

ACR–AIUM–SPR–SRU PRACTICE PARAMETER FOR THE PERFORMANCE OF AN ULTRASOUND EXAMINATION OF SOLID ORGAN TRANSPLANTS

The American College of Radiology, with more than 40,000 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 care¹. 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.

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), the Society for Pediatric Radiology (SPR), 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.

This practice parameter has been developed to assist practitioners performing ultrasound studies of solid organ transplants (liver, kidney, or pancreas). Sonography is a proven and useful procedure for the evaluation of transplanted solid organs. Although it is not possible to detect every abnormality of a transplanted organ using ultrasound examination, adherence to the following practice parameter will maximize the probability of detecting abnormalities. Because of the differences in anatomic and imaging considerations for each type of transplanted organ (liver, kidney, or pancreas), the ultrasound examination of each organ type will be approached in separate sections in the current document.

Throughout this practice parameter, references to Doppler evaluation may include spectral, color, or power Doppler individually or in any combination. Whenever a long axis view is indicated, it could be either in the sagittal or coronal plane. Both long axis and transverse views may be obtained with oblique transducer orientation to obtain long-axis and short-axis views relative to the organ being evaluated. The performance of any ultrasound examination is subject to limitations of acoustic window and/or penetration, and therefore it is understood that it may not be feasible or possible to obtain specific images or measurements suggested throughout this practice parameter.

II. INDICATIONS/CONTRAINDICATIONS

Indications for an ultrasound examination of the solid organ transplant include, but are not limited to, the following:

A. Liver transplant

1. Performance of a screening ultrasound to establish a baseline following transplantation as per hospital surveillance protocol [1,2]
2. Evaluation for vascular patency and for suspected thrombosis or stenosis [3]
3. Evaluation for possible fluid collection
4. Assessment of the biliary tree for dilation, stricture, biloma, or abscess
5. Assessment of the transplant in the setting of abnormal liver function tests
6. Evaluation for pain, fever, sepsis, or other clinical issues
7. Follow-up of abnormal findings on prior transplant ultrasound or other imaging studies
8. Evaluation for recurrent malignancy or posttransplant lymphoproliferative disorder [4-8]
9. Evaluation for cirrhosis or recurrent underlying liver disease
10. Re-evaluation of the liver transplant and vasculature after final abdominal wall closure
11. Evaluation for iatrogenic injury or complications following biopsy of the transplanted liver

B. Renal Transplant

1. Performance of a screening ultrasound to establish a baseline following transplantation as per hospital surveillance protocol
2. Evaluation for vascular patency and for suspected thrombosis or stenosis [9]
3. Evaluation for possible fluid collection
4. Evaluation for suspected hydronephrosis, hydroureter, or bladder abnormality
5. Assessment of the transplant in the setting of abnormal laboratory or clinical values (eg, elevated creatinine, low or decreased urine output)
6. Evaluation for pain, fever, sepsis, hematuria, or other clinical issues
7. Evaluation of the transplant in the setting of hypertension or bruit

8. Follow-up of abnormal findings on prior transplant ultrasound
9. Evaluation for iatrogenic injury or complications following biopsy of the transplanted kidney
10. Evaluation for recurrent malignancy or posttransplant lymphoproliferative disorder

C. Pancreas Transplant

1. Performance of a screening ultrasound to establish a baseline following transplantation as per hospital surveillance protocol
2. Evaluation for vascular patency and for suspected thrombosis or stenosis
3. Evaluation for possible fluid collection or assessment of drainage catheter output
4. Assessment of the transplant in the setting of abnormal laboratory values or clinical parameters (eg, elevated blood glucose, lipase levels)
5. Assessment of the transplant in the setting of infection, pancreatitis, or other clinical issues
6. Follow-up of abnormal findings on prior transplant ultrasound
7. Evaluation for iatrogenic injury or complications following biopsy of the transplanted pancreas

Ultrasound of the transplanted liver, kidney(s), or pancreas should be performed when there is a valid medical reason. There are no absolute contraindications.

III. QUALIFICATIONS AND RESPONSIBILITIES OF THE PHYSICIAN

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 \[10\]](#).

IV. SPECIFICATIONS FOR INDIVIDUALS EXAMINATIONS

In addition to grayscale imaging, spectral, color, and/or power Doppler are used in the evaluation of transplanted organs. Careful attention to technique is necessary to optimize the color and spectral Doppler examination. This includes using an appropriate sample volume and optimizing the spectral Doppler waveforms, which may require adjusting the settings (eg, scale, baseline, pulse repetition frequency [PRF]). When obtaining spectral Doppler measurements, the sample gate should be placed in the center of the arterial lumen, and its size should be optimized for the size of the vessel being insonated. Angle correction is needed for all velocity measurements and should be obtained using an angle of insonation of $<60^\circ$. For any vessel, if no flow is identified, an attempt should be made to ensure that Doppler parameters have been optimized (eg, decrease PRF, reduce wall filter, increase gain); the use of power Doppler and microvascular settings may be helpful. Spectral analysis may include measurements such as velocity, resistive index, and acceleration time. If there is difficulty identifying the transplant vasculature or perfusion, a contrast ultrasound examination may be helpful.

IV. SPECIFICATIONS FOR INDIVIDUALS EXAMINATIONS

A. Liver

Grayscale, color Doppler, and spectral Doppler examinations of the liver transplant vasculature should be performed. Before the ultrasound examination, the surgical anatomy and reconstructive techniques for that particular patient should be confirmed when this information is available. Diagrammatic depictions by the clinical team can be very helpful in this regard. Comparison with prior examinations should be made when possible.

1. Grayscale evaluation of the transplanted liver: A complete grayscale examination of the liver should be performed, including long-axis and transverse views. The liver parenchyma should be assessed for focal and/or diffuse abnormalities, and the echogenicity and echotexture of the liver should be noted. The liver surface can be evaluated for nodularity using a high-frequency transducer. The biliary tree should be evaluated and the caliber of the common bile duct measured when possible. The subphrenic and subhepatic spaces should be investigated for possible fluid collections, as well as the abdominal wall at the site of the surgical incision in patients with recent transplantation. Grayscale images of the hepatic vessels,

including the portal vein and its branches, hepatic veins, and inferior vena cava (IVC), should be obtained. Patients in whom recurrent fibrosis is suspected, elastography may be a helpful noninvasive means of detecting and quantifying the degree of fibrosis [11-13].

2. Doppler evaluation of the transplanted liver: Clarification of the vascular surgical anatomy is essential for accurate interrogation of the transplant vasculature as variant anastomoses due to aberrant vessels, arterial conduits or venous jump grafts may be present. The typical vessels that should be examined include the main hepatic artery and right and left intrahepatic arteries, hepatic veins, IVC, main portal vein, and intrahepatic portal veins in whole-liver transplants. The extrahepatic main hepatic artery, solitary hepatic artery, hepatic vein, and portal vein should be evaluated in segmental or partial liver transplants. The vascular anastomoses (hepatic arterial, portal venous, hepatic venous, and IVC) should be interrogated.

a. Hepatic arteries: The hepatic arteries should be interrogated to confirm normal flow and exclude complications such as thrombosis, stenosis, pseudoaneurysm, or arteriovenous fistula. Both the main hepatic artery and the intrahepatic arteries should be evaluated when possible.

i. Main hepatic artery: The main hepatic artery should be imaged along its length when possible. An attempt should be made to interrogate the native artery, region of the anastomosis, and the donor artery. Color Doppler evaluation should be obtained to demonstrate the presence of flow, configuration of the vessel evaluating for redundancy, and any possible areas of color Doppler aliasing, which may suggest turbulent or high-velocity flow. Spectral Doppler waveform morphology should be assessed. Velocity measurements may be obtained at the anastomosis and within the native and donor portions of the hepatic artery and at any areas of color-flow aliasing. Doppler indices calculated from spectral Doppler waveforms obtained at these locations may include the peak systolic velocity (PSV), the resistive index ($RI = \text{systolic velocity} - \text{diastolic velocity} / \text{systolic velocity}$), and acceleration time (AT = time between end diastole and the first systolic peak) [2].

ii. Intrahepatic arteries: The presence of flow should be confirmed in the intrahepatic (right and left hepatic) arteries. RI should be calculated from spectral Doppler waveforms obtained at these locations. Spectral Doppler waveform morphology should be assessed visually. ATs can also be measured if the waveform appears abnormal, as in a tardus parvus waveform [14,15].

Comparison should be made with prior examinations when possible. Although the hepatic arterial waveform may normally change with time, some changes in waveform configuration, RI, or PSV may require further evaluation [3,16-18].

If there is difficulty in confirming hepatic arterial flow on routine grayscale and Doppler examinations, contrast-enhanced ultrasound may be helpful in evaluating hepatic artery thrombosis, stenosis, or hepatic artery hypoperfusion syndrome/splenic arterial steal [19-27]. Ultrasound contrast in this setting can improve flow detection in the hepatic artery and may be helpful in other vessels as well.

b. Portal vein: The main portal vein and its right and left branches should be scanned in their entirety including the portal vein anastomosis. Images should document the presence and direction of flow, and any areas of color Doppler aliasing. Spectral Doppler evaluation should include an assessment of the waveform as well as angle-corrected peak velocity measurements proximal, at, and distal to the main portal vein anastomosis. If there appears to be a significant change in velocities within the portal vein, an anastomotic to preanastomotic velocity ratio can be performed [28,29].

c. Hepatic veins and IVC: The type of surgical anastomosis (piggyback or side-to-side technique with or without cavotomy versus interposition) and any preoperative anatomic variants should be determined before scanning when possible. Color and spectral Doppler tracings should be obtained from the right, middle, and left hepatic veins; from the IVC in whole-liver transplants; and from the existing hepatic veins and IVC in partial-liver transplants. In the case of a piggyback or side-to-side hepatic venous anastomosis, both the recipient IVC and the hepatic vein confluence/donor IVC segment should be interrogated. Flow should be verified and the waveform assessed for the degree

of phasicity [29,30]. Contrast-enhanced ultrasound can be helpful to detect thrombosis [31].

Comparison with any prior examinations should be made when possible. Follow-up examinations may be helpful if the initial ultrasound examination shows an abnormal waveform.

IV. SPECIFICATIONS FOR INDIVIDUALS EXAMINATIONS

B. Renal Transplant

Grayscale, color Doppler, power Doppler, and spectral Doppler examinations of the renal transplant(s) should be performed. Before the ultrasound examination, the surgical anatomy should be confirmed when this information is available. Comparison with prior examinations should be made when possible.

1. Grayscale evaluation of the transplant kidney [32]. Longitudinal and transverse views should be obtained of the transplant kidney, and the longest renal length should be measured. Renal cortical echogenicity should be noted, and evaluation for focal lesions should be performed. Any focal renal lesion should be documented and measured. Cystic lesions should be interrogated with Doppler to exclude the presence of a pseudoaneurysm. The renal collecting system should be assessed for evidence of hydronephrosis and, if present, the level of obstruction determined. The perinephric space should be assessed for fluid collections. Transverse and longitudinal images of the urinary bladder should be obtained. If a ureteral stent is in place, an attempt should be made to determine the proximal and distal extent of the stent [33,34]. Visualization of a ureteral jet should be reported if it is seen [3,16,18,35].

For patients in whom more than one transplant kidney is present and evaluation of more than one transplant is required, each component of the examination should be performed for each renal transplant. Images for each graft should be clearly labeled as appropriate (eg, "medial kidney," "lateral kidney").

2. Doppler evaluation of the transplant kidney [14,36-39]. The vessels that should be examined include the main renal artery and vein, including anastomoses whenever possible, the adjacent external iliac artery and vein, and the intrarenal arteries of the transplanted kidney. If the main renal transplant artery and vein are anastomosed to vessels other than the external iliac vessels, ie, the common iliac artery/vein or aorta/ IVC, these anastomoses should be specifically interrogated.
 - a. Main renal artery or arteries: The number of main renal arteries should be recorded. If more than one artery is present with separate anastomoses, each anastomosis should be similarly evaluated. Color Doppler images of the main renal artery or arteries from the transplant kidney to the anastomosis should be obtained wherever possible. Velocity measurements should be obtained at the anastomosis as well as in the proximal, mid, and distal aspects of the renal artery. Any areas of color-flow aliasing suggestive of high-velocity flow should be interrogated with spectral Doppler and velocity measurements obtained. Doppler parameters should include PSV and may also include AT, RI, and/or pulsatility index, and/or renal artery to external or common iliac artery PSV ratio [40,41]. Occasionally the renal artery may be anastomosed to the common iliac artery or the aorta. Dual-screen or split-screen images using grayscale and color Doppler are useful to record any vessel caliber discrepancies or stenoses.
 - b. Main renal vein: Color Doppler images should be obtained throughout its course from the renal hilum to the anastomosis. Spectral Doppler images should be obtained from the transplant renal vein at the anastomosis and distal to the anastomosis [29,30,35].
 - c. External iliac artery and vein: Color and spectral Doppler images of the external iliac artery and vein should be obtained proximal, and distal to the main renal artery and main renal vein anastomoses. If the anastomoses are to vessels other than the external iliacs, these anastomotic regions should be interrogated in a similar fashion. Calculation of renal artery to iliac artery PSV ratio may be helpful in evaluating for renal artery stenosis [34,42].
 - d. Intrarenal arteries: Color or power Doppler images of the entire kidney should be obtained to provide a global assessment of transplant renal perfusion and to assess for vascular abnormalities such as pseudoaneurysm or AV fistula which if detected should be further evaluated with spectral

Doppler [43]. Contrast-enhanced ultrasound may be a useful tool in better assessing renal transplant perfusion [44-47]. B-flow imaging and other newer microvascular imaging techniques may also be helpful. Doppler indices calculated from spectral Doppler waveforms obtained in the intrarenal arteries in the upper pole, interpolar region, and lower pole of the transplant kidney should include RI and may include AT if a tardus parvus waveform is present.

- e. Intrarenal veins: Color Doppler images and/or spectral Doppler waveforms may be obtained to assess venous flow within the transplant.

IV. SPECIFICATIONS FOR INDIVIDUALS EXAMINATIONS

C. Pancreas Transplant

Grayscale, color Doppler, and spectral Doppler examinations of the pancreas transplant should be performed. Before the ultrasound examination, the surgical anatomy should be confirmed when this information is available. Comparison with prior examinations should be made when possible. The sonographic evaluation of the transplanted pancreas may be limited by reduced acoustic windows, thereby limiting the ability to obtain the suggested images.

1. Grayscale evaluation of the transplanted pancreas [48-52]. Imaging of the entire pancreas transplant should be performed in transverse and longitudinal planes. The echogenicity and echotexture of the pancreatic parenchyma should be assessed. The orientation of the graft should be ascertained, and grayscale images of the arterial Y-graft, arterial vasculature, and donor portal vein should be obtained to assess for evidence of intraluminal abnormalities. The pancreatic duct should be imaged. The peritransplant space should be assessed for fluid collections. For patients with enteric drainage of the transplanted pancreas, evaluation of the adjacent bowel may be helpful to depict areas of dilatation that may suggest obstruction. For patients with urinary bladder drainage of the transplanted pancreas, images of the urinary bladder should be obtained in transverse and longitudinal planes. If a pancreatic stent is in place, attempts should be made to determine the location of the proximal and distal portions of the stent.
2. Doppler evaluation of the transplanted pancreas. The structures that should be examined include the transplant arterial Y-graft, the transplant superior mesenteric artery (SMA) and splenic artery, the recipient artery (typically the common or external iliac artery), the transplant superior mesenteric vein, splenic vein, and portal vein, and the recipient vein (typically an iliac vein or superior mesenteric vein) [50].

- a. Transplant arteries: Color Doppler images should be obtained of the Y-graft from the recipient arterial anastomosis, across both limbs of the Y-graft to both the SMA and splenic arterial anastomoses. Images should be assessed for any areas of color-flow aliasing. Spectral Doppler images should be obtained within the recipient artery proximal to the Y-graft anastomosis and within the Y-graft itself, with assessment of waveform morphology [50,52].

Spectral Doppler images with angle correction should be obtained within the splenic artery and SMA of the transplanted pancreas and at any areas of color-flow aliasing. Doppler parameters obtained at these locations should include PSV and may include RI [50,53,54].

Color or power Doppler images of the entire pancreas transplant should be obtained to assess global vascularity. Spectral Doppler evaluation of intraparenchymal pancreatic arteries should be performed in the pancreatic head, body, and tail, and RI may be calculated [42].

- b. Transplant veins: Color and spectral Doppler images should be obtained of the graft splenic vein, superior mesenteric vein, and portal vein to recipient venous anastomosis. Spectral Doppler assessment with angle correction and measurement of peak velocity may be performed within the graft portal vein, at the graft portal vein-venous anastomosis and distal to the anastomosis, and within the recipient vein [55]. Additional measurements at sites of color-flow aliasing may be helpful. Intraparenchymal venous flow should also be documented in the head and tail of the transplant pancreas.

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. The initials of the operator should be accessible on the images or electronically on PACS. 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 \[56\]](#).

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 \[57\]](#).

Grayscale and Doppler evaluation of the transplant parenchymal organs should be performed using a scanner with color and spectral Doppler capabilities. Transducer selection should be based on body habitus and the location of the transplant. Curvilinear and sector transducers may be used; in adults, mean frequencies between 2 and 9 MHz are most commonly used, whereas in children, higher frequencies may be employed. Higher frequencies may also be employed with more superficially placed renal and pancreas transplants. Linear-array transducers may be used for further anatomic detail in superficially located kidney or pancreas transplants as well as in pediatric patients.

When Doppler studies are performed, the Doppler frequency may differ from the imaging frequency. The equipment should be adjusted to operate at the highest clinically appropriate frequency, realizing that there is a trade-off between resolution and beam penetration. Image quality should be optimized while keeping total ultrasound exposure as low as reasonably achievable.

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/Clinical-Resources/Practice-Parameters-and-Technical-Standards>).

ACKNOWLEDGEMENTS

This practice parameter was revised according to the process described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (<https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards>) by the Committee on Practice Parameters – Ultrasound of the ACR Commission on Ultrasound and the Committee on Practice Parameters – Pediatric Radiology of the ACR Commission on Pediatric Radiology, in collaboration with the AIUM, the SPR, and the SRU.

Writing Committee – members represent their societies in the initial and final revision of this practice parameter

ACR

Gabriel, Helena MD, Chair
Fung, Christopher MD
Itani, Malak MD
Kurian, Jessica MD

SRU

Khati, Nadia J MD
Rosenberg, Henrietta MD

SPR

Linam, Leann MD
Riedesel, Erica MD

AIUM

Revzin, Margarita A MD, MS

Committee on Practice Parameters - Ultrasound

(ACR Committee responsible for sponsoring the draft through the process)

Dahiya, Nirvikar MD, Chair
Bohm-Velez, Marcela MD
Carnahan, Molly MD
Gabriel, Helena MD
Itani, Malak MD
Penna, Rupinder MD
Squires, Judy H MD

Azadi, Javad MD
Burgan, Constantine MD
Fung, Christopher MD
Gunabushanam, Gowthaman MBBS, MD
Melany, Michelle MD
Sohaey, Roya MD

Committee on Practice Parameters – Pediatric Imaging

(ACR Committee responsible for sponsoring the draft through the process)

Levin, Terry L MD, Chair
Amodio, John B MD
Blumfield, Einat MD
Goldman-Yassen, Adam MD
Lala, Shailee V MD
Laufer, Adina MD
Maloney, John A MD
Shah, Summit MD
Vatsky, Seth DO

Alizai, Hamza MD
Betz, Bradford W MD
Collard, Michael MD
Lai, Hollie A MD
Lasiacka, Zofia M MD, PhD
Li, Arleen MD
Noda, Sakura MD
Trout, Andrew T MD

Barth, Richard MD, Chair, Commission on Pediatric Radiology
Larson, David B MBA, MD, Chair, Commission on Quality and Safety
Nicola, Lauren MD, Chair, Commission on Ultrasound

Comments Reconciliation Committee

Siebert, Derrick MD - CSC, Chair
Amodio, John B MD
Crummy, Timothy MD, MHA - CSC
Fung, Christopher MD
Itani, Malak MD
Kurian, Jessica MD
Levin, Terry L MD
Nicola, Lauren MD
Riedesel, Erica MD
Schoppe, Kurt MD - CSC

Weissman, Ian DO - CSC, Co-Chair
Barth, Richard MD
Dahiya, Nirvikar MD
Gabriel, Helena MD
Khatri, Nadia J MD
Larson, David B MBA, MD
Linam, Leann MD
Revzin, Margarita A MD, MS
Rosenberg, Henrietta MD

REFERENCES

1. Garcia-Criado A, Gilabert R, Nicolau C, et al. Early detection of hepatic artery thrombosis after liver transplantation by Doppler ultrasonography: prognostic implications. Journal of ultrasound in medicine :

- official journal of the American Institute of Ultrasound in Medicine 2001;20:51-8.
2. Uzochukwu LN, Bluth EI, Smetherman DH, et al. Early postoperative hepatic sonography as a predictor of vascular and biliary complications in adult orthotopic liver transplant patients. *AJR. American journal of roentgenology* 2005;185:1558-70.
 3. Garcia-Criado A, Gilabert R, Berzigotti A, Bru C. Doppler ultrasound findings in the hepatic artery shortly after liver transplantation. *AJR. American journal of roentgenology* 2009;193:128-35.
 4. Fung JJ, Jain A, Kwak EJ, Kusne S, Dvorchik I, Eghtesad B. De novo malignancies after liver transplantation: a major cause of late death. *Liver transplantation : official publication of the American Association for the Study of Liver Diseases and the International Liver Transplantation Society* 2001;7:S109-18.
 5. Yao FY, Gautam M, Palese C, et al. De novo malignancies following liver transplantation: a case-control study with long-term follow-up. *Clinical transplantation* 2006;20:617-23.
 6. Roayaie S, Schwartz JD, Sung MW, et al. Recurrence of hepatocellular carcinoma after liver transplant: patterns and prognosis. *Liver transplantation : official publication of the American Association for the Study of Liver Diseases and the International Liver Transplantation Society* 2004;10:534-40.
 7. Singh AK, Nachiappan AC, Verma HA, et al. Postoperative imaging in liver transplantation: what radiologists should know. *Radiographics : a review publication of the Radiological Society of North America, Inc* 2010;30:339-51.
 8. Crossin JD, Muradali D, Wilson SR. US of liver transplants: normal and abnormal. *Radiographics : a review publication of the Radiological Society of North America, Inc* 2003;23:1093-114.
 9. Brown ED, Chen MY, Wolfman NT, Ott DJ, Watson NE, Jr. Complications of renal transplantation: evaluation with US and radionuclide imaging. *Radiographics : a review publication of the Radiological Society of North America, Inc* 2000;20:607-22.
 10. 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 January 13, 2023.
 11. Lutz HH, Schroeter B, Kroy DC, Neumann U, Trautwein C, Tischendorf JJ. Doppler Ultrasound and Transient Elastography in Liver Transplant Patients for Noninvasive Evaluation of Liver Fibrosis in Comparison with Histology: A Prospective Observational Study. *Dig Dis Sci* 2015;60:2825-31.
 12. Crespo G, Lens S, Gambato M, et al. Liver stiffness 1 year after transplantation predicts clinical outcomes in patients with recurrent hepatitis C. *Am J Transplant* 2014;14:375-83.
 13. Barrault C, Roudot-Thoraval F, Tran Van Nhieu J, et al. Non-invasive assessment of liver graft fibrosis by transient elastography after liver transplantation. *Clin Res Hepatol Gastroenterol* 2013;37:347-52.
 14. Dodd GD, 3rd, Memel DS, Zajko AB, Baron RL, Santaguida LA. Hepatic artery stenosis and thrombosis in transplant recipients: Doppler diagnosis with resistive index and systolic acceleration time. *Radiology* 1994;192:657-61.
 15. De Gaetano AM, Cotroneo AR, Maresca G, et al. Color Doppler sonography in the diagnosis and monitoring of arterial complications after liver transplantation. *Journal of clinical ultrasound : JCU* 2000;28:373-80.
 16. Nolten A, Sproat IA. Hepatic artery thrombosis after liver transplantation: temporal accuracy of diagnosis with duplex US and the syndrome of impending thrombosis. *Radiology* 1996;198:553-9.
 17. Gonzalez FX, Rimola A, Grande L, et al. Predictive factors of early postoperative graft function in human liver transplantation. *Hepatology* 1994;20:565-73.
 18. Garcia-Criado A, Gilabert R, Salmeron JM, et al. Significance of and contributing factors for a high resistive index on Doppler sonography of the hepatic artery immediately after surgery: prognostic implications for liver transplant recipients. *AJR. American journal of roentgenology* 2003;181:831-8.
 19. Hom BK, Shrestha R, Palmer SL, et al. Prospective evaluation of vascular complications after liver transplantation: comparison of conventional and microbubble contrast-enhanced US. *Radiology* 2006;241:267-74.
 20. Sidhu PS, Shaw AS, Ellis SM, Karani JB, Ryan SM. Microbubble ultrasound contrast in the assessment of hepatic artery patency following liver transplantation: role in reducing frequency of hepatic artery arteriography. *Eur Radiol* 2004;14:21-30.
 21. Berstad AE, Brabrand K, Foss A. Clinical utility of microbubble contrast-enhanced ultrasound in the diagnosis of hepatic artery occlusion after liver transplantation. *Transpl Int* 2009;22:954-60.
 22. Garcia-Criado A, Gilabert R, Bianchi L, et al. Impact of contrast-enhanced ultrasound in the study of hepatic artery hypoperfusion shortly after liver transplantation: contribution to the diagnosis of artery steal

- syndrome. *Eur Radiol* 2015;25:196-202.
23. Zheng RQ, Mao R, Ren J, et al. Contrast-enhanced ultrasound for the evaluation of hepatic artery stenosis after liver transplantation: potential role in changing the clinical algorithm. *Liver transplantation : official publication of the American Association for the Study of Liver Diseases and the International Liver Transplantation Society* 2010;16:729-35.
 24. Lu Q, Zhong XF, Huang ZX, et al. Role of contrast-enhanced ultrasound in decision support for diagnosis and treatment of hepatic artery thrombosis after liver transplantation. *Eur J Radiol* 2012;81:e338-43.
 25. Ren J, Wu T, Zheng BW, Tan YY, Zheng RQ, Chen GH. Application of contrast-enhanced ultrasound after liver transplantation: Current status and perspectives. *World J Gastroenterol* 2016;22:1607-16.
 26. Kim JS, Kim KW, Lee J, et al. Diagnostic Performance for Hepatic Artery Occlusion After Liver Transplantation: Computed Tomography Angiography Versus Contrast-Enhanced Ultrasound. *Liver transplantation : official publication of the American Association for the Study of Liver Diseases and the International Liver Transplantation Society* 2019;25:1651-60.
 27. Goh Y, Neo WT, Teo YM, et al. Role of contrast-enhanced ultrasound in the evaluation of post-liver transplant vasculature. *Clinical radiology* 2020;75:832-44.
 28. Mullan CP, Siewert B, Kane RA, Sheiman RG. Can Doppler sonography discern between hemodynamically significant and insignificant portal vein stenosis after adult liver transplantation? *AJR. American journal of roentgenology* 2010;195:1438-43.
 29. Chong WK, Beland JC, Weeks SM. Sonographic evaluation of venous obstruction in liver transplants. *AJR. American journal of roentgenology* 2007;188:W515-21.
 30. Ko EY, Kim TK, Kim PN, Kim AY, Ha HK, Lee MG. Hepatic vein stenosis after living donor liver transplantation: evaluation with Doppler US. *Radiology* 2003;229:806-10.
 31. Im J, Jeong WK, Lee MW, et al. Quantitative analysis of contrast-enhanced ultrasonography following living donor liver transplantation: early diagnosis of middle hepatic venous occlusion. *Med Ultrason* 2021;23:390-95.
 32. Akbar SA, Jafri SZ, Amendola MA, Madrazo BL, Salem R, Bis KG. Complications of renal transplantation. *Radiographics : a review publication of the Radiological Society of North America, Inc* 2005;25:1335-56.
 33. Parthipun AA, Pilcher J. Renal Transplant Assessment: Sonographic Imaging. *Ultrasound Clinics* 2010;5:379-99.
 34. Langer J, Jones L. Sonographic Evaluation of the Renal Transplant. *Ultrasound Clinics* 2007;2:73-83.
 35. Brody MB, Rodgers SK, Horrow MM. Spectrum of normal or near-normal sonographic findings after orthotopic liver transplantation. *Ultrasound Q* 2008;24:257-65.
 36. Park SB, Kim JK, Cho KS. Complications of renal transplantation: ultrasonographic evaluation. *Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine* 2007;26:615-33.
 37. Friedewald SM, Molmenti EP, Friedewald JJ, Dejong MR, Hamper UM. Vascular and nonvascular complications of renal transplants: sonographic evaluation and correlation with other imaging modalities, surgery, and pathology. *Journal of clinical ultrasound : JCU* 2005;33:127-39.
 38. Cosgrove DO, Chan KE. Renal transplants: what ultrasound can and cannot do. *Ultrasound Q* 2008;24:77-87; quiz 141-2.
 39. Norton PT, DeAngelis GA, Ogur T, Saad WE, Hagspiel KD. Noninvasive vascular imaging in abdominal solid organ transplantation. *AJR. American journal of roentgenology* 2013;201:W544-53.
 40. de Morais RH, Muglia VF, Mamere AE, et al. Duplex Doppler sonography of transplant renal artery stenosis. *Journal of clinical ultrasound : JCU* 2003;31:135-41.
 41. Patel U, Khaw KK, Hughes NC. Doppler ultrasound for detection of renal transplant artery stenosis- threshold peak systolic velocity needs to be higher in a low-risk or surveillance population. *Clinical radiology* 2003;58:772-7.
 42. Loubeyre P, Abidi H, Cahen R, Tran Minh VA. Transplanted renal artery: detection of stenosis with color Doppler US. *Radiology* 1997;203:661-5.
 43. Horrow MM, Parsikia A, Zaki R, Ortiz J. Immediate postoperative sonography of renal transplants: vascular findings and outcomes. *AJR. American journal of roentgenology* 2013;201:W479-86.
 44. Schwenger V, Hankel V, Seckinger J, et al. Contrast-enhanced ultrasonography in the early period after kidney transplantation predicts long-term allograft function. *Transplant Proc* 2014;46:3352-7.
 45. Korda D, Deak PA, Kozma V, Kiss G, Doros A. Role of Contrast-Enhanced Ultrasound in the Follow-up of

Revised 2024 (Resolution 24) Patients. Transplant Proc 2016;48:2544-47.

46. Zeisbrich M, Kihm LP, Druschler F, Zeier M, Schwenger V. When is contrast-enhanced sonography preferable over conventional ultrasound combined with Doppler imaging in renal transplantation? Clin Kidney J 2015;8:606-14.
47. Morgan TA, Jha P, Poder L, Weinstein S. Advanced ultrasound applications in the assessment of renal transplants: contrast-enhanced ultrasound, elastography, and B-flow. Abdom Radiol (NY) 2018;43:2604-14.
48. Vandermeer FQ, Manning MA, Frazier AA, Wong-You-Cheong JJ. Imaging of whole-organ pancreas transplants. Radiographics : a review publication of the Radiological Society of North America, Inc 2012;32:411-35.
49. Yuh WT, Wiese JA, Abu-Yousef MM, et al. Pancreatic transplant imaging. Radiology 1988;167:679-83.
50. Gimenez JM, Bluth EI, Simon A, Troxclair L. Evaluation of pancreatic allografts with sonography. Journal of ultrasound in medicine : official journal of the American Institute of Ultrasound in Medicine 2012;31:1041-51.
51. Morgan TA, Smith-Bindman R, Harbell J, Kornak J, Stock PG, Feldstein VA. US Findings in Patients at Risk for Pancreas Transplant Failure. Radiology 2016;280:281-9.
52. Tolat PP, Foley WD, Johnson C, Hohenwarter MD, Quiroz FA. Pancreas transplant imaging: how I do it. Radiology 2015;275:14-27.
53. Nelson NL, Largen PS, Stratta RJ, et al. Pancreas allograft rejection: correlation of transduodenal core biopsy with Doppler resistive index. Radiology 1996;200:91-4.
54. Aideyan OA, Foshager MC, Benedetti E, Troppmann C, Gruessner RW. Correlation of the arterial resistive index in pancreas transplants of patients with transplant rejection. AJR. American journal of roentgenology 1997;168:1445-7.
55. Foshager MC, Hedlund LJ, Troppmann C, Benedetti E, Gruessner RW. Venous thrombosis of pancreatic transplants: diagnosis by duplex sonography. AJR. American journal of roentgenology 1997;169:1269-73.
56. 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 January 13, 2023.
57. 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 January 23, 2023.

*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Practice Parameter

2014 (Resolution 25)

Revised 2019 (Resolution 33)

Amended 2019 (Resolution 23)

Revised 2024 (Resolution 24)