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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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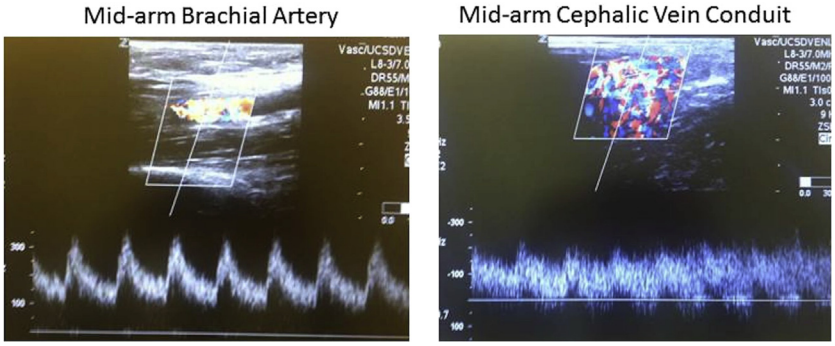

Fig 1. Pulsed Doppler velocity spectra recorded from the midarm brachial artery and cephalic vein conduit of a brachial-cephalic dialysis access fistula. Note, there is a less disturbed flow pattern in the brachial artery compared with spectral broadening of flow turbulence in the vein conduit.

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.

Table I. Indication for dialysis access revision in 62 patients

Indication for revision	*No.*
Low VF (<600 mL/min)	24
Bleeding/infection	13
Thrombosis/failed thrombolysis	10
Conduit aneurysm	9
Infection	2
Unable to cannulate conduit	2
Arterial steal with hand ischemia	2

VF, Volume flow.

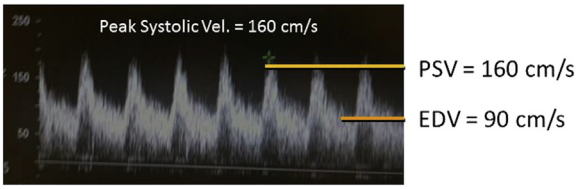

Fig 2. Brachial artery velocity spectral waveform recorded using a 60° Doppler angle and center-stream pulsed-Doppler sample volume location. The value of peak systolic velocity (*PSV*) and end-diastolic velocity (*EDV*) are estimated by visual inspection of the waveform. Note the values selected are within, not above, the pulsed Doppler spectral waveform.

Access VF was determined from a brachial artery velocity spectra (60° Doppler angle, center-stream pulsed Doppler volume) recording (Fig 2), visual inspection of the spectral waveform for measurement of PSV and EDV, and calculation of artery diameter from the B-mode image. The PSV and EDV values are selected from within the spectral waveform at peak systole and end diastole to more closely approximate the TAV. The highest PSV transient in the spectral waveform envelope should not be used because this value would contribute to overestimation of VF. Calculation of the pulse cycle TAV can be made using the formula: TAV = EDV + 1/3 (PSV−EDV).[1] VF can be estimated by TAV × cross-sectional area or from the values of the brachial artery PSV, the EDV/PSV ratio, and artery diameter. VF was classified in three categories: low (<600 mL/min), acceptable (600-800 mL/min), or high (>800 mL/min).

B-mode imaging of the access conduit was also performed for ease of cannulation based on conduit diameter >5 to 6 mm, skin depth <0.6 mm, and superficial conduit length >10 cm. The presence of large, patent venous side-branches ≤10 cm of the artery-vein anastomosis was also noted. Because the time required to complete this limited duplex study was typically less than 5 minutes, we refer to this evaluation as the "Fast, 5-min Dialysis Duplex Scan."

Data analysis. Values are expressed as mean ± standard deviation or standard error of the mean, where appropriate. The Student *t*-test was used to compare continuous variables (VF, PSV, and diameter). The χ^2 test was used to compare categoric variables. Correlation of the brachial artery with access conduit VF measurements was performed using a scatter plot of values. Standard least squares linear regression analysis and the correlation coefficient (R^2) were used to compare simultaneous VF measurements from the brachial artery and access conduit.

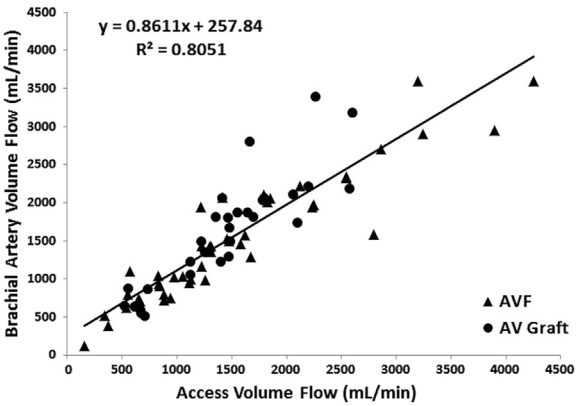

Fig 3. Scatter plot of brachial artery vs access conduit volume flow (VF) measurements in 75 patients with an autogenous vein fistula (*AVF*, n = 40) or arteriovenous (*AV*) bridge graft (n = 30). Linear correlation coefficient (R^2) was 0.8051.

RESULTS

Validation of brachial artery VF in 75 patients. A scatter plot (Fig 3) of brachial artery and access conduit VF measurements recorded during a duplex evaluation of dialysis access function demonstrated a high degree of correlation ($R^2 = 0.805$, $y = 0.86x + 258$. The linear correlation coefficient was similar for autogenous vein (n = 45; $R^2 = 0.80$) and bridge graft (n = 30; $R^2 = 0.78$) dialysis accesses. Brachial artery diameter was a mean (standard deviation) of 6.1 ± 1.4 mm (range, 4.1- 9 mm), and vein conduit diameter was a mean of 7.0 ± 3.1 mm (range, 3.7-17 mm). PSV was higher ($P <$ .05) in the brachial artery (214 ± 77 cm/s) than in the vein (180 ± 94 cm/s) or bridge graft (202 ± 84 cm/s) conduits. For VFs in the >800 mL/min category (1780 ± 690), brachial artery PSV was 239 ± 69 cm/s, which was significantly higher ($P <$ .001) than the PSV (128 ± 13 cm/s) accesses with 600 to 800 mL/min flow (711 ± 21 mL/min), and the PSV (94 ± 13) in accesses with <600 mL/min flow (509 ± 70 mL/min; Fig 4). A PSV/EDV ratio of >0.4 correlated with a VF measurement of >800 mL/min in the brachial artery.

This analysis resulted in the use of PSV and EDV/PSV ratio criteria to define three clinically relevant VF categories to interpret brachial artery velocity spectra during the Fast, 5-min Dialysis Duplex Scan (Fig 5) when the brachial artery diameter is estimated to be ≥4.5 mm: low: <600 mL/min, VF−PSV <100 cm/s, EDV/PSV ratio <0.2; acceptable: 600 to 800 mL/min,

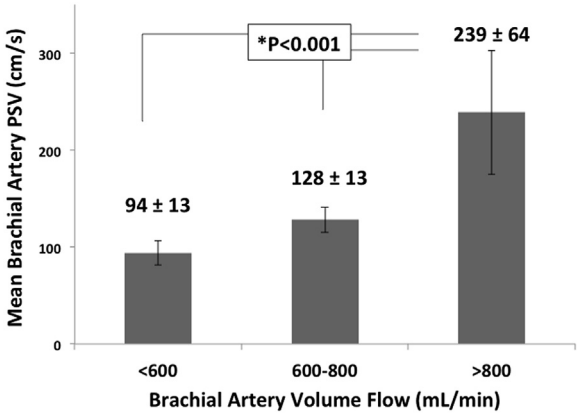

Fig 4. Brachial artery peak systolic velocity (*PSV*) relative to volume flow (VF) category. PSV was higher in the >800 mL/min category. Data are shown as mean ± standard deviation.

VF−PSV <150 cm/s, EDV/PSV ratio of 0.2 to 0.4, and high: >800 mL/min, VF−PSV >150 cm/s, EDV/PSV ratio >0.4.

Application of the Fast, 5-min Dialysis Duplex Scan. The fast, 5-min Dialysis Duplex Scan performed in 148 consecutive patients after primary or revised dialysis access procedures demonstrated brachial artery velocity spectra predictive of access VF >600 mL/min in 86% of patients—70 of 86 primary (81%) and 58 of 62 (93%) revised dialysis accesses (Table II). High (>800 mL/min) VF was recorded more frequently after revised bridge graft access procedures (88% [29 of 33]) than after a predialysis autogenous vein fistula (35% [12 of 34]). The VF data demonstrated access flow was related to vein outflow diameter with a greater proportion of brachial-basilic accesses in the high >800 mL/min VF category (57% [20 of 35]) compared with brachial-cephalic (47% [19 of 40]) and radial-cephalic (21% [7 of 32]) autogenous vein accesses ($P <$ .05). The conduit imaging portion of the Fast, 5-min Dialysis Duplex Scan identified only three patients with brachial artery VF >600 mL/min and conduit anatomy problematic for cannulation based on a skin depth >0.6 mm or large vein conduit side branches.

Brachial artery velocity spectra indicated access VF < 800 mL/min was associated with maturation failure and access revision before release for hemodialysis. The revision rate was higher ($P <$ .0001) in low-flow (<600 mL/min) accesses (15 of 21 [71%]) compared with four of 40 accesses (10%) with a VF of 600 to 800 mL/min, and two of 87 accesses (2.3%) with an initial VF of >800 mL/min (Tables III and IV). A sclerotic vein segment producing low access VF was the most common indication for access revision and was treated by balloon angioplasty or open repair. The incidence of revision after primary autogenous vein dialysis access was highest after brachial-cephalic anastomosis (26% [9 of 35]) compared with brachial-basilic transposition (14% [3 of 22]) and radial-cephalic (9% [2 of 21]) fistulas. Of note, only one of 34 bridge grafts required revision due to low flow before hemodialysis usage. One patient who underwent a redo brachial-brachial bridge graft procedure and access VF of 600 to 800 mL/min required ligation due to concomitant arterial steal (hand ischemia) and central vein occlusion (limb edema).

The VF of autogenous dialysis accesses was observed to increase in three patients with initially low <600 mL/min VF to the 600 to 800 mL/min category on serial testing. Autogenous vein accesses with VF >600 mL/min were typically released for hemodialysis after 8 to 12 weeks of maturation and healing; whereas new or revised bridge grafts had cannulation at 2 days to 3 weeks, depending on polytetrafluoroethylene graft type. The access in eight of the 31 predialysis patients was approved for cannulation based on duplex scan findings, but the decision to proceed with hemodialysis was pending at the time of this analysis.

DISCUSSION

An important quality initiative in caring for the end-stage renal disease patient on dialysis or needing dialysis in the future is maturation of an autogenous vein fistula.[10,11] This requires preprocedural vein mapping, use of vein transposition techniques to superficialize basilic or brachial veins, and duplex ultrasound testing to verify access maturation. Access VF is a crucial hemodynamic parameter and needs to be >600 mL/min, a level that predicts successful dialysis and long-term patency. In the validation portion of this study, the use of duplex ultrasound imaging to measure access conduit VF demonstrated values ranging from <400 mL/min to 4000 mL/min. We had two goals in developing the Fast, 5-min Dialysis Duplex Scan: to simplify the estimation of access VF and to make the clinical assessment of dialysis access maturation more objective.

The validation study confirmed a high correlation of brachial artery VF with access conduit VF over the range encountered in clinical practice, including identification of the low flow (<600 mL/min) dialysis access. Use of the brachial artery velocity spectra to assess dialysis access hemodynamics and maturation has been previously reported and is suggested as a recording site in the K/DOQI practice guidelines.[3,5] Using the brachial artery as the VF recording site has several advantages, including its deeper tissue location, which facilitates diameter measurement and use of a 60° pulsed-Doppler angle correction, less turbulent blood flow, and the absence of surgical site hematoma or edema. In excess of 90% of brachial artery flow is diverted into the low outflow resistance dialysis access circuit, and the brachial artery is the preferred site to measure VF of the wrist radiocephalic fistula because the ulnar artery contributes to access flow in >50% of patients.[5] Measurement of VF from only the inflow radial artery would therefore underestimate access VF. Our experience in the outpatient clinic has been that the duplex recording and visual inspection of the brachial artery velocity spectral waveform is easy to perform and interpret, and in selected patients (ie, predialysis and

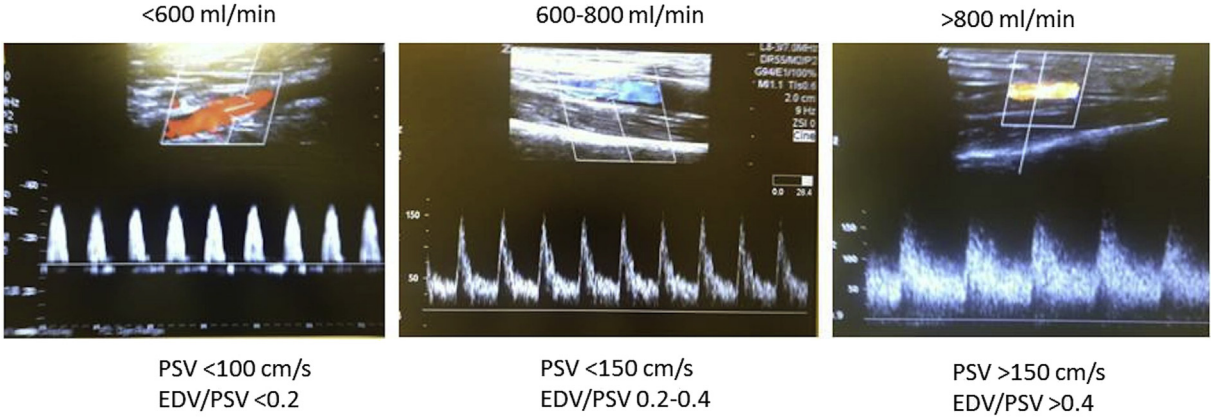

Fig 5. Representative images of brachial velocity spectra waveforms and velocity spectra criteria used to define the three volume flow (VF) categories: low, <600 mL/min; acceptable, 600 to 800 mL/min; and high, >800 mL/min. *EDV,* End-diastolic velocity; *PSV,* peak systolic velocity.

Table II. Estimated brachial artery volume flow (*VF*) after 86 primary (predialysis, on-dialysis) and 62 revised (autogenous vein, bridge graft) dialysis access procedures

		Estimated VF, mL/min		
Access procedure	*No.*	*<600, No. (%)*	*600-800, No. (%)*	*>800, No. (%)*
Primary				
Predialysis	34	6	16	12
On dialysis via a cuffed catheter	52	11	16	25
Revised				
Autogenous vein	29	3	5	21
Bridge graft	33	1	3	29
Total	148	21(14)	40 (27)	87 (59)

on-dialysis cohorts), provides useful, objective hemodynamic information in the early period about dialysis access maturation, which is not available by clinical assessment alone.

Most patients undergoing a successful upper extremity dialysis access procedure based on clinical assessment will have a duplex-measured VF >600 mL/min. In our experience, the time to maturation (ie, release of the access for hemodialysis) was similar for forearm (radial-cephalic) and arm (brachial-cephalic, brachial-basilic) autogenous vein fistulas with acceptable (600-800 mL/min) or high (>800 mL/min) VF. Only three of 61 patients required revision after a primary autogenous vein access when duplex testing confirmed VF >600 mL/min and anatomy appropriate for cannulation. Essentially all bridge graft accesses (new or revised) had VF >800 mL/min, and only one patient did not proceed to dialysis due to arterial steal and limb edema requiring access ligation. All patients with primary and revised autogenous vein accesses were eventually released for hemodialysis.

When the Fast, 5-min Dialysis Duplex Scan identified low (<600 mL/min) VF, a complete duplex scan of the dialysis access reconstruction should be performed. In this study, a sclerotic vein segment has the most frequent abnormality identified; and testing resulted in access revision postponing access maturation by ~1 month. The most common secondary procedures were a brachial-basilic vein transposition or polytetrafluoroethylene bridge graft in the same upper extremity. The two patients requiring distal revascularization-interval ligation procedures had high VF before and after the procedure to relieve hand ischemia.

The Fast, 5-min Dialysis Duplex Scan was developed to provide the access surgeon with an easy method to estimate VF, an important hemodynamic predictor of access maturation. The duplex imaging skills to perform the study are easily mastered and are similar to an intraoperative duplex assessment after carotid endarterectomy. The brachial artery is imaged, and a Doppler angle-corrected pulsed-Doppler recording of brachial artery flow is obtained. The PSV value and the EDV/PSV ratio are used to classify access flow as low, acceptable, or high; the latter category is predictive of flow maturation.

Visual inspection of the velocity spectral waveform is sufficient to determine PSV and estimate the EDV/PSV, where a value of >0.4 indicates low outflow resistance. In brachial arteries with a diameter of ≥4.5, a PSV >150 cm/s with a diastolic/systolic velocity ratio >0.4 correlates with >800 mL/min VF.[1] As the diastolic-to-systolic ratio decreases, so does VF. Low access flow due to a sclerotic venous outflow is characterized by a brachial artery PSV <100 and diastolic-to-systolic ratio <0.2, and a contrast fistulogram should be obtained to identify and repair all >50% diameter-reducing stenoses. If the cause of low flow is a small-caliber <5 mm vein, balloon-assisted maturation can be performed by percutaneous transluminal angioplasty. Duplex testing can be performed

Table III. The incidence of dialysis access revision (n = 14) relative to access type and estimated volume flow (*VF*) category in 34 predialysis and 42 on-dialysis patients

		Estimated VF, mL/min			
Access type	*No.*	*<600*	*600-800*	*>800*	*Total revisions, No.*
Predialysis					
Radial-cephalic	12	–	10	2	0
Brachial-cephalic	15	4	4	7	
Revision		3 Low flow		1-PTA sclerotic vein	4
Brachial-basilic	7	2	2	3	2
Revision		1 Low flow 1 Thrombosis			
On dialysis					
Radial-cephalic	9	2	4	3	2
Revision		2 Low flow			
Radial-basilic transposition	1		1		
Brachial-cephalic	20	6	6	8	5
Revision		3 Low flow	1 Central vein stenosis	1 Side-branch ligation	
Brachial-basilic	15	3	5	7	1
Revision		1 Low flow			
Bridge graft	7			7	

Table IV. The incidence of dialysis access revision (n = 7) relative to access type and estimated volume flow (*VF*) category in 62 patients after a dialysis access revision procedure

		Estimated VF, mL/min			
Revised access type	*No.*	*<600*	*600-800*	*>800*	*Total revisions, No.*
Redo dialysis access	12		1	11	–
Vein	10				
Bridge graft	2				
DRIL procedure	2			2	–
Cephalic vein transposition	2	1	1		2
Revision		1 Angioplasty	1 Low-flow		
Basilic vein transposition	8	2	2	4	3
Revision		2 Low flow	1 Depth >6 mm		
Vein patch/inter brachial-cephalic	5		1	4	
Bridge					
Interposition	13		1	12	
Radial-cephalic	1			1	
Brachial-brachial	19	1	2	16	2
Revision		1 Low flow	Ligation		

DRIL, Distal revascularization—interval ligation procedure.

immediately after a secondary intervention to verify an increase in brachial artery VF.

The experience gleaned from this study suggests an early duplex evaluation is most likely to benefit patients undergoing construction of an autogenous vein dialysis access fistula. In patients on dialysis via a cuffed dialysis catheter, the Fast, 5-min Dialysis Duplex Scan may reduce time to catheter removal by early identification of patients with low-flow accesses. In our experience, this occurred in ~20% of patients undergoing a first upper extremity (primary) dialysis access placement. Testing can be performed using any duplex ultrasound instrument with color and pulsed Doppler capability. In the vascular laboratory, use of the brachial artery as a recording site for VF estimate should be included in testing protocols for dialysis access evaluation (Current Procedural Terminology code 93990 [American Medical Association, Chicago, Ill]).

The estimation of VF is more reproducible when a recording site with less disturbed flow (ie, turbulence), patterns is used. VF should not be measured at or in the region of anastomoses or at sites of stenosis because of turbulent flow conditions that grossly overestimate VF. Also, examination time can be reduced because the need for multiple VF measurements from the vein or bridge graft conduit is not necessary.

After dialysis access construction or a revision procedure, duplex testing should be performed before hemodialysis is initiated.[12,13] Using the limited duplex scan detailed in this study, the access surgeon can easily verify a VF sufficient for dialysis, confirm appropriate conduit anatomy for

cannulation, and identify other conditions such as large vein conduit side branches that impair access maturation and vein wall thickening (ie, arterialization). Thereafter, the need for duplex surveillance requires a medical indication. Any sign of access dysfunction, such as cannulation difficulty or poor thrill, is an indication for duplex testing.

CONCLUSIONS

The hemodynamic flow data detailed in this study provide surgeons and vascular laboratory staff with expected values after autogenous vein and bridge grafts accesses. Further validation of the Fast, 5-min Dialysis Duplex Scan is necessary, but its application after access construction is supported by current K/DOQI clinical practice guidelines, which recommend access conduits meet the 6-6-6 criteria (>600 mL/min flow, ≥6 mm in diameter, and <6 mm skin depth).[3]

AUTHOR CONTRIBUTIONS

Conception and design: DB, KHH, SK
Analysis and interpretation: DB, SK, KHH, JL, AB
Data collection: DB, SK, KHH AB
Writing the article: DB, SK
Critical revision of the article: JL, AB
Final approval of the article: DB, KHH, SK, JL, AB
Statistical analysis: DB, AB
Obtained funding: Not applicable
Overall responsibility: DB

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DISCUSSION

Dr Willis H. Wagner (*Los Angeles, Calif*). The study presented by Dr Ko from a collaboration between the University of California-San Diego group and their affiliated Kaiser colleagues investigated a novel, rapid technique to assess dialysis access volume flow and stratify patients at risk for early failure of maturation due to structural abnormalities. Using a 5-minute abbreviated duple ultrasound examination of the brachial artery, the authors demonstrated a high correlation between calculated brachial artery flow and flow through both native fistulae and bridge grafts originating from either the brachial or radial arteries. In fact, the correlation between brachial and access flows appeared even tighter in the clinically important group with volume flow of less than 800 mL/min. Using brachial artery peak systolic and end-diastolic velocities, the authors were able to categorize patients into groups with low, adequate, and high flow accesses. The study group was rather heterogeneous including patients who were undergoing primary access creation as well as patients undergoing revision for reasons other than flow problems, such as infection, bleeding or aneurysms. This is a very intriguing pilot study and could potentially simplify our post-op evaluation of these challenging dialysis access patients. Our own protocol includes a complete duplex evaluation by the vascular lab at 4 to 6 weeks post-op. This thorough exam takes 20 to 40 minutes depending on the patient's anatomy. We do not perform any post-op imaging of bridge grafts. This leads to my first question:

It appeared that all of your primary bridge graft patients had high flows and none needed revision. Do you see any merit to this exam in a patient with good caliber arteries and veins who undergoes a bridge graft and returns to your clinic with a good thrill? Similarly, why study a patient with a well-functioning graft or fistula who has a revision for infection or bleeding?

My second question concerns how is patient care altered when a low-flow dialysis access is identified? Have you done any analysis of the anatomic abnormalities found in the patients with low flow? Many experts have questioned whether the emphasis on all-autogenous access has resulted in too many operations on patients whose fistulae never mature. The key clinical question is could you have identified any factors on your pre-op imaging that would have reliably predicted subsequent low flow?

Finally, considering that some of your patients with brachial artery hemodynamics consistent with low flow improved with time, what do you currently do with a patient who presents with low flow on the first post-op scan?

Dr Sae Hee Ko. Thank you for the review of our manuscript and for your questions. The objectives of our study were to validate duplex ultrasound measurement of brachial artery volume flow , referred to as the "Fast, 5-min Dialysis Duplex Scan," and

then use this new diagnostic method to confirm newly constructed or revised dialysis accesses had sufficient volume flow and cannulation anatomy for successful hemodialysis usage. We believe the brachial artery is the proper site to estimate dialysis access volume flow, being easy to image and record the velocity spectra waveform, a predictable diameter range (4-6mm), and its less turbulent flow than the more superficial vein or prosthetic conduits.

We confirmed a high correlation between simultaneous brachial artery and access volume flow measurements in 30 patients following dialysis access bridge grafting and 45 patients with autogenous fistulas, indicating volume flow estimated from a brachial artery recording site can be used to assess dialysis flow maturation. This "Fast, 5-min Dialysis Duplex Scan" was then used clinically in 148 consecutive patients following primary access construction or revision of existing dialysis access estimating volume flow based on the waveform values of brachial artery peak systolic velocity (PSV), end diastolic velocity (EDV), and the ratio of EDV/PSV ratio. This limited duplex scan also included imaging the access conduit to examine the depth from skin surface, confirm adequate cannulation, and assess for hematoma, and large vein side branches diverting access flow. Dialysis access flow was classified into "low", "acceptable," or "high" flow categories. "Low" flow, i.e. <600 ml/min, access has a brachial artery PSV < 100cm/s, EDV/PSV < 0.1; while "High" flow, i.e. >800 ml/min, accesses have a brachial artery PSV >150 cm/s, EDV/PSV > 0.4.Of the 148 patients, 21 (14%) patients had low flow access; and of these, 15 (71%) patients required revision prior to successful hemodialysis usage.

In response to your questions:

1. It is true than dialysis bridge grafts are associated with high-volume flow and the value of an early duplex scan is less in this patient cohort. The yield of early duplex scanning is most beneficial after autogenous dialysis access placement – to confirm flow maturation (>800 ml/min) and identify cannulation problems. Patients with a well-functioning access that undergo revision for infection or bleeding may benefit from an early scan if the access configuration was changed or surgical site healing problems are evident.
2. The most common structural abnormality found in patients with low flow access was a sclerotic or small caliber vein segment. All of our patients received preoperative vein mapping, using cephalic or basilic veins ≥3mm in diameter. We did not identify any ultrasound features on preoperative imaging other than vein diameter that predicted subsequent low flow.
3. When a "low-flow" dialysis access is identified at the first clinic visit, we scan the access conduit for an anatomic problem, and if identified, revision is recommended. If only a small caliber is imaged, surveillance with a repeat duplex scan in 4 weeks is recommended. We did observe in several patients that access flow increased with time, but typically the fast 5-minute duplex scan performed 1 to 2 weeks after the procedure identified potential maturation problems including low flow, access stenosis, large side branches, inadequate vein diameter, or depth greater than 6 mm for cannulation. We believe early duplex scanning can expedite dialysis access maturation by early revision of those accesses with low-volume flow. A high-flow access confirmed at the initial duplex scan predicted subsequent successful hemodialysis.