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All Sites	VAS-DP-21	Kelly Swagell	
Title		Version Date	Version Number:
Arterio-venous fistula ultrasound		Dec 2021	1.1

### Scope & purpose

Duplex ultrasound is used to assess the function of arterio-venous fistulae (AVF) for Haemodialysis.

Common indications for performing this examination include:

- Post-op. surveillance
- Failure to mature (on basis of physical appearance)
- ? failing or non-functioning AVF
- Difficulty accessing for dialysis
- Suspected steal syndrome
- Arm swelling
- ? aneurysm or false aneurysm
- Post intervention, e.g. angioplasty

### Personnel

Clinical vascular scientists (CVS), including trainees.

### Principles / performance characteristics

The aim of the scan is to assess the function of arterio-venous fistulae (AVF). This includes the evaluation of inflow, outflow, identification of large competing vein branches, and assessment of the depth from the skin surface.

An arterio-venous fistulae can be achieved with the patient's native vessels or with the use of a prosthetic graft (AVG). The principles of the scan remain the same with either type of fistula.

One of the key principles is to assess the Volume Flow Rates (VFR). Normally, high velocity flow and low resistant waveforms are encountered in the 'feeding' artery and fistula. For adequate dialysis, the fistula should ideally measure >0.5cm diameter with an estimate VFR of at least 600L/min. When less than 300 to 400mL/min, the fistula may not be maturing or obstruction may be present (ref 1). To maintain patency VFRs in a graft should be higher than for native fistulae, possibly in excess of 800mL/min. A VFR of <500mL/min is considered abnormal, and <=600mL/min indicates impending risk of thrombosis. VFR may be considered pathologically high if exceeding around 2L/min in conjunction with symptoms (e.g. shortness of breath) (ref 2).

### Service users & background

Patients referred for this type of scan will be under the care of the renal team. The scan will be fundamental in the management of patients who have chronic kidney disease and require or will require a fistula for haemodialysis.

There are few contraindications for AVF assessment; however, limitations may include the following:

- Recent bleeding from the access site
- Very aneurysmal or tortuous fistula
- Raised BMI
- Severe oedema/swelling
- Dressings, casts, open wounds, staples, haematoma etc.

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- Acoustic shadowing
- Patients who are unable to cooperate due to reduced cognitive functions e.g. Alzheimer's or dementia and through involuntary movements
- Examinations undertaken at the patient's bedside may be limited due to equipment and room dimensions
- Patient discomfort

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### Facilities, equipment & special supplies

Duplex ultrasound machine with both linear and curvilinear transducers available. There should be a selection of transducers delivering a wide range of frequencies (high and low).

The examination couch should be height adjustable. The CVS's chair should provide good lumbar support, be height adjustable and allow for the CVS to move close to the examination couch.

Cleaning materials should be available in line with local and manufacturer's guidelines. These are available either in each procedure room or located in the laboratory store room.

### Calibration

Across all sites annual calibration and safety checks of the ultrasound equipment are performed by Clinical Engineering (Trust contract with GE Healthcare).

### Quality control

Second opinions from vascular scientist colleagues are requested routinely if clarification is sought.

Trainee vascular scientists have all AVF scans checked until they are signed off by a senior colleague for competency.

### Environmental & safety controls

Infection control procedures followed in accordance with Trust infection control and risk assessment policies – Please see 'Personal Protective Equipment (PPE) for infection prevention and control' policy, 'Hand Hygiene' policy and 'Staff Risk Assessments' which are all available through the Trust Intranet.

Tristel wipes are for cleaning the ultrasound machines and probes after patient use. Universal Clinell wipes are for cleaning all other equipment. Where high risk infection presents or post-op wounds are present use probe covers with sterile gel or Tegaderm dressings, in addition to routine cleaning.

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### Arterio-venous fistula ultrasound protocol (ref 1, 2 and 3)

	<b>Preceding document</b> VAS-MP-6 Patient management
1.	The patient is asked to remove their clothing to expose the fistula site. The most likely site is the upper limb. If scanning the upper limb the patient can be examined in the supine position (the head and shoulders can be raised) or the patient can be seated. The limb to be examined may be abducted to nearly 90 degrees and the arm supported.
2.	Examine the entire fistula circuit, from arterial inflow to distal venous outflow, and graft if present. Pay particular attention to the anastomosis, perianastomotic region, and the region for dialysis access, any areas of aliasing, and the outflow vessels.
3.	<p>The following vessels may be assessed, depending on the site of the fistula:</p> <ul style="list-style-type: none"> <li>• Brachiocephalic vein</li> <li>• Subclavian vein</li> <li>• Axillary vein</li> <li>• Brachial veins</li> <li>• Cephalic vein</li> <li>• Basilic vein</li> <li>• Subclavian artery</li> <li>• Axillary artery</li> <li>• Brachial artery</li> <li>• Radial artery</li> <li>• Ulnar artery</li> <li>• Common femoral vein</li> <li>• Deep femoral vein</li> <li>• Femoral vein</li> <li>• Common femoral artery</li> <li>• Profunda femoris artery</li> <li>• Superficial femoral artery</li> </ul>
4.	<p>The following imaging modes should be used to evaluate the arteries and veins:</p> <p><b>B-mode</b></p> <ul style="list-style-type: none"> <li>• ascertain anatomy, assess aneurysms (maximum external anterior-posterior diameter), peri-fistula fluid (e.g. pseudoaneurysms, seroma), prominent branches and stenoses, and abnormal vessel contents</li> <li>• measure aneurysms in transverse, outer wall to outer wall</li> <li>• fistula depth may also be measured</li> </ul> <p><b>Colour and Spectral Doppler</b></p> <ul style="list-style-type: none"> <li>• determine presence/absence of flow and its direction throughout the fistula circuit, distal to the fistula and in any prominent branches</li> <li>• quantify volume flow rates</li> <li>• identify abnormal flow patterns and quantify stenoses</li> <li>• assess pseudoaneurysms</li> </ul> <p>The machine controls should be optimised continually throughout the scan to obtain</p>

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	the best image to aid with diagnosis.
5.	<p><b>Volume Flow Rates (VFR)</b></p> <p>Ideally in the upper limb, VFRs should be assessed in the brachial artery, even for forearm fistulas (ref 4). In radiocephalic fistulas, flow to the fistula is usually from both the radial and ulnar artery via the palmar arch. Measuring flow in the brachial artery accounts for all of the flow to the fistula (ref 4). If there is a high bifurcation of the brachial artery, the VFR should be assessed in the subclavian or axillary artery (whichever has better views) above the level of the bifurcation (ref 4 and 5). If you are unable to take a VFR in any of the above mentioned vessels, you should take it in the ulnar or radial arteries, however, one must acknowledge that taking it in the ulnar or radial under estimates volume flow and is therefore not as accurate, due to potential supply of fistula flow from collaterals and palmar arch (ref 6). With an AVG VFRs can be recorded in the feeding artery and graft (ref 2).</p> <p>VFR measurements recorded in veins are prone to error due to several reasons but largely due to turbulent non-axial flow and non-circular cross-sectional area (ref 4). If the VFR needs to be recorded (such as requested by the clinician) in the draining vein then care must be taken to try to record the measurement in a straight, uniform segment with no dilatations, flow turbulence or valve sites present.</p> <p>When calculating VFR:</p> <ul style="list-style-type: none"> <li>• Image in longitudinal in B-mode and then select the spectral Doppler. Open the sample volume gate to cover the entire width of the vessel. Make sure the Doppler angle is &lt;60 degrees</li> <li>• Obtain a spectral waveform. Try and ensure you have a good spectral trace. Check the flow waveform is regular and doesn't contain evidence of flow disturbance or low-frequency bruits. Ensure the waveform only includes signal from the artery and optimise the Doppler gain to minimise spectral broadening</li> <li>• When calculating the volume flow open the callipers on the spectral trace to include at least three cardiac cycles. When measuring the vessel diameter place the callipers accurately (measured 90 degrees to vessel walls, inner wall to inner wall) (ref 3)</li> <li>• Ideally, record at least 5cm proximal to the anastomosis in the brachial artery (ref 7).</li> </ul> <p>As there are inherent errors in measuring VFR, the average of at least three VFR values should be stated in the report with all VFR's measured at the same location in the vessel (ref 1).</p>
6.	<p><b>Grading stenosis</b></p> <p>Doppler angles must be kept below 60 degrees. Areas of aliasing or reduction in calibre should be examined for a stenosis. Ensure light placement of the probe to make sure you are not compressing the vein and causing a stenosis. Velocity ratios (intra-stenosis vs. pre-stenosis velocity) can be used to grade stenoses in the inflow artery and AVG (but not at its anastomosis or within the vein), see table 1.</p> <p><b>Table 1: Arterial velocity grading criteria.</b></p>

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		<table><tr><th>Peak Systolic Velocity Ratio (Vs/Vp)</th><th>Reported stenosis</th></tr><tr><td>&lt; 2</td><td>&lt;50% stenosis</td></tr><tr><td>2</td><td>~50% stenosis</td></tr><tr><td>2.1-3.9</td><td>50-74% stenosis</td></tr><tr><td>4</td><td>~75% stenosis</td></tr><tr><td>&gt;4</td><td>&gt;75% stenosis</td></tr><tr><td>No flow detected</td><td>Occluded</td></tr></table>	Peak Systolic Velocity Ratio (Vs/Vp)	Reported stenosis	< 2	<50% stenosis	2	~50% stenosis	2.1-3.9	50-74% stenosis	4	~75% stenosis	>4	>75% stenosis	No flow detected	Occluded	
Peak Systolic Velocity Ratio (Vs/Vp)	Reported stenosis																
< 2	<50% stenosis																
2	~50% stenosis																
2.1-3.9	50-74% stenosis																
4	~75% stenosis																
>4	>75% stenosis																
No flow detected	Occluded																
<div>Vs = Highest PSV at site of stenosis, Vp = pre-stenosis PSV (ref 4).</div>																	
<p>Stenoses are more difficult to grade at the fistula anastomosis, where there is often acute angulation or disparity between inflow vessel and fistula calibres and higher velocities are normally found. Suggested grading criteria for a &gt;50% stenosis include a two to three fold velocity increase (3:1 ratio) or &gt;400cm/s PSV (ref 8).</p> <p>Care must be taken when quantifying the degree of stenosis within the veins due to the inherent errors involved (for example, due to the tortuosity and irregular calibre of the veins). Velocity ratios are to be used with caution, taking into account the B-mode appearances. Stenoses may be graded &gt;50% or &gt;75% stenosis within the vein.</p>																	
7.	<p><b>Steal syndrome</b></p> <p>Steal syndrome is diagnosed clinically, and ultrasound can provide haemodynamic evidence to support this (it is common for there to be non-pathologic flow reversal in the brachial or radial arteries distal to a fistula). Colour and spectral Doppler are used to assess waveforms and flow direction in the arteries perfusing the limb distal to the anastomosis (ref 1 and 2).</p>																
	<p><b>Subsequent documents:</b> <i>VAS-MP-6 Patient management, VAS-MP-1 Results processing</i></p>																

## Reporting

The diagrammatic report is a record and interpretation of observations made during the AVF ultrasound examination; it should be written by the CVS undertaking the examination.

The report should include correct patient demographics, date of examination, examination type, the name and status of the CVS, and any clinical history deemed relevant.

The diagram should include:

- Feeding artery: VFR, any areas of stenosis, diameter and PSV
- Anastomosis: diameter, PSV, presence of any significant stenosis
- Venous outflow: diameter (at several locations in the upper limb), depth, any significant stenosis, locations of any large draining tributaries diverting flow away from the fistula, VFR if indicated, flow direction if abnormal, patency of central veins
- Graft (if present): VFR, any significant stenosis, presence of thrombus
- During the scan if any other abnormalities are identified they should be demonstrated on the diagram, this may include occlusions, pseudoaneurysms, thrombus, dissection

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- If steal syndrome is suspected, document the direction of flow in radial and ulnar arteries, PSV and waveforms at the level of the wrist
- Anything limiting the examination

Any incidental findings should be documented and further imaging recommended when clinically appropriate.

Some patients will see the renal team in a one stop clinic and results will be reviewed the same day. If a patient is not being seen that day in clinic and significant findings were identified (i.e. VFR <600ml/min, thrombus within fistula etc), the referring clinical team should be contacted before the patient leaves the department.

## References

1.	VAS-ED-14. Vascular Technology Professional Performance Guidelines Native Arterio-Venous Fistula (AVF) Duplex Ultrasound Examination: Upper Limb.
2.	VAS-ED-13. Vascular Technology Professional Performance Guidelines Duplex Ultrasound Examination of Prosthetic Arterio-Venous Dialysis Grafts (AVG).
3.	VAS-ED-26. SVU; Vascular Technology Professional Performance Guidelines; Evaluation of Haemodialysis Access (2019).
4.	Thrush, A. and Hartshorne, T. (2010). <i>Vascular Ultrasound: How, why and when</i> , 3rd edn, Elsevier Limited: London
5.	Chowdhury S, Goss D, Mistry H et al, Duplex ultrasound volumetric flow analysis prior to and after hemodialysis in patients with brachiocephalic fistulae. J Vasc Access 2013 Oct-Dec;14(4):342-7
6.	Wiese P, Nonnast-Daniel B, Colour Doppler ultrasound in dialysis access, Nephrol Dial Transplant (2004) 19: 1956–1963
7.	Beathard G.A, Lok C.E, Glickman M.H, Definitions and End Points for Interventional Studies for Arteriovenous Dialysis Access. Clin J Am Soc Nephrol 2017.
8.	American Institute of Ultrasound in Medicine Practice Guideline for the Performance of a Vascular Ultrasound Examination for Postoperative Assessment of Dialysis Access (2014). <i>Journal of ultrasound in medicine</i> . 33(7):1321-32.