

AIUM Practice Parameter for the Performance of an Ultrasound Examination of Solid-Organ Transplants

Introduction

The American Institute of Ultrasound in Medicine (AIUM) is a multidisciplinary association dedicated to advancing the safe and effective use of ultrasound in medicine through professional and public education, research, development of clinical practice parameters, and accreditation of practices performing ultrasound examinations.

The *AIUM Practice Parameter for the Performance of an Ultrasound Examination of Solid-Organ Transplants* was developed (or revised) by the AIUM in collaboration with other organizations whose members use ultrasound for performing this examination(s) (see “Acknowledgments”). Recommendations for personnel requirements, the request for the examination, documentation, quality assurance, and safety may vary among the organizations and may be addressed by each separately.

This practice parameter is intended to provide the medical ultrasound community with recommendations for the performance and recording of high-quality ultrasound examinations. The parameter reflects what the AIUM considers the appropriate criteria for this type of ultrasound examination but is not intended to establish a legal standard of care. Examinations performed in this specialty area are expected to follow the parameter with recognition that deviations may occur depending on the clinical situation.

Throughout this practice parameter, references to a Doppler evaluation may include spectral, color, or power Doppler imaging 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 an oblique transducer orientation to obtain long- and short-axis views relative to the organ being evaluated. The performance of any ultrasound examination is subject to limitations of the acoustic window and/or penetration; therefore, it is understood that it may not be feasible or possible to obtain specific images or measurements suggested throughout this practice parameter.

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Indications

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 examination to establish a baseline following transplantation as per the hospital surveillance protocol.¹
2. Evaluation for vascular patency and for suspected thrombosis or stenosis.²
3. Evaluation for a possible fluid collection or assessment of drainage catheter output.
4. Assessment of the biliary tree for dilatation, a stricture, biloma, or an abscess.
5. Assessment of the transplant in the setting of abnormal liver function test results.
6. Evaluation for pain, fever, sepsis, or other clinical issues.
7. Follow-up of abnormal findings on a prior transplant ultrasound examination.
8. Evaluation for recurrent malignancy or post-transplant lymphoproliferative disorder.²⁻⁷
9. Evaluation for cirrhosis or recurrent underlying liver disease.
10. Reevaluation 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 examination to establish a baseline following transplantation as per the hospital surveillance protocol.
2. Evaluation for vascular patency and for suspected thrombosis or stenosis.⁸
3. Evaluation for a possible fluid collection or assessment of drainage catheter output.⁸
4. Evaluation for suspected hydronephrosis, hydro-ureter, or a bladder abnormality.
5. Assessment of the transplant in the setting of abnormal laboratory or clinical values (eg, elevated creatinine and 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 a prior transplant ultrasound examination.
9. Evaluation for iatrogenic injury or complications following biopsy of the transplanted kidney.
10. Evaluation for recurrent malignancy or post-transplant lymphoproliferative disorder.

C. Pancreas Transplant

1. Performance of a screening ultrasound examination to establish a baseline following transplantation as per the hospital surveillance protocol.
2. Evaluation for vascular patency and for suspected thrombosis or stenosis.
3. Evaluation for a 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 and lipase levels).
5. Assessment of the transplant in the setting of infection, pancreatitis, or other clinical issues.
6. Follow-up of abnormal findings on a prior transplant ultrasound examination.
7. Evaluation for iatrogenic injury or complications following biopsy of the transplanted pancreas.
8. Evaluation of the response to treatment (eg, immunosuppressive therapy in the setting of rejection).

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

Qualifications and Responsibilities of Personnel

Physicians interpreting or performing this type of ultrasound examination should meet the specified AIUM Training Guidelines in accordance with AIUM accreditation policies.

Sonographers performing the ultrasound examination should be appropriately credentialed in the specialty area in accordance with AIUM accreditation policies.

Physicians not personally performing the examination must provide supervision, as defined by the

Centers for Medicare and Medicaid Services Code of Federal Regulations 42 CFR §410.32.

Request for the Examination

The written or electronic request for an ultrasound examination must originate from a physician or other appropriately licensed health care provider or under the provider's direction. The clinical information provided should allow for the performance and interpretation of the appropriate ultrasound examination and should be consistent with relevant legal and local health care facility requirements.

Specification of the Examination

In addition to grayscale imaging, spectral, color, and/or power Doppler imaging 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, and pulse repetition frequency). 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 less than 60°. For any vessel, if no flow is identified, an attempt should be made to ensure that Doppler parameters have been optimized (eg, decrease the pulse repetition frequency, or reduce the wall filter); the use of power Doppler and microvascular settings may be helpful. Spectral analysis may include measurements such as the velocity, resistive index (RI), and acceleration time (AT). If there is difficulty identifying the transplant vasculature or perfusion, a contrast ultrasound examination may be helpful.

A. Liver Transplant

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. A 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 echo texture 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.^{9–11}
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, a pseudoaneurysm, or an 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 donor artery. A Doppler evaluation should be performed to show 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 RI (systolic velocity – diastolic velocity/systolic velocity), and AT (time between end-diastole and the first systolic peak).¹²

- ii. Intrahepatic arteries: The presence of flow should be confirmed in the intrahepatic (right and left hepatic) arteries. The RI should be calculated from spectral Doppler waveforms obtained at these locations. Spectral Doppler waveform morphology should be assessed visually. Acceleration times can also be measured if the waveform appears abnormal, as in a tardus parvus waveform.^{13,14}

A comparison should be made with prior examinations when possible. Although the hepatic arterial waveform may normally change with time, some changes in the waveform configuration, RI, or PSV may require further evaluation.^{2,15–17}

If there is difficulty in confirming hepatic arterial flow on routine grayscale and Doppler examinations, an ultrasound contrast examination may be helpful in evaluating hepatic artery thrombosis, stenosis, or hepatic artery hypoperfusion syndrome/splenic arterial steal.^{18–24}

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. A 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 obtained.^{25,26}

- 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.^{26,27}

A 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. Before the ultrasound examination, the surgical anatomy should be confirmed when this information is available. A comparison with prior examinations should be made when possible.

- 1. Grayscale evaluation of the transplant kidney²⁸: 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 an 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 extents of the stent.^{29,30} Visualization of a

ureteral jet should be reported if it is seen.^{3,15,17,31}

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” and “lateral kidney”).

2. Doppler evaluation of the transplant kidney^{13,32–35}: 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 imaging, and velocity measurements obtained. Doppler indices should include the PSV and may include AT, RI, and/or pulsatility index and/or renal artery-to-external or common iliac artery PSV ratio.^{36,37} 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 imaging 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.^{26,27,31}
 - 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 iliac artery and vein, 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.^{30,38}

- 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.³⁹ 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 the RI and may include the AT if a tardus parvus waveform is present. Contrast-enhanced ultrasound may be a useful tool in better assessing renal transplant perfusion.^{40–42}
- 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. Before the ultrasound examination, the surgical anatomy should be confirmed when this information is available. A comparison with prior examinations should be made when possible. The ultrasound 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^{43–47}: Imaging of the entire pancreas transplant should be performed in transverse and longitudinal planes. The echogenicity and echo texture 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).⁴⁵

- 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.^{45,47}

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 the PSV and may include the RI.^{45,48,49}

Color or power Doppler images of the entire pancreas transplant should be obtained to assess global vascularity. A spectral Doppler evaluation of intraparenchymal pancreatic arteries should be performed in the pancreatic head, body, and tail, and the RI may be calculated.³⁸

- b. Transplant veins: Color and spectral Doppler images should be obtained of the graft splenic vein, superior mesenteric vein, and portal vein to the recipient venous anastomosis. A 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.⁵⁰ 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.

Documentation

Accurate and complete documentation is essential for high-quality patient care. Written reports and ultrasound images/video clips that contain diagnostic information should be obtained and archived, with recommendations for follow-up studies if clinically applicable, in accordance with the *AIUM Practice Parameter for Documentation of an Ultrasound Examination*.

Equipment Specifications

Grayscale and Doppler evaluations of the transplant parenchymal organs should be performed using a scanner with color and spectral Doppler capabilities. Transducer selection should be based on the 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 used. Higher frequencies may also be used 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.

Quality and Safety

Policies and procedures related to quality assurance and improvement, safety, infection control, and equipment performance monitoring should be

developed and implemented in accordance with the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

ALARA (as Low as Reasonably Achievable) Principle

The potential benefits and risks of each examination should be considered. The ALARA principle should be observed for factors that affect the acoustic output and by considering the transducer dwell time and total scanning time. Further details on ALARA may be found in the current AIUM publication *Medical Ultrasound Safety*.

Infection Control

Transducer preparation, cleaning, and disinfection should follow manufacturer recommendations and be consistent with the AIUM Guidelines for Cleaning and Preparing External- and Internal-Use Ultrasound Transducers Between Patients, Safe Handling, and Use of Ultrasound Coupling Gel.

Equipment Performance Monitoring

Monitoring protocols for equipment performance should be developed and implemented in accordance with the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

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