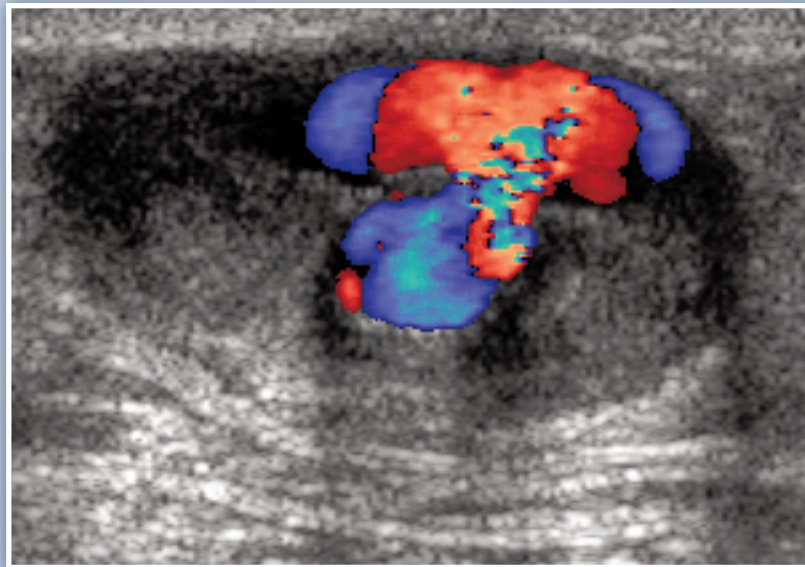


AIUM Practice Parameter for the Performance of a

Vascular Ultrasound Examination for Postoperative Assessment of Dialysis Access

Parameter developed in collaboration with the American College of Radiology (ACR) and the Society of Radiologists in Ultrasound (SRU).



The American Institute of Ultrasound in Medicine (AIUM) is a multidisciplinary association dedicated to advancing the safe and effective use of ultrasound in medicine through professional and public education, research, development of parameters, and accreditation. To promote this mission, the AIUM is pleased to publish in conjunction with the American College of Radiology (ACR) and the Society of Radiologists in Ultrasound (SRU) this *AIUM Practice Parameter for the Performance of a Vascular Ultrasound Examination for Postoperative Assessment of Dialysis Access*. We are indebted to the many volunteers who contributed their time, knowledge, and energy to bringing this document to completion.

The AIUM represents the entire range of clinical and basic science interests in medical diagnostic ultrasound, and, with hundreds of volunteers, this multidisciplinary organization has promoted the safe and effective use of ultrasound in clinical medicine for more than 50 years. This document and others like it will continue to advance this mission.

Practice parameters of the AIUM are intended to provide the medical ultrasound community with parameters for the performance and recording of high-quality ultrasound examinations. The parameters reflect what the AIUM considers the minimum criteria for a complete examination in each area but are not intended to establish a legal standard of care. AIUM-accredited practices are expected to generally follow the parameters with recognition that deviations from these parameters will be needed in some cases, depending on patient needs and available equipment. Practices are encouraged to go beyond the parameters to provide additional service and information as needed.



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I. Introduction

The clinical aspects contained in specific sections of this parameter (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American Institute of Ultrasound in Medicine (AIUM), the American College of Radiology (ACR), and the Society of Radiologists in Ultrasound (SRU). Recommendations for physician requirements, written request for the examination, procedure documentation, and quality control vary among the organizations and are addressed by each separately.

Hemodialysis access maintenance is an important health care concern. To improve the care of dialysis patients, the National Kidney Foundation established the Kidney Disease Outcomes Quality Initiative in 2000 and updated it in 2006.¹⁻³ The project set recommendations for placement and monitoring of hemodialysis access.

The failure rate of hemodialysis access in the first year is high.⁴ Clinical monitoring of access function is recommended to detect deterioration in function of the access before thrombosis occurs.⁵⁻⁷ However, in grafts, a stenosis may be present in a significant number of patients with normal findings on clinical evaluation.⁸ In one study, the sensitivity of clinical examination for venous anastomotic stenosis was 57%.⁹ In patients who have abnormal flow volumes, salvage procedures or surgical revision may lengthen the life of the access, but there is conflicting data in the literature.¹⁰⁻¹³ In a data analysis of 40,132 Medicare beneficiaries, the benefits of percutaneous intervention were greatest in patients with new access or low access flow rates.⁴ Differences in flow within an arteriovenous fistula (AVF) versus graft must be considered, as there are different diagnostic criteria associated with these two access types. This parameter is intended to help physicians in the performance of hemodialysis monitoring by ultrasound, to ensure a high-quality examination, and to promote further understanding of potential salvage options.

These parameters will address primarily upper extremity hemodialysis access. Although lower extremity hemodialysis grafts have a significant role in patients without usable upper extremity access, the Doppler diagnostic criteria for lower extremity graft evaluation are less well defined.

II. Indications/Contraindications

Indications for dialysis access ultrasound include but are not limited to:

1. Patients whose vascular access is unable to deliver a dialysis blood flow rate greater than 400 mL/min;
2. Patients with development of persistent ipsilateral upper extremity edema or pain after access placement surgery or a hemodialysis session;
3. Patients with prolonged immaturity (>6 weeks) of a surgically created AVF;
4. Patients suspected of having a pseudoaneurysm, AVF or graft stenosis, a perigraft soft tissue infection, or an adjacent fluid collection;

5. Patients with decreased or absent thrill or abnormal bruit over a fistula;
6. Follow-up after revision of an immature fistula;
7. Patients with signs of vascular steal (cold fingers or hand or other signs of distal limb ischemia);
8. Access collapse during hemodialysis;
9. Prolonged bleeding (>20 minutes) from access needle sites after dialysis despite local pressure;
10. An unexplained decrease in the delivered dose of dialysis (Kt/V); Kt/V is the product of dialyzer clearance and time divided by the volume of water in the patient;
11. Difficult cannulation;
12. Thrombus aspiration;
13. Elevated venous pressure greater than 200 mm Hg on a 300-mL/min pump; and
14. Elevated recirculation time of 15% or greater.

There are no absolute contraindications to performance of this examination, but there may be physical limitations that prevent a complete duplex examination, such as the presence of indwelling catheters, open wounds, recent surgery, scar tissue or calcification, especially in the regions of multiple puncture sites, severe edema, contractures, or other reasons for immobility.

III. Qualifications and Responsibilities of Personnel

See www.aium.org for AIUM Official Statements including *Standards and Guidelines for the Accreditation of Ultrasound Practices* and relevant Physician Training Guidelines.

IV. Written Request for the Examination

The written or electronic request for an ultrasound examination should provide sufficient information to allow for the appropriate performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider or under the provider's direction. The accompanying clinical information should be provided by a physician or other appropriate health care provider familiar with the patient's clinical situation and should be consistent with relevant legal and local health care facility requirements.

V. Specifications of the Examination

An ultrasound examination for evaluating postoperative hemodialysis access is designed to detect abnormalities that may cause the access to thrombose, function poorly, not be accessible for dialysis, or produce undesired symptoms in the arm.

It is important to understand the anatomic configuration of the dialysis access to enable accurate characterization of the usability of the access. Review of clinical records can be useful if there is history of documented variant anatomy or surgery such as failed fistulas or jump grafts. A forearm AVF directly connects an artery (usually radial) to a vein (usually cephalic) at the wrist or distal forearm to increase flow in the draining vein (forearm cephalic vein AVF). This allows dilatation and wall thickening in the vein for subsequent access to allow hemodialysis. An upper arm AVF can connect the brachial artery at the antecubital (AC) fossa to the cephalic vein (upper arm cephalic vein AVF) or to a transposed basilic vein (basilic vein transposed AVF). If AVF creation is not possible, graft configurations may include a forearm loop graft anastomosed to the brachial artery and AC vein at the AC fossa, an upper arm straight graft from the brachial artery at the AC fossa to the cranial basilic vein, or an upper arm loop graft anastomosed to the axillary artery and axillary vein.

Regardless of whether an examination is requested for failure to mature or dysfunction in a previously usable hemodialysis access, the components of the sonographic study of both AVFs and grafts are similar.^{14,15} Copious ultrasound gel and careful attention to limit pressure applied by the transducer will minimize deformity of the vein, which may affect measurements of the vein diameter. Evaluation of inflow, outflow, turbulent or stenotic flow, and outpouching, identification of large competing vein branches, and assessment of the depth from the skin surface are basics of a hemodialysis access examination. Characterization of any collection near the access should be performed.

Note: For anatomic localization of an abnormality in the upper extremity venous structures, the words “cranial” and “caudal” are preferred, since there is some uncertainty in the use of the terms “proximal” and “distal” with regard to the veins. Alternatively, the location of a draining vein stenosis may be described by its distance from the anastomosis. The longitudinal, or long axis, is parallel to or along the length of the vein. The transverse, or short axis, is perpendicular to the long axis of the vein. For describing the location selected to measure the velocity that is used as the denominator in the peak velocity ratio of a stenosis, the term “2 cm upstream” may be used. The artery supplying the anastomosis is commonly described as the “feeding artery” or “arterial inflow.”

A. Upper Extremity AVF Examination for Fistula Dysfunction

Sonographic evaluation of an AVF seeks to detect stenosis, which may limit flow within the AVF. The most common site of stenosis is the arteriovenous anastomosis.^{10,16} The draining vein is another focus of a postoperative AVF ultrasound examination, since it is the region that is accessed for hemodialysis, sometimes resulting in stenosis.

The initial evaluation to measure the fistula diameter and to detect stenosis is performed with grayscale imaging. Using color and spectral Doppler imaging in a long-axis plane, the peak systolic velocity (PSV) at the anastomosis is compared to the PSV in the artery 2 cm upstream from the anastomosis. A PSV ratio (anastomosis/artery 2 cm upstream) greater than 3:1 has been suggested to represent a stenosis with diameter reduction greater than 50%.^{17,18} However, the stenosis may be correlated with grayscale imaging, since there is often sharp angulation of the venous origin at the anastomosis, which may simulate Doppler findings of stenosis.

Incorrect Doppler angle correction and incorrect Doppler settings can also contribute to measurement error.¹⁹ The Doppler angle of insonation should be maintained at 60° or less.

In addition to the area of the anastomosis, any visible narrowing of the draining vein on grayscale imaging or color aliasing of flow within the vein should be further assessed with velocity measurements by spectral Doppler imaging. The PSV at the narrowing is compared with the PSV of the vein 2 cm upstream. A draining vein PSV ratio (narrowed draining vein/vein 2 cm upstream) greater than 2:1 suggests stenosis of 50% or greater, whether present in a patient with either an AVF or a graft.¹⁵ If there is poor draining vein flow in the absence of anastomotic stenosis, the downstream (cranial) venous system may be stenotic or thrombosed. Assessment of spectral Doppler waveforms in the ipsilateral internal jugular vein and subclavian vein can suggest central stenosis, which may be further assessed with other imaging modalities.

An AVF must have adequate arterial inflow to mature and function.²⁰ The rate of arterial stenosis may be much higher in dysfunctional AVFs (40%) or grafts (29%) than in functional access routes, and more than half of patients with arterial stenosis have associated venous abnormalities.²¹ Poststenotic arterial waveforms with parvus and tardus characteristics should be considered abnormal in the inflow vessel (feeding artery). The failure to document velocity elevation in the presence of lumen diameter reduction by B-mode imaging may indicate inflow disease/stenosis or low systemic pressure. Fortunately, inflow stenosis is uncommon (5% of patients) in a newly created AVF.^{22,23}

The direction of arterial flow distal from the anastomosis of an AVF may be evaluated to determine whether flow to the hand is reversed or bidirectional. Distal arterial steal is common in AVFs, although it is usually asymptomatic.²⁴ Symptoms of hand ischemia after AVF creation are more common in diabetics with arterial disease in the setting of previous failed AVFs.²⁵ Hand ischemia may occur for several reasons: inflow artery stenosis or occlusion, either in the feeding or a more proximal artery (such as the subclavian artery); outflow artery stenosis or occlusion; and excessive fistula flow. Ultrasound evaluation may assist in the diagnosis of each of these etiologies.²⁶ Alternatively, pulse-volume recordings of the upper extremities with and without access compression will provide an indication of the adequacy of flow. Other non-stenotic abnormalities such as pseudoaneurysms, hematomas, and abscesses can be diagnosed by a combination of grayscale and duplex Doppler ultrasound. Color Doppler imaging should be used to evaluate any collection adjacent to the fistula.

B. Evaluation of AVF Failure to Mature

A large proportion (28%–53%) of surgically created AVFs are not initially usable for hemodialysis.^{27–29} The mature AVF must be easily palpable and allow cannulation by two 17-gauge needles. If an adequate AVF is not clinically identified in the first 4 to 8 weeks after surgical access creation, an ultrasound examination can be performed to detect a correctable anatomic problem.

The anastomosis is evaluated for stenosis using the same diagnostic criteria defined in the section above on an upper extremity AVF examination for fistula dysfunction. Again, a PSV ratio of anastomosis greater than 3:1 compared with the feeding artery 2 cm upstream should suggest anastomotic stenosis. Special attention is given to detect stenosis of the draining vein, using a 2:1 threshold ratio for stenosis.

Volumetric blood flow is measured in the midportion of the draining vein in a region of the vein that is straight and nontapering, without turbulent flow. The Doppler gate is adjusted to encompass the lumen of the vein with the alignment of the sample volume markers perpendicular to the venous walls. The angle of Doppler insonation for blood flow calculation is standardized at 60° or less to minimize the degree of measurement error. A sequence of 3 to 4 cardiac cycles is obtained to allow calculation of time-averaged velocities. The average of 3 to 5 measurements is reported.¹²

If no stenosis is identified, thresholds for venous diameter and blood flow may suggest whether the AVF is mature for hemodialysis. An AVF with a venous diameter of at least 4 to 6 mm and blood flow of at least 500 to 600 mL/min predicts an AVF that has a high likelihood of successful hemodialysis.^{14,30} The lower range of values may be chosen to reduce abandonment of a fistula that may subsequently mature and recognizes the measurement error in determining flow. A draining vein that is greater than 5 to 6 mm in depth from the skin may mature but be too deep for consistent cannulation, and the draining vein in these situations may require superficialization.

Venous branches are noted and documented based on the size and distance from the anastomosis. In these patients, large draining venous branches (competing veins) may be surgically ligated to increase flow through the main draining vein to allow AVF maturation.³¹ The venous drainage to the level of the medial subclavian vein may be evaluated if not done previously on a preoperative study, since downstream venous stenosis or thrombosis may inhibit AVF maturation.

C. Upper Extremity Examination for Graft Dysfunction

In a graft, the venous anastomosis is the most common location of stenosis. A PSV ratio (anastomosis/graft 2 cm upstream) greater than 2:1 is used as a threshold to diagnose a 50% stenosis at the venous anastomosis, and a 3:1 ratio suggests a 75% stenosis.^{8,15} The arterial anastomosis of grafts has more variability in flow velocity relative to the upstream feeding artery than fistulas. A PSV ratio greater than 3:1 should raise concern for stenosis at the arterial anastomosis of a graft, but there is lower specificity than at other locations.¹⁵ As part of a complete study, the graft should be inspected with grayscale, color, and spectral Doppler imaging. A PSV measurement at the mid graft should be obtained. Likewise, the draining vein in the limb cranial to the graft should be evaluated with color Doppler imaging for signs of narrowing and/or aliasing. In regions of suspected narrowing in the draining vein of a graft, a PSV ratio should be calculated with a 2:1 threshold ratio applied for diagnosis of stenosis, in a manner similar to the draining vein of an AVF. The sites of any stenoses are documented, and the length of the stenosis is noted. A normal color Doppler examination is useful, since it precludes the need for further imaging.³²

Normal blood flow volumes within grafts are commonly higher than those within AVFs, but even flow rates of 500 to 1300 mL/min have been reported with graft stenosis. Blood flow less than 500 mL/min should lead to a fistulogram, even if no anatomic etiology for the low blood flow is found.

The central veins of the chest can also be examined. In the absence of any other etiology for access dysfunction, the central veins of the chest should be evaluated, especially if there is reason to suspect central venous stenosis such as arm swelling, shoulder collaterals, or a history of prolonged or multiple subclavian or internal jugular vein catheterizations. In some patients, multiple stenoses may be present; persistent slow flow after treatment of an inflow stenosis may unmask a central abnormality. Close attention to detail is required, since some central stenoses may be missed by sonographic evaluation.³²

Evaluation of the feeding artery should be performed in the same manner as for AVF evaluation described above. Reversal of flow in the distal artery may occur and is often asymptomatic, similar to patients with AVFs.

D. Routine Sonographic Monitoring of Functional Access

There is uncertainty, and even doubt, in the literature of whether aggressive routine monitoring and angioplasty of a hemodialysis access, especially in a graft, can predict or affect subsequent thrombosis or cumulative patency.^{4,33–41}

VI. Documentation

Adequate documentation is essential for high-quality patient care. There should be a permanent record of the ultrasound examination and its interpretation. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and side (right or left) of the anatomic site imaged. An official interpretation (final report) of the ultrasound findings should be included in the patient's medical record. Retention of the ultrasound examination should be consistent both with clinical needs and with relevant legal and local health care facility requirements.

Reporting should be in accordance with the *AIUM Practice Parameter for Documentation of an Ultrasound Examination*.

VII. Equipment Specifications

The sonographic evaluation of the peripheral veins and arteries should include both real-time imaging of the veins and their contents and evaluation of the flow signals originating from within the lumen of the veins. Real-time imaging should be conducted at the highest clinically appropriate frequency, realizing that there is a trade-off between resolution and beam penetration. This should usually be at a frequency of 7 MHz or greater, with the occasional need for a lower-frequency transducer, such as during insonation of the central veins. To determine flow rates, higher-resolution transducers are needed, preferably 9 to 15 MHz. In most cases, a linear or curved linear transducer is preferable to obtain adequate images. The flow signals originating from within the lumen of the vein should be evaluated with a Doppler frequency of 2.5 MHz or greater. A display of the relative amplitude and direction of moving blood should be available.

Imaging and flow analysis are currently performed with duplex sonography, using range gating. Color Doppler imaging is used to detect aliasing that is indicative of stenosis and to facilitate the examination.

VIII. Quality Control and Improvement, Safety, Infection Control, and Patient Education

Policies and procedures related to quality control, patient education, infection control, and safety should be developed and implemented in accordance with the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

Equipment performance monitoring should be in accordance with the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

IX. ALARA Principle

The potential benefits and risks of each examination should be considered. The ALARA (as low as reasonably achievable) principle should be observed when adjusting controls that affect the acoustic output and by considering transducer dwell times. Further details on ALARA may be found in the AIUM publication *Medical Ultrasound Safety, Third Edition*.

Acknowledgments

This parameter was revised by the AIUM in collaboration with the American College of Radiology (ACR) and the Society of Radiologists in Ultrasound (SRU) according to the process described in the AIUM *Clinical Standards Committee Manual*.

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