ACR–AIUM–SRU PRACTICE PARAMETER FOR THE PERFORMANCE OF VASCULAR ULTRASOUND FOR POSTOPERATIVE ASSESSMENT OF HEMODIALYSIS ACCESS

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PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question. The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The purpose of this document is to assist practitioners in achieving this objective.

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[1] *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, 831 N.W.2d 826 (Iowa 2013) *Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also,* Stanley v. McCarver, *63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.*

I. INTRODUCTION

The clinical aspects contained in specific sections of this practice parameter (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American College of Radiology (ACR), the American Institute of Ultrasound in Medicine (AIUM), and the Society of Radiologists in Ultrasound (SRU). Recommendations for Qualifications and Responsibilities of Personnel,

Written Requests for the Examination, Documentation, and Quality Control and Improvement, Safety, Infection Control, and Patient Education vary among the organizations and are addressed by each separately.

As the number of patients with kidney failure requiring hemodialysis each year exceeds 660,000 patients, initial creation and maintenance of a functional hemodialysis access is an increasingly critical health care concern [1]. To improve the care of hemodialysis patients, the National Kidney Foundation established the Kidney Disease Outcomes Quality Initiative (KDOQI) in 2000 and updated it in 2006 and 2019 [2-4]. The project set recommendations for placement and monitoring of hemodialysis access. Overall, there has been a movement toward earlier and more frequent hemodialysis in patients with chronic kidney disease, which in turn has resulted in more complications, requiring an estimated 68% increase in interventions to repair accesses [5].

The failure rate of hemodialysis access in the first year is high [6]. In 5.1% of patients, early thrombosis occurs within 18 days of arteriovenous fistula (AVF) creation and is associated with small arterial diameter, forearm location, small draining vein diameter, protamine use, female sex, surgeon frustration/concern during access creation procedure, and reduced or absent thrill at surgery [7]. After fistula maturation and use, subsequent failure is frequently associated with thrombosis secondary to underlying focal stenosis, most commonly at the anastomosis. Clinical monitoring of AVF function is recommended to detect deterioration in function before thrombosis occurs [8-10]. However, in arteriovenous grafts (AVGs), an occult stenosis may be present in a significant number of patients with normal findings on clinical evaluation [11,12]. The reported sensitivity of clinical examination for stenosis in AVGs is only 36%–57% [13,14]. 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 [15-18]. In a data analysis of 40,132 CMS beneficiaries, the benefits of percutaneous intervention were greatest in patients with new-access or low-access flow rates [6]. Differences in flow parameters within an AVF versus an AVG must be considered, because different diagnostic Doppler criteria for stenosis are associated with these two access types. This practice parameter is intended to help physicians in the performance of hemodialysis access evaluation by ultrasound, ensure a high-quality diagnostic examination, and promote further understanding of potential salvage options.

These practice 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 diagnostic Doppler criteria for lower-extremity hemodialysis graft evaluation are less well-defined.

II. INDICATIONS/CONTRAINDICATIONS

A. Indications for hemodialysis access ultrasound include, but are not limited to, the following:

1. Hemodialysis access blood flow inadequate for dialysis, defined as flow volume less than 500–600 ml/min or patients who have interval 25% decrease in blood flow.
2. Patients who develop persistent ipsilateral upper-extremity edema or pain after access placement or during hemodialysis.
3. Patients with delayed maturity (>6 weeks) of a surgically created AVF.
4. Patients suspected of having a pseudoaneurysm (PSA), AVF, or graft stenosis, perigraft soft-tissue infection, or adjacent fluid collection.
5. Patients with decreased or absent thrill or abnormal bruit over hemodialysis access.
6. Follow-up after intervention
7. Patients with clinical signs or symptoms of hand/digit ischemia typically during or immediately following hemodialysis but that may occur at other times.
8. Access collapses during hemodialysis.
9. Prolonged bleeding (>20 min) from access needle sites.
10. Unexplained decrease in delivered dose of hemodialysis (Kt/V). Kt/V is the product of dialyzer clearance and time divided by volume of water in the patient.
11. Repeated difficult cannulation.
12. Thrombus aspiration during hemodialysis.
13. Elevated venous pressure greater than 200 mmHg on a 300 mL/min pump.
14. Elevated recirculation time >15%

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

III. QUALIFICATIONS AND RESPONSIBLITIES OF PERSONNEL

Core Privileging: This procedure is considered part of or amendable to image-guided core privileging. See the ACR–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound Examinations [19].

IV. SPECIFICATIONS OF THE EXAMINATION

The ultrasound examination is designed to detect abnormalities that may cause access thrombosis, poor function, inability to access for dialysis, or undesirable upper-extremity symptoms and to assess for causes of AVF nonmaturation.

It is important to understand the anatomic configuration of the hemodialysis access to enable accurate and complete evaluation. Review of clinical records can be useful if there is history of documented variant anatomy or surgery, such as failed fistulas or jump grafts. Although previous guidelines have emphasized a "Fistula-First" approach, newer data suggests a patient-centered approach to customize access to the individual patient according to the End-Stage Kidney Disease Life Plan [4].

AVFs are most commonly placed in the upper extremity, either in the forearm or upper arm. 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 results in dilatation and wall thickening of the vein, allowing for frequent cannulation for hemodialysis. An upper arm AVF is typically created at the antecubital fossa and connects the brachial artery to the cephalic vein or at the basilic vein, which is usually transposed more anterolaterally for easier access and is called a basilic vein transposition fistula. Percutaneous techniques have been introduced in some centers for minimally invasive creation of AVFs through radiofrequency or thermal energy. Following creation, these systems would be assessed for dysfunction and/or maturity in a similar fashion as typical surgical AVFs [20], although their use is not widespread.

If AVF creation is not possible or not preferred, a prosthetic graft may be placed to create an AVG. A graft is a tube, typically using polytetrafluoroethylene (PTFE) material, connecting an artery and vein that is used to provide a conduit for needle access during hemodialysis. Graft configurations may include a forearm loop graft anastomosed between the brachial artery and an antecubital vein at the antecubital fossa, an upper arm straight graft from the brachial artery at the antecubital fossa to the axillary or proximal basilic vein, or an upper arm loop graft anastomosed to the axillary artery and axillary vein.

Whether an examination is requested for failure to mature or dysfunction, the components of the sonographic study of both AVFs and grafts are similar [21,22]. Copious amounts of ultrasound gel and careful attention to apply only limited pressure from the transducer will minimize deformity of the vein, which may affect measurements of the vein diameter. Evaluation of arterial inflow, venous outflow, turbulent or stenotic flow, anterior AVF vein wall depth from skin, and identification of PSAs, large or numerous accessory veins or an area of significant diameter narrowing are basic components of the hemodialysis access examination. Characterization of any collection/mass 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 because there is inconsistency in the use of the terms "proximal" and "distal" with regards 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 vessel. Transverse, or short, axis is perpendicular to the long axis of the vessel. When measuring the velocity in the feeding artery or draining vein to be used as the denominator in the peak velocity ratio of a stenosis, the location may be described as "2 cm upstream," indicating the distance from the anastomosis. The artery supplying the anastomosis is commonly described as the "feeding artery" or "arterial inflow."

IV. SPECIFICATIONS OF THE EXAMINATION

A. Upper-Extremity AVF Examination for Fistula Dysfunction

Decreased blood flow in a hemodialysis fistula is a hallmark of access dysfunction. Sonographic evaluation of an AVF seeks to detect stenosis, which may limit flow within the AVF and progress to thrombosis [23].

Initial evaluation to measure fistula diameter and to detect stenosis is performed with grayscale imaging. Significant stenosis is usually defined as luminal narrowing equal to or exceeding 50% compared with the normal vascular segment (artery or vein) located upstream to the stenosis [15,24,25]. Using color and spectral Doppler in a long axis plane, the peak systolic velocity (PSV) at the anastomosis is compared with the PSV in the feeding 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% [26-28]. A small study using PSV >375 cm/s for the detection of AVF anastomotic stenosis >50% demonstrated a sensitivity and specificity of 96% (26/27) and 76% (13/17), respectively [29]. However, any anastomotic stenosis should be confirmed with grayscale imaging because there is often sharp angulation of the venous origin at the anastomosis, which may elevate PSV, simulating a stenosis [30]. It is important to note that although a stenosis is present, AVF vein blood flow may be adequate and the AVF usable for hemodialysis [31].
Inaccurate Doppler angle correction and incorrect Doppler settings can contribute to velocity measurement error [32]. The Doppler angle of insonation should be maintained at =60°, and the angle correction cursor should be parallel to the vessel wall. In the setting of stenosis, the resistive index (RI) measured within the inflow artery is greater than 0.5 in 84% (99/118) of patients, compared with an RI < 0.5 in 71% (10/14) of those without dysfunction [33].

In addition to the area of the anastomosis, any visible narrowing of the draining vein on grayscale imaging or area of color aliasing within the vein should be further assessed with velocity measurements by spectral Doppler. The PSV at the narrowing is compared with the PSV of the vein 2 cm upstream (caudal). A draining vein PSV ratio (narrowed draining vein/vein 2 cm upstream) greater than 2:1 suggests stenosis of =50% [22]. Alternatively, a large retrospective study of stenoses (excluding the anastomotic region) showed poor accuracy of the PSV ratio and a better sensitivity (89%) for 50% stenosis using PSV < <500;500 cm/s. However, the location of stenosis was not described, and volume flows were not reported [34]. Doelman et al using PSV > >375;375 cm/s detected draining vein stenoses, including those in the cephalic vein, with a 91% sensitivity (31/34) and 95% specificity (71/75), respectively [29]. If there is poor draining vein flow in the absence of anastomotic stenosis, the downstream (cranial) venous system may be stenotic or thrombosed. Of note, after access creation, the dilation of the venous portion occurs in an irregular fashion throughout—often varying with anatomy, such as vascular curves, juxta-anastomotic region, and branching such that determining relative stenosis are challenging [35].

Assessment of spectral Doppler waveforms in the ipsilateral internal jugular vein and subclavian vein can detect signs of central stenosis, which may be further assessed with other imaging modalities. Central stenosis can be present even with high flow in an access, which may lead to arm swelling. Multiple abnormalities may be present in a single dysfunctional access [36], and it is important to complete a full assessment.
An AVF must have adequate arterial inflow to mature and function [37]. The prevalence of an inflow arterial stenosis is much higher in dysfunctional AVFs (40%) or grafts (29%) than in functional accesses, and more than half of all patients with inflow arterial stenosis have associated venous abnormalities [24]. Poststenotic arterial waveforms with parvus tardus characteristics should be considered abnormal in the inflow vessel (feeding artery). The lack of velocity elevation in the presence of luminal narrowing on grayscale may indicate inflow disease/stenosis or low systemic pressure [28,38,39].

The direction of flow in the artery caudally located to the anastomosis of an AVF may be evaluated to determine if flow in the artery is reversed or bidirectional. Reversal of arterial flow is common in AVFs and is usually asymptomatic and does not require intervention [40]. Arterial steal symptoms are more common in upper arm accesses with a brachial artery anastomosis. In a large prospective series of AVF-related hand ischemia, 7% of patients with hemodialysis access AVFs had symptoms, and 4% required intervention. Intervention is associated with female sex, diabetes, capacious outflow veins, and coronary artery disease [41]. Hand ischemia may occur for several reasons: inflow artery stenosis or occlusion, either in the feeding or a more proximal/central artery (such as the subclavian artery), outflow artery stenosis or occlusion, poor arterial collaterals, or excessive fistula

flow volume. Doppler ultrasound evaluation may assist in the diagnosis of each of these etiologies [42]. In addition, pulse-volume recordings of the upper extremities with and without access compression will provide an indication of adequacy of flow and impact of the access on digital perfusion as some patients may have fixed arterial disease as a cause for their digital ischemia. Alternatively, the fistula can be manually compressed just beyond the arterial anastomosis to see if this maneuver redirects flow toward the hand or alleviates symptoms.

Other nonstenotic abnormalities, such as PSA, hematoma, and abscess, can be diagnosed by a combination of grayscale and duplex Doppler ultrasound. Color Doppler should be used to evaluate for flow within any collection adjacent to the fistula. Grayscale and color Doppler imaging can diagnose aneurysmal dilatation, which may not be detected angiographically if mural thrombus fills at least 50% of the lumen [33]. A small aneurysm in a draining vein may not require treatment if the overlying skin remains intact or if asymptomatic [4]. However, a PSA secondary to repeated needle sticks in a graft or rarely AVF may worsen and lead to hemorrhage; it can require surgical management if >1 cm in diameter, especially if it contains mural thrombus [43]. Anastomotic PSAs typically require surgical intervention [4].

IV. SPECIFICATIONS OF THE EXAMINATION

B. Evaluation of AVF for Failure to Mature

A normal AVF may take up to 3 months to fully mature and be usable for dialysis. Additionally, a large proportion (28%-60%) of surgically created AVFs do not initially adequately mature such that they become usable for hemodialysis within a typical maturation period of 6 weeks–6 months [44-47]. A mature AVF must be easily palpable and support cannulation by two 17-gauge needles. Clinical determination of fistula maturity by skilled nursing was reportedly 80% accurate [48] in one study; however, palpation had a 96% sensitivity in another study if a thrill was present [49]. If an adequate AVF is not clinically identified in the first 4–8 weeks after surgical access creation, ultrasound can be performed to assess for a potentially correctable anatomic problem. In a series of 153 patients with surveillance Doppler evaluation 4–8 weeks after access creation (but before attempted hemodialysis), ultrasound detected nine occluded fistulas. An additional 40% had significant lesions even though only 17% had an abnormal clinical examination. In this series, 70% of the AVFs that underwent secondary intervention matured, compared with 25% without intervention [50]. If the fistula is still not useable after 3 months despite interventions, this is considered failure to mature [51]. A prospective study of 602 fistulas suggested that low blood flow and small venous diameter at 2 weeks are predictive of AVFs that may not develop optimally at 6 weeks [48]. Follow-up evaluation of the 602 AVFs showed that measurement of AVF blood flow rate, AVF diameter, and distance of the anterior AVF vein wall from the skin was moderately predictive of AVF maturation [52]. A separate study showed increased risk of failure to mature if blood flow was <413 mL/min at 2 weeks after fistula creation [53].

The anastomosis is evaluated for stenosis using the same diagnostic criteria defined in the section above on upper-extremity AVF examination for fistula dysfunction. Again, a greater than 3:1 PSV ratio of anastomosis 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 at the point of narrowing relative to 2 cm upstream within the vein.

Blood flow is measured in the midportion of the AVF draining vein where the vein is straight and nontapering, without turbulent flow, typically around 10 cm cranial to the anastomosis [36]. The Doppler gate is adjusted to encompass the lumen of the vein with 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 three–five cardiac cycles is obtained to allow for the calculation of time-averaged velocities, and the average of three separate measurements is reported [17]. On follow-up examinations, blood flow should be measured in the same location.

If no stenosis is identified, thresholds for AVF vein diameter and blood flow and AVF depth from the skin may suggest whether the AVF is adequately mature for hemodialysis [52]. An AVF with venous diameter of at least 0.4– 0.6 cm and blood flow of at least 500–600 mL/min predicts that an AVF has a high likelihood of supporting successful hemodialysis [21,36]. The lower range of values may be chosen to reduce abandonment of a fistula that may subsequently mature and to recognize the measurement error in determining flow volumes. In one study, fistulas measuring >0.4 cm in diameter and with volume flow > 500 mL/min were usable for hemodialysis

in 95% of patients, whereas those measuring < 0.4 cm in diameter and with volume flow <500 mL/min matured in only 33% of patients [21]. Another study of 125 hemodialysis fistulas and bridge grafts found that a volume flow threshold of 800 mL/min had improved accuracy for the detection of access dysfunction relative to a 500-mL/min threshold [54]. Yet another study found a 0.5-cm diameter to be a better diameter threshold than 0.4 cm [49]. A draining vein that is greater than 0.5–0.6 cm deep to the skin surface may mature but be too deep for consistent cannulation, and the draining vein in these situations may require superficialization. Lastly, there should be at least 5–6 cm of straight vein to allow placement of the dialysis needles.

Venous branches are documented based on size and distance from the anastomosis. Large draining venous branches (accessory veins) may be surgically ligated to increase flow through the main draining vein to allow AVF maturation [55]. The venous drainage to the level of the medial subclavian vein may be evaluated if not done previously on a preoperative study because downstream central venous stenosis or thrombosis may inhibit AVF maturation.

Therapy for AVF dysfunction depends on the underlying abnormality and its location. Treatment of stenosis in the anastomotic/juxta-anastomotic region relies primarily on balloon angioplasty. Persistent dysfunction after 2–3 weeks following angioplasty should encourage repeat ultrasound to evaluate for a second abnormality or insufficient dilatation. If there are accessory veins associated with stenosis, they are addressed by treating the underlying stenosis first. If no stenosis is present, the accessory veins can be treated with surgical ligation, coiled during angiography, or percutaneously occluded with minimally invasive image-guided ligation. For treatment of a deep draining vein, an incision can be made to allow the vein to rise closer to the surface, or superficial lipectomy can be performed. Successful superficialization may allow hemodialysis access maturation in 3–6 weeks [56].

IV. SPECIFICATIONS OF THE EXAMINATION

C. Upper-Extremity Examination for Graft Dysfunction

As part of a complete study, the graft should be evaluated with grayscale, color, and spectral Doppler. Graft failure that is due to thrombosis is easily diagnosed by physical examination, but ultrasound can be used. Differentiation of occlusive versus nonocclusive thrombosis can be made by color or power Doppler. In a graft, the venous anastomosis is the most common site of stenosis [35]. 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 [11,22]. If there is a borderline PSV ratio suggesting stenosis, PSV > 400 cm/s or visible narrowing greater than 50% can help make the diagnosis [27]. In another study, Doelman et al used PSV > 310 cm/s to detect stenosis with a sensitivity and specificity of 95% (20/21) and 100% (10/10), respectively, at the venous anastomosis. 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 for signs of narrowing or aliasing. In regions of suspected narrowing in the draining vein of a graft, a PSV ratio (stenosis versus inflow venous segment 2 cm) 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 stenosis is noted. A normal color Doppler examination is useful because it precludes the need for further imaging [57].

The arterial anastomosis of a hemodialysis graft has more variability in flow velocity relative to the upstream feeding artery than in a fistula. 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 [22]. Using a threshold PSV > 310 cm/sec for detection of stenosis, the sensitivity was 50% and the specificity was 93% at the arterial anastomosis [29].

Normal blood flow volumes within grafts are commonly higher than in AVFs, but flow rates of 500–1,300 ml/min have been reported with graft stenosis. Blood flow volume <500 mL/min should lead to a fistulogram even if no anatomic etiology for the low blood flow volume is found.

The venous outflow should be followed into the subclavian vein to assess for stenosis. 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 even if they were normal at evaluation before graft placement, especially if there is reason to suspect central venous stenosis, such as arm swelling, shoulder collaterals, or history of prolonged or

multiple subclavian or internal jugular vein catheterizations. In some patients, multiple stenosis may be present; persistent slow flow after treatment of an inflow stenosis may unmask a central abnormality. Close attention to detail is required because some central stenoses may be missed by sonographic evaluation [57].

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

Grafts may have disruption/degeneration of the PTFE material, and this may be directly visible on grayscale. There may be associated hematoma adjacent to the area of disruption. If disruption of the graft material is suspected, the finding can be further evaluated by Doppler to detect PSA or graft degeneration. A patent PSA will appear anechoic with or without associated mural thrombus with swirling of flow on color Doppler and a yin-yang appearance within the sac similar to the appearance of PSAs in other parts of the body.

IV. SPECIFICATIONS OF THE EXAMINATION

D. Routine Sonographic Monitoring of Functional Access

Controversy remains in the literature as to whether or not aggressive routine monitoring and angioplasty of a hemodialysis access, especially in a graft, can prevent subsequent thrombosis and significantly extend patency and longevity [6,58-67]. The most recent KDOQI update recommends against preemptive treatment of stenosis in the absence of clinical signs [4]. A recent Cochrane analysis suggests that correction of surveillance-detected stenosis in absence of access dysfunction does not extend access longevity but may have promise in fistulas by reducing hospitalizations and catheter use [68]. Accordingly, " 2013 Appropriate Use Criteria for Peripheral Vascular Ultrasound and Physiological testing Part II: Testing for Venous Disease and Evaluation of Hemodialysis Access: A Report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force" guidelines suggest that routine surveillance is rarely appropriate for the asymptomatic functioning of hemodialysis AVF or AVG [69].

V. DOCUMENTATION

Adequate documentation is essential for high-quality patient care. There should be a permanent record of the ultrasound examination and its interpretation. Comparison with prior relevant imaging studies may prove helpful. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should generally be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and image orientation. An official interpretation (final report) of the ultrasound examination should be included in the patient's medical record. Retention of the ultrasound examination images should be consistent both with clinical need and with relevant legal and local health care facility requirements.

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [70].

VI. EQUIPMENT SPECIFICATIONS

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Real Time Ultrasound Equipment [71].

The sonographic evaluation of the peripheral veins and arteries should include both real-time imaging of the vessels and their contents and evaluation of the flow signals originating from within the lumen using grayscale as well as color and spectral Doppler with careful attention to the anastomoses and any area of perceived narrowing/stenosis or intraluminal echoes/thrombus. Grayscale imaging of the anastomosis is critical as color Doppler may obscure thrombus synechiae or overwrite focal narrowing, resulting in either overestimation or underestimation of stenosis. 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 9–15 MHz. In most cases, a linear transducer is preferable to obtain optimal images. The flow signals originating from within the lumen of the vessels should be evaluated with a Doppler frequency of 2.5 MHz or above. 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 in the center of

the vessel and angle correction with a Doppler angle <60°. Color Doppler is used to detect aliasing that is indicative of stenosis and to facilitate the examination. Color and spectral Doppler are also useful for the evaluation of PSA or nonocclusive thrombus. Appropriate gain and scale settings should be used. The wall filter should be chosen as appropriate for the vessel interrogated.

VII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

ACKNOWLEDGEMENTS

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