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Estimation of brachial artery volume flow by duplex ultrasound imaging predicts dialysis access maturation

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Objective: **This study validated duplex ultrasound measurement of brachial artery volume flow (VF) as predictor of dialysis access flow maturation and successful hemodialysis.**

Methods: **Duplex ultrasound was used to image upper extremity dialysis access anatomy and estimate access VF within 1 to 2 weeks of the procedure. Correlation of brachial artery VF with dialysis access conduit VF was performed using a standardized duplex testing protocol in 75 patients. The hemodynamic data were used to develop brachial artery flow velocity criteria (peak systolic velocity and end-diastolic velocity) predictive of three VF categories: low (<600 mL/min), acceptable (600-800 mL/min), or high (>800 mL/min). Brachial artery VF was then measured in 148 patients after a primary (n = 86) or revised (n = 62) upper extremity dialysis access procedure, and the VF category correlated with access maturation or need for revision before hemodialysis usage. Access maturation was conferred when brachial artery VF was >600 mL/min and conduit imaging indicated successful cannulation based on anatomic criteria of conduit diameter >5 mm and skin depth <6 mm.**

Results: **Measurements of VF from the brachial artery and access conduit demonstrated a high degree of correlation ($R^2 = 0.805$) for autogenous vein (n = 45; $R^2 = 0.87$) and bridge graft (n = 30; $R^2 = 0.78$) dialysis accesses. Access VF of >800 mL/min was predicted when the brachial artery lumen diameter was >4.5 mm, peak systolic velocity was >150 cm/s, and the diastolic-to-systolic velocity ratio was >0.4. Brachial artery velocity spectra indicating VF <800 mL/min was associated ($P < .0001$) with failure of access maturation. Revision was required in 15 of 21 (71%) accesses with a VF of <600 mL/min, 4 of 40 accesses (10%) with aVF of 600 to 800 mL/min, and 2 of 87 accesses (2.3%) with an initial VF of >800 mL/min. Duplex testing to estimate brachial artery VF and assess the conduit for ease of cannulation can be performed in 5 minutes during the initial postoperative vascular clinic evaluation.**

Conclusions: **Estimation of brachial artery VF using the duplex ultrasound, termed the "Fast, 5-min Dialysis Duplex Scan," facilitates patient evaluation after new or revised upper extremity dialysis access procedures. Brachial artery VF correlates with access VF measurements and has the advantage of being easier to perform and applicable for forearm and also arm dialysis access. When brachial artery velocity spectra criteria confirm a VF >800 mL/min, flow maturation and successful hemodialysis are predicted if anatomic criteria for conduit cannulation are also present. (J Vasc Surg 2015;61:1521-8.)**

The challenges of dialysis access flow maturation prompted our vascular group to evaluate the clinical value of volume flow (VF) measurements in the early postoperative period to predict successful hemodialysis usage. By using duplex ultrasound, nonmaturing accesses would be identified by low VF values, and imaging of the arterial anastomosis and conduit could be used to direct the type of remedial procedure necessary.[1,2] Although the National Kidney Foundation Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines recommend monthly surveillance of VF to identify low flow (<600 mL/min) accesses, the assessment of access patency and maturation is still largely based on clinical assessment (presence of thrill and visual inspection of the conduit for ease of cannulation); that is, the "look, touch, and auscultation" assessment.[3] Threshold VF values for newly constructed autogenous dialysis access have not been established, but effective hemodialysis during a 3-to 4-hour session with a circuit flow of 350 to 450 mL/min requires an access flow twice that level (ie, in the >800 mL/min range).[3] It is generally accepted an access VF of <600 mL/min is low, associated with ineffective hemodialysis, and is at increased risk for thrombosis.[4,5]

Measurement of dialysis access VF using duplex ultrasound imaging is a validated technique compared with flowmeters and has been used to document flow changes with access maturation, predict thrombotic risk, and verify VF increases after secondary interventions.[2,6-9] The VF

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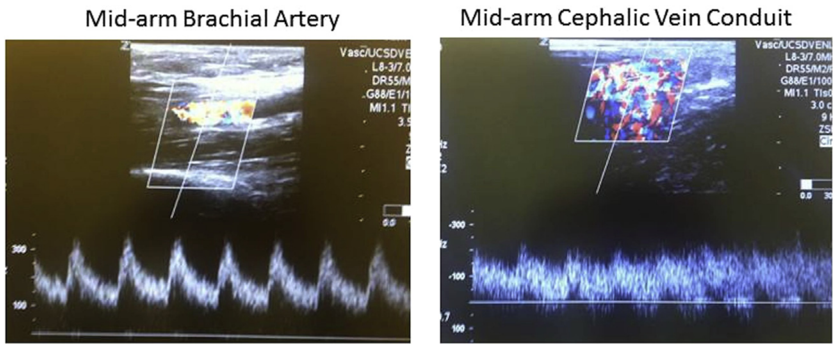

Fig 1. Pulsed Doppler velocity spectra recorded from the midarm brachial artery and cephalic vein conduit of a brachial-cephalic dialysis access fistula. Note, there is a less disturbed flow pattern in the brachial artery compared with spectral broadening of flow turbulence in the vein conduit.

measurement is typically made from access conduit vein or a prosthetic bridge graft using a standardized protocol of operator measurement of lumen diameter, Doppler angle-corrected velocity spectra recording using a sample volume that encompasses the flow lumen, and duplex instrumentation software to calculate VF.

Our group has evolved to using the brachial artery velocity spectra waveform to estimate access VF due to its advantages of less turbulent blood flow at the recording site, ease of brachial artery imaging, and applicability to assess arm and forearm dialysis accesses. We have demonstrated the feasibility of this testing in the outpatient clinic setting—referring to the assessment as the "Fast, 5-min Dialysis Duplex Scan" of dialysis maturation.[1] In this study, we sought to validate use of the brachial artery for the estimation of access VF by correlating simultaneous measurements obtained from autogenous vein and bridge grafts and developing brachial artery velocity spectra criteria predictive of a low (600 mL/min), acceptable (600-800 mL/min), and high (>800 mL/min) dialysis access flow. These brachial artery VF categories were then applied to a consecutive series of patients after a new, primary (first access in the upper extremity), or a revised (redo access or revision of a nonfunctional access) dialysis access procedure. Duplex testing was performed in the early postoperative period with the objective to confirm a VF level predictive of dialysis access flow maturation and subsequent effective hemodialysis usage.

METHODS

Our Vascular Quality Initiative (VQI) database of patients undergoing dialysis access procedures and postoperative duplex ultrasound testing was retrospectively queried. Use of patient data and test results was under the category of secondary use of pre-existing data as defined by the Institutional Review Board and the Health Insurance Portability and Accountability Act.

Duplex ultrasound was used to image upper extremity dialysis access anatomy and estimate VF after an upper extremity dialysis access procedure. VF measurements were recorded in 75 patients (30 women, 45 men) from the inflow brachial artery proximal to the anastomosis and the midaccess vein conduit (n = 40) or prosthetic graft (n = 35) using a linear array transducer, duplex instrumentation (GE Logic 9 ultrasound system; GE Medical Systems, Milwaukee, Wisc) and VF software. Recording sites were remote from the anastomosis and were selected in a segment of constant diameter and least disturbed flow turbulence.

As shown in Fig 1, the velocity spectra recording from the brachial artery demonstrate less disturbed flow than a recording for the venous conduit of a brachial-cephalic vein dialysis access fistula. The VF levels were correlated with each other and used to develop brachial artery velocity spectra criteria (peak systolic velocity [PSV] and end-diastolic velocity [EDV]) predictive of three VF categories: low (<600 mL/min), acceptable (600-800 mL/min), or high (>800 mL/min). The VF measurements were performed using a standardized protocol of vessel lumen diameter measurement, 60° pulsed-Doppler angle-corrected velocity spectral recordings, operator-adjusted sample volume size to encompass the vessel lumen cross-sectional area, and duplex instrument software calculation of VF using the time-averaged velocity (TAV) over a 3-pulse cycle; where VF = TAV × cross-sectional area. PSV and diameters were also recorded at brachial and access conduit recording sites.

In an additional 148 patients (59 women, 89 men), a duplex ultrasound (Ultra SP scanner, 8-3 MHz linear array transducer; Zonare, Mountain View, Calif) evaluation was performed in the outpatient vascular clinic to image access conduit anatomy and estimate brachial VF ≤2 weeks of a primary (n = 86) or revised (n = 62) dialysis access procedure. In the primary dialysis access group, 34 of the 86 procedures (40%; all autogenous vein access) were performed before dialysis on patients referred from nephrology with stage IV end-stage renal disease and the expectation of requiring dialysis within several months. All patients had undergone preoperative vein mapping. In the revised dialysis access group, low access flow was the most common indication for revision (Table I). Revision of an existing or construction of a new bridge graft access was performed in 33 of 62 patients (53%).

Duplex testing was performed with the patient seated in a chair and the arm resting on an examination table.