ACR–AIUM–SPR–SRU PRACTICE PARAMETER FOR THE PERFORMANCE OF DUPLEX SONOGRAPHY OF NATIVE RENAL VESSELS

Revised 2023 (Resolution 35)*

The American College of Radiology, with more than 30,000 members, is the principal organization of radiologists, radiation oncologists, and clinical medical physicists in the United States. The College is a nonprofit professional society whose primary purposes are to advance the science of radiology, improve radiologic services to the patient, study the socioeconomic aspects of the practice of radiology, and encourage continuing education for radiologists, radiation oncologists, medical physicists, and persons practicing in allied professional fields.

The American College of Radiology will periodically define new practice parameters and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review and approval. The practice parameters and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice parameter and technical standard by those entities not providing these services is not authorized.

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 revised collaboratively by the American College of Radiology (ACR), the American Institute of Ultrasound in Medicine (AIUM), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU). Recommendations for Qualifications and Responsibilities of Personnel, Written Request 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.

Ultrasound using grayscale imaging, color Doppler imaging, and spectral Doppler analysis is a proven and useful procedure for evaluating the renovascular system. Occasionally, an additional and/or specialized examination may be necessary. Although it is not possible to detect every abnormality, adherence to the following practice parameters will maximize the probability of detecting most renovascular abnormalities.

II. INDICATIONS AND CONTRAINDICATIONS

Indications for renal duplex sonography include, but are not limited to:

1. Evaluation of patients with hypertension when there is a strong suspicion of renovascular hypertension (for example, uncontrolled hypertension despite optimal medical therapy, hypertension with progressive decline in renal function, progressive decline in renal function associated with angiotensin-converting enzyme inhibition therapy, abrupt onset of hypertension) [1,2]
2. Follow-up of patients with known renovascular disease who have undergone renal artery stent placement, angioplasty, or surgical bypass, or who have a known unilateral stenosis with concern for a stenosis in the contralateral kidney
3. Evaluation of an abdominal or flank bruit
4. Evaluation of a suspected vascular abnormality, such as an aneurysm, pseudoaneurysm, arteriovenous malformation, fistula, or following treatment of any of the above
5. Evaluation of vascular causes of renal insufficiency, eg, renal resistance measurements for evaluation of acute kidney injury and chronic kidney disease [3,4]
6. Evaluation of flow in patients with known aortic dissection, prior aortic intervention (including aortic stent grafts), trauma, other abnormalities or conditions that may compromise renal blood flow, and in patients with suspected renal parenchymal infarct.
7. Evaluation of discrepant renal size, defined as length discrepancy between the right and left kidney of >2 cm in adults.
8. Concern for aortic or renal artery thrombosis in infants who have or have had an aortic catheter, such as an umbilical arterial catheter
9. Evaluation of unilateral hydronephrosis in children and adolescents [5]
10. Evaluation for congenital or syndromic causes of renovascular hypertension
11. Evaluation for renal vein stenosis or thrombosis
12. Evaluation of renal tumor extension into the main renal vein and differentiation of bland from tumor renal vein thrombus
13. Evaluation of the renal vein in patients with suspected Nutcracker syndrome (compression of the left renal vein as it traverses the space between the aorta and superior mesenteric artery).

There are no absolute contraindications to performing this examination.

III. QUALIFICATIONS AND RESPONSIBILITIES 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 [6].

IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for renal duplex sonography should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state scope of practice requirements. (ACR Resolution 35, adopted in 2006 – revised in 2016, Resolution 12-b)

The study is generally performed for both kidneys. If not, the report should state the reason for a unilateral study (eg, evaluation of unilateral renal stent, known solitary kidney, etc).

When possible, obtaining the following grayscale and color/spectral Doppler images is recommended:

IV. SPECIFICATIONS OF THE EXAMINATION

A. Renal Arteries

The study consists of grayscale imaging of the kidneys and limited grayscale views of the aorta with color and spectral Doppler of the intrarenal and extrarenal vessels and juxtarenal aorta.

1. Grayscale Imaging

The longest renal length should be measured and reported. In patients who have not had recent cross-sectional imaging of the kidneys, a complete renal ultrasound examination may be considered. See the ACR–AIUM–SPR–SRU Practice Parameter for the Performance of an Ultrasound Examination of the Abdomen and/or Retroperitoneum [7]. Longitudinal and transverse views of the aorta should be obtained at the level of the kidneys and above.

2. Color and Spectral Doppler Evaluation

Analysis of the main renal artery and intrarenal arterial waveforms should be performed to evaluate for renal artery stenosis.

Careful attention to technique is important to ensure accurate results. This may include selecting a transducer that is appropriate for the patient's body habitus, optimizing color Doppler parameters, using an appropriate spectral Doppler sample volume, optimizing the velocity scale for the size of the waveform to avoid color and spectral Doppler aliasing, and/or to improve evaluation of waveform morphology. This may require adjusting the scale (increasing or decreasing the baseline, pulse repetition frequency, and/or selecting a transducer with a different frequency). Angle correction is essential for determining blood flow velocity. Angle correction is typically made by placing the angle correction cursor parallel to the vessel walls. For renal evaluation angle between the direction of flowing blood and the ultrasound beam should be as small as feasible and should not exceed 60°.

a. Main renal artery and aorta evaluation
The entire main renal artery should be scanned along its long axis using optimized color Doppler

parameters. Occasionally, power Doppler or grayscale imaging may be necessary to localize a portion of the artery. Inability to visualize a specific segment (eg, the origin) of the main renal artery should be reported.

Spectral Doppler waveforms should be obtained along the length of the main renal artery from the origin to the hilum at the lowest feasible angle of insonation.

At a minimum, the highest peak systolic velocities should be recorded at the origin/proximal, mid, and hilar segments of the main renal artery [8-25]. Peak systolic velocity should also be recorded at any site of color aliasing, narrowing, or suspected stenosis. If there is a significant stenosis, spectralDoppler waveforms should be recorded within the stenosis (to detect the high velocity jet flow) and distal to the stenosis (to detect post stenotic turbulence). In some patients, the distal disturbed waveform may be a sign of upstream stenosis. In young children/infants, one measurement of peak systolic velocity in the main renal artery is acceptable [24].

An effort should also be made to search for accessory/duplicated renal arteries [24,26,27]. When visualized, peak systolic velocities should be recorded as described above.

An appropriate angle-corrected spectral Doppler waveform from the abdominal aorta at or slightly cephalad to the origins of the renal arteries should be recorded. Aortic peak systolic velocity at this level is used to calculate the renal aortic ratio or the ratio of the highest peak systolic velocity in the stenosed segment of the main renal artery compared with the peak systolic velocity in the aorta.

Renal artery stent evaluation should include (when possible) documenting peak systolic velocities in the proximal renal artery (if possible), within the stent, and distal to the stent [28].

In infants with aortic thrombus after umbilical artery catheterization, the relationship of the thrombus to the right and left renal artery orifice and flow around the thrombus should be documented. If aortic thrombus is located near a renal artery orifice, waveforms should be obtained in the involved main and intraparenchymal renal arteries to assess renal perfusion.

b. Intrarenal arterial evaluation

Spectral Doppler waveforms should be recorded from segmental, interlobar, or arcuate arteries in the upper and lower poles and in the interpolar region (mid portion) of each kidney. It is important to use a fast sweep speed and optimize the velocity scale to ensure accurate and reproducible measurements. If acceleration index measurements are used in assessment, angle correction is needed; the angle of insonation should be as low as possible, usually 30° or less.

Intrarenal waveform analysis consists of quantitative and/or qualitative evaluation of the arterial Doppler waveforms. Quantitative evaluation may include acceleration times, acceleration indices [29,30], and/or resistive indices [31-33]. For qualitative analysis, the morphology of the waveform should be assessed, including the presence of a normal sharp systolic upstroke versus an abnormal tardus parvus waveform [25,27,29,30]. It may be necessary to document more than one spectral Doppler waveform in a specific region to ensure optimal interpretation This is especially true in children in whom motion artifact can significantly degrade spectral and color Doppler image quality.

3. Contrast-enhanced ultrasound (CEUS)

The use of microbubble ultrasound contrast agents may be helpful in identification of the main renal arteries, in detection of duplicated or accessory renal arteries, in assessment of renal perfusion, and in more accurately depicting and localizing renal artery stenoses [34]. Note: This would be an off-label use of CEUS based upon current FDA approval status.

IV. SPECIFICATIONS OF THE EXAMINATION

B. Renal Veins

1. For routine evaluation of the renal veins (ie, an examination not performed specifically for evaluation of suspected renal vein pathology), grayscale and color Doppler longitudinal views of the main renal veins with accompanying spectral Doppler waveform should be obtained.

2. If there is specific concern for renal vein stenosis or thrombosis, or if abnormal findings are present on routine examination, a more detailed protocol may be performed and may include the following:
    a. Grayscale Evaluation : The main renal vein should be imaged in longitudinal and transverse views. Note should be made of any area of suspected stenosis and/or intraluminal thrombus.
    b. Color and Spectral Doppler Evaluation: The main renal vein color and spectral Doppler waveforms and intrarenal venous spectral waveforms should be obtained to evaluate for renal vein abnormalities such as thrombosis or stenosis. In suspected stenosis or compression, velocity should be recorded proximal to, within, and distal to the affected segment. When renal vein thrombus is present on grayscale imaging, color, power, and/or spectral Doppler may be used to evaluate for vascularity within the thrombus which would suggest tumor thrombus. The presence or absence of tumor or bland thrombus extending into the inferior vena cava should be documented.

    c. CEUS: The use of microbubble ultrasound contrast agents may be helpful in identification of main renal vein stenosis and/or thrombosis as well as tumor vascularity within thrombus. Note: This would be an off-label use of CEUS based upon current FDA approval status.

V. DOCUMENTATION

Reporting and communication efforts should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging Findings [35].

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 include 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.

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 [36].

Duplex and color Doppler ultrasound of the renal arteries should be performed in real time using a scanner with color and spectral Doppler capabilities. Transducer selection should be based on body habitus. In adults, typically used transducer frequencies range from 2–9 MHz. In neonates, transducer frequencies of 7–15 MHz are typically used.

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).

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REFERENCES

1. Textor SC. Current approaches to renovascular hypertension. The Medical clinics of North America 2009;93:717-32, Table of Contents.
2. Textor SC, Lerman L. Renovascular hypertension and ischemic nephropathy. American journal of hypertension 2010;23:1159-69.
3. Faubel S, Patel NU, Lockhart ME, Cadnapaphornchai MA. Renal relevant radiology: use of ultrasonography in patients with AKI. Clin J Am Soc Nephrol 2014;9:382-94.
4. Wu H, Liu K, Darko IN, et al. Predictive value of renal resistive index for the onset of acute kidney injury and its non-recovery: A systematic review and meta-analysis. Clin Nephrol 2020;93:172-86.
5. Brkljacic B, Kuzmic AC, Dmitrovic R, Rados M, Vidjak V. Doppler sonographic renal resistance index and resistance index ratio in children and adolescents with unilateral hydronephrosis. European radiology 2002;12:2747-51.
6. American College of Radiology. ACR–SPR–SRU Practice Parameter for the Performance and Interpretation of Diagnostic Ultrasound Examinations. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/US-Perf-Interpret.pdf. Accessed February 11, 2022.
7. American College of Radiology. ACR–AIUM–SPR–SRU Practice Parameter for the Performance of an Ultrasound Examination of the Abdomen and/or Retroperitoneum. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/US-Abd-Retro.pdf Accessed February 11, 2022.
8. Conkbayir I, Yucesoy C, Edguer T, Yanik B, Yasar Ayaz U, Hekimoglu B. Doppler sonography in renal artery stenosis. An evaluation of intrarenal and extrarenal imaging parameters. Clinical imaging 2003;27:256-60.
9. Halpern EJ, Deane CR, Needleman L, Merton DA, East SA. Normal renal artery spectral Doppler waveform: a closer look. Radiology 1995;196:667-73.
10. Hoffmann U, Edwards JM, Carter S, et al. Role of duplex scanning for the detection of atherosclerotic renal artery disease. Kidney international 1991;39:1232-9.
11. Kliewer MA, Tupler RH, Carroll BA, et al. Renal artery stenosis: analysis of Doppler waveform parameters and tardus-parvus pattern. Radiology 1993;189:779-87.
12. Kohler TR, Zierler RE, Martin RL, et al. Noninvasive diagnosis of renal artery stenosis by ultrasonic duplex scanning. Journal of vascular surgery : official publication, the Society for Vascular Surgery [and] International Society for Cardiovascular Surgery, North American Chapter 1986;4:450-6.
13. Miralles M, Cairols M, Cotillas J, Gimenez A, Santiso A. Value of Doppler parameters in the diagnosis of renal artery stenosis. Journal of vascular surgery : official publication, the Society for Vascular Surgery [and] International Society for Cardiovascular Surgery, North American Chapter 1996;23:428-35.
14. Motew SJ, Cherr GS, Craven TE, et al. Renal duplex sonography: main renal artery versus hilar analysis. Journal of vascular surgery : official publication, the Society for Vascular Surgery [and] International Society

for Cardiovascular Surgery, North American Chapter 2000;32:462-9; 69-71.
15. Nchimi A, Biquet JF, Brisbois D, et al. Duplex ultrasound as first-line screening test for patients suspected of renal artery stenosis: prospective evaluation in high-risk group. European radiology 2003;13:1413-9.
16. Olin JW, Piedmonte MR, Young JR, DeAnna S, Grubb M, Childs MB. The utility of duplex ultrasound scanning of the renal arteries for diagnosing significant renal artery stenosis. Annals of internal medicine 1995;122:833-8.
17. Pellerito JS, Zweibel WJ. Ultrasound assessment of native renal vessels and and renal allografts. In: Zwiebel WJ, Pellerito JS, ed. *Introduction to Vascular Ultrasonography*. 5th ed. Philadelphia, PA: Elsevier Saunders; 2005:611-36.
18. Staub D, Canevascini R, Huegli RW, et al. Best duplex-sonographic criteria for the assessment of renal artery stenosis--correlation with intra- arterial pressure gradient. Ultraschall Med 2007;28:45-51.
19. Taylor DC, Kettler MD, Moneta GL, et al. Duplex ultrasound scanning in the diagnosis of renal artery stenosis: a prospective evaluation. Journal of vascular surgery : official publication, the Society for Vascular Surgery [and] International Society for Cardiovascular Surgery, North American Chapter 1988;7:363-9.
20. Textor SC. Atherosclerotic renal artery stenosis: how big is the problem, and what happens if nothing is done? Journal of hypertension. Supplement : official journal of the International Society of Hypertension 2005;23:S5-13.
21. van der Hulst VP, van Baalen J, Kool LS, et al. Renal artery stenosis: endovascular flow wire study for validation of Doppler US. Radiology 1996;200:165-8.
22. Williams GJ, Macaskill P, Chan SF, et al. Comparative accuracy of renal duplex sonographic parameters in the diagnosis of renal artery stenosis: paired and unpaired analysis. AJR. American journal of roentgenology 2007;188:798-811.
23. Bude RO, Rubin JM, Platt JF, Fechner KP, Adler RS. Pulsus tardus: its cause and potential limitations in detection of arterial stenosis. Radiology 1994;190:779-84.
24. Coley BD. Pediatric applications of abdominal vascular Doppler: Part II. Pediatr Radiol 2004;34:772-86.
25. Chavhan GB, Parra DA, Mann A, Navarro OM. Normal Doppler Spectral Waveforms of Major Pediatric Vessels: Specific Patterns. RadioGraphics 2008;28:691-706.
26. Bude RO, Forauer AR, Caoili EM, Nghiem HV. Is it necessary to study accessory arteries when screening the renal arteries for renovascular hypertension? Radiology 2003;226:411-6.
27. Dillman JR, Smith EA, Coley BD. Ultrasound imaging of renin-mediated hypertension. Pediatr Radiol 2017;47:1116-24.
28. Napoli V, Pinto S, Bargellini I, et al. Duplex ultrasonographic study of the renal arteries before and after renal artery stenting. European radiology 2002;12:796-803.
29. Stavros AT, Parker SH, Yakes WF, et al. Segmental stenosis of the renal artery: pattern recognition of tardus and parvus abnormalities with duplex sonography. Radiology 1992;184:487-92.
30. Martin RL, Nanra RS, Wlodarczyk J, DeSilva A, Bray AE. Renal hilar Doppler analysis in the detection of renal artery stenosis. J Vascular Technology 1991;15:173-80.
31. Garcia-Criado A, Gilabert R, Nicolau C, et al. Value of Doppler sonography for predicting clinical outcome after renal artery revascularization in atherosclerotic renal artery stenosis. Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine 2005;24:1641-7.
32. Radermacher J, Chavan A, Bleck J, et al. Use of Doppler ultrasonography to predict the outcome of therapy for renal-artery stenosis. The New England journal of medicine 2001;344:410-7.
33. Zeller T, Frank U, Muller C, et al. Predictors of improved renal function after percutaneous stent-supported angioplasty of severe atherosclerotic ostial renal artery stenosis. Circulation 2003;108:2244-9.
34. Li T, Mao Y, Zhao B, et al. Value of contrast-enhanced ultrasound for diagnosis and follow-up of renal artery stenosis in patients with chronic kidney disease. Abdominal radiology (New York) 2022;47:1853-61.
35. American College of Radiology. ACR Practice Parameter for Communication of Diagnostic Imaging Findings. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CommunicationDiag.pdf. Accessed February 10, 2022.
36. American College of Radiology. ACR-AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Real Time Ultrasound Equipment. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/US-Equip.pdf. Accessed February 11, 2022.

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