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Triplex Ultrasound Evaluation of Late Failure Hemodialysis Access Fistulae

Triplex ultrasound, the integration of B-mode, color Doppler imaging and quantitative pulsed-wave Doppler analysis has become the gold standard for initial evaluation of dysfunctional hemodialysis access grafts and fistulae. This article focuses on its use in assessing autogenous arteriovenous fistulae (AVFs) that have failed after at least three months of successful use.

Autogenous arteriovenous fistulae (AVFs) are the preferred route of vascular access in patients with end stage renal disease (ESRD) undergoing long-term hemodialysis treatment. In 1997, the U.S. National Kidney Foundation published the Kidney Disease Outcomes Quality Initiative (KDOQI) Guidelines for Vascular access which recommended AVF as the first choice for dialysis access in patients with competent vascular conduits. Subsequently, in 2003, the Fistula First initiative was launched in an effort to achieve better patient outcomes by reducing the complications and sequelae associated with other vascular access methods such as central venous catheters, prosthetic arteriovenous grafts, and peritoneal dialysis. AVFs are cited by most articles in the medical literature as "*the optimal access with the longest survival and fewest complications of any form of vascular access*" [1].

In an autogenous AVF, an artery is surgically anastomosed to a vein, most commonly in the upper arm (brachiocephalic fistula) or in the forearm (Brescia-Cimino fistula). High pressure arterial blood emptying into a passive, low pressure venous conduit creates a hemodynamic state which can provide the high volume flow rate necessary for adequate exchange between the patient and the dialysis device.

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A mature and adequately functioning AVF delivers ≥ 600 mL/min; typical dialysis device exchange volumes require between 300-500 ml/min.. Triplex ultrasound examination is the optimal method for the evaluation of the adequate functioning of the AVF [Figures 1 and 2]

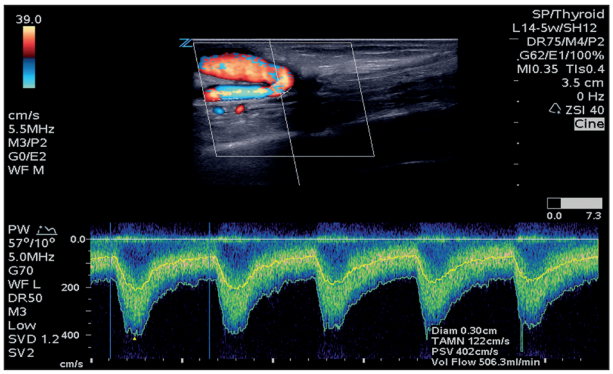

FIGURE 1. Triplex findings at a normal anastomosis. PSV 402 cm/sec, Volume flow 506 mL/min.

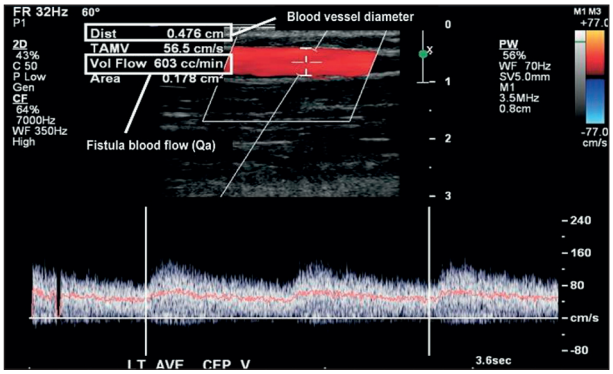

FIGURE 2. Normal mid-graft triplex findings. PSV 120 cm/sec, volume flow 603 mL/min.

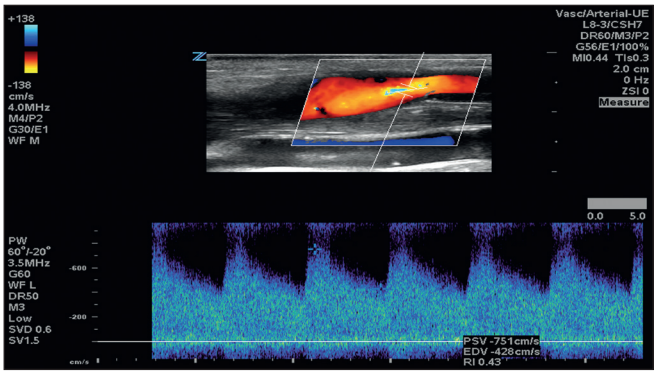

FIGURE 3. Triplex findings in a mid-graft stenosis. CDI-directed PW Doppler demonstrate PSV >700 cm/sec, EDV >400 cm/sec.

LATE FAILURE OF AVF

Late failure of an AVF is defined as the inability to use the conduit after at least three months of use. Primary, or early, failure occurs prior to its use or within three months of its use and is not discussed in this article.

The main cause of late failure is vascular stenotic lesions leading to decreased flow volume, inadequate dialysis and eventual occlusive thrombosis. Most stenotic lesions occur at or near the arterial anastomosis. However, focal lesions may also occur at the site of repeated needle cannulation. [Figure 3] Thrombosis in the central venous outflow tract (cephalic venous arch) can also lead to AVF dysfunction and eventual failure. Other causes of failure include vascular steal and aneurysms [2].

IDENTIFICATION OF STENOSIS

Accurate identification of the cause and location of a significant stenosis is essential if the AVF is to be salvaged using either catheter-based or surgical interventional methods. Triplex ultrasound evaluation is the method of choice and has become the gold standard for initial evaluation of a dysfunctional AVF. The integration of high resolution B-mode, color Doppler imaging (CDI), and quantitative pulsed-wave (PW) Doppler tracings permit comprehensive assessment of both the anatomic and hemodynamic status

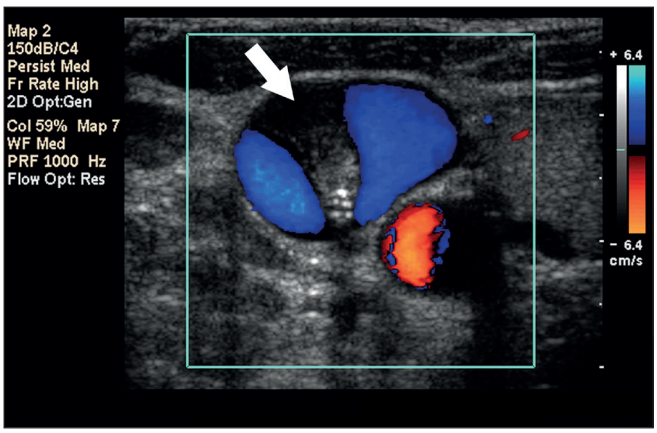

FIGURE 4. Venous outflow thrombosis. Non-occlusive echogenic clot is seen in the central lumen of the internal jugular vein (arrow)..

of arterial inflow, full length of the AVF, and venous outflow. The superficial location of AVFs makes these ideally suited for imaging with high frequency linear array transducers that provide exceptional B-mode spatial resolution, enhanced CDI sensitivity and minimized effects of aliasing on the PW Doppler tracing.

Another sonographic criterion that is useful in assessing the functionality of an AVF is volume flow measurement. Software algorithms that integrate conduit diameter and the time average velocity (TAV) of blood flow within using color Doppler imaging can calculate an estimated volume of flow (mL/min). Because of limitations in traditional beam former technology and variance in methods of measuring TAV, there is poor statistical correlation between ultrasound obtained flow volumes and those obtained from control flow phantoms. Normal values in an adequately functioning AVF vary widely from 600-1500 mL/min. Most authors accept 600 mL/min as the minimum value for successful utilization of an AVF.

Ultrasound criteria in late AVF failure:

- PSV ratio (anastomosis: 2cm upstream): >3:1 suggests >75% anastomotic stenosis
- B-mode suggests venous stenosis (AP Diameter <3 cm)
- Volume flow <500 ml/min should lead to fistulogram
- Steal is present if PW waveforms augment during AVF compression

TABLE 1. Ultrasound criteria in late AVF failure.

Emerging ultrasound technologies, such as ZONE Sonography Technology, which perform volume flow calculations directly on channel domain data and not on a gain-dependent spectral Doppler waveform, permit more precise and reproducible data points.

Identification of significantly stenotic areas either at the anastomosis or along the length of the AVF is accomplished using CDI-directed PW Doppler criteria [Table 1]; venous outflow stenoses are best assessed with B-mode imaging. [Figure 4]. Frequently, ultrasound findings alone can provide the information necessary to make patient management decisions and plan any intervention necessary to salvage an AVF. This is particularly true for anastomotic and upstream areas. Identification of thrombosis or stenosis in the venous outflow conduits in the axilla or neck usually requires a contrast fistulogram for further assessment.

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