periodically be measured along with access flows, a value of <10% is usually clinical unimportant and is thought to be secondary to cardiopulmonary recirculation (KDOQI, 2006; Schneditz, Kaufman, Polaschegg, Levin, & Daugirdas, 1992). A high value of recirculation (>10%) may indicate a significant stenosis, which is usually above and/or more central to where the AVF or AVG is being cannulated. Other clinical signs of a stenosis above or more central to the cannulation sites or a cannulation site include prolonged bleeding after coming off dialysis or spontaneous bleeding often called a blowout, which can be life threatening if not treated, and is often very distressing for the patient.

A swollen sometimes painful arm is another sign of a central stenosis. When the whole of the patient's arm is very swollen, this usually indicates a stenosis or occlusion more central to the thoracic inlet.

Volume flow within an AVF or an AVG can be measured using a variety of devices including a transonic machine while the patient is on dialysis. It can also be measured by Doppler ultrasound (DUS) (Figure 1). Volume flow should be measured within the brachial artery ipsilateral to the fistula 5 cm above the anastomosis. Volume flow is calculated by preprogrammed software using time-averaged velocity and vessel area.

If a declining volume flow is measured over time or a volume flow of less than 600 mL/min is measured, these are indicators of dialysis fistula dysfunction and a risk of thrombosis (Schwarz et al., 2003). A low volume flow or declining volume flow is most commonly associated with a juxtaanastomotic or proximal stenosis of the AVF. Other signs of a significant juxtaanastomotic stenosis include a poorly palpable thrill or pulse, poor maturation, and difficulties in cannulation.

When dialysis fistula dysfunction is diagnosed, then the patient may be referred for DUS assessment before intervention. DUS has a high sensitivity and specificity in the diagnosis of vascular access

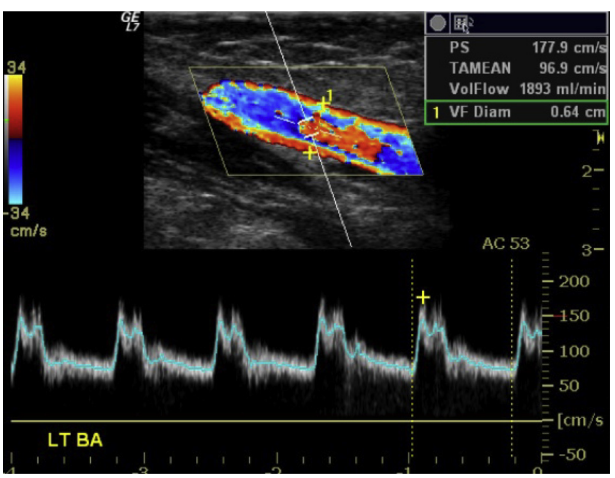

Figure 1. Doppler ultrasound image demonstrating measurement of volume flow within the brachial artery.

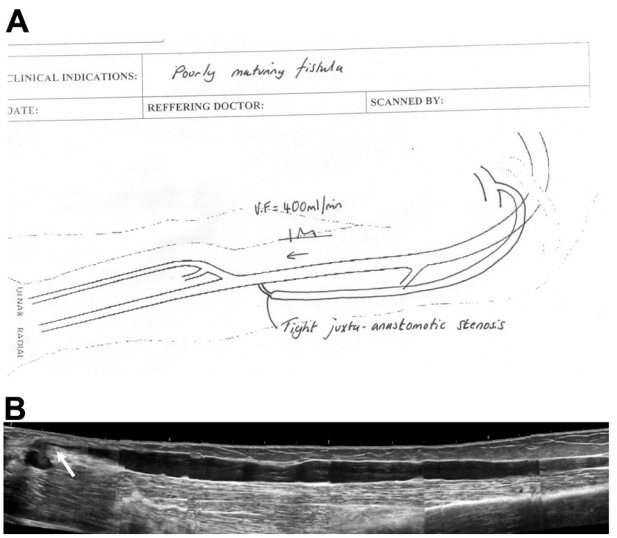

Figure 2. Same patient. (A) Doppler ultrasound report. Volume flow (VF) is low at 400 mL/min. There is a tight juxtaanastomotic stenosis. (B) B-mode ultrasound image demonstrating the juxtaanastomotic stenosis (*white arrow*) and a long segment of upper arm cephalic vein.

stenosis. The technique, in the hands of an experienced operator, has high accuracy and reproducibility in detecting more than 90% of significant stenoses (Doelman et al., 2005; Finlay, Longley, Foshager, & Letourneau, 1993; Nonnast-Daniel et al., 1992). The report provides the clinician with a road map of the fistula, and a treatment plan can be made (Figure 2A and B).

The venous outflow tract can be imaged using DUS from the anastomosis to the thoracic inlet. The more central veins that are deeper within the chest are not seen. Where a central venous stenosis is suspected, a referral for a fistulogram plus intervention is usually made. A diagnosis of dialysis fistula dysfunction is mandatory before treatment as venous stenoses are seen in well-functioning AVFs where they do not usually require treatment.

Different types of stenosis are seen on DUS, and characterization of stenosis type may have implications for the type of treatment patients receive. Yamamoto et al. (2012) described three types of stenosis seen on US in the outflow vein of AV grafts: a vascular constriction type, a neointimal proliferation type, and a third type that has features of both constriction and neointimal proliferation. The author's observations confirm the three different types of AV stenosis reported: a type with the appearance of neointimal proliferation/venous neointimal hyperplasia, a type with a more fibrotic appearance/vascular constriction, and mixed type where there is vascular constriction with intimal hyperplasia (Figures 3–5).

The access circuit

The most common types of autologous AVFs are radiocephalic, brachiocephalic, and basilic vein transpositions (Figures 6–8).

The access circuit or venous outflow tract of an AVF or an AVG is from the arterial anastomosis to the right atrium. The venous outflow tract is not uniform; flow dynamics, anatomy, and patency rates vary from the arterial anastomosis to the right atrium. For example, cephalic arch stenoses have a high rate of recurrence and relatively high rupture and perforation rate (Sivanathan, Menashe, & Halin, 2014).

AVGs may be placed as a forearm loop graft, upper arm graft, or interposition graft. Arteriovenous loop grafts may also be placed in