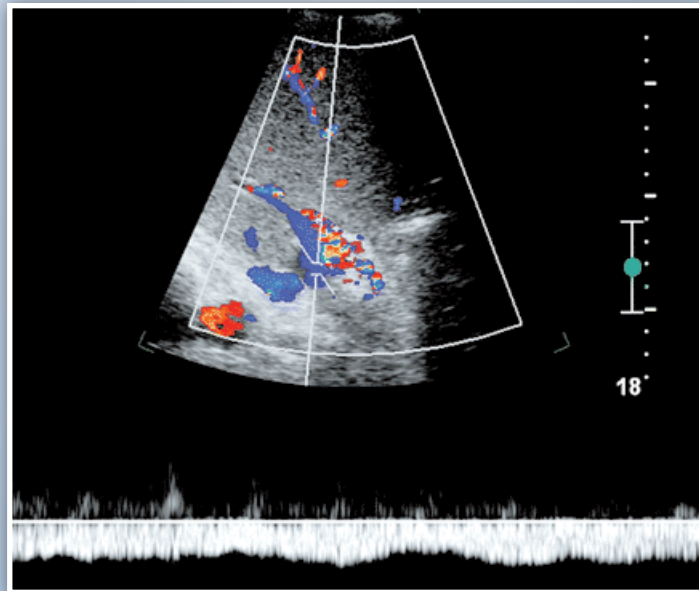


AIUM Practice Guideline for the Performance of an

Ultrasound Examination of Solid-Organ Transplants

*Guideline developed in collaboration with the American College of Radiology (ACR),
the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU).*



The American Institute of Ultrasound in Medicine (AIUM) is a multi-disciplinary association dedicated to advancing the safe and effective use of ultrasound in medicine through professional and public education, research, development of guidelines, and accreditation. To promote this mission, the AIUM is pleased to publish, in conjunction with the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU), this *AIUM Practice Guideline for the Performance of an Ultrasound Examination of Solid-Organ Transplants*. We are indebted to the many volunteers who contributed their time, knowledge, and energy to bringing this document to completion.

The AIUM represents the entire range of clinical and basic science interests in medical diagnostic ultrasound, and, with hundreds of volunteers, the AIUM has promoted the safe and effective use of ultrasound in clinical medicine for more than 50 years. This document and others like it will continue to advance this mission.

Practice guidelines of the AIUM are intended to provide the medical ultrasound community with guidelines for the performance and recording of high-quality ultrasound examinations. The guidelines reflect what the AIUM considers the minimum criteria for a complete examination in each area but are not intended to establish a legal standard of care. AIUM-accredited practices are expected to generally follow the guidelines with recognition that deviations from these guidelines will be needed in some cases, depending on patient needs and available equipment. Practices are encouraged to go beyond the guidelines to provide additional service and information as needed.



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I. Introduction

The clinical aspects contained in specific sections of this guideline (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American Institute of Ultrasound in Medicine (AIUM), the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU). Recommendations for physician requirements, written request for the examination, procedure documentation, and quality control vary among the organizations and are addressed by each separately.

This guideline 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. While it is not possible to detect every abnormality of a transplanted organ using ultrasound examinations, adherence to the following guideline will maximize the probability of detecting abnormalities. Due to 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 a separate section in the following document.

Throughout this guideline, references to 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 a sagittal or coronal plane. Both long-axis and transverse views may be obtained with oblique transducer orientation to obtain long- and short-axis views of the organ being insonated. 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 guideline.

II. Qualifications and Responsibilities of the Physician

See the AIUM Official Statement *Training Guidelines for Physicians Who Evaluate and Interpret Diagnostic Ultrasound Examinations* and the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

III. Indications/Contraindications

Indications for an ultrasound examination of a 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 after transplantation as per the hospital surveillance protocol^{1,2};
2. Follow-up of abnormal findings on a prior transplant ultrasound examination;
3. Assessment of the transplant in the setting of abnormal liver function tests^{3,4};
4. Evaluation for pain, fever, sepsis, or laboratory abnormalities;

5. Evaluation for a possible fluid collection or assessment of drainage catheter output;
6. Assessment of the biliary tree for dilatation, a stricture, biloma, or an abscess;
7. Evaluation for vascular patency; and
8. Evaluation for malignancy, either recurrent or posttransplant lymphoproliferative disorder.⁵⁻⁷

B. Renal Transplant:

1. Performance of a screening ultrasound examination to establish a baseline after transplantation as per the hospital surveillance protocol;
2. Follow-up of abnormal findings on a prior transplant ultrasound examination;
3. Evaluation for pain, fever, sepsis, or abnormal laboratory or clinical values (eg, elevated creatinine and low or decreased urine output);
4. Evaluation for vascular patency;
5. Assessment of hematuria or known or suspected hydronephrosis, hydroureter, or bladder abnormality;
6. Evaluation for a possible fluid collection or assessment of drainage catheter output;
7. Evaluation of the transplant in the setting of hypertension or bruit;
8. Evaluation for iatrogenic injury or complications after biopsy of a transplanted kidney; and
9. Evaluation for malignancy, either recurrent or posttransplant lymphoproliferative disorder.

C. Pancreas Transplant:

1. Performance of a screening ultrasound examination to establish a baseline after transplantation as per the hospital surveillance protocol;
2. Follow-up of abnormal findings on a prior transplant ultrasound examination.
3. Assessment of graft dysfunction in patients with abnormal laboratory values or clinical parameters (eg, elevated blood glucose);
4. Evaluation for suspected stenosis or thrombosis of the vasculature;
5. Evaluation of pain at or near the surgical site;
6. Evaluation of the response to treatment (eg, immunosuppressive therapy in the setting of rejection);
7. Evaluation for iatrogenic injury or complications after biopsy of a transplanted pancreas; and
8. Assessment of the transplant in the setting of infection or pancreatitis.

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.

IV. Written Request for the Examination

The written or electronic request for an ultrasound examination should provide sufficient information to allow for the appropriate performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider or under the provider's direction. The accompanying clinical information should be provided by a physician or other appropriate health care provider familiar with the patient's clinical situation and should be consistent with relevant legal and local health care facility requirements.

V. Specifications for Individual Examinations

In addition to grayscale imaging, spectral, color, and 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 [PRF]). When obtaining spectral Doppler measurements, the sample gate should be placed in the center of the arterial lumen and its size optimized for the size of the vessel being insonated. Angle correction is needed for all velocity measurements and should be obtained by using an angle of insonation 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 PRF and reduce wall filter); the use of power Doppler imaging may be helpful. Spectral analysis may include measurements such as the velocity, resistive index (RI), and acceleration time (AT).

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. Comparisons 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 biliary tree should be evaluated and the caliber of the common duct measured when possible. The subphrenic and subhepatic spaces should be investigated for possible fluid collections. Grayscale images of the hepatic vessels, including the portal vein, hepatic veins, and inferior vena cava (IVC), should be obtained.
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. 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 hepatic artery thrombosis, stenosis, a pseudo-

aneurysm, 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 obtained to demonstrate the presence of flow, configuration of the vessel, 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), RI (systolic velocity – diastolic velocity/systolic velocity), and 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. Resistive indices 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.^{8,9}

Comparisons with prior examinations should be made when possible. Although the hepatic arterial waveform may change normally with time, some changes in the waveform configuration, RI, or PSV may require further evaluation.^{3,10–12}

- b. Portal Vein—The main portal vein and right and left branches should be scanned in their entirety, including the portal vein anastomosis. Images should document the presence of flow, the direction of flow, and any areas of possible color Doppler aliasing. Spectral Doppler evaluation should include an assessment of the waveform as well as angle-corrected peak velocity measurements proximal to, at, and distal to the main portal vein anastomosis. If there appears to be a discrepancy in velocities within the portal vein, an anastomotic-to-preanastomotic velocity ratio can be performed.^{13,14}

3. *Hepatic Veins and IVC*—The type of surgical anastomosis (piggyback versus interposition) should be determined before scanning when possible. Color and spectral Doppler tracings should be obtained from the right, middle, and left hepatic veins and the IVC in whole-liver transplants and from the existing hepatic veins and IVC in partial-liver transplants. In the case of a piggyback hepatic venous anastomosis, both the recipient IVC and the piggybacked hepatic vein confluence/donor IVC segment should be interrogated. Flow should be verified and the waveform assessed for the degree of phasicity.^{14,15}

Comparisons with 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, 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 Transplanted Kidney*—Longitudinal and transverse views of the transplanted kidney and bladder should be obtained, and the longest renal length should be measured. The renal collecting system should be assessed for evidence of hydronephrosis, and, if present, the level of obstruction should be determined. The perinephric space should be assessed for evidence of fluid collections. Transverse and longitudinal images of the urinary bladder should be included. If a ureteral stent is in place, an attempt should be made to determine the proximal and distal extent of the stent.^{16,17}

For patients in whom more than 1 transplanted kidney is present and evaluation of more than 1 transplant is required, each component of the examination should be performed for each renal transplant. Images for each graft should be clearly labeled in such situations as appropriate (eg, “medial kidney” and “lateral kidney”).

2. *Doppler Evaluation of the Transplanted Kidney*—Doppler evaluation of the transplanted kidney or kidneys should be performed for assessment of transplant vascularity. 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.
 - a. *Main Renal Artery or Arteries*—The number of main renal arteries should be recorded. If more than 1 artery is present with separate anastomoses, each anastomosis should be similarly evaluated. Color Doppler images of the main renal artery or arteries from the transplanted kidney to the anastomosis should be obtained wherever possible. Velocity measurements should be obtained at the anastomosis and distal to the anastomosis whenever possible and at any areas of color flow aliasing suggestive of high-velocity flow. Doppler indices should include the PSV and may include the AT, RI, and/or pulsatility index.^{18,19}
 - b. *Main Renal Vein*—Color Doppler images should be obtained from the transplant renal vein throughout its course from the kidney to anastomosis. Spectral Doppler images should be obtained from the transplant renal vein at the anastomosis and distal to the anastomosis.
 - c. *External Iliac Artery and Vein*—Color and spectral Doppler images of the external iliac artery and vein should be obtained cephalad to the main renal artery and main renal vein anastomoses. Calculation of the renal artery-to-iliac artery PSV ratio may be helpful in evaluating for renal artery stenosis.^{17,20}
 - 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. Doppler indices calculated from spectral Doppler waveforms

obtained in the interlobar or segmental arteries in the upper pole, interpolar region, and lower pole of the transplanted kidney should include the RI and may include the 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.

C. *Pancreas Transplant*

Grayscale, color Doppler, and spectral Doppler examinations of a pancreas transplant should be performed. Before the ultrasound examination, the surgical anatomy should be confirmed when this information is available. Comparisons with prior examinations should be made when possible. The sonographic evaluation of the transplanted pancreas may be limited by reduced acoustic windows, which may impact the feasibility of obtaining the suggested images.

1. *Grayscale Evaluation of the Transplanted Pancreas*—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 assessed. 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 assess for areas of dilatation, which 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.^{21,22}
2. *Doppler Evaluation of the Transplanted Pancreas*—The structures that should be examined include the transplant arterial Y-graft, the transplant superior mesenteric artery 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).²³
 - a. **Transplant Arteries**—Color Doppler images of the Y-graft from the recipient arterial anastomosis, across both limbs of the Y-graft to both the superior mesenteric artery and splenic arterial anastomoses, should be obtained. 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, and the waveforms should be assessed for morphology.²³

Spectral Doppler images with angle correction should be obtained within the splenic artery and superior mesenteric artery 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 RIs.^{23–25}

Color or power Doppler images of the entire pancreas transplant should be obtained to assess the global vascularity of the graft. A spectral Doppler evaluation of intraparenchymal pancreatic arteries should be performed in the pancreatic head, body, and tail, and RIs may be calculated.²³

- b. **Transplant Veins**—Color and spectral Doppler images of the graft splenic vein, superior mesenteric vein, and portal vein to the recipient venous anastomosis should be obtained. Spectral Doppler assessment with angle correction and measurement of the peak velocity may be performed within the graft portal vein, at the graft portal vein–venous anastomosis, and distal to the anastomosis within the recipient vein.²⁶ Additional measurements at areas of color flow aliasing may be helpful. Intraparenchymal venous flow should also be documented in the head and tail of the transplanted pancreas.

VI. Documentation

Adequate documentation is essential for high-quality patient care. There should be a permanent record of the ultrasound examination and its interpretation. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and side (right or left) of the anatomic site imaged. An official interpretation (final report) of the ultrasound findings should be included in the patient's medical record. Retention of the ultrasound examination should be consistent both with clinical needs and with relevant legal and local health care facility requirements.

Reporting should be in accordance with the *AIUM Practice Guideline for Documentation of an Ultrasound Examination*.

VII. Equipment Specifications

Grayscale and Doppler evaluations of the transplant parenchymal organs should be performed in real time using a scanner with color Doppler and spectral 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 6 MHz are most commonly used, whereas in children, higher frequencies may be used. Linear array transducers may be used for further anatomic detail in superficially located kidney or pancreas transplants.

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 control, patient education, infection control, and safety should be developed and implemented in accordance with the *AIUM Standards and Guidelines for the Accreditation of Ultrasound Practices*.

Equipment performance monitoring should be in accordance with the AIUM *Standards and Guidelines for the Accreditation of Ultrasound Practices*.

IX. ALARA Principle

The potential benefits and risks of each examination should be considered. The ALARA (as low as reasonably achievable) principle should be observed when adjusting controls that affect the acoustic output and by considering transducer dwell times. Further details on ALARA may be found in the AIUM publication *Medical Ultrasound Safety, Third Edition*.

Acknowledgments

This guideline was revised by the AIUM in collaboration with the American College of Radiology (ACR), Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU) according to the process described in the AIUM *Clinical Standards Committee Manual*.

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