American College of Radiology
ACR Appropriateness Criteria®

Lower Extremity Arterial Claudication-Imaging Assessment for Revascularization

Variant: 1 Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler lower extremity	Usually Appropriate	O
Arteriography lower extremity	Usually Appropriate	☢☢
MRA abdomen and pelvis with bilateral lower extremity runoff with IV contrast	Usually Appropriate	O
CTA abdomen and pelvis with bilateral lower extremity runoff with IV contrast	Usually Appropriate	☢☢☢☢
CTA abdomen and pelvis with bilateral lower extremity runoff without and with IV contrast	Usually Appropriate	☢☢☢☢☢
MRA abdomen and pelvis with bilateral lower extremity runoff without IV contrast	May Be Appropriate	O
MRA lower extremity without and with IV contrast	May Be Appropriate	O
MRA lower extremity without IV contrast	May Be Appropriate	O
CTA lower extremity with IV contrast	May Be Appropriate	☢☢☢
CTA lower extremity without and with IV contrast	May Be Appropriate	☢☢☢

Panel Members

Ezana M. Azene, MD, PhD[a]; Michael L. Steigner, MD[b]; Ayaz Aghayev, MD[c]; Sarah Ahmad, MD[d]; Rachel E. Clough, MD, PhD[e]; Maros Ferencik, MD, PhD, MCR[f]; Sandeep S. Hedgire, MD[g]; Caitlin W. Hicks, MD, MS[h]; David S. Kirsch, MD[i]; Yoo Jin Lee, MD[j]; Lee A. Myers, MD[k]; Prashant Nagpal, MD[l]; Nicholas Osborne, MD, MS[m]; Anil K. Pillai, MD[n]; Beth Ripley, MD, PhD[o]; Nimarta Singh, MD, MPH[p]; Richard Thomas, MD, MBBS[q]; Sanjeeva P. Kalva, [r].

Summary of Literature Review

Introduction/Background

Claudication is a symptom complex characterized by pain and weakness in an active muscle group, reproducibly precipitated by similar amounts of exercise and promptly relieved by rest. Claudication is most commonly a manifestation of peripheral artery disease (PAD), which affects 3% to 7% of the general population and 20% of people >70 years of age [1]. Other disease entities can present similarly with "pseudoclaudication." The most common nonarterial cause is neurogenic disease (especially spinal stenosis), but other diseases, such as compartment syndromes, pelvic tumors, and chronic venous occlusion, have also been associated with symptoms similar to claudication [2].

Estimates of the prevalence of claudication in the general population range from 1.6% to almost 8%, depending on age, sex, the geographic location of the population, and the diagnostic criteria used [2,3]. In most studies, fewer than 10% of patients with intermittent claudication progress to

chronic limb-threatening ischemia in 5 years [4,5]. However, one large meta-analysis of 16,440 patients demonstrated that 21% of patients with intermittent claudication progressed to chronic limb-threatening ischemia [6].

The presence of vascular disease in patients with symptoms of claudication is reliably established by a variety of noninvasive hemodynamic tests. In the absence of demonstrable arterial disease, imaging studies of other systems, such as the lumbar spine or soft tissues of the pelvis, may be indicated. If peripheral vascular disease is confirmed, additional studies may be indicated to screen the heart and carotid arteries for involvement [2].

Noninvasive hemodynamic tests such as the ankle brachial index, toe brachial index, segmental pressures, and pulse volume recordings are considered the first diagnostic modalities necessary to reliably establish the presence and severity of arterial obstructions [2]. Near infrared thermography shows promise as an additional noninvasive examination [7,8]. Once confirmed by noninvasive hemodynamic studies, if intervention beyond medical management is indicated, vascular imaging is used for diagnosing individual lesions and to triage patients for possible percutaneous or surgical intervention [2,9]. The indications for surgical or percutaneous intervention are controversial, and thus specific indications for imaging studies remain ill-defined. Factors that influence this decision include 1) the natural history of limb and patient survival, 2) the patient's tolerance of symptoms and resulting changes in lifestyle, 3) the effectiveness of medical or exercise therapy, 4) the potential risks of invasive tests and treatments, and 5) the short-term and long-term outcomes of surgery or interventional procedures [2].

Special Imaging Considerations

CT angiography (CTA) in the tibial arteries is limited by the difficulty in accurately timing the image acquisition with respect to arrival of the iodine bolus: images acquired too late will have problematic venous contamination; images acquired too early will not have adequate contrast enhancement. More common with newer CT technologies is imaging too early either for one leg with slow flow from outflow disease or for both legs secondary to the very fast scanning protocols. Delayed images of the calves can be obtained to catch the bolus in these patients.

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 (i.e., only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (i.e., 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: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

A. Arteriography lower extremity

Catheter angiography is often helpful for imaging the peripheral arteries, providing a dynamic and accurate depiction of the peripheral vascular system [10,11]. The development of digital subtraction has enhanced the ability of contrast angiography to visualize vessels that are poorly opacified and permits multiple views while minimizing the amount of contrast injected. Digital subtraction angiography (DSA) allows visualization of the lumen in the presence of densely calcified arteries, especially those in the below knee segment. In addition, DSA allows dynamic assessment of the arteries to evaluate extrinsic compression (as in popliteal artery entrapment). Endovascular treatment of peripheral vascular disease—including angioplasty, stenting, excimer laser, and atherectomy—is commonly used [2].

The presence of diffusely diseased arteries can present challenges during angiography, because stenosis severity can be difficult to determine in the absence of normal arterial segments for comparison. In addition, serial lesions, luminal irregularity, and the degree of collateral development may produce effects on the blood flow that are difficult to quantify angiographically.

The main drawbacks of arteriography in patients with claudication are its invasive nature and the known complications from catheterization [2,10]. These difficulties can be avoided by using examinations such as duplex ultrasound (US), MR angiography (MRA), or CTA to accurately triage patients with confirmed PAD for percutaneous or surgical treatments. For the latter, preoperative arteriography may not be needed.

Finally, arteriography has inconsistent correlation between the hemodynamic or functional effects and the morphology of the arterial lesions [12]. Several studies have reported this problem, but in some of them the problem may be accentuated by less-than-optimal angiographic technique (eg, single-projection, nonselective injections).

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

B. CTA abdomen and pelvis with bilateral lower extremity runoff with IV contrast

CTA is commonly used for imaging peripheral vascular disease. Multidetector CT scanners, including helical and multistation axial acquisitions, enable rapid scanning of the entire arterial system [13]. When compared with catheter arteriography, CTA offers volumetric as opposed to planar images. The volumetric acquisition enables extensive image postprocessing, including multiplanar reformatted and maximum-intensity projection images to create an arterial road map [13]. With optimized timing of the acquisition, CT images include collaterals and arteries distal to occlusions that may not appear on catheter angiography images. Like MRA, CTA is a cross-sectional technique, which shows nonvascular findings, as well as vascular lesions associated with aneurysms and cystic adventitial disease that are not detected with the projectional technique of catheter arteriography.

Unlike imaging of the peripheral arteries, CTA is considered to have replaced catheter angiography as the reference standard for imaging of the aorta [13,14]. CTA can readily detect stenosis caused

by plaque or thrombus in the aorta and iliac arteries that may be contributing to symptoms of claudication.

CTA alone can be used to plan treatment, including assessment of the length, severity, and number of stenoses [15,16]. Compared with catheter angiography, the sensitivity and specificity of CTA for detection of stenoses >50% diameter are 90% to 100% [10,17-20]. Accuracy in patients with bypass grafts is excellent compared with duplex US [21]. CTA is also more clinically useful than duplex US [21]. However, heavily calcified atheromatous disease can limit the ability to interpret CT images. This drawback is usually more pronounced in tibial arteries. Identification of patients who may be unsuitable candidates for CTA of the tibial arteries (eg, >80 years of age, diabetic, on dialysis) will reduce the number of nondiagnostic studies [22]. Dual-energy CTA can reduce blooming and beam-hardening artifact created by heavily calcified atheromatous disease and metallic stents [23].

Compared with MRA, CT has the advantages of more rapid acquisition, better safety in patients with pacemakers or defibrillators, and generally less severe artifacts from metal. Finally, claustrophobia is far less of a problem.

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.
C. CTA abdomen and pelvis with bilateral lower extremity runoff without and with IV contrast

CTA is commonly used for imaging peripheral vascular disease. Multidetector CT scanners, including helical and multistation axial acquisitions, enable rapid scanning of the entire arterial system [13]. When compared with catheter arteriography, CTA offers volumetric as opposed to planar images. The volumetric acquisition enables extensive image postprocessing, including multiplanar reformatted and maximum-intensity projection images to create an arterial road map [13]. With optimized timing of the acquisition, CT images include collaterals and arteries distal to occlusions that may not appear on catheter angiography images. Like MRA, CTA is a cross-sectional technique, which shows nonvascular findings as well as vascular lesions associated with aneurysms and cystic adventitial disease that are not detected with the projectional technique of catheter arteriography.

Unlike imaging of the peripheral arteries, CTA is considered to have replaced catheter angiography as the reference standard for imaging of the aorta [13,14]. CTA can readily detect stenosis caused by plaque or thrombus in the aorta and iliac arteries that may be contributing to symptoms of claudication.

CTA alone can be used to plan treatment, including assessment of the length, severity, and number of stenoses [15,16]. Compared with catheter angiography, the sensitivity and specificity of CTA for detection of stenoses >50% diameter are 90% to 100% [10,17-20]. Accuracy in patients with bypass grafts is excellent compared with duplex US [21]. CTA is also more clinically useful than duplex US [21]. However, heavily calcified atheromatous disease can limit the ability to interpret CT images. This drawback is usually more pronounced in tibial arteries. Identification of patients who may be unsuitable candidates for CTA of the tibial arteries (eg, >80 years of age, diabetic, on dialysis) will reduce the number of nondiagnostic studies [22]. Dual-energy CTA can reduce blooming and beam-hardening artifact created by heavily calcified atheromatous disease and metallic stents [23]. CTA without intravenous (IV) contrast can be performed before CTA with IV

contrast to fine-tune the scan range and identify calcified plaque and calcium within thrombus [24].

Compared with MRA, CT has the advantages of more rapid acquisition, better safety in patients with pacemakers or defibrillators, and generally less severe artifacts from metal. Finally, claustrophobia is far less of a problem.

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.
D. CTA lower extremity with IV contrast

CTA is commonly used for imaging peripheral vascular disease. Multidetector CT scanners, including helical and multistation axial acquisitions, enable rapid scanning of the entire arterial system [13]. When compared with catheter arteriography, CTA offers volumetric as opposed to planar images. The volumetric acquisition enables extensive image postprocessing, including multiplanar reformatted and maximum-intensity projection images to create an arterial road map [13]. With optimized timing of the acquisition, CT images include collaterals and arteries distal to occlusions that may not appear on catheter angiography images. Like MRA, CTA is a cross-sectional technique, which shows nonvascular findings, as well as vascular lesions associated with aneurysms and cystic adventitial disease that are not detected with the projectional technique of catheter arteriography.

CTA alone can be used to plan treatment, including assessment of the length, severity, and number of stenoses [15,16]. Compared with catheter angiography, the sensitivity and specificity of CTA for detection of stenoses >50% diameter are 90% to 100% [10,17-20]. Accuracy in patients with bypass grafts is excellent compared with duplex US [21]. CTA is also more clinically useful than duplex US [21]. However, heavily calcified atheromatous disease can limit the ability to interpret CT images. This drawback is usually more pronounced in tibial arteries. Identification of patients who may be unsuitable candidates for CTA of the tibial arteries (eg, >80 years of age, diabetic, on dialysis) will reduce the number of nondiagnostic studies [22]. Dual-energy CTA can reduce blooming and beam-hardening artifact created by heavily calcified atheromatous disease and metallic stents [23].

Compared with MRA, CT has the advantages of more rapid acquisition, better safety in patients with pacemakers or defibrillators, and generally less severe artifacts from metal. Finally, claustrophobia is far less of a problem.
CTA of one or both lower extremities can be performed without imaging the abdomen and pelvis when aortoiliac disease is not a concern or the state of the aorta and iliac arteries is already known.

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.
E. CTA lower extremity without and with IV contrast

CTA is commonly used for imaging peripheral vascular disease. Multidetector CT scanners, including helical and multistation axial acquisitions, enable rapid scanning of the entire arterial system [13]. When compared with catheter arteriography, CTA offers volumetric as opposed to planar images. The volumetric acquisition enables extensive image postprocessing, including multiplanar reformatted and maximum-intensity projection images to create an arterial road map [13]. With optimized timing of the acquisition, CT images include collaterals and arteries distal to occlusions that may not appear on catheter angiography images. Like MRA, CTA is a cross-

sectional technique, which shows nonvascular findings as well as vascular lesions associated with aneurysms and cystic adventitial disease that are not detected with the projectional technique of catheter arteriography.

CTA alone can be used to plan treatment, including assessment of the length, severity, and number of stenoses [15,16]. Compared with catheter angiography, the sensitivity and specificity of CTA for detection of stenoses >50% diameter are 90% to 100% [10,17-20]. Accuracy in patients with bypass grafts is excellent compared with duplex US [21]. CTA is also more clinically useful than duplex US [21]. However, heavily calcified atheromatous disease can limit the ability to interpret CT images. This drawback is usually more pronounced in tibial arteries. Identification of patients who may be unsuitable candidates for CTA of the tibial arteries (eg, >80 years of age, diabetic, on dialysis) will reduce the number of nondiagnostic studies [22]. Dual-energy CTA can reduce blooming and beam-hardening artifact created by heavily calcified atheromatous disease and metallic stents [23]. CTA without IV contrast can be performed before CTA with IV contrast to fine-tune the scan range and identify calcified plaque and calcium within thrombus [24].

Compared with MRA, CT has the advantages of more rapid acquisition, better safety in patients with pacemakers or defibrillators, and generally less severe artifacts from metal. Finally, claustrophobia is far less of a problem.

CTA of one or both lower extremities can be performed without imaging the abdomen and pelvis when aortoiliac disease is not a concern or the state of the aorta and iliac arteries is already known.

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

F. MRA abdomen and pelvis with bilateral lower extremity runoff with IV contrast

Contrast-enhanced MRA (CE-MRA) techniques continue to evolve and improve. Three-dimensional imaging, contrast enhancement with gadolinium, subtraction, cardiac gating, bolus chase, parallel imaging, optimized K-space filling, 3T magnet strength, and improved coil technology have led to improved temporal resolution, spatial resolution, and signal-to-noise ratio in CE-MRA. Its sensitivity and specificity for detection of stenoses >50% are now in the 90% to 100% range [25-27]. Unlike with CTA, the presence of calcium in small vessels does not result in a CE-MRA artifact [28]. Furthermore, dedicated time-resolved CE-MRA of the tibial and pedal arteries significantly increases diagnostic accuracy of tibial and pedal lesions compared with standard multistation CE-MRA. Time-resolved CE-MRA also reduces insufficient arterial filling and venous contamination, which are common limitations of standard multistation CE-MRA [28]. Although CE-MRA has not supplanted angiography as a reference standard, one small study demonstrated that 3T CE-MRA with calf compression (to prevent venous contamination) resulted in better visualization of tibial arteries than DSA [29]. For these reasons, CE-MRA is ideally suited for patients at high risk for calcification of the tibial and pedal arteries, particularly patients with diabetes and patients >80 years of age [28,30].

In comparison with duplex US, CE-MRA is more accurate for detecting and quantifying significant stenoses and for preoperative planning [31]. In a randomized controlled trial comparison with duplex US, CE-MRA for the initial imaging workup of patients with PAD reduced the need for additional imaging [32]. In a meta-analysis comparison with CTA, CE-MRA had equivalent sensitivity and specificity for detecting arterial lesions from the aorta to the tibial arteries in patients with intermittent claudication [26].

Some technical problems limit the utility of CE-MRA for imaging PAD. Challenges may include image quality related to low signal-to-noise ratio, limited spatial resolution, motion artifacts, long acquisition times, and loss of signal in arterial segments within metal stents or adjacent to metallic clips or prosthetic joints. Some of these problems have been addressed successfully with the use of newer imaging sequences and newer stent designs.

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

G. MRA abdomen and pelvis with bilateral lower extremity runoff without IV contrast

Noncontrast MRA techniques predate CE-MRA in their development. However, long acquisition time and motion artifacts limit the use of these techniques in the abdomen and peripheral arteries [33]. To that end, recent advancements in noncontrast MRA techniques for imaging PAD have expanded the sequence options from time-of-flight and phase-contrast imaging to include electrocardiogram-gated fresh-blood partial Fourier fast spin echo, balanced steady-state free precession, and arterial spin labeling [33]. Two alternative approaches using balanced steady state for peripheral noncontrast MRA applications include flow-sensitive dephasing and quiescent-interval single shot [30,33-35]. When compared with bolus-chase and time-resolved gadolinium-enhanced MRA, initial studies of fresh-blood imaging of the tibial and pedal arteries have provided accurate imaging when technically successful. Overall, these methods are being increasingly adopted for patients with severe renal insufficiency at risk of developing nephrogenic systemic fibrosis.

Some technical problems limit the utility of noncontrast MRA for imaging PAD. Challenges may include image quality related to low signal-to-noise ratio, limited spatial resolution, motion artifacts, long acquisition times, unreliable visualization of lesions with high flow and turbulence (excessive signal loss at regions of high-grade stenoses), nonvisualization of patent vessel segments with reversed blood flow, and loss of signal in arterial segments within metal stents or adjacent to metallic clips or prosthetic joints. Some of these problems have been addressed successfully with the use of newer imaging sequences. With the newer noncontrast techniques, cardiac arrhythmia can impair image quality, limiting evaluation of the distal tibial and pedal arteries. Although useful tools to improve image quality have been suggested, larger-scale trials are required for evaluation of small-vessel PAD with noncontrast MRA [29,36].

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

H. MRA lower extremity without and with IV contrast

MRA of one or both lower extremities can be performed without imaging the abdomen and pelvis when aortoiliac disease is not a concern or the state of the aorta and iliac arteries is already known.

CE-MRA techniques continue to evolve and improve. Three-dimensional imaging, contrast enhancement with gadolinium, subtraction, cardiac gating, bolus chase, parallel imaging, optimized K-space filling, 3T magnet strength, and improved coil technology have led to improved temporal resolution, spatial resolution, and signal-to-noise ratio in CE-MRA. Its sensitivity and specificity for detection of stenoses >50% are now in the 90% to 100% range [25-27]. Unlike with CTA, the presence of calcium in small vessels does not result in a CE-MRA artifact [28]. Furthermore, dedicated time-resolved CE-MRA of the tibial and pedal arteries significantly increases diagnostic accuracy of tibial and pedal lesions compared with standard multistation CE-

MRA. Time-resolved CE-MRA also reduces insufficient arterial filling and venous contamination, which are common limitations of standard multistation CE-MRA [28]. Although CE-MRA has not supplanted angiography as a reference standard, one small study demonstrated that 3T CE-MRA with calf compression (to prevent venous contamination) resulted in better visualization of tibial arteries than DSA [29]. For these reasons, CE-MRA is ideally suited for patients at high risk for calcification of the tibial and pedal arteries, particularly patients with diabetes and patients >80 years of age [28,30].

In comparison with duplex US, CE-MRA is more accurate for detecting and quantifying significant stenoses and for preoperative planning [31]. In a randomized controlled trial comparison with duplex US, CE-MRA for the initial imaging workup of patients with PAD reduced the need for additional imaging [32]. In a meta-analysis comparison to CTA, CE-MRA had equivalent sensitivity and specificity for detecting arterial lesions from the aorta to the tibial arteries in patients with intermittent claudication [26].

Some technical problems limit the utility of CE-MRA for imaging PAD. Challenges may include image quality related to low signal-to-noise ratio, limited spatial resolution, motion artifacts, long acquisition times, and loss of signal in arterial segments within metal stents or adjacent to metallic clips or prosthetic joints. Some of these problems have been addressed successfully with the use of newer imaging sequences and newer stent designs.

Noncontrast MRA techniques predate CE-MRA in their development. However, long acquisition time and motion artifacts limit the use of these techniques in the abdomen and peripheral arteries [33]. To that end, recent advancements in noncontrast MRA techniques for imaging PAD have expanded the sequence options from time-of-flight and phase-contrast imaging to include electrocardiogram-gated fresh-blood partial Fourier fast spin echo, balanced steady-state free precession, and arterial spin labeling [33]. Two alternative approaches using balanced steady state for peripheral noncontrast MRA applications include flow-sensitive dephasing and quiescent-interval single shot [30,33-35]. When compared with bolus-chase and time-resolved gadolinium-enhanced MRA, initial studies of fresh-blood imaging of the tibial and pedal arteries have provided accurate imaging when technically successful. Overall, these methods are being increasingly adopted for patients with severe renal insufficiency at risk of developing nephrogenic systemic fibrosis.

Some technical problems limit the utility of noncontrast MRA for imaging PAD. Challenges may include image quality related to low signal-to-noise ratio, limited spatial resolution, motion artifacts, long acquisition times, unreliable visualization of lesions with high flow and turbulence (excessive signal loss at regions of high-grade stenoses), nonvisualization of patent vessel segments with reversed blood flow, and loss of signal in arterial segments within metal stents or adjacent to metallic clips or prosthetic joints. Some of these problems have been addressed successfully with the use of newer imaging sequences. With the newer noncontrast techniques, cardiac arrhythmia can impair image quality, limiting evaluation of the distal tibial and pedal arteries. Although useful tools to improve image quality have been suggested, larger-scale trials are required for evaluation of small-vessel PAD with noncontrast MRA [29,36].

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

I. MRA lower extremity without IV contrast

MRA of one or both lower extremities can be performed without imaging the abdomen and pelvis when aortoiliac disease is not a concern or the state of the aorta and iliac arteries is already known.

Noncontrast MRA techniques predate CE-MRA in their development. However, long acquisition time and motion artifacts limit the use of these techniques in the abdomen and peripheral arteries [33]. To that end, recent advancements in noncontrast MRA techniques for imaging PAD have expanded the sequence options from time-of-flight and phase-contrast imaging to include electrocardiogram-gated fresh-blood partial Fourier fast spin echo, balanced steady-state free precession, and arterial spin labeling [33]. Two alternative approaches using balanced steady state for peripheral noncontrast MRA applications include flow-sensitive dephasing and quiescent-interval single shot [30,33-35]. When compared with bolus-chase and time-resolved gadolinium-enhanced MRA, initial studies of fresh-blood imaging of the tibial and pedal arteries have provided accurate imaging when technically successful. Overall, these methods are being increasingly adopted for patients with severe renal insufficiency at risk of developing nephrogenic systemic fibrosis.

Some technical problems limit the utility of noncontrast MRA for imaging PAD. Challenges may include image quality related to low signal-to-noise ratio, limited spatial resolution, motion artifacts, long acquisition times, unreliable visualization of lesions with high flow and turbulence (excessive signal loss at regions of high-grade stenoses), nonvisualization of patent vessel segments with reversed blood flow, and loss of signal in arterial segments within metal stents or adjacent to metallic clips or prosthetic joints. Some of these problems have been addressed successfully with the use of newer imaging sequences. With the newer noncontrast techniques, cardiac arrhythmia can impair image quality, limiting evaluation of the distal tibial and pedal arteries. Although useful tools to improve image quality have been suggested, larger-scale trials are required for evaluation of small-vessel PAD with noncontrast MRA [29,36].

Variant 1: Lower extremity arterial claudication-imaging assessment for revascularization. Initial imaging.

J. US duplex Doppler lower extremity

Duplex US of the extremities can be used to identify the location, degree, and extent of stenosis to the level of the knee [37]. Although duplex US includes images in grayscale or in color or power Doppler, the clinically relevant information derived from duplex studies has been validated from analysis of the velocity of blood flow.

The sensitivity and specificity for the diagnosis of stenoses >50% in diameter from the iliac arteries to the popliteal arteries are each approximately 90% to 95% [37-39]. Accuracy of the duplex examination depends on the ability of the technique to visualize the vessel adequately. The use of color improves accuracy [40]. Accuracy is diminished in examinations of the iliac arteries if bowel gas or tortuosity obscures the iliac vessels. Dense calcification can also obscure flow, particularly if flow is slow. Accuracy of duplex US is also decreased in the setting of multiple sequential lesions [41].

Duplex US has been established as a useful surveillance tool for arterial bypass grafts with established criteria for graft stenosis and thresholds for reintervention [42]. However, evidence and standards for duplex US surveillance after endovascular treatment are lacking, although duplex US is commonly used for this indication [42]. In comparison with CE-MRA, duplex US is less accurate for detecting significant stenoses and for preoperative planning [31]. In a randomized controlled

trial comparison with CE-MRA, duplex US for the initial imaging workup of patients with PAD increased the need for additional imaging [32]. CTA is more clinically useful than duplex US [21].

Advantages of duplex US include its portability and lack of IV contrast agent. Disadvantages include limited sonographic windows resulting in nondiagnostic segments of the aorta and iliac arteries. Duplex US may underestimate the extent of disease when multiple "tandem" stenotic segments are present in series [43]. Patient discomfort during the procedure may limit adequate visualization.

Summary of Highlights

- **Variant 1:** US duplex Doppler lower extremity or arteriography lower extremity or MRA abdomen and pelvis with bilateral lower extremity runoff with IV contrast or CTA abdomen and pelvis with bilateral lower extremity runoff with IV contrast or CTA abdomen and pelvis with bilateral lower extremity runoff without and with IV contrast is usually appropriate for the initial imaging assessment for revascularization in the setting of lower extremity arterial claudication. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

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.

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.”

References

1. Leng GC, Lee AJ, Fowkes FG, et al. Incidence, natural history and cardiovascular events in symptomatic and asymptomatic peripheral arterial disease in the general population. Int J Epidemiol 1996;25:1172-81.
2. Hirsch AT, Haskal ZJ, Hertzer NR, et al. ACC/AHA 2005 guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): executive summary a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease) endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. J Am Coll Cardiol 2006; 47(6):1239-1312.
3. Alzamora MT, Fores R, Baena-Diez JM, et al. The peripheral arterial disease study

(PERART/ARTPER): prevalence and risk factors in the general population. BMC Public Health 2010;10:38.

4. Muluk SC, Muluk VS, Kelley ME, et al. Outcome events in patients with claudication: a 15-year study in 2777 patients. Journal of vascular surgery 2001;33:251-7; discussion 57-8.

5. Gerhard-Herman MD, Gornik HL, Barrett C, et al. 2016 AHA/ACC Guideline on the Management of Patients with Lower Extremity Peripheral Artery Disease: Executive Summary. Vasc Med 2017;22:NP1-NP43.

6. Sigvant B, Lundin F, Wahlberg E. The Risk of Disease Progression in Peripheral Arterial Disease is Higher than Expected: A Meta-Analysis of Mortality and Disease Progression in Peripheral Arterial Disease. European journal of vascular and endovascular surgery : the official journal of the European Society for Vascular Surgery 2016;51:395-403.

7. Fuglestad MA, Hernandez H, Gao Y, et al. A low-cost, wireless near-infrared spectroscopy device detects the presence of lower extremity atherosclerosis as measured by computed tomographic angiography and characterizes walking impairment in peripheral artery disease. J Vasc Surg. 71(3):946-957, 2020 03.

8. Huang CL, Wu YW, Hwang CL, et al. The application of infrared thermography in evaluation of patients at high risk for lower extremity peripheral arterial disease. J Vasc Surg. 2011;54(4):1074-1080.

9. Rutherford RB, Lowenstein DH, Klein MF. Combining segmental systolic pressures and plethysmography to diagnose arterial occlusive disease of the legs. Am J Surg 1979; 138(2):211-218.

10. Ofer A, Nitecki SS, Linn S, et al. Multidetector CT angiography of peripheral vascular disease: a prospective comparison with intraarterial digital subtraction angiography. AJR. 2003;180(3):719-724.

11. Vahl AC, Geselschap J, Montauban van Swijndregt AD, et al. Contrast enhanced magnetic resonance angiography versus intra-arterial digital subtraction angiography for treatment planning in patients with peripheral arterial disease: a randomised controlled diagnostic trial. Eur J Vasc Endovasc Surg. 2008;35(5):514-521; discussion 522-513.

12. Thiele BL, Strandness DE, Jr. Accuracy of angiographic quantification of peripheral atherosclerosis. Prog Cardiovasc Dis. 1983;26(3):223-236.

13. Kumamaru KK, Hoppel BE, Mather RT, Rybicki FJ. CT angiography: current technology and clinical use. Radiol Clin North Am. 2010;48(2):213-235, vii.

14. Hiratzka LF, Bakris GL, Beckman JA, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with Thoracic Aortic Disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation 2010;121:e266-369.

15. Fotiadis N, Kyriakides C, Bent C, Vorvolakos T, Matson M. 64-section CT angiography in patients with critical limb ischaemia and severe claudication: comparison with digital subtractive angiography. Clin Radiol. 66(10):945-52, 2011 Oct.

16. Schernthaner R, Stadler A, Lomoschitz F, et al. Multidetector CT angiography in the assessment of peripheral arterial occlusive disease: accuracy in detecting the severity, number, and length of stenoses. Eur Radiol. 2008;18(4):665-671.

17. Catalano C, Fraioli F, Laghi A, et al. Infrarenal aortic and lower-extremity arterial disease: diagnostic performance of multi-detector row CT angiography. Radiology. 2004;231(2):555-563.

18. Fine JJ, Hall PA, Richardson JH, Butterfield LO. 64-slice peripheral computed tomography angiography: a clinical accuracy evaluation. J Am Coll Cardiol. 2006;47(7):1495-1496.

19. Heijenbrok-Kal MH, Kock MC, Hunink MG. Lower extremity arterial disease: multidetector CT angiography meta-analysis. Radiology. 2007;245(2):433-439.

20. Willmann JK, Wildermuth S, Pfammatter T, et al. Aortoiliac and renal arteries: prospective intraindividual comparison of contrast-enhanced three-dimensional MR angiography and multi-detector row CT angiography. Radiology. 226(3):798-811, 2003 Mar.

21. Kayhan A, Palabiyik F, Serinsoz S, et al. Multidetector CT angiography versus arterial duplex USG in diagnosis of mild lower extremity peripheral arterial disease: is multidetector CT a valuable screening tool? European journal of radiology 2012;81:542-6.

22. Ouwendijk R, Kock MC, van Dijk LC, van Sambeek MR, Stijnen T, Hunink MG. Vessel wall calcifications at multi-detector row CT angiography in patients with peripheral arterial disease: effect on clinical utility and clinical predictors. Radiology. 2006;241(2):603-608.

23. Machida H, Tanaka I, Fukui R, et al. Dual-Energy Spectral CT: Various Clinical Vascular Applications. Radiographics 2016;36:1215-32.

24. Hallett RL, Fleischmann D. Tools of the trade for CTA: MDCT scanners and contrast medium injection protocols. Techniques in vascular and interventional radiology 2006;9:134-42.

25. Cambria RP, Kaufman JA, L'Italien GJ, et al. Magnetic resonance angiography in the management of lower extremity arterial occlusive disease: a prospective study. J Vasc Surg. 1997;25(2):380-389.

26. Jens S, Koelemay MJ, Reekers JA, Bipat S. Diagnostic performance of computed tomography angiography and contrast-enhanced magnetic resonance angiography in patients with critical limb ischaemia and intermittent claudication: systematic review and meta-analysis. Eur Radiol 2013;23:3104-14.

27. Loewe C, Schoder M, Rand T, et al. Peripheral vascular occlusive disease: evaluation with contrast-enhanced moving-bed MR angiography versus digital subtraction angiography in 106 patients. AJR. 2002;179(4):1013-1021.

28. Iglesias J, Pena C. Computed tomography angiography and magnetic resonance angiography imaging in critical limb ischemia: an overview. [Review]. Tech Vasc Interv Radiol. 17(3):147-54, 2014 Sep.

29. Zhu YQ, Zhao JG, Wang J, et al. Patency of runoff detected by MR angiography at 3.0 T with cuff-compression: a predictor of successful endovascular recanalization below the knee. Eur Radiol. 24(11):2857-65, 2014 Nov.

30. Hodnett PA, Ward EV, Davarpanah AH, et al. Peripheral arterial disease in a symptomatic diabetic population: prospective comparison of rapid unenhanced MR angiography (MRA) with contrast-enhanced MRA. AJR Am J Roentgenol 2011;197:1466-73.

31. Visser K, Hunink MG. Peripheral arterial disease: gadolinium-enhanced MR angiography versus color-guided duplex US--a meta-analysis. Radiology. 2000;216(1):67-77.

32. de Vries M, Ouwendijk R, Flobbe K, et al. Peripheral arterial disease: clinical and cost comparisons between duplex US and contrast-enhanced MR angiography--a multicenter randomized trial. Radiology. 2006;240(2):401-410.

33. Miyazaki M, Akahane M. Non-contrast enhanced MR angiography: Established techniques. J Magn Reson Imaging. 2012;35(1):1-19.

34. Hanrahan CJ, Lindley MD, Mueller M, et al. Diagnostic Accuracy of Noncontrast MR Angiography Protocols at 3T for the Detection and Characterization of Lower Extremity Peripheral Arterial Disease. J Vasc Interv Radiol. 29(11):1585-1594.e2, 2018 11.

35. Offerman EJ, Hodnett PA, Edelman RR, Koktzoglou I. Nonenhanced methods for lower-extremity MRA: a phantom study examining the effects of stenosis and pathologic flow waveforms at 1.5T. J Magn Reson Imaging. 33(2):401-8, 2011 Feb.

36. Hoey ET, Ganeshan A, Puni R, Henderson J, Crowe PM. Fresh blood imaging of the peripheral vasculature: an emerging unenhanced MR technique. AJR Am J Roentgenol. 2010; 195(6):1444-1448.

37. Jager KA, Phillips DJ, Martin RL, et al. Noninvasive mapping of lower limb arterial lesions. Ultrasound Med Biol. 1985;11(3):515-521.

38. Fletcher JP, Kershaw LZ, Chan A, Lim J. Noninvasive imaging of the superficial femoral artery using ultrasound Duplex scanning. J Cardiovasc Surg (Torino). 1990;31(3):364-367.

39. Leng GC, Whyman MR, Donnan PT, et al. Accuracy and reproducibility of duplex ultrasonography in grading femoropopliteal stenoses. J Vasc Surg. 1993;17(3):510-517.

40. de Vries SO, Hunink MG, Polak JF. Summary receiver operating characteristic curves as a technique for meta-analysis of the diagnostic performance of duplex ultrasonography in peripheral arterial disease. Acad Radiol. 1996;3(4):361-369.

41. Allard L, Cloutier G, Durand LG, Roederer GO, Langlois YE. Limitations of ultrasonic duplex scanning for diagnosing lower limb arterial stenoses in the presence of adjacent segment disease. J Vasc Surg. 1994;19(4):650-657.

42. Martinez-Rico C, Marti-Mestre X, Jimenez-Guiu X, Espinar-Garcia E, Cervellera-Perez D, Vila-Coll R. Ultrasound Surveillance in Endovascular Revascularization of Lower Limbs. Ann Vasc Surg. 56:274-279, 2019 Apr.

43. Chan KA, Junia A. Lower extremity peripheral artery disease: a basic approach. [Review]. Br J Hosp Med (Lond). 81(3):1-9, 2020 Mar 02.

44. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf.

Disclaimer

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring

physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as 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.

[a]Gundersen Health System, La Crosse, Wisconsin. [b]Panel Chair, Brigham & Women's Hospital, Boston, Massachusetts. [c]Panel Vice-Chair, Brigham & Women's Hospital, Boston, Massachusetts. [d]University of Toronto, Toronto, Ontario, Canada; American College of Physicians. [e]St Thomas' Hospital, King's College, School of Biomedical Engineering and Imaging Science, London, United Kingdom; Society for Cardiovascular Magnetic Resonance. [f]Knight Cardiovascular Institute, Oregon Health & Science University, Portland, Oregon; Society of Cardiovascular Computed Tomography. [g]Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts. [h]Johns Hopkins University School of Medicine, Baltimore, Maryland; Society for Vascular Surgery. [i]Ochsner Hospital, New Orleans, Louisiana. [j]University of California San Francisco, San Francisco, California. [k]Keck School of Medicine of USC, Los Angeles, California; Committee on Emergency Radiology-GSER. [l]University of Wisconsin, Madison, Wisconsin. [m]University of Michigan, Ann Arbor, Michigan; Society for Vascular Surgery. [n]UT Southwestern Medical Center, Dallas, Texas. [o]VA Puget Sound Health Care System and University of Washington, Seattle, Washington. [p]Mercyhealth, Rockford, Illinois. [q]Lahey Hospital and Medical Center, Burlington, Massachusetts. [r]Specialty Chair.