New 2025

American College of Radiology
ACR Appropriateness Criteria®
Imaging After Liver Transplant

<u>Variant: 1</u> Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler abdomen	Usually Appropriate	O
CT abdomen with IV contrast	Usually Appropriate	☢☢☢
CT abdomen with IV contrast multiphase	Usually Appropriate	☢☢☢☢
US abdomen	May Be Appropriate	O
MRI abdomen without and with IV contrast with MRCP	May Be Appropriate (Disagreement)	O
CT abdomen without and with IV contrast	May Be Appropriate	☢☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
MRI abdomen without and with IV contrast	Usually Not Appropriate	O
MRI abdomen without IV contrast	Usually Not Appropriate	O
MRI abdomen without IV contrast with MRCP	Usually Not Appropriate	O
CT abdomen without IV contrast	Usually Not Appropriate	☢☢☢
CTA abdomen with IV contrast	Usually Not Appropriate	☢☢☢

<u>Variant: 2</u> Adult. Liver transplant. Postoperative complications, suspected vascular etiology. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler abdomen	Usually Appropriate	O
CT abdomen with IV contrast	Usually Appropriate	☢☢☢
CTA abdomen with IV contrast	Usually Appropriate	☢☢☢
CT abdomen with IV contrast multiphase	Usually Appropriate	☢☢☢☢
MRI abdomen without and with IV contrast	May Be Appropriate	O
CT abdomen without and with IV contrast	May Be Appropriate	☢☢☢☢
US abdomen	Usually Not Appropriate	O
Radiography abdomen	Usually Not Appropriate	☢☢
MRI abdomen without and with IV contrast with MRCP	Usually Not Appropriate	O
MRI abdomen without IV contrast	Usually Not Appropriate	O
MRI abdomen without IV contrast with MRCP	Usually Not Appropriate	O
CT abdomen without IV contrast	Usually Not Appropriate	☢☢☢

<u>Variant: 3</u> Adult. Liver transplant. Postoperative complications, suspected biliary etiology. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US abdomen	Usually Appropriate	O
US duplex Doppler abdomen	Usually Appropriate	O
MRI abdomen without and with hepatobiliary contrast	Usually Appropriate	O
MRI abdomen without and with IV contrast with MRCP	Usually Appropriate	O
MRI abdomen without IV contrast with MRCP	Usually Appropriate	O

MRI abdomen without and with IV contrast	May Be Appropriate	O
CT abdomen with IV contrast	May Be Appropriate	☢☢☢
CT abdomen with IV contrast multiphase	May Be Appropriate	☢☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
MRI abdomen without IV contrast	Usually Not Appropriate	O
CT abdomen without IV contrast	Usually Not Appropriate	☢☢☢
CT abdomen without and with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 4 Adult. Post liver transplant. Surveillance.

Procedure	Appropriateness Category	Relative Radiation Level
MRI abdomen without and with hepatobiliary contrast	Usually Appropriate	O
MRI abdomen without and with IV contrast	Usually Appropriate	O
MRI abdomen without and with IV contrast with MRCP	Usually Appropriate	O
CT abdomen with IV contrast multiphase	Usually Appropriate	☢☢☢☢
US abdomen	May Be Appropriate (Disagreement)	O
US duplex Doppler abdomen	May Be Appropriate (Disagreement)	O
MRI abdomen without IV contrast	May Be Appropriate	O
MRI abdomen without IV contrast with MRCP	May Be Appropriate	O
CT abdomen with IV contrast	May Be Appropriate	☢☢☢
CT abdomen without and with IV contrast	May Be Appropriate	☢☢☢☢
Radiography abdomen	Usually Not Appropriate	☢☢
CT abdomen without IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢

Panel Members

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Summary of Literature Review

Introduction/Background

Liver transplantation is currently the treatment of choice for patients with acute or advanced chronic liver failure. Indications include but are not limited to noncholestatic cirrhosis, cholestatic liver disease, biliary atresia, acute hepatic necrosis, metabolic conditions, and malignancy [1]. Since the introduction of liver transplantation in 1963 [2], there have been considerable advances in donor organ preservation, surgical techniques, and immunosuppressive agents. Currently, the 1-year, 3-year, and 5-year graft survival rates after liver transplant are 93.2%, 87.3%, and 84.1%, respectively [3]. Additionally, there were more than 10,660 liver transplants performed in 2023 [3]. Early detection and treatment of postoperative complications has significantly contributed to improved graft and patient survival.

Complications that can lead to liver allograft failure or patient mortality include vascular abnormalities, biliary complications, infection, rejection, and recurrent or posttransplant malignancy. Imaging plays a vital role in detecting these complications. Although imaging in most centers starts on postoperative day 0 or day 1, the imaging protocol and follow-up thereafter can be variable from institution to institution.

Special Imaging Considerations

Multiphase CT is CT with 2 to 4 phases done during contrast administration.

For the purposes of distinguishing between CT and CT angiography (CTA), ACR Appropriateness Criteria topics use the definition in the ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA) [4]:

"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial and/or venous enhancement, depending on the vascular structures to be analyzed. The resultant volumetric data set is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and reconstructions/reformats. Only in CTA; however, is 3-D rendering a required element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

Contrast-enhanced US (CEUS) may also be of benefit in the evaluation of liver transplant patients in the immediate postoperative period. A meta-analysis of 13 studies consisting of 2,281 CEUS studies demonstrated pooled sensitivity and specificity of 90% and100%, respectively, for the identification of vascular complications after liver transplantation with CEUS [5]. Additionally, CEUS using microbubble contrast can reduce the false-positive rate by detecting flow not captured on standard Doppler imaging [6].

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously wherein each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.

Liver allografts are vulnerable in the immediate postoperative period, and the main objective of early noninvasive imaging is to identify or exclude biliary, vascular, and parenchymal complications. Additionally, there is an overlapping spectrum of clinical and laboratory findings for patients with and without complications [7]. Because multiple vascular anastomoses are required during transplantation, vascular complications are of particular concern in the immediate postoperative period. Protocols vary from institution to institution but consist of daily liver function tests and imaging on postoperative day 0 or day 1.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
A. CT Abdomen with IV Contrast

A retrospective study of 75 patients by Lee et al [8] demonstrated sensitivity, specificity, and diagnostic accuracy of CT for diagnosis of overall complications in the early period of 93.6%, 90.2%, and 92%, respectively. The most common complication was active bleeding, and the second most common complication was portal vein thrombosis/stenosis. Of note, there were 3 false-negatives in the early period, including one case of bile leakage, one case of bile duct stenosis, and one case of hepatic artery stenosis, which were not detected with the use of CT. CTs were performed in single (portal venous), dual (arterial and portal venous), or triple (arterial, portal venous, and equilibrium) phases. Multiphase CT is superior to single phase CTs due to the ability to evaluate arterial, venous, and other structures during a single examination [7,8].

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
B. CT Abdomen with IV Contrast Multiphase

A retrospective study of 170 patients by Boraschi et al [7] demonstrated a sensitivity and specificity of CT in the detection of vascular and biliary adverse events of 100% and 97% and 83% and 100%, respectively. Additionally, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of CT in the identification of all early abdominal complications after liver transplantation were 96%, 97%, 87%, 99%, and 97%, respectively. CTs were performed with unenhanced, arterial, and portal venous phases.

A retrospective study of 75 patients by Lee et al [8] demonstrated sensitivity, specificity, and diagnostic accuracy of CT for diagnosis of overall complications in the early period of 93.6%, 90.2%, and 92%, respectively. The most common complication was active bleeding, and the second most common complication was portal vein thrombosis/stenosis. Of note, there were 3 false-negatives in the early period, including one case of bile leakage, one case of bile duct stenosis, and one case of hepatic artery stenosis, which were not detected with the use of CT. CTs were performed in single (portal venous), dual (arterial and portal venous), or triple (arterial, portal venous, and equilibrium) phases. Multiphase CT is superior to single phase CTs due to the ability to evaluate arterial, venous, and other structures during a single examination [7,8]. The addition of an unenhanced phase to a CT abdomen with IV contrast multiphase may provide some limited additional value by helping to differentiate hyperdense surgical material or clips from active bleeding.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
C. CT Abdomen without and with IV Contrast

A retrospective study of 170 patients by Boraschi et al [7] demonstrated a sensitivity and specificity of CT in the detection of vascular and biliary adverse events of 100% and 97% and 83% and 100%, respectively. Additionally, the sensitivity, specificity, PPV, NPV, and diagnostic accuracy of CT in the identification of all early abdominal complications after liver transplantation were 96%, 97%, 87%, 99%, and 97%, respectively. CTs were performed with unenhanced, arterial, and portal venous phases. Multiphase CT is superior to single phase CTs due to the ability to evaluate arterial, venous, and other structures during a single examination [7,8].The addition of an unenhanced phase may provide some limited additional value by helping to differentiate hyperdense surgical material or clips from active bleeding, but likely less so than a multiphase CT.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
D. CT Abdomen without IV Contrast

CT abdomen without intravenous (IV) contrast as a stand-alone examination has limited usefulness in the immediate postoperative period and is used to evaluate peritransplant fluid collections. Low liver allograft attenuation on unenhanced CT can be associated with mortality and graft failure according to a study by Kim et al [9]; however, this was performed at 1 month after the operation.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
E. CTA Abdomen with IV Contrast

There is no relevant literature to support the need for 3-D reconstructions that are generated with CTA protocol of the abdomen with IV contrast as the initial imaging test after orthotopic liver transplantation.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
F. MRI Abdomen without and with IV Contrast

Although MRI may be used to detect biliary complications after liver transplantation or as a confirmatory study after ultrasound (US), there is no relevant literature to support the use of MRI as the initial imaging test for immediate postoperative imaging after liver transplantation. MRI is often difficult to obtain in the immediate postoperative prior due to the acuity of these patients and difficulty with breath-holding, sedation, ascites, etc.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
G. MRI Abdomen without and with IV Contrast with MRCP

Although MRI may be used to detect biliary complications after liver transplantation or as a confirmatory study after US, there is no relevant literature to support the use of MRI as the initial imaging test for immediate postoperative imaging after liver transplantation. MRI is often difficult to obtain in the immediate postoperative prior due to the acuity of these patients and difficulty with breath-holding, sedation, etc.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
H. MRI Abdomen without IV Contrast

Although MRI may be used to detect biliary complications after liver transplantation or as a confirmatory study after US, there is no relevant literature to support the use of MRI as the initial imaging test for immediate postoperative imaging after liver transplantation. MRI is often difficult to obtain in the immediate postoperative prior due to the acuity of these patients and difficulty with breath-holding, sedation, etc.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
I. MRI abdomen without IV contrast with MRCP

Although MRI may be used to detect biliary complications after liver transplantation or as a confirmatory study after US, there is no relevant literature to support the use of MRI as the initial imaging test for immediate postoperative imaging after liver transplantation. MRI is often difficult to obtain in the immediate postoperative prior due to the acuity of these patients and difficulty with breath-holding, sedation, etc.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
J. Radiography Abdomen

There is no relevant literature to support the use of abdominal radiography as the initial imaging test after orthotopic liver transplant with the exception of radiographs to look for retained surgical instruments/materials.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
K. US Abdomen

US is useful for the detection of complications in the immediate postoperative period after liver transplantation. Grayscale/B-mode US imaging of the allograft can evaluate for abnormalities in the hepatic parenchyma and biliary tree and for peritransplant fluid collections. However, given that the detection of vascular complication is of the utmost importance in the immediate postoperative period, there is no relevant literature to support the use of grayscale/B-mode imaging alone as the initial imaging test. US duplex Doppler is considered the more optimal procedure for the detection of complications in the immediate postoperative period of liver transplantation due to its ability to evaluate hepatic vasculature, biliary tree, and hepatic parenchyma [7].

US is sensitive but not specific in the evaluation of peritransplant fluid collections because bile, lymph, blood, and pus can all present on imaging as a simple fluid collection [10]. Additionally, the extent of fluid collections is better evaluated with CT and MRI.

Variant 1: Adult. Liver transplant. Immediate postoperative imaging. Initial imaging.
L. US Duplex Doppler Abdomen

US duplex Doppler of the abdomen is an optimal imaging procedure for the detection of complications in the immediate postoperative period after liver transplantation due to its ability to evaluate hepatic vasculature, biliary tree, and hepatic parenchyma. Additionally, these patients are often very sick, and this procedure can be performed at the bedside in the early postoperative period [7,8,11,12].

Because multiple vascular anastomoses are required during transplantation, vascular complications are of particular concern in the immediate postoperative period. Arterial complications are more common than venous ones. In normal liver arterial spectral waveforms, the arterial acceleration time is <0.08 seconds, and the resistive index (RI) [(peak systolic velocity − peak diastolic velocity) / peak systolic velocity)] is between 0.5 and 0.8 [13].

A retrospective study of 110 patients by Uzochukwu et al [14] demonstrated that low early posttransplant hepatic artery resistive indices (<0.6) were 100% sensitive and 80% specific for vascular complications but not for biliary complications. A study of 522 patients demonstrates a 100% sensitivity of US compared with angiography for the detection of early hepatic artery thrombosis [15]. However, duplex US can be susceptible to false-positives due to low cardiac output, arterial spasm, and severe parenchymal edema [16]. Low RI, prolonged systolic acceleration time, and focal peak velocities >200 cm/s are suggestive of hepatic arterial stenosis [6]. Dodd et al [17] demonstrate in a series of 125 patients that when Doppler criteria for arterial complications are combined, the diagnostic sensitivity and specificity for arterial thrombosis or stenosis are 97% and 64%, respectively. A study of 46 patients demonstrated that abnormal values for RI and acceleration time were 67% sensitive and 96% specific for arterial stenosis, and sensitivity and specificity were 81% and 60% when at least one abnormal value was found [18]. Lack of flow in the hepatic artery is suggestive of hepatic thrombosis, and US correctly identifies more than 90% of cases of hepatic artery thrombosis [19].

A retrospective study of 94 patients by Chong et al [20] demonstrated an anastomotic velocity threshold of >125 cm/s as 73% sensitive and 95% specific for portal venous stenosis, an anastomotic to preanastomotic velocity ratio of 3:1 as 73% sensitive and 100% specific for venous stenosis, and a venous pulsatility index of <0.45 as 95.7% specific for outflow venous stenosis.

On Doppler US, abnormal hepatic venous flow may manifest as increased phasicity, decreased phasicity, or absent hepatic venous flow. Abnormal portal venous flow usually manifests as increased pulsatility, slow portal venous flow, hepatofugal flow, or absent portal venous flow [21].

It is important to note that Doppler findings should be interpreted with caution in the immediate postoperative period since transient abnormalities can be observed that resolve spontaneously after a few days [20].

Although Doppler US is a noninvasive method of identifying adverse events in liver transplant recipients, a normal US examination cannot exclude the presence of biliary, vascular, and/or parenchymal complications [7].

US is a satisfactory screening tool for detecting biliary ductal dilation after orthotopic liver transplantation, with a reported sensitivity of 71% for depicting post–liver transplantation biliary obstruction according to a series [22].

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

Because multiple vascular anastomoses are required during liver transplantation, vascular complications are of concern. They occur in up to 7% of deceased donors and 13% of living donors [19]. Arterial complications include thrombosis, stenosis, pseudoaneurysm, and splenic artery steal syndrome. Venous complications are less common and include stenosis, thrombosis, and occlusion of the portal veins, hepatic veins and inferior vena cava [6]. Early diagnosis of vascular complications is crucial to improve the likelihood of graft and patient survival.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

A. CT Abdomen with IV Contrast

CT of the abdomen may be useful for the evaluation of suspected vascular complications in liver transplant patients. Contrast-enhanced CT is useful in selected cases, such as when US is equivocal, there is persistent clinical suspicion, or more detailed anatomic assessment of vascular complications is required to plan endovascular intervention [19]. CT also has a key role in ruling out false-positive and false-negative cases prompted by US [16].

A retrospective study of 170 patients by Boraschi et al [7] demonstrated a sensitivity and specificity of CT in the detection of vascular adverse events of 100% and 97%, respectively.

Another study of 75 patients by Lee et al [8] demonstrated sensitivity, specificity, and diagnostic accuracy of CT for diagnosing vascular complications in the early period (<3 months) of 97.1%, 92.6%, and 94.3%, respectively. Furthermore, they demonstrated sensitivity, specificity, and diagnostic accuracy of vascular complications in the late period (>3 months) of 83.3%, 100%, and 98.9%, respectively. The most common vascular complication found during their study in the early period was active bleeding, and the second most common was portal vein thrombosis/stenosis.

Hepatic artery thrombosis is one of the most feared and most common complications, affecting 2% to 12% of transplants [6,7]. CT was found to be 89% sensitive and 100% specific in the detection of hepatic artery thrombosis [18].

CT is superior to MR angiography in terms of speed and imaging quality. Studies have shown good correlation between CT and conventional angiography in the detection of vascular lesions, with sensitivities up to 100% and specificities up to 89% [7].

Multiphase CT is superior to single phase CTs due to the ability to evaluate arterial, venous, and other structures during a single examination [7,8]. The addition of an unenhanced phase may provide limited additional value by helping to differentiate hyperdense surgical material or clips from active bleeding, but likely less so than a multiphase CT.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.
B. CT Abdomen with IV Contrast Multiphase

CT of the abdomen may be useful for the evaluation of suspected vascular complications in liver transplant patients. Contrast-enhanced CT is useful in selected cases, such as when US is equivocal, there is persistent clinical suspicion, or more detailed anatomic assessment of vascular complications is required to plan endovascular intervention [19]. CT also has a key role in ruling out false-positive and false-negative cases prompted by US [16].

A retrospective study of 170 patients by Boraschi et al [7] demonstrated a sensitivity and specificity of CT in the detection of vascular adverse events of 100% and 97%, respectively.

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Multiphase CT is superior to single phase CTs due to the ability to evaluate arterial, venous, and other structures during a single examination [7,8]. The addition of an unenhanced phase may provide limited additional value by helping to differentiate hyperdense surgical material or clips from active bleeding, but likely less so than a multiphase CT.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.
C. CT Abdomen Without and With IV Contrast

CT of the abdomen may be useful for the evaluation of suspected vascular complications in liver transplant patients. Contrast-enhanced CT is useful in selected cases, such as when US is equivocal, there is persistent clinical suspicion, or more detailed anatomic assessment of vascular complications is required to plan endovascular intervention [19]. CT also has a key role in ruling out false-positive and false-negative cases prompted by US [16].

A retrospective study of 170 patients by Boraschi et al [7] demonstrated a sensitivity and specificity of CT in the detection of vascular adverse events of 100% and 97%, respectively.

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Multiphase CT is superior to single phase CTs due to the ability to evaluate arterial, venous, and other structures during a single examination [7,8]. The addition of an unenhanced phase may provide limited additional value by helping to differentiate hyperdense surgical material or clips from active bleeding, but likely less so than a multiphase CT.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.
D. CT Abdomen Without IV Contrast

There is no relevant literature to support the use of CT abdomen without IV contrast as the initial imaging test after orthotopic liver transplant for suspected vascular complications.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.
E. CTA Abdomen With IV Contrast

CTA of the abdomen may be useful for the evaluation of suspected arterial vascular complications in liver transplant patients. Contrast-enhanced CT is useful in selected cases, such as when US is equivocal, there is persistent clinical suspicion, or more detailed anatomic assessment of vascular complications is required to plan endovascular intervention [19]. CT also has a key role in ruling out false-positive and false-negative cases prompted by US [16].

A retrospective study of 170 patients by Boraschi et al [7] demonstrated a sensitivity and specificity of CT in the detection of vascular adverse events of 100% and 97%, respectively.

Another study of 75 patients by Lee et al [8] demonstrated sensitivity, specificity, and diagnostic accuracy of CT for diagnosing vascular complications in the early period (<3 months) of 97.1%, 92.6%, and 94.3%, respectively. Furthermore, they demonstrated sensitivity, specificity, and diagnostic accuracy of vascular complications in the late period (>3 months) of 83.3%, 100%, and 98.9%, respectively. The most common vascular complication found during their study in the early period was active bleeding, and the second most common was portal vein thrombosis/stenosis.

A retrospective study of 481 patients demonstrated that a systematic CTA at the end of the first postoperative week reduced retransplantation rates due to late hepatic artery thrombosis by detecting patients at risk who required specific treatment [23].

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology.

Initial imaging.

F. MRI Abdomen Without and With IV Contrast

MRI is mainly a confirmatory study after US, and there is no relevant literature to support its use as the initial imaging test after orthotopic liver transplant for suspected vascular complications. MRI has a limited role for the acute assessment of vascular complications after liver transplantation [19]. When used with US, MRI can help quantify the degree and length of the stenosis [6].

A study of 76 patients by Kim et al [24] using MRI of the abdomen with and without IV contrast for the diagnosis of hepatic artery stenosis demonstrated sensitivity, PPV, NPV, and accuracy of 100%, 74%, 29%, 100%, and 77%, respectively. In diagnosing portal venous stenosis, the same study demonstrated a sensitivity, PPV, NPV, and accuracy of 100%, 84%, 35%, and 85%, respectively. Thus, MRI was sensitive but not specific in the detecting of vascular stenosis.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

G. MRI abdomen without and with IV contrast with MRCP

There is no relevant literature to support the use of MRI abdomen without and with IV contrast with MR cholangiopancreatography (MRCP) as the initial imaging test after orthotopic liver transplant for suspected vascular complications.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

H. MRI Abdomen Without IV Contrast

There is no relevant literature to support the use of MRI abdomen without IV contrast as the initial imaging test after orthotopic liver transplant for suspected vascular complications.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

I. MRI Abdomen Without IV Contrast with MRCP

There is no relevant literature to support the use of MRI abdomen without IV contrast with MRCP as the initial imaging test after orthotopic liver transplant for suspected vascular complications.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

J. Radiography Abdomen

There is no relevant literature to support the use of abdominal radiography as the initial imaging test after orthotopic liver transplant for suspected vascular complications.

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

K. US Abdomen

US is useful for the detection of complications in the immediate postoperative period after liver transplantation. Grayscale/B-mode US imaging of the allograft can evaluate for abnormalities in the hepatic parenchyma, biliary tree, and peritransplant fluid collections. However, given that the detection of vascular complication is of the utmost importance in the immediate postoperative period, there is no relevant literature to support the use of grayscale/B-mode imaging alone as the initial imaging test. US duplex Doppler is considered the more optimal procedure for the detection of complications in the immediate postoperative period of liver transplantation due to its ability to evaluate hepatic vasculature, biliary tree, and hepatic parenchyma [7].

Variant 2: Adult. Liver transplant. Postoperative complications. Suspected vascular etiology. Initial imaging.

L. US Duplex Doppler Abdomen

US duplex Doppler of the abdomen is an optimal imaging procedure for the detection of complications in the immediate postoperative period after liver transplantation due to its ability to evaluate hepatic vasculature, biliary tree, and hepatic parenchyma. Additionally, these patients are often very sick, and this procedure can be easily performed at the bedside [7,8,11,12].

Because multiple vascular anastomoses are required during transplantation, vascular complications are of particular concern in the immediate postoperative period. Arterial complications are more common than venous. In normal liver arterial spectral waveforms, the arterial acceleration time is <0.08 seconds, and the RI [(peak systolic velocity − peak diastolic velocity) / peak systolic velocity)] is between 0.5 and 0.8 [13].

A retrospective study of 110 patients by Uzochukwu et al [14] demonstrates that low early posttransplant hepatic artery resistive indices (<0.6) were 100% sensitive and 80% specific for vascular complications but not for biliary complications. A study of 522 patients demonstrates 100% sensitivity of US compared with angiography for the detection of early hepatic artery thrombosis [15]. However, duplex US can be susceptible to false-positives due to low cardiac output, arterial spasm, and severe parenchymal edema [16]. Low RI, prolonged systolic acceleration time, and focal peak velocities >200 cm/s are suggestive of hepatic arterial stenosis [6]. Dodd et al [17] demonstrate in a series of 125 patients that when Doppler criteria for arterial complications are combined, the diagnostic sensitivity and specificity for arterial thrombosis or stenosis are 97% and 64%, respectively. A study of 46 patients demonstrates that abnormal values for RI and acceleration time were 67% sensitive and 96% specific for arterial stenosis, and sensitivity and specificity were 81% and 60% when at least one abnormal value was found [18]. Lack of flow in the hepatic artery is suggestive of hepatic thrombosis, and US correctly identifies more than 90% of cases of hepatic artery thrombosis [19].

A retrospective study of 94 patients by Chong et al [20] demonstrated an anastomotic velocity threshold of >125 cm/s as 73% sensitive and 95% specific for portal venous stenosis, an anastomotic to preanastomotic velocity ratio of 3:1 as 73% sensitive and 100% specific for venous stenosis, and a venous pulsatility index of <0.45 as 95.7% specific for outflow venous stenosis.

On Doppler US, abnormal hepatic venous flow may manifest as increased phasicity, decreased phasicity, or absent hepatic venous flow. Abnormal portal venous flow usually manifests as increased pulsatility, slow portal venous flow, hepatofugal flow, or absent portal venous flow [21].

It is important to note that Doppler findings should be interpreted with caution in the immediate postoperative period because transient abnormalities can be observed that result spontaneously after a few days [20].

Although Doppler US is a noninvasive method of identifying adverse events in liver transplant recipients, a normal US examination cannot exclude the presence of biliary, vascular, and/or parenchymal complications [7].

US is a satisfactory screening tool for detecting biliary ductal dilation after orthotopic liver transplantation, with a reported sensitivity of 71% for depicting post–liver transplantation biliary obstruction according to a series [22].

CEUS may also be of benefit in the evaluation of liver transplant patients in the immediate postoperative period. A meta-analysis of 13 studies consisting of 2,281 CEUS studies demonstrates a pooled sensitivity and specificity of 90% and100%, respectively, for the identification of vascular complications after liver transplantation with CEUS [5]. Additionally, CEUS using microbubble contrast can reduce the false-positive rate by detecting flow not captured on standard Doppler imaging [6].

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.

Approximately 25% of liver transplants develop biliary complications, commonly within the first 3 months. Complications include leak, biliary obstruction, stone/cast formation, biliary stricture, and recurrent biliary disease [12].

Biliary strictures occur in 15% to 18% of liver transplant recipients, are the most common cause of biliary obstruction, and can be classified as anastomotic or nonanastomotic [12,25].

Anastomotic strictures occur due to technical surgical issues and fibro-proliferative response to ischemia at the site of the biliary anastomosis, with resultant short segment bile duct narrowing, upstream continuously dilated intrahepatic and extrahepatic bile ducts, and downstream normal caliber duct. As such, these strictures tend to be isolated [11,12]. Nonanastomotic strictures are secondary to ischemia related injury, immunological injury, and bile salt-induced injury. Multiple segments of bile duct undergo necrosis, with subsequent multiple long fibrotic strictures with intervening segments of bile duct dilation. Although both the intra- and extrahepatic bile ducts can be involved, most cases involve the hilar bile duct. Necrosis of the biliary epithelium can result in poor visualization of the hilar bile duct luminal contour.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
A. CT Abdomen With IV Contrast

CT has a role as a second-line modality after US if vascular complications are suspected or for assessment of a collection but not for assessment of biliary complications [16].

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
B. CT Abdomen With IV Contrast Multiphase

CT has a role as a second-line modality after US if vascular complications are suspected or for assessment of a collection but not for assessment of biliary complications [16].

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
C. CT Abdomen Without and With IV Contrast

CT has a role as a second-line modality after US if vascular complications are suspected or for assessment of a collection but not for assessment of biliary complications [16]. A noncontrast examination might demonstrate biliary dilation and/or a perihepatic collection, but a contrast-enhanced phase would be necessary for assessment of the vascular anatomy and patency.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
D. CT Abdomen Without IV Contrast

CT has a role as a second-line modality after US if vascular complications are suspected or for assessment of a collection but not for assessment of biliary complications [16]. A noncontrast examination might demonstrate biliary dilation and/or a perihepatic collection, but a contrast-enhanced phase would be necessary for assessment of the vascular anatomy and patency.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
E. MRI abdomen without and with hepatobiliary contrast

If there is clinical suspicion for biliary obstruction, or if an US shows a perihepatic fluid collection or biliary abnormality, an MRI can provide useful anatomic detail [25].

Administration of IV contrast is essential for assessing vascular patency. In addition, administration of hepatobiliary contrast agents may be helpful when evaluation of the biliary system is required. Gadoxetate disodium has a 50% hepatic uptake and excretion into the biliary system, which allows for acquiring hepatobiliary images (approximately 20 minutes following administration of contrast). Contrast-filled bile ducts, during the hepatobiliary phase, appear hyperintense on T1-weighted images, allowing for the detection of active biliary leaks by demonstrating contrast extravasation into a perihepatic fluid collection/biloma [26]. For the detection of bile leak, the delayed phase may require an extended delay of 60 to 180 minutes, especially in those patients with dilated bile ducts or moderate hepatic dysfunction [27,28]. Gadoxetate disodium-enhanced MRI in combination with MRCP improves the sensitivity and specificity for detection of biliary leaks after liver transplantation, with reported sensitivity and specificity of 76% and 100%.

The combination of gadoxetate disodium-enhanced MRI and MRCP improves the accuracy for detection of both anastomotic and nonanastomotic biliary strictures, with reported sensitivity and specificity of 79% and 96% to 100%, respectively [26].

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
F. MRI Abdomen Without and With IV Contrast

If there is clinical suspicion for biliary obstruction, or if an US shows a perihepatic fluid collection or biliary abnormality, an MRI can provide useful anatomic detail [25].

In a study on 232 liver transplant patients with suspected biliary complications (impaired liver function and/or sonographic biliary abnormalities), MRI with MRCP had a sensitivity, specificity, PPV, NPV, and accuracy for the detection of all types of biliary complications of 99%, 96%, 95%, 99%, and 97% respectively [29]. In 207 patients, the examination was performed without IV contrast. This suggests that MRI with MRCP but without IV contrast could still be helpful in diagnosing biliary complications. However, if a biliary stricture or leak is secondary to vascular compromise, this may not be detected on a noncontrast examination.

MRCP has been reported to be >95% sensitive, specific, and accurate for depicting anastomotic strictures [25]. As such, whenever possible, inclusion of MRCP images in the imaging protocol should be considered.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.

G. MRI Abdomen Without and With IV Contrast with MRCP

If there is clinical suspicion for biliary obstruction, or if an US shows a perihepatic fluid collection or biliary abnormality, an MRI can provide useful anatomic detail [25].

In a study on 232 liver transplant patients with suspected biliary complications (impaired liver function and/or sonographic biliary abnormalities), MRI with MRCP had a sensitivity, specificity, PPV, NPV, and accuracy for the detection of all types of biliary complications of 99%, 96%, 95%, 99%, and 97% respectively [29]. In 207 patients, the examination was performed without IV contrast.

Garg et al [30], in a prospective study of 34 patients, reported that compared with findings at direct cholangiography, MRCP presented a 96.9% sensitivity, 96.9% PPV, and 94.1% accuracy for the detection of biliary complications. The sensitivity, specificity, PPV, NPV, and accuracy for the detection of anastomotic strictures, biliary leak, and biliary stone or sludge on MRCP were reported to be 100%, 84.6%, 91.3%, 100%, and 94.1%; 72.7%, 95.7%, 88.9%, 88%, and 88.2%; and 80%, 100%, 100%, 96.7%, and 97.1%, respectively.

In another study of 27 liver transplant recipients, the authors reported a statistically significant correlation between the MRCP findings and both the endoscopic retrograde cholangiography and percutaneous transhepatic cholangiography findings, with a sensitivity of 94.4%, a specificity of 88.9%, and a PPV and NPV of 94.4% and 88.9%, respectively [31]. The combination of gadoxetate disodium-enhanced MRI and MRCP improves the accuracy for the detection of both anastomotic and nonanastomotic biliary strictures, with reported sensitivity and specificity of 79% and 96% to 100%, respectively [26].

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.

H. MRI Abdomen Without IV Contrast

There is no relevant literature and a lack of data regarding MRI abdomen without IV contrast in this clinical scenario.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.

I. MRI Abdomen Without IV Contrast with MRCP

MRCP has been reported to be more than 95% sensitive, specific, and accurate for depicting anastomotic strictures [25]. As such, whenever possible, inclusion of MRCP images in the imaging protocol should be considered.

In a study on 232 liver transplant patients with suspected biliary complications (impaired liver function and/or sonographic biliary abnormalities), MRI with MRCP had a sensitivity, specificity, PPV, NPV, and accuracy for the detection of all types of biliary complications of 99%, 96%, 95%, 99%, and 97% respectively [29]. In 207 patients, the examination was performed without IV contrast. This suggests that MRI with MRCP but without IV contrast could still be helpful in diagnosing biliary complications. However, if a biliary stricture or leak is secondary to vascular compromise, this may not be detected on a noncontrast examination.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
J. Radiography Abdomen

There is no relevant literature supporting the use of abdominal radiography for the evaluation of posttransplant biliary complications.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
K. US Abdomen

US is the first-line modality for assessing postoperative biliary complications after liver transplantation, with a reported sensitivity of 71% for detecting post–liver transplant biliary obstruction [11,25].

US can identify peritransplant fluid collections, calculi, and biliary dilation/obstruction [12]. It can also be helpful to distinguish between anastomotic and nonanastomotic strictures. The skipped and irregular dilatation of intrahepatic bile ducts, and nonvisualization of hilar bile duct luminal contour (due to lengthy fibrotic bile duct strictures with necrosis of the biliary epithelium resulting in poor visualization of the hilar bile duct luminal contour) and can help distinguish between anastomotic and nonanastomotic strictures [11].

US has a high PPV and NPV for diagnosing biliary obstruction (80% and 90%); however, the sensitivity is low (38%-66%). The absence of biliary dilatation does not exclude the possibility of a biliary stricture [6]. Although US is sensitive for detecting posttransplant fluid collections, it is not specific, as bile, blood, pus can all look similar.

Variant 3: Adult. Liver transplant. Postoperative complications. Suspected biliary etiology. Initial imaging.
L. US Duplex Doppler Abdomen

A duplex US study with B-mode images and Doppler images allows for contemporaneous evaluation of the hepatic parenchyma, biliary system, and hepatic vasculature and as such is the ideal initial imaging examination to detect posttransplant complications [10].

Because the arterial supply of intrahepatic ducts and the donor proximal common bile duct is solely derived from the reconstructed hepatic artery, vascular compromise can result in biliary stricturing. Nonanastomotic strictures should prompt a Doppler assessment of the hepatic artery to assess for a stricture [12].

A normal US cannot exclude the presence of parenchymal, biliary, or vascular complications; in these cases, cross-sectional imaging with CT or MRI may be indicated [10].

Variant 4: Adult. Post liver-transplant. Surveillance.

The rate of hepatic malignancy after liver transplantation is higher than in the overall population, with the increased incidence partly attributed to chronic immunosuppressive therapy. This may include recurrence of the primary malignancy or posttransplant lymphoproliferative disorder [12,26].

Posttransplantation hepatocellular carcinoma (HCC) recurrence occurs in 11% to 20% of patients, with a median survival of <1 year from the time of diagnosis, with recurrence usually seen in the first 2 years after transplantation. As of now, there are no specific recommendations for surveillance of recurrence of HCC after liver transplantation in the radiology literature. However, the American Association for the Study of Liver Diseases (AASLD) advises surveillance for detection of posttransplant HCC recurrence using multiphasic contrast-enhanced abdominal CT or MRI and chest CT scan [32]. Additionally, an International Consensus conference report recommended that posttransplant monitoring may include 6 to 12 monthly contrast-enhanced CT or MRI along with alpha-fetoprotein measurements [33,34]. There is institutional variation in the timing of the examinations, with some institutions performing cross-sectional imaging with either multiphase contrast-enhanced CT or MRI of the abdomen once every 3 to 6 months for the first 1 to 5 year,s with the time interval changing to every 6 to 12 months at some point after the first year [35,36]. The optimal timing and duration of posttransplant imaging is uncertain and will depend on the indication for transplant; however, risk scores may be considered to guide decisions [32].

Variant 4: Adult. Post liver-transplant. Surveillance.
A. CT Abdomen With IV Contrast

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred.

Variant 4: Adult. Post liver-transplant. Surveillance.
B. CT Abdomen With IV Contrast Multiphase

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Multiphase CT is considered one of the optimal choices for this scenario and may be appropriate based on institutional practice [35-37]. Additionally, the AASLD advises surveillance for detection of posttransplant HCC recurrence using multiphasic contrast-enhanced abdominal CT or MRI and chest CT scan [32].

Variant 4: Adult. Post liver-transplant. Surveillance.
C. CT abdomen without and with IV contrast

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred.

Variant 4: Adult. Post liver-transplant. Surveillance.
D. CT Abdomen Without IV Contrast

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred.

Variant 4: Adult. Post liver-transplant. Surveillance.
E. FDG-PET/CT Skull Base to Mid-Thigh

Fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET can be helpful for confirmation of recurrence in the liver once a suspicious observation is seen on routine posttransplant surveillance with either CT or MRI, but there is no current data to support the use of FDG-PET/CT as an initial screening tool [35].

Variant 4: Adult. Post liver-transplant. Surveillance.
F. MRI Abdomen Without and With Hepatobiliary Contrast

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients or different contrast agents. Multiphase CT and MRI are considered optimal choices for this scenario and may be useful based on institutional practice [35-37]. Additionally, AASLD advises surveillance for detection of posttransplant HCC recurrence using multiphasic contrast-enhanced abdominal CT or MRI and chest CT scan [32].

Variant 4: Adult. Post liver-transplant. Surveillance.
G. MRI Abdomen Without and With IV Contrast

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Multiphase CT and MRI are considered optimal choices for this scenario and may be useful based on institutional practice [35-37]. Additionally, AASLD advises surveillance for detection of posttransplant HCC recurrence using multiphasic contrast-enhanced abdominal CT or MRI and chest CT scan [32].

Variant 4: Adult. Post liver-transplant. Surveillance.
H. MRI Abdomen Without and With IV Contrast With MRCP

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred.

Variant 4: Adult. Post liver-transplant. Surveillance.
I. MRI Abdomen Without IV Contrast

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred.

Variant 4: Adult. Post liver-transplant. Surveillance.
J. MRI Abdomen Without IV Contrast With MRCP

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred.

Variant 4: Adult. Post liver-transplant. Surveillance.
K. Radiography Abdomen

There is no relevant literature supporting the use of abdominal radiography for surveillance in this population.

Variant 4: Adult. Post liver-transplant. Surveillance.
L. US Abdomen

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred. Some experts; however, suggest that US abdomen and US duplex Doppler abdomen may be performed after transplant for surveillance in certain scenarios.

Variant 4: Adult. Post liver-transplant. Surveillance.
M. US Duplex Doppler Abdomen

There is no relevant literature comparing the performance characteristics of the different imaging modalities for surveillance in posttransplant patients. Anecdotally, contrast-enhanced cross-sectional examinations seem to be preferred. Some experts; however, suggest that US abdomen and US duplex Doppler abdomen may be performed after transplant for surveillance in certain scenarios.

Summary of Highlights

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- **Variant 1**: US duplex Doppler abdomen or CT abdomen with IV contrast or CT abdomen with IV contrast multiphase is usually appropriate as the initial imaging for immediate postoperative imaging after liver transplant. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). The panel did not agree on recommending MRI abdomen without and with IV contrast with MRCP in this clinical scenario. There is insufficient medical literature to conclude whether these patients would benefit from this imaging procedure, but it may be appropriate.

- **Variant 2**: US duplex Doppler abdomen or CT abdomen with IV contrast or CTA abdomen with IV contrast or CT abdomen with IV contrast multiphase is usually appropriate as the initial imaging for liver transplant postoperative complication of suspected vascular etiology. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

- **Variant 3**: US abdomen or US duplex Doppler abdomen or MRI abdomen without and with hepatobiliary contrast or MRI abdomen without and with IV contrast with MRCP or MRI abdomen without IV contrast with MRCP is usually appropriate as the initial imaging for liver transplant postoperative complication of suspected biliary etiology. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

- **Variant 4**: MRI abdomen without and with hepatobiliary contrast or MRI abdomen without and with IV contrast or MRI abdomen without and with IV contrast with MRCP or CT abdomen with IV contrast multiphase is usually appropriate as the initial imaging for surveillance after liver transplantation. These procedures are equivalent alternative (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). The panel did not agree on recommending US abdomen or US duplex Doppler abdomen in this clinical scenario. There is insufficient medical literature to conclude whether these patients would benefit from these imaging procedures but it may be appropriate.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that predates the use of the current understanding of language inclusive of diversity in sex, intersex, gender, and gender-diverse people. The data variables regarding sex and gender used in the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv

☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies.”

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Disclaimer

investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

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