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Duplex Doppler Imaging of Dialysis Fistulae and Grafts

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Arteriovenous fistulae and grafts for hemodialysis access are a lifeline in patients with end-stage renal disease. A significant cause of morbidity and mortality in this population is dialysis access dysfunction. Duplex ultrasound imaging is an excellent modality to evaluate arteriovenous fistulae and grafts, the 2 main types of long-term hemodialysis access. This review provides a detailed Doppler ultrasound protocol for evaluation of fistulae or grafts to familiarize imagers with their normal appearance, highlighting common dialysis access complications.

Introduction

Arteriovenous (AV) fistulae and grafts for dialysis access are a lifeline for patients with end-stage chronic renal disease, which is an increasing problem worldwide.[1] Therefore, the successful construction of these fistulae and grafts and the maintenance of their patency are crucial. Unfortunately, access dysfunction is among the most significant causes of morbidity in this population.[2] It has been estimated that 20% of all hospitalizations in this subgroup of patients is secondary to dialysis access dysfunction, with the annual cost of creating and managing dialysis access in the United States surpassing 1 billion dollars per year.[3,4]

There are 2 main types of long-term hemodialysis access: (1) autologous AV fistula and (2) synthetic AV grafts.

The AV fistula described in 1966 by Brescia and Cimino continues to be the first choice for dialysis access,[5] because they have the longest survival and require the smallest number of interventions.[6] For example, the cost of dialysis access care for AV grafts has been shown to be 5-fold greater as compared with AV fistulae.[7] The most common complication leading to graft failure is graft thrombosis. In greater than 80% of thrombosed grafts, thrombosis is the consequence of stenosis at the venous anastomosis or draining veins.[8,9] In 1997, the National Kidney Foundation published the Dialysis Outcome Quality Initiative guidelines for the improvement of renal care.[10] According to the initial[10] and subsequent revisions in 2000[11] and 2006,[12] the 2 foremost vascular access recommendations were (1) placement of native AV fistulae as the preferred access type, and (2) early detection of hemodynamically significant stenosis likely to cause dysfunction or lead to access thrombosis.

As an alternative to traditional angiographic evaluation, ultrasound is a noninvasive and inexpensive modality for the assessment of dialysis access stenosis.[13,14] Although the role of duplex ultrasound as part of a surveillance program is not completely delineated,[15,16] advances in Doppler technology and the superficial location of AV fistulae and grafts enables high-quality duplex and color Doppler evaluation. Ultrasound can detect and localize abnormalities at an early stage amendable to intervention, potentially leading to improved longevity and function; early detection with duplex ultrasound of blood flow < 500 mL/min or stenosis $> 50\%$, which are prognosticators of access thrombosis within 6 months,[17] can lead to early intervention before access failure. Moreover, when there is concern for mild access dysfunction on clinical assessment, using ultrasound can avoid the risks associated with angiography. This article reviews the sonographic techniques involved in the evaluation of dialysis vascular access, including the assessment of the most common access complications.

Types of Vascular Access for Hemodialysis

AV Fistula

An AV fistula is surgically created by direct anastomosis of a native artery to an outflow vein. There are several configurations of AV fistulae. The preferred type is the forearm *Brescia-Cimino* radio-cephalic fistula, with a side-to-side anastomosis performed most commonly, just proximal to the wrist between the radial artery and the cephalic vein (of note, anatomical notation of proximal and distal is with respect to the heart). The radiocephalic fistula can also be constructed with end-to-side, side-to-end, or end-to-end anastomoses. Although infrequent, appropriately sized dorsal or volar forearm veins can be transposed within the forearm for dialysis access in some patients.[18] An alternative configuration

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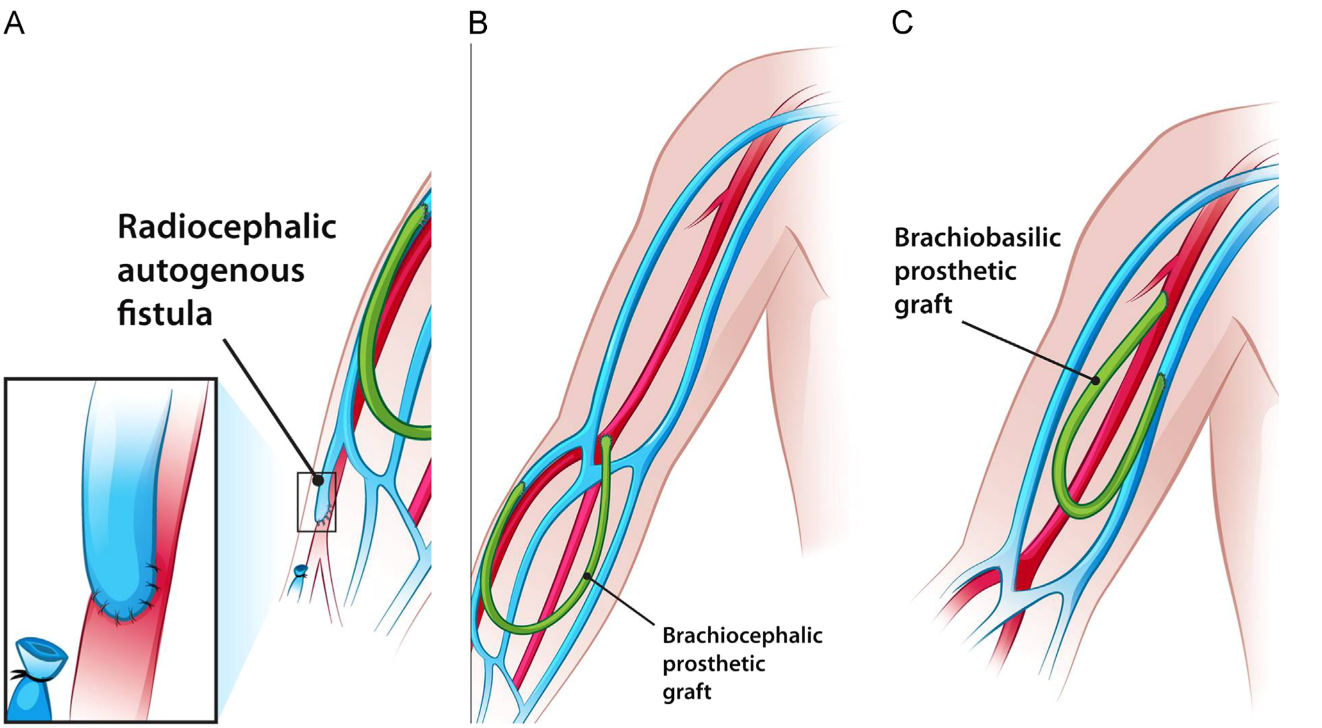

Fig. 1. Example diagrams of AV fistula and grafts. (A) Radiocephalic AV fistula located at the anatomic snuff box at the wrist, also known as the "snuff box fistula." (B) Brachiocephalic loop graft. (C) Brachiobasilic loop graft. (Color version of figure is available online.)

anastomosing the radial artery to the cephalic vein is the "snuff box fistula," with anastomosis just distal to the wrist within the anatomical snuff box (Fig 1A). This is the most distal site for AV fistula, preserving proximal vessels for construction of an additional AV fistula in the event of failure.[19]

The second preferred configuration is the upper-arm brachiocephalic fistula, with anastomosis of the brachial artery and cephalic vein near the antecubital fossa. The third most common type is the brachiobasilic fistula, which involves transposition of the basilic vein to a more central and superficial location along the anterior surface of the forearm, with anastomosis to the brachial artery at the antecubital fossa.[14] Less common configurations include anastomosis of the ulnar artery to the basilic vein,[20] side-to-side anastomoses of the proximal radial artery with the median antebrachial vein,[21] brachial artery to the median antecubital vein, and lower extremity fistula involving the superficial femoral artery anastomosed to the common femoral vein.

AV Graft

AV grafts are second to AV fistulae as the preferred dialysis access system and are made by anastomosing a synthetic conduit, typically made of polytetrafluoroethylene (PTFE), between a native artery and vein. Grafts have either a looped or straight configuration. There are 3 common upper extremity graft patterns: the forearm loop graft, the upper-arm straight graft, and the upper-arm loop graft. The most common forearm loop graft is the brachiocephalic graft (Fig 1B).[22] The forearm graft-arterial anastomosis is created distal to the antecubital fossa, to prevent graft compression while flexing the elbow. The upper-arm straight graft is anastomosed between the brachial artery and the basilic vein. To avoid compression at the elbow, the upper-arm graft is anastomosed to the brachial artery just proximal to the antecubital fossa. The most common upper-arm loop graft configuration is the brachiobasilic graft (Fig 1C).

Other types include the straight forearm graft (radial artery to cephalic vein) and less commonly when access sites are depleted, an upper-arm loop graft between the axillary artery and vein.[14] In select patients, when the vessels in the upper extremities are unusable, thigh grafts may be placed. These usually entail a loop of PTFE connected end-to-side with the superficial femoral artery and end-to-end with the great saphenous vein, or end-to-side with the common femoral vein.[14,22]

Differences in AV Fistulae vs Grafts

Table 1 summarizes differences between AV fistulae and grafts. AV fistulae are more cost effective, compared with grafts.[23] Fistulae typically require 1-2 months for maturation, whereas grafts require 2-4 weeks. AV fistulae have greater patency rates as well as lower associated morbidity and mortality. However, fistulae are more likely than grafts to experience "primary" failure, defined as failure before access can be used for hemodialysis. A systematic review shows a 23% failure rate of AV fistula.[24] Failure rates for lower arm fistulae were significantly higher as compared with upper-arm fistulae (28% vs 20%). However, the long-term patency of AV fistulae is superior to grafts once they mature.[24-26] Grafts are more likely to require thrombectomy and access intervention than a native fistula.[27] Grafts demonstrate a greater *risk of infection*[28-31] and a higher rate of uncomplicated aneurysm formation. Complicated (thrombosed, bleeding, infected) aneurysms developed at similar rates in grafts and fistulae in a retrospective review.[32]

"Steal" phenomenon, described as marked decrease or reversal of flow in the portion of the artery distal to the fistula, can lead to hand ischemia. Based on the type and location of AV fistula or graft, the risk of severe access-related peripheral ischemia varies from 1%-2% in radiocephalic AV fistulae to 5%-15% in brachiocephalic or basilic fistulae and grafts.[33-35] An even greater incidence of steal syndrome has been reported with femoral (native or allograft) access (16%-36%).[36,37]