2019 (Resolution 33)*

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

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 in light of 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 the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also 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 sole 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 or assessment of drainage catheter output
   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
   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 or assessment of drainage catheter output [9]
   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
8. Evaluation of response to treatment (eg, immunosuppressive therapy in the setting of rejection)

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 Performing and Interpreting Diagnostic Ultrasound Examinations [10].

IV. SPECIFICATIONS FOR INDIVIDUAL 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°. 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); 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.

A. Liver

Grayscale, color Doppler, and spectral Doppler examinations of the liver transplant vasculature should be performed. Prior to the ultrasound examination, the surgical anatomy and reconstructive techniques for that particular patient should be confirmed when this information is available. 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 can the abdominal wall near the surgical incision in patients with recent transplantation. Grayscale images of the hepatic vessels, including the portal vein, hepatic veins, and inferior vena cava (IVC), should be obtained. In 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: The 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. 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 = systolic velocity-diastolic velocity/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, ultrasound contrast examination may be helpful in evaluating hepatic artery thrombosis, stenosis, or hepatic artery hypoperfusion syndrome/splenic arterial steal [19-25]. 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 [26,27].

   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 [27,28].

   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.

B. Renal Transplant

Grayscale, color Doppler, power Doppler, and spectral Doppler examinations of the renal transplant(s) should be performed. Prior to 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 [29]. 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. 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 [30,31]. Visualization of a ureteral jet should be reported if it is seen [3,16,18,32].

   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 [14,33-36]. 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 indices should include PSV and may include AT, RI, and/or pulsatility index (PI), and/or renal artery to external or common iliac artery PSV ratio [37,38]. 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 [27,28,32].
   c. External iliac artery and vein: Color and spectral Doppler images of the external iliac artery and vein should be obtained proximal, at, 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 [31,39].
   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 [40]. 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. Contrast-enhanced ultrasound may be a useful tool in better assessing renal transplant perfusion [41-43].
   e. Intrarenal veins: Color Doppler images and/or spectral Doppler waveforms may be obtained to assess venous flow within the transplant.

C. Pancreas Transplant

Grayscale, color Doppler, and spectral Doppler examinations of the pancreas transplant should be performed. Prior to 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 [44-48]. 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) [46].
   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 [46,48].

      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 indices obtained at these locations should include PSV and may include RI [46,49,50].

      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 [39].

   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 [51]. 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. WRITTEN REQUEST FOR THE EXAMINATION

The written or electronic request for an examination of the sold organ transplant 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). The provision of 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)

VI. 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 [52].

VII. EQUIPMENT SPECIFICATIONS

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.

VIII. 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).

Equipment performance monitoring should be in accordance with the ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Real Time Ultrasound Equipment [53].

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