American College of Radiology
ACR Appropriateness Criteria®
Workup of Noncerebral Systemic Arterial Embolic Source

Variant 1: **Known upper extremity arterial occlusion. Suspected embolic etiology. Next imaging study to determine source.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	O
US echocardiography transthoracic resting	Usually Appropriate	O
MRA chest without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without IV contrast	Usually Appropriate	O
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
MRA chest without IV contrast	May Be Appropriate	O
US duplex Doppler abdomen	Usually Not Appropriate	O
Aortography chest	Usually Not Appropriate	☢☢☢

Variant 2: **Known arterial occlusion in the mesenteric or renal arterial system or renal infarcts. Suspected embolic etiology. Next imaging study to determine source.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	O
US echocardiography transthoracic resting	Usually Appropriate	O
MRA chest and abdomen without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without IV contrast	Usually Appropriate	O
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
CTA chest and abdomen with IV contrast	Usually Appropriate	☢☢☢☢
US duplex Doppler abdomen	May Be Appropriate	O
MRA chest and abdomen without IV contrast	May Be Appropriate	O
MRA chest without and with IV contrast	May Be Appropriate	O
MRA chest without IV contrast	May Be Appropriate	O
Aortography chest and abdomen	Usually Not Appropriate	☢☢☢☢

Variant 3: **Known lower extremity arterial occlusion. Suspected embolic etiology. Next imaging study to determine source.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	O
US echocardiography transthoracic resting	Usually Appropriate	O
MRA chest abdomen pelvis without and with IV contrast	Usually Appropriate	O
MRA chest without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without IV contrast	Usually Appropriate	O
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
CTA chest abdomen pelvis with IV contrast	Usually Appropriate	☢☢☢☢☢
MRA chest abdomen pelvis without IV contrast	May Be Appropriate	O
MRA chest without IV contrast	May Be Appropriate	O
US duplex Doppler abdomen	Usually Not Appropriate	O
Aortography chest abdomen pelvis	Usually Not Appropriate	☢☢☢☢

Variant 4: **Known multiorgan system arterial occlusions. Suspected embolic etiology. Next imaging study to determine source.**

Procedure	Appropriateness Category	Relative Radiation Level
US echocardiography transesophageal	Usually Appropriate	O
US echocardiography transthoracic resting	Usually Appropriate	O
MRA chest abdomen pelvis without and with IV contrast	Usually Appropriate	O
MRA chest abdomen pelvis without IV contrast	Usually Appropriate	O
MRA chest without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without and with IV contrast	Usually Appropriate	O
MRI heart function and morphology without IV contrast	Usually Appropriate	O
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT heart function and morphology with IV contrast	Usually Appropriate	☢☢☢☢
CTA chest abdomen pelvis with IV contrast	Usually Appropriate	☢☢☢☢☢
US duplex Doppler abdomen	May Be Appropriate	O
MRA chest without IV contrast	May Be Appropriate	O

WORKUP OF NONCEREBRAL SYSTEMIC ARTERIAL EMBOLIC SOURCE

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Summary of Literature Review

Introduction/Background

Noncerebral systemic arterial embolism is an important cause of patient morbidity and mortality [1]. Arterial emboli can originate from a variety of cardiac and noncardiac sources. Cardiac sources include thrombus within the left atrium and left ventricle, valvular disease such as endocarditis, and cardiac neoplasms. Noncardiac sources of arterial embolism include thrombus and atherosclerosis within the aorta and peripheral arteries.

Intracardiac thrombus has been thoroughly described in the cardiology and neurology literature with several factors that predispose its formation and the potential for arterial embolization. For example, atrial fibrillation has been shown to be a significant risk factor for atrial thrombogenesis [2,3]. Complex left atrial appendage morphology also confers increased likelihood of thrombus development [4]. Myocardial infarction often results in focal hypokinesis or akinesis of the left ventricular myocardium, which predisposes to thrombus formation [5,6]. Aortic and mitral valve endocarditis as well as valvular neoplasms are other potential sources for arterial embolism detectable with imaging [7,8]. Aortic thrombi tend to be associated with aortic pathology including dissection, aneurysm, or ulcerative lesions [9,10]. Thrombus formation can also occur in the aorta secondary to hypercoagulable states such as malignancy, trauma, postoperative states, hormonal therapy, and inherited hypercoagulable disorders [1,11,12].

When a cardiac or noncardiac embolic source dislodges, the resulting embolus can occlude a variety of peripheral and visceral arteries causing ischemia [1,9,11,12]. Characteristic locations for noncerebral arterial occlusion include the upper extremities, abdominal viscera, and lower extremities [1,9,11]. Ischemia in these regions can progress to tissue infarction resulting in limb amputation, bowel resection, or nephrectomy. Determining the source of arterial embolism is essential in order to direct treatment decisions. Treatment options vary and include anti-coagulation, endovascular or surgical embolectomy, and peripheral arterial angioplasty with or without stenting to maintain long-term vascular patency [1,9,11-14].

The variants in this document assume that the diagnosis of an arterial occlusion has already been established by other means. For example, in the setting of an acute onset cold painful leg, the use of lower extremity arteriography, CT angiography (CTA), or MR angiography (MRA) could be employed to demonstrate arterial occlusion. This document specifically pertains to the workup of a suspected embolic etiology of the already known arterial occlusion.

Special Imaging Considerations

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) [15]:

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"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset 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.

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 where each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Known upper extremity arterial occlusion. Suspected embolic etiology. Next imaging study to determine source.

The variant assumes that an upper extremity arterial occlusion has already been established. Typically, this diagnosis is made by CTA, arteriography, or MRA, although the clinical examination or another imaging study could also be used.

Aortography Chest

Conventional catheter aortography has largely been replaced by noninvasive imaging modalities such as CTA and MRA given their high sensitivity/specificity for detecting aortic pathologies such as mural thrombus [16,17]. Aortography is typically used as an alternative diagnostic strategy following initial noninvasive imaging and when therapeutic interventions are being considered [11,17].

CT Heart Function and Morphology With IV Contrast

The primary role of cardiac CT in the initial evaluation of upper extremity arterial embolic occlusion is in the workup of cardiac thrombus as a source. Multiple studies have established high rates of atrial thrombus detection by cardiac CT compared to transesophageal echocardiography (TEE) [18-27]. Meta-analyses have found sensitivities of 96% to 99% and specificities of 92% to 94% for detection of left atrial or left atrial appendage thrombus with cardiac CT compared to a TEE reference standard [28-30]. When compared with intraoperative findings, cardiac CT was 100% sensitive and 85% specific for finding left atrial thrombus [31]. Complex left atrial appendage morphologies which predispose to thrombus formation can also be characterized by cardiac CT [32-34]. Additionally, cardiac CT can differentiate left ventricular thrombus from the myocardial wall with 1 study demonstrating a sensitivity, specificity, and positive and negative predictive values of 94%, 97%, 94%, and 97%, respectively [35]. Studies have also demonstrated cardiac CT to have comparable accuracy to TEE for identification of vegetations in the setting of infective endocarditis, another potential source of arterial embolism [36-38]. Cardiac CT can identify cardiac neoplasms, both benign and malignant, which have the potential to shed and embolize to distal arterial beds [39,40].

CTA Chest With IV Contrast

Multidetector chest CTA with intravenous (IV) contrast can be used to evaluate for at-risk atherosclerotic plaque or the presence of thrombus in the thoracic aorta. CTA is useful in the assessment of the size, extent, and location of an embolic source in the aorta, which can aid in management decisions [13,41]. A number of small studies have used chest CTA to detect aortic mural thrombus that was suspected of embolization [1,12-14,42]. Specific data on the sensitivity and specificity of this imaging modality are lacking.

MRA Chest Without and With IV Contrast
Chest MRA without and with IV contrast can be used to evaluate for the presence of thrombus in the thoracic aorta. In 1 study, detection of thoracic aorta pathology by contrast-enhanced chest MRA was equivalent in sensitivity, specificity, and diagnostic accuracy compared to noncontrast MRA, although only a single case of thrombus was included in the analysis [43]. On the other hand, in a small analysis which included 9 patients with aortic thrombus, contrast-enhanced MRA had a lower thrombus detection rate compared to a noncontrast examination, although this finding was not statistically significant [44]. Data comparing MRA of the chest to other imaging modalities are lacking.

MRA Chest Without IV Contrast
Chest MRA without IV contrast is an imaging study, which can detect the presence of thrombus in the thoracic aorta. One small study found this examination to have a higher detection rate for aortic thrombus when compared with contrast-enhanced MRA, although the difference was not statistically significant [44]. In another study, sensitivity, specificity, and diagnostic accuracy of unenhanced steady-state free precession MRA were 100% for the detection of thoracic aorta pathology compared to a contrast-enhanced MRA reference standard; however, this analysis only included 1 case of mural thrombus [43]. Data comparing MRA of the chest to other imaging modalities are lacking.

MRI Heart Function and Morphology Without and With IV Contrast
Cardiac MR is a noninvasive imaging study that can detect intracardiac thrombus as well as valvular and neoplastic pathologies. A meta-analysis of 7 studies showed that delayed contrast-enhanced cardiac MR had a pooled sensitivity of 100% and a specificity of 99% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. In another meta-analysis, there was no significant difference in sensitivity and specificity between cardiac CT and cardiac MR in the detection of left atrial appendage thrombus [29]. Contrast-enhanced cardiac MR had a sensitivity of 88% and a specificity of 99% compared to surgical or pathological confirmation of left ventricular thrombus [46]. Cardiac MR is also an accurate imaging modality for the evaluation of valvular disease, including aortic and mitral valve vegetations, which can dislodge and result in arterial embolism [37,47]. Additionally, cardiac MR offers detailed soft tissue characterization for the analysis of benign and malignant intracardiac neoplasms [39,48].

MRI Heart Function and Morphology Without IV Contrast
Cardiac MR without contrast provides a detailed anatomic evaluation of the heart chambers. In the workup of embolic sources, the primary role of cardiac MR is in the identification of intracardiac thrombus. A meta-analysis of 7 studies showed that cine cardiac MR had a pooled sensitivity of 91% and a specificity of 93% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. Furthermore, cine cardiac MR had an 82% sensitivity and a 100% specificity in detecting left ventricle thrombus in postmyocardial infarction patients compared with a standard delayed enhancement cardiac MR [49]. Cardiac MR without contrast is also capable of identifying valvular pathology and cardiac neoplasms, although data on its applicability in the setting of systemic arterial embolism are lacking.

US Duplex Doppler Abdomen
There is no relevant literature to support the use of Doppler ultrasound (US) of the abdomen as an initial imaging modality in the evaluation of the source of known embolic upper extremity arterial occlusion.

US Echocardiography Transesophageal
TEE is an invasive diagnostic study with the ability to detect cardiac pathology predisposed to embolism. TEE has a sensitivity of 93% to 100% and a specificity of 95% to 99% for detecting left atrial appendage thrombus when compared to intraoperative findings [31,50,51]. Furthermore, TEE can evaluate left ventricular systolic dysfunction, spontaneous echo contrast, slow left atrial appendage peak flow velocities, and complex left atrial appendage morphologies, which are all associated with left atrial thrombus and thromboembolic risk [2,4]. In addition, TEE can detect left ventricular thrombus with 1 study reporting a 40% sensitivity and a 96% specificity for the modality compared to findings at surgery or pathology [46]. Proximal aortic thrombus can also be assessed using TEE, although evaluation is limited by blind spots (distal ascending aorta and proximal aortic arch) owing to air in the trachea [10,13]. Detection of valvular disease and intracardiac neoplasms can also be accomplished with TEE.

US Echocardiography Transthoracic Resting
Transthoracic echocardiography (TTE) is a noninvasive imaging modality capable of detecting cardiac pathology susceptible to embolism. TTE is inferior to TEE in the assessment of left atrial appendage thrombus because the

transducer is distant from the left atrium when placed on the chest [52]. In 1 study, a cardiac embolic source was detected by TEE in about 40% of patients with normal TTE [53]. In another study, a cardiac embolic source was identified by TTE in 15% of the study group compared with 57% by TEE [54]. Sensitivity and specificity were 23% and 96%, respectively, for the detection of left ventricular thrombus compared to findings at surgery or pathology [46]. In the detection of left ventricle thrombus, contrast-enhanced TTE had a 64% sensitivity and a 99% specificity compared to a delayed enhancement cardiac MR standard [49]. TTE can also be applied for the diagnosis of valvular disease and cardiac neoplasms. There is no evidence to support the use of TTE in the evaluation of aortic thrombus.

Variant 2: Known arterial occlusion in the mesenteric or renal arterial system or renal infarcts. Suspected embolic etiology. Next imaging study to determine source.

The variant assumes that a mesenteric/renal arterial occlusion or renal infarct has already been established. Typically, this diagnosis is made by CTA, arteriography, or MRA, although the clinical examination or another imaging study could also be used (see the ACR Appropriateness Criteria® topic on "Imaging of Mesenteric Ischemia" [55]).

Aortography Chest and Abdomen

Conventional catheter aortography has largely been replaced by noninvasive imaging modalities such as CTA and MRA given their high sensitivity/specificity for detecting aortic pathologies such as mural thrombus [16,17]. Aortography is typically used as an alternative diagnostic strategy following initial noninvasive imaging and when therapeutic interventions are being considered [11,17].

CT Heart Function and Morphology With IV Contrast

The primary role of cardiac CT in the initial evaluation of mesenteric or renal arterial embolic occlusion is in the workup of cardiac thrombus as a source. Multiple studies have established high rates of atrial thrombus detection by cardiac CT compared to TEE [18-27]. Meta-analyses have found sensitivities of 96% to 99% and specificities of 92% to 94% for detection of left atrial or left atrial appendage thrombus with cardiac CT compared to a TEE reference standard [28-30]. When compared to intraoperative findings, cardiac CT was 100% sensitive and 85% specific for finding left atrial thrombus [31]. Complex left atrial appendage morphologies that predispose to thrombus formation can also be characterized by cardiac CT [32-34]. Additionally, cardiac CT can differentiate left ventricular thrombus from the myocardial wall, with 1 study demonstrating a sensitivity, specificity, and positive and negative predictive values of 94%, 97%, 94%, and 97%, respectively [35]. Studies have also demonstrated cardiac CT to have comparable accuracy to TEE for identification of vegetations in the setting of infective endocarditis, another potential source of arterial embolism [36-38]. Cardiac CT can identify cardiac neoplasms, both benign and malignant, which have the potential to shed and embolize to distal arterial beds [39,40].

CTA Chest With IV Contrast

In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta, and a CTA limited to the chest may be diagnostic. As such, multidetector chest CTA with IV contrast can be used to evaluate for at-risk atherosclerotic plaque or the presence of thrombus in the thoracic aorta. CTA is useful in the assessment of the size, extent, and location of an embolic source in the aorta, which can aid in management decisions [13,41]. A number of small studies have used chest CTA to detect aortic mural thrombus that was suspected of embolization [1,12-14,42]. Specific data on the sensitivity and specificity of this imaging modality are lacking.

CTA Chest and Abdomen With IV Contrast

Multidetector CTA with IV contrast can be used to evaluate for the presence of at-risk atherosclerotic plaque or thrombus in the aorta in its entirety. CTA is useful in the assessment of the size, extent, and location of an embolic source in the aorta, which can aid in management decisions [13,41]. Aortic intraluminal thrombus is oftentimes associated with aneurysm, particularly in the abdomen, which is readily detected by CTA [56,57]. A number of small studies have used CTA to detect aortic mural thrombus that was suspected of embolization [1,12-14,42]. Specific data on the sensitivity and specificity of this imaging modality are lacking.

MRA Chest Without and With IV Contrast

In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta and an MRA limited to the chest may be diagnostic. In 1 study, detection of thoracic aorta pathology by contrast-enhanced chest MRA was equivalent in sensitivity, specificity, and diagnostic accuracy compared to noncontrast MRA, although only a single case of thrombus was included in the analysis [43]. On the other hand, in a small analysis which included 9 patients with aortic thrombus, contrast-enhanced MRA had a lower thrombus detection rate compared to a noncontrast examination, although this finding was not statistically significant [44]. Data comparing MRA of the chest to other imaging modalities are lacking.

MRA Chest Without IV Contrast

In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta and an MRA limited to the chest may be diagnostic. One small study found this examination to have a higher detection rate for aortic thrombus when compared with contrast-enhanced MRA, although the difference was not statistically significant [44]. In another study, sensitivity, specificity, and diagnostic accuracy of unenhanced steady-state free precession MRA were 100% for the detection of thoracic aorta pathology compared to a contrast-enhanced MRA reference standard; however, this analysis only included 1 case of mural thrombus [43]. Data comparing MRA of the chest to other imaging modalities is lacking.

MRA Chest and Abdomen Without and With IV Contrast

MRA of the chest and abdomen without and with IV contrast can be used to evaluate for presence of an embolic source in the aorta in its entirety. In 1 study, detection of thoracic aorta pathology by contrast-enhanced chest MRA was equivalent in sensitivity, specificity, and diagnostic accuracy compared to noncontrast MRA, although only a single case of thrombus was included in the analysis [43]. On the other hand, in a small analysis which included 9 patients with aortic thrombus, contrast-enhanced MRA had a lower thrombus detection rate compared to a noncontrast examination, although this finding was not statistically significant [44]. Contrast-enhanced MRA of the abdomen has been used for intraluminal thrombus detection in the setting of aneurysms, although comparative data are insufficient [56-58]. Data comparing MRA of the chest and abdomen to other imaging modalities are lacking.

MRA Chest and Abdomen Without IV Contrast

Chest and abdomen MRA without IV contrast can be used to evaluate for the presence of an embolic source in the aorta in its entirety. One small study found this examination to have a higher detection rate for aortic thrombus when compared with contrast-enhanced MRA, although the difference was not statistically significant [44]. In another study, sensitivity, specificity, and diagnostic accuracy of unenhanced steady-state free precession MRA were 100% for the detection of thoracic aorta pathology compared to a contrast-enhanced MRA reference standard; however, this analysis only included 1 case of mural thrombus [43]. Noncontrast MRA has been used for the detection of abdominal aortic intraluminal thrombus, although there are insufficient data comparing it to contrast-enhanced MRA [56-58]. Data comparing MRA of the chest and abdomen to other imaging modalities are lacking.

MRI Heart Function and Morphology Without and With IV Contrast

Cardiac MR is a noninvasive imaging study that can reliably detect intracardiac thrombus as well as valvular and neoplastic pathologies. A meta-analysis of 7 studies showed that delayed contrast-enhanced cardiac MR had a pooled sensitivity of 100% and a specificity of 99% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. In another meta-analysis, there was no significant difference in sensitivity and specificity between cardiac CT and cardiac MR in the detection of left atrial appendage thrombus [29]. Contrast-enhanced cardiac MR had a sensitivity of 88% and a specificity of 99% compared to surgical or pathological confirmation of left ventricular thrombus [46]. Cardiac MR is also an accurate imaging modality for the evaluation of valvular disease, including aortic and mitral valve vegetations, which can dislodge and result in arterial embolism [37,47]. Additionally, cardiac MR offers detailed soft tissue characterization for the analysis of benign and malignant intracardiac neoplasms [39,48].

MRI Heart Function and Morphology Without IV Contrast

Cardiac MR without contrast provides a detailed anatomic evaluation of the heart chambers. In the workup of embolic sources, the primary role of cardiac MR is in the identification of intracardiac thrombus. A meta-analysis of 7 studies showed that cine cardiac MR had a pooled sensitivity of 91% and a specificity of 93% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. Furthermore, cine cardiac MR had an 82% sensitivity and 100% specificity in detecting left ventricle thrombus in postmyocardial infarction patients compared to a standard delayed enhancement cardiac MR [49]. Cardiac MR without contrast is also capable of identifying valvular pathology and cardiac neoplasms, although data on its applicability in the setting of systemic arterial embolism are lacking.

US Duplex Doppler Abdomen

There is no relevant literature to support the use of Doppler US of the abdomen as an initial imaging modality in the evaluation of the source of known embolic mesenteric/renal arterial occlusion. However, some imaging protocols may include limited views of the abdominal aorta that may detect intraluminal aortic thrombus or significant atherosclerotic disease [56].

US Echocardiography Transesophageal

TEE is an invasive diagnostic study with the ability to detect cardiac pathology predisposed to embolism. TEE has a sensitivity of 93% to 100% and a specificity of 95% to 99% for detecting left atrial appendage thrombus when compared to intraoperative findings [31,50,51]. Furthermore, TEE can evaluate left ventricular systolic dysfunction, spontaneous echo contrast, slow left atrial appendage peak flow velocities, and complex left atrial appendage morphologies, which are all associated with left atrial thrombus and thromboembolic risk [2,4]. In addition, TEE can detect left ventricular thrombus, with 1 study reporting a 40% sensitivity and a 96% specificity for the modality compared to findings at surgery or pathology [46]. Proximal aortic thrombus can also be assessed using TEE, although evaluation is limited by blind spots (distal ascending aorta and proximal aortic arch) owing to air in the trachea [10,13]. Detection of valvular disease and intracardiac neoplasms can also be accomplished with TEE.

US Echocardiography Transthoracic Resting

TTE is a noninvasive imaging modality capable of detecting cardiac pathology susceptible to embolism. TTE is inferior to TEE in the assessment of left atrial appendage thrombus because the transducer is distant from the left atrium when placed on the chest [52]. In 1 study, a cardiac embolic source was detected by TEE in about 40% of patients with normal TTE [53]. In another study, a cardiac embolic source was identified by TTE in 15% of the study group compared with 57% by TEE [54]. Sensitivity and specificity were 23% and 96%, respectively, for the detection of left ventricular thrombus compared to findings at surgery or pathology [46]. In the detection of left ventricle thrombus, contrast-enhanced TTE had a 64% sensitivity and 99% specificity compared to a delayed enhancement cardiac MR standard [49]. TTE can also be applied for the diagnosis of valvular disease and cardiac neoplasms. There is no evidence to support the use of TTE in the evaluation of aortic thrombus.

Variant 3: Known lower extremity arterial occlusion. Suspected embolic etiology. Next imaging study to determine source.

The variant assumes that a lower extremity arterial occlusion has already been established. Typically, this diagnosis is made by CTA, arteriography, or MRA, although the clinical examination or another imaging study could also be used (see the ACR Appropriateness Criteria® topic on “Sudden Onset of Cold, Painful Leg” [59]).

Aortography Chest, Abdomen, and Pelvis

Conventional catheter aortography has largely been replaced by noninvasive imaging modalities such as CTA and MRA given their high sensitivity/specificity for detecting aortic pathologies such as mural thrombus [16,17]. Aortography is typically used as an alternative diagnostic strategy following initial noninvasive imaging and when therapeutic interventions are being considered [11,17].

CT Heart Function and Morphology With IV Contrast

The primary role of cardiac CT in the initial evaluation of lower extremity arterial embolic occlusion is in the workup of cardiac thrombus as a source. Multiple studies have established high rates of atrial thrombus detection by cardiac CT compared to TEE [18-27]. Meta-analyses have found sensitivities of 96% to 99% and specificities of 92% to 94% for detection of left atrial or left atrial appendage thrombus with cardiac CT compared to a TEE reference standard [28-30]. When compared to intraoperative findings, cardiac CT was 100% sensitive and 85% specific for finding left atrial thrombus [31]. Complex left atrial appendage morphologies, which predispose to thrombus formation, can also be characterized by cardiac CT [32-34]. Additionally, cardiac CT can differentiate left ventricular thrombus from the myocardial wall with 1 study demonstrating a sensitivity, specificity, and positive and negative predictive values of 94%, 97%, 94%, and 97%, respectively [35]. Studies have also demonstrated cardiac CT to have comparable accuracy to TEE for identification of vegetations in the setting of infective endocarditis, another potential source of arterial embolism [36-38]. Cardiac CT can identify cardiac neoplasms, both benign and malignant, which have the potential to shed and embolize to distal arterial beds [39,40].

CTA Chest With IV Contrast

In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta and a CTA limited to the chest may be diagnostic. As such, multidetector chest CTA with IV contrast can be used to evaluate for at-risk atherosclerotic plaque or the presence of thrombus in the thoracic aorta. CTA is useful in the assessment of the size, extent, and location of an embolic source in the aorta, which can aid in management decisions [13,41]. A number of small studies have used chest CTA to detect aortic mural thrombus that was suspected of embolization [1,12-14,42]. Specific data on the sensitivity and specificity of this imaging modality are lacking.

CTA Chest, Abdomen, and Pelvis With IV Contrast
Multidetector CTA with IV contrast can be used to evaluate for the presence of at-risk atherosclerotic plaque or thrombus in the aorta in its entirety. CTA is useful in the assessment of the size, extent, and location of an embolic source in the aorta, which can aid in management decisions [13,41]. Aortic intraluminal thrombus is oftentimes associated with aneurysm, particularly in the abdomen, which is readily detected by CTA [56,57]. A number of small studies have used CTA to detect aortic mural thrombus that was suspected of embolization [1,12-14,42]. Specific data on the sensitivity and specificity of this imaging modality are lacking.

MRA Chest Without and With IV Contrast
In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta and an MRA limited to the chest may be diagnostic. In 1 study, detection of thoracic aorta pathology by contrast-enhanced chest MRA was equivalent in sensitivity, specificity, and diagnostic accuracy compared to noncontrast MRA, although only a single case of thrombus was included in the analysis [43]. On the other hand, in a small analysis which included 9 patients with aortic thrombus, contrast-enhanced MRA had a lower thrombus detection rate compared to a noncontrast examination, although this finding was not statistically significant [44]. Data comparing MRA of the chest to other imaging modalities are lacking.

MRA Chest Without IV Contrast
In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta and an MRA limited to the chest may be diagnostic. One small study found this examination to have a higher detection rate for aortic thrombus when compared with contrast-enhanced MRA, although the difference was not statistically significant [44]. In another study, sensitivity, specificity, and diagnostic accuracy of unenhanced steady-state free precession MRA were 100% for the detection of thoracic aorta pathology compared to a contrast-enhanced MRA reference standard; however, this analysis only included 1 case of mural thrombus [43]. Data comparing MRA of the chest to other imaging modalities is lacking.

MRA Chest, Abdomen, and Pelvis Without and With IV Contrast
MRA of the chest, abdomen, and pelvis without and with IV contrast can be used to evaluate for the presence of an embolic source in the aorta in its entirety. In 1 study, detection of thoracic aorta pathology by contrast-enhanced chest MRA was equivalent in sensitivity, specificity, and diagnostic accuracy compared to noncontrast MRA, although only a single case of thrombus was included in the analysis [43]. On the other hand, in a small analysis which included 9 patients with aortic thrombus, contrast-enhanced MRA had a lower thrombus detection rate compared to a noncontrast examination, although this finding was not statistically significant [44]. Contrast-enhanced MRA of the abdomen has been used for intraluminal thrombus detection in the setting of aneurysms, although comparative data is insufficient [56-58]. Data comparing MRA of the chest, abdomen, and pelvis to other imaging modalities is lacking.

MRA Chest, Abdomen, and Pelvis Without IV Contrast
Chest, abdomen, and pelvis MRA without IV contrast can be used to evaluate for the presence of an embolic source in the aorta in its entirety. One small study found this examination to have a higher detection rate for aortic thrombus when compared with contrast-enhanced MRA, although the difference was not statistically significant [44]. In another study, sensitivity, specificity, and diagnostic accuracy of unenhanced steady-state free precession MRA were 100% for the detection of thoracic aorta pathology compared to a contrast-enhanced MRA reference standard, however this analysis only included 1 case of mural thrombus [43]. Noncontrast MRA has been used for the detection of abdominal aortic intraluminal thrombus, although there is insufficient data comparing it to contrast-enhanced MRA [56-58]. Data comparing MRA of the chest, abdomen, and pelvis to other imaging modalities is lacking.

MRI Heart Function and Morphology Without and With IV Contrast
Cardiac MR is a noninvasive imaging study that can reliably detect intracardiac thrombus as well as valvular and neoplastic pathologies. A meta-analysis of 7 studies showed that delayed contrast-enhanced cardiac MR had a pooled sensitivity of 100% and a specificity of 99% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. In another meta-analysis, there was no significant difference in sensitivity and specificity between cardiac CT and cardiac MR in the detection of left atrial appendage thrombus [29]. Contrast-enhanced cardiac MR had a sensitivity of 88% and a specificity of 99% compared to surgical or pathological

confirmation of left ventricular thrombus [46]. Cardiac MR is also an accurate imaging modality for the evaluation of valvular disease, including aortic and mitral valve vegetations, which can dislodge and result in arterial embolism [37,47]. Additionally, cardiac MR offers detailed soft tissue characterization for the analysis of benign and malignant intracardiac neoplasms [39,48].

MRI Heart Function and Morphology Without IV Contrast
Cardiac MR without contrast provides a detailed anatomic evaluation of the heart chambers. In the workup of embolic sources, the primary role of cardiac MR is in the identification of intracardiac thrombus. A meta-analysis of 7 studies showed that cine cardiac MR had a pooled sensitivity of 91% and a specificity of 93% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. Furthermore, cine cardiac MR had an 82% sensitivity and a 100% specificity in detecting left ventricle thrombus in postmyocardial infarction patients compared with a standard delayed enhancement cardiac MR [49]. Cardiac MR without contrast is also capable of identifying valvular pathology and cardiac neoplasms, although data on its applicability in the setting of systemic arterial embolism are lacking.

US Duplex Doppler Abdomen
There is no relevant literature to support the use of Doppler US of the abdomen as an initial imaging modality in the evaluation of the source of known embolic lower extremity arterial occlusion. However, some imaging protocols may include limited views of the abdominal aorta, which may detect intraluminal aortic thrombus or significant atherosclerotic disease [56].

US Echocardiography Transesophageal
TEE is an invasive diagnostic study with the ability to detect cardiac pathology predisposed to embolism. TEE has a sensitivity of 93% to 100% and a specificity of 95% to 99% for detecting left atrial appendage thrombus when compared to intraoperative findings [31,50,51]. Furthermore, TEE can evaluate left ventricular systolic dysfunction, spontaneous echo contrast, slow left atrial appendage peak flow velocities, and complex left atrial appendage morphologies, which are all associated with left atrial thrombus and thromboembolic risk [2,4]. In addition, TEE can detect left ventricular thrombus, with 1 study reporting a 40% sensitivity and a 96% specificity for the modality compared to findings at surgery or pathology [46]. Proximal aortic thrombus can also be assessed using TEE, although evaluation is limited by blind spots (distal ascending aorta and proximal aortic arch) owing to air in the trachea [10,13]. Detection of valvular disease and intracardiac neoplasms can also be accomplished with TEE.

US Echocardiography Transthoracic Resting
TTE is a noninvasive imaging modality capable of detecting cardiac pathology susceptible to embolism. TTE is inferior to TEE in the assessment of left atrial appendage thrombus because the transducer is distant from the left atrium when placed on the chest [52]. In 1 study, a cardiac embolic source was detected by TEE in about 40% of patients with normal TTE [53]. In another study, a cardiac embolic source was identified by TTE in 15% of the study group compared with 57% by TEE [54]. Sensitivity and specificity were 23% and 96%, respectively, for the detection of left ventricular thrombus compared to findings at surgery or pathology [46]. In the detection of left ventricle thrombus, contrast-enhanced TTE had a 64% sensitivity and a 99% specificity compared to a delayed enhancement cardiac MR standard [49]. TTE can also be applied for the diagnosis of valvular disease and cardiac neoplasms. There is no evidence to support the use of TTE in the evaluation of aortic thrombus.

Variant 4: Known multiorgan system arterial occlusions. Suspected embolic etiology. Next imaging study to determine source.

The variant assumes that multiorgan arterial occlusions have already been established. Typically, these diagnoses are made by CTA, arteriography, or MRA, although the clinical examination or another imaging study could also be used.

CT Heart Function and Morphology With IV Contrast
The primary role of cardiac CT in the initial evaluation of multiorgan system arterial embolic occlusion is in the workup of cardiac thrombus as a source. Multiple studies have established high rates of atrial thrombus detection by cardiac CT compared to TEE [18-27]. Meta-analyses have found sensitivities of 96% to 99% and specificities of 92% to 94% for detection of left atrial or left atrial appendage thrombus with cardiac CT compared to a TEE reference standard [28-30]. When compared with intraoperative findings, cardiac CT was 100% sensitive and 85% specific for finding left atrial thrombus [31]. Complex left atrial appendage morphologies, which predispose to thrombus formation, can also be characterized by cardiac CT [32-34]. Additionally, cardiac CT can differentiate left ventricular thrombus from the myocardial wall, with 1 study demonstrating a sensitivity, specificity, and

positive and negative predictive values of 94%, 97%, 94%, and 97%, respectively [35]. Studies have also demonstrated cardiac CT to have comparable accuracy to TEE for identification of vegetations in the setting of infective endocarditis, another potential source of arterial embolism [36-38]. Cardiac CT can identify cardiac neoplasms, both benign and malignant, which have the potential to shed and embolize to distal arterial beds [39,40].

CTA Chest With IV Contrast

In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta, and a CTA limited to the chest may be diagnostic. As such, multidetector chest CTA with IV contrast can be used to evaluate for at-risk atherosclerotic plaque or the presence of thrombus in the thoracic aorta. CTA is useful in the assessment of the size, extent, and location of an embolic source in the aorta, which can aid in management decisions [13,41]. A number of small studies have used chest CTA to detect aortic mural thrombus that was suspected of embolization [1,12-14,42]. Specific data on the sensitivity and specificity of this imaging modality are lacking.

CTA Chest, Abdomen, and Pelvis With IV contrast

Multidetector CTA with IV contrast can be used to evaluate for the presence of at-risk atherosclerotic plaque or thrombus in the aorta in its entirety. CTA is useful in the assessment of the size, extent, and location of an embolic source in the aorta, which can aid in management decisions [13,41]. Aortic intraluminal thrombus is oftentimes associated with aneurysm, particularly in the abdomen, which is readily detected by CTA [56,57]. A number of small studies have used CTA to detect aortic mural thrombus that was suspected of embolization [1,12-14,42]. Specific data on the sensitivity and specificity of this imaging modality are lacking.

MRA Chest Without and With IV Contrast

In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta and an MRA limited to the chest may be diagnostic. In 1 study, detection of thoracic aorta pathology by contrast-enhanced chest MRA was equivalent in sensitivity, specificity, and diagnostic accuracy compared to noncontrast MRA, although only a single case of thrombus was included in the analysis [43]. On the other hand, in a small analysis which included 9 patients with aortic thrombus, contrast-enhanced MRA had a lower thrombus detection rate compared to a noncontrast examination, although this finding was not statistically significant [44]. Data comparing MRA of the chest to other imaging modalities are lacking.

MRA Chest Without IV Contrast

In some conditions or clinical scenarios, there may be a high suspicion that the embolic source is in the thoracic aorta and an MRA limited to the chest may be diagnostic. One small study found this examination to have a higher detection rate for aortic thrombus when compared with contrast-enhanced MRA, although the difference was not statistically significant [44]. In another study, sensitivity, specificity, and diagnostic accuracy of unenhanced steady-state free precession MRA were 100% for the detection of thoracic aorta pathology compared to a contrast-enhanced MRA reference standard; however, this analysis only included 1 case of mural thrombus [43]. Data comparing MRA of the chest to other imaging modalities is lacking.

MRA Chest, Abdomen, and Pelvis Without and With IV Contrast

MRA of the chest, abdomen, and pelvis without and with IV contrast can be used to evaluate for the presence of an embolic source in the aorta in its entirety. In 1 study, detection of thoracic aorta pathology by contrast-enhanced chest MRA was equivalent in sensitivity, specificity, and diagnostic accuracy compared to noncontrast MRA, although only a single case of thrombus was included in the analysis [43]. On the other hand, in a small analysis which included 9 patients with aortic thrombus, contrast-enhanced MRA had a lower thrombus detection rate compared to a noncontrast examination, although this finding was not statistically significant [44]. Contrast-enhanced MRA of the abdomen has been used for intraluminal thrombus detection in the setting of aneurysms, although comparative data is insufficient [56-58]. Data comparing MRA of the chest, abdomen, and pelvis to other imaging modalities is lacking.

MRA Chest, Abdomen, and Pelvis Without IV Contrast

Chest, abdomen, and pelvis MRA without IV contrast can be used to evaluate for the presence of an embolic source in the aorta in its entirety. One small study found this examination to have a higher detection rate for aortic thrombus when compared with contrast-enhanced MRA, although the difference was not statistically significant [44]. In another study, sensitivity, specificity, and diagnostic accuracy of unenhanced steady-state free precession MRA were 100% for the detection of thoracic aorta pathology compared to a contrast-enhanced MRA reference standard, however this analysis only included 1 case of mural thrombus [43]. Noncontrast MRA has been used for the detection of abdominal aortic intraluminal thrombus, although there is insufficient data comparing it to contrast-enhanced MRA [56-58]. Data comparing MRA of the chest, abdomen, and pelvis to other imaging modalities is lacking.

MRI Heart Function and Morphology Without and With IV Contrast

Cardiac MR is a noninvasive imaging study that can reliably detect intracardiac thrombus as well as valvular and neoplastic pathologies. A meta-analysis of 7 studies showed that delayed contrast-enhanced cardiac MR had a pooled sensitivity of 100% and a specificity of 99% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. In another meta-analysis, there was no significant difference in sensitivity and specificity between cardiac CT and cardiac MR in the detection of left atrial appendage thrombus [29]. Contrast-enhanced cardiac MR had a sensitivity of 88% and a specificity of 99% compared to surgical or pathological confirmation of left ventricular thrombus [46]. Cardiac MR is also an accurate imaging modality for the evaluation of valvular disease, including aortic and mitral valve vegetations, which can dislodge and result in arterial embolism [37,47]. Additionally, cardiac MR offers detailed soft tissue characterization for the analysis of benign and malignant intracardiac neoplasms [39,48].

MRI Heart Function and Morphology Without IV Contrast

Cardiac MR without contrast provides a detailed anatomic evaluation of the heart chambers. In the workup of embolic sources, the primary role of cardiac MR is in the identification of intracardiac thrombus. A meta-analysis of 7 studies showed that cine cardiac MR had a pooled sensitivity of 91% and a specificity of 93% for detecting left atrial and left atrial appendage thrombus in patients with atrial fibrillation [45]. Furthermore, cine cardiac MR had an 82% sensitivity and a 100% specificity in detecting left ventricle thrombus in postmyocardial infarction patients compared with a standard delayed enhancement cardiac MR [49]. Cardiac MR without contrast is also capable of identifying valvular pathology and cardiac neoplasms, although data on its applicability in the setting of systemic arterial thromboembolism are lacking.

US Duplex Doppler Abdomen

There is no relevant literature to support the use of Doppler US of the abdomen as an initial imaging modality in the evaluation of the source of known embolic multiorgan arterial occlusion. However, some imaging protocols may include limited views of the abdominal aorta, which may detect intraluminal aortic thrombus or significant atherosclerotic disease [56].

US Echocardiography Transesophageal

TEE is an invasive diagnostic study with the ability to detect cardiac pathology predisposed to embolism. TEE has a sensitivity of 93% to 100% and a specificity of 95% to 99% for detecting left atrial appendage thrombus when compared with intraoperative findings [31,50,51]. Furthermore, TEE can evaluate left ventricular systolic dysfunction, spontaneous echo contrast, slow left atrial appendage peak flow velocities, and complex left atrial appendage morphologies, which are all associated with left atrial thrombus and thromboembolic risk [2,4]. In addition, TEE can detect left ventricular thrombus with 1 study reporting a 40% sensitivity and a 96% specificity for the modality compared to findings at surgery or pathology [46]. Proximal aortic thrombus can also be assessed using TEE, although evaluation is limited by blind spots (distal ascending aorta and proximal aortic arch) owing to air in the trachea [10,13]. Detection of valvular disease and intracardiac neoplasms can also be accomplished with TEE.

US Echocardiography Transthoracic Resting

TTE is a noninvasive imaging modality capable of detecting cardiac pathology susceptible to embolism. TTE is inferior to TEE in the assessment of left atrial appendage thrombus because the transducer is distant from the left atrium when placed on the chest [52]. In 1 study, a cardiac embolic source was detected by TEE in about 40% of patients with normal TTE [53]. In another study, a cardiac embolic source was identified by TTE in 15% of the study group compared with 57% by TEE [54]. Sensitivity and specificity were 23% and 96%, respectively, for the detection of left ventricular thrombus compared to findings at surgery or pathology [46]. In the detection of left ventricle thrombus, contrast-enhanced TTE had a 64% sensitivity and a 99% specificity compared to a delayed enhancement cardiac MR standard [49]. TTE can also be applied for the diagnosis of valvular disease and cardiac neoplasms. There is no evidence to support the use of TTE in the evaluation of aortic thrombus.

Summary of Recommendations

- **Variant 1**: TEE, TTE, MRI heart function and morphology without and with IV contrast, MRI heart function and morphology without IV contrast, and CT heart function and morphology with IV contrast are usually appropriate for determining the cardiac source of a known upper extremity arterial occlusion with a suspected embolic 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). Furthermore, CTA of the chest with IV contrast and MRA of the chest without and with IV contrast are equivalent alternatives that are usually appropriate for determining a central arterial source of a known upper extremity arterial occlusion with a suspected embolic etiology. During the workup of an upper extremity embolic source, cardiac and cross-sectional angiographic imaging may be complementary (both are performed) in certain clinical scenarios/conditions.

- **Variant 2**: TEE, TTE, MRI heart function and morphology without and with IV contrast, MRI heart function and morphology without IV contrast, and CT heart function and morphology with IV contrast are usually appropriate for determining the cardiac source of a known visceral arterial occlusion with a suspected embolic 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). Furthermore, CTA of the chest and abdomen with IV contrast and MRA of the chest and abdomen without and with IV contrast are equivalent alternatives that are usually appropriate for determining a central arterial source of a known visceral arterial occlusion with a suspected embolic etiology. CTA of the chest with IV contrast is usually appropriate in some clinical situations in which there is a high suspicion of the embolic source originating in the thoracic aorta. During the workup of a visceral embolic source, cardiac and cross-sectional angiographic imaging may be complementary (both are performed) in certain clinical scenarios/conditions.
- **Variant 3**: TEE, TTE, MRI heart function and morphology without and with IV contrast, MRI heart function and morphology without IV contrast, and CT heart function and morphology with IV contrast are usually appropriate for determining the cardiac source of a known lower extremity arterial occlusion with a suspected embolic 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). Furthermore, CTA of the chest, abdomen, and pelvis with IV contrast and MRA of the chest, abdomen, and pelvis without and with IV contrast are equivalent alternatives that are usually appropriate for determining a central arterial source of a known lower extremity arterial occlusion with a suspected embolic etiology. CTA of the chest with IV contrast or MRA of the chest without and with IV contrast are usually appropriate in some clinical situations in which there is a high suspicion of the embolic source originating in the thoracic aorta. During the workup of a lower extremity embolic source, cardiac and cross-sectional angiographic imaging may be complementary (both are performed) in certain clinical scenarios/conditions.
- **Variant 4**: TEE, TTE, MRI heart function and morphology without and with IV contrast, MRI heart function and morphology without IV contrast, and CT heart function and morphology with IV contrast are usually appropriate for determining the cardiac source of known multiorgan system arterial occlusions with a suspected embolic 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). Furthermore, CTA of the chest, abdomen, and pelvis with IV contrast, MRA of the chest, abdomen, and pelvis without and with IV contrast, and MRA of the chest, abdomen, and pelvis without IV contrast are equivalent alternatives that are usually appropriate for determining a central arterial source of known multiorgan system arterial occlusions with a suspected embolic etiology. CTA of the chest with IV contrast or MRA of the chest without and with IV contrast are usually appropriate in some clinical situations when there is a high suspicion of the embolic source originating in the thoracic aorta. During the workup of a multiorgan system embolic source, cardiac and cross-sectional angiographic imaging may be complementary (both are performed) in certain clinical scenarios/conditions.

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 go to www.acr.org/ac.

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 [60].

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 (eg, 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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