

**American College of Radiology
ACR Appropriateness Criteria®
Sudden Onset of Cold, Painful Leg**

Variant 1: Sudden onset of cold, painful leg.

Radiologic Procedure	Rating	Comments	RRL*
Arteriography lower extremity	8	This procedure is the preferred option if clinical suspicion of acute arterial obstruction is intermediate to high.	☢ ☢ ☢
CTA lower extremity with IV contrast	7	Consider in place of arteriography if clinical suspicion of arterial obstruction is low and patient has a stable baseline eGFR ≥ 45 mL/min).	☢ ☢ ☢
MRA lower extremity without and with IV contrast	7	This procedure may help reduce total contrast dose. Consider prior to arteriography in patients with mild to moderate chronic kidney disease (GFR 30–89 mL/min).	O
MRA lower extremity without IV contrast	5	This procedure should be considered in patients with eGFR < 30 mL/min who are not yet on dialysis.	O
US duplex Doppler lower extremity	5	This procedure may be helpful for problem solving or targeted examinations (eg, bypass graft).	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

SUDDEN ONSET OF COLD, PAINFUL LEG

Expert Panel on Vascular Imaging: Clifford R. Weiss, MD¹; Ezana M. Azene, MD, PhD²; Bill S. Majdalany, MD³; Ali F. AbuRahma, MD⁴; Jeremy D. Collins, MD⁵; Christopher J. Francois, MD⁶; Marie D. Gerhard-Herman, MD⁷; Heather L. Gornik, MD⁸; John M. Moriarty, MB, BCh⁹; Patrick T. Norton, MD¹⁰; Thomas Ptak, MD, PhD¹¹; Stephen P. Reis, MD¹²; Frank J. Rybicki, MD, PhD¹³; Sanjeeva P. Kalva, MD.¹⁴

Summary of Literature Review

Introduction/Background

Acute onset of a cold, painful leg, also known as acute limb ischemia (ALI), although not directly a significant cause of mortality, contributes significantly to morbidity. The etiologies are limited, the most common being arterial occlusion. Total venous outflow occlusion is another cause but much less common. It often results in what is known clinically as “phlegmasia cerulea dolens” (precursor to venous gangrene), with lower-extremity swelling, pain, and a dusky color. It is differentiated from arterial occlusion by the presence of distal arterial pulses. Other causes, such as prolonged exposure to cold and trauma, are rare and usually clinically obvious.

ALI generally requires urgent treatment. Appropriate care of the patient requires assessing the source (ie, embolic versus thrombotic occlusion) and extent of the underlying arterial obstruction. The available diagnostic studies include invasive catheter angiography and noninvasive testing. Noninvasive imaging modalities include duplex ultrasound (US), magnetic resonance angiography (MRA), and computed tomography angiography (CTA).

The published literature on imaging of peripheral artery disease (PAD) focuses almost exclusively on patients with chronic PAD. This includes asymptomatic PAD, leg pain with exertion (ie, intermittent claudication), and critical limb ischemia (CLI, defined as chronic leg or foot pain at rest, skin ulceration, or gangrene). By comparison, the literature focused on imaging patients with ALI is very limited. Consequently, the following discussion relies heavily on studies of patients with chronic PAD.

Variant 1: Sudden onset of cold, painful leg.

Arteriography

Arteriography (digital subtraction angiography [DSA]) performed with iodinated contrast material remains the diagnostic gold standard for detecting peripheral vascular occlusive disease. However, new and less invasive modalities are gradually replacing it [1-6]. The ability to diagnose and treat disease in a single procedure [7-9] is a major benefit of DSA that remains unmatched in the treatment of acute ischemic vascular disease. There has been extensive debate regarding the cost-benefit ratios when comparing DSA and MRA. Because of the invasive character of DSA, there is a recovery period typically lasting 4 hours or more. In some countries, patients remain in the hospital overnight [10,11]. If complications from DSA occur, additional intervention and prolongation of the hospital stay may add cost as well as morbidity or even mortality. To be truly cost effective, any noninvasive method would have to supplant DSA, not just precede or supplement it.

The reported incidence of complications with DSA varies greatly. There are also risks associated with iodinated contrast materials. Most worrisome are the rare fatal systemic reactions and contrast-induced nephropathy. The nephrotoxic effects are important to consider as many patients who present with the sudden onset of a cold, painful leg are elderly, diabetic, and have impaired renal function [10]. Carbon dioxide angiography or other imaging modalities that do not use iodinated contrast material should be considered in patients with estimated glomerular filtration rate (eGFR) <45 mL/min/1.73 m² [12]. Also, many patients will have repeated catheter angiography over the course of their disease, and minimizing patient radiation exposure should always be considered. Angiography has also been criticized for its imperfect evaluation of outflow vessels, specifically for limited visualization of pedal vasculature and patent distal vessels beyond significant obstructive lesions [5,13].

¹Principal Author, Johns Hopkins Bayview Medical Center, Baltimore, Maryland. ²Research Author, Gundersen Health System, La Crosse, Wisconsin. ³Panel Vice-chair, University of Michigan Health System, Ann Arbor, Michigan. ⁴West Virginia University, Charleston, West Virginia, Society of Vascular Surgery. ⁵Northwestern Medicine, Chicago, Illinois. ⁶University of Wisconsin, Madison, Wisconsin. ⁷Brigham & Women’s Hospital, Boston, Massachusetts, American College of Cardiology. ⁸Cleveland Clinic Heart and Vascular Institute, Cleveland, Ohio, American College of Cardiology. ⁹University of California Los Angeles, Los Angeles, California. ¹⁰University of Virginia Health System, Charlottesville, Virginia. ¹¹Massachusetts General Hospital, Boston, Massachusetts. ¹²University of Texas Southwestern Medical Center, Dallas, Texas. ¹³Specialty Chair, Ottawa Hospital Research Institute and the Department of Radiology, The University of Ottawa, Ottawa, Ontario, Canada. ¹⁴Panel Chair, UT Southwestern Medical Center, Dallas.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Reprint requests to: publications@acr.org

Magnetic Resonance Angiography

MRA has high sensitivity and specificity for detecting arterial occlusive disease, using DSA as a gold standard [2,3,5,14-17]. Early imaging protocols required 30 minutes or more of acquisition time. However, recent advances, including 3T magnetic fields, parallel imaging, multichannel coils, sequences such as time-resolved MRA, and enhanced acquisition speed, enable rapid assessment of ALI [2,13,18-21]. In addition to decreased total examination times, faster acquisition reduces motion artifact and venous contamination. Motion artifact can also be corrected with automated image registration protocols [22]. Improved spatial resolution translates to thinner slices and clearer depiction of small vessels [2,13,19]. Most information needed for the interventional radiologist or vascular surgeon is routinely illustrated with MRA, such as a general road map of arterial anatomy, including runoff vessels and collaterals, as well as the location and extent of significant stenoses and occlusions.

Limitations include less accurate evaluation of smaller arteries, which means that more time-consuming sequences are required to get better results. Also, limited information can currently be obtained on a routine basis regarding the character of vessel walls and detailed flow dynamics, although time-resolved contrast-enhanced MRA techniques are beginning to provide qualitative flow information [13,18,20,21]. Overestimation of stenosis has been reported in native arteries and in patients with vascular stents secondary to artifacts [23]. Overestimation in native arteries varies among sequences [23] and may or may not be a clinical problem in specific cases. This uncertainty highlights the poor consensus on optimal protocols. In part, this is a function of the continuing evolution of technology, both software and hardware.

Another concern with MRA is that most techniques have required the administration of a gadolinium-based contrast material. However, MRA has few associated complications, with the realization of the risk of nephrogenic systemic fibrosis in patients with underlying renal dysfunction [24] who receive these contrast materials. There has been increased interest in using other modalities or limiting the use of gadolinium-based contrast material in such patients. Significantly lower contrast doses can be used at 3T compared to 1.5T without compromising image quality [25]. Noncontrast MRA may prove useful [24,26-30]. However, further improvements will be required, particularly in techniques for assessing pedal circulation [28,31]. Finally, blood-pool gadolinium-chelate contrast materials have prolonged retention in the intravascular space and allow for steady-state imaging [23,32-35] that, in turn, can enable high spatial resolution acquisitions. Additional studies will be needed to confirm potential clinical benefits and cost-effectiveness of such agents.

Computed Tomography Angiography

Multidetector-row technology has dramatically shortened CT acquisition times, improved spatial resolution, and improved vascular image quality depicted with CT. Multidetector CT (MDCT) scanners can image from the diaphragm to the ankles in <30 seconds using a single-contrast bolus [11,36]. The use of 64-row or greater MDCT significantly increases the accuracy of stenosis detection, particularly in smaller vessels [6,37-39]. Dynamic, time-resolved “4-D” CTA may improve accuracy even further [37]. However, additional studies are needed before this can be confirmed.

Sophisticated postprocessing tools enable multiplanar visualization in all 3 orthogonal axes as well as in any oblique axis. In addition to multiplanar reconstructions, both volume rendering and maximum-intensity projections can be used, each with advantages and disadvantages. Maximum-intensity projections are very accurate for larger vessels (as distal as the infrapopliteal region) but less accurate for smaller vessels [40,41]. Volume rendering, including endoluminal reconstruction, is good for evaluating embolic or vascular endothelial injury. It is also valuable in evaluating heavily calcified vessels. However, interpretation from volume-rendered images or maximum-intensity projections alone is insufficient to characterize vascular lesions [41] and should always be accompanied by an assessment of the raw axial dataset and multiplanar reformatted images.

CTA has proven comparably accurate to MRA in evaluating peripheral arterial diseases [4,6,41]. The advantages of CTA over MRA are its excellent spatial resolution, widespread availability, cost-effectiveness, and usability in patients who have contraindications to MR imaging (MRI), such as those who have pacemakers or defibrillators [42].

One disadvantage of CTA is its limited ability to depict the lumen in heavily calcified arteries. Calcium-induced artifact causes an overestimation of stenosis [41,43]. In theory, dual-energy or spectral CTA can provide image reconstructions at various x-ray energy levels and can be used to distinguish between vascular calcium and iodinated contrast material [44]. Initial studies have shown improved accuracy of stenosis detection and grading with dual-energy CTA compared to conventional CTA [45,46]. However, early studies also suggest dual-energy CTA may still overestimate high-grade vessel stenosis as occlusion [47]. Dual-energy CTA may also correlate

less well with DSA in calcified calf and pedal arteries [48]. Expanded clinical use of dual-energy CTA will require further validation and assessment of relative radiation doses.

Complications related to iodinated contrast material are similar to those in catheter-based angiography and have been discussed above. Cumulative radiation dose is also a concern; CTA has been increasingly used for both preprocedural planning and postprocedural surveillance. Recent advances in hardware and software, however, have achieved lower radiation dosages for a single CTA examination [40]. Also, techniques tailored to the evaluation of lower-limb vasculature have been published that allow reduced patient radiation by decreasing kVp while preserving the ability to evaluate the smaller lower-limb vessels [49,50]. Decreasing kVp also has the added advantage of allowing lower doses of iodinated contrast material as kVp approaches the iodine K-edge [50].

Ultrasound Duplex Doppler

In this patient population, duplex US is limited by the need for operator expertise, by poor accessibility of vessels, by heavy calcification, and often by poor overall accuracy if multilevel disease is present [3,51,52]. Its advantages are that it can provide useful physiologic as well as anatomic information. Further, it is noninvasive, widely available, and relatively inexpensive.

Echocardiography

Transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) are generally not part of the initial workup but may be useful if patient symptoms could be from cardiac embolization, particularly in patients with known atrial fibrillation [53]. TEE is more invasive and time-consuming than TTE but affords better visualization of the left atrium. TEE may be useful to look for sources of emboli when TTE is indeterminate.

In the acute setting, however, this knowledge is unlikely to influence the immediate evaluation. Similarly, cardiac CT or MRI may identify or exclude cardiac thrombus or areas of cardiac dysfunction that might be the source of emboli, but this knowledge is not likely to have clinical impact in the acute setting.

Noninvasive Physiologic Testing

Noninvasive physiologic testing includes measurement of ankle-brachial index (ABI), segmental blood pressures, Doppler waveforms, handheld Doppler, pulse-volume recordings, transcutaneous oxygen pressure measurement (TcPO₂), and exercise treadmill testing. Segmental studies, TcPO₂, and exercise treadmill testing are of little use in the diagnosis and management of ALI [54]. However, ABI measurement and handheld Doppler are simple, rapid, and reliable methods to confirm arterial occlusion as the etiology of sudden onset of cold leg when the cause is not obvious. Both ABI and handheld Doppler can also serve as objective baseline tests to follow the patient after intervention [55]. Useful physiologic information may also be obtained. In this clinical setting, other noninvasive tests generally are not helpful as they do not provide specific information that will alter or guide therapy.

Summary of Recommendations

- Arteriography (DSA) remains the gold standard for diagnosing acute limb ischemia and continues to be the only modality that allows diagnosis and simultaneous treatment of pathology. This advantage alone will ensure that it continues to be a valuable tool.
- Noninvasive imaging with MRA or CTA before arteriography (DSA) or surgery is accepted and common. Both MRA and CTA can be used for diagnosis and may help surgical or interventional planning.
- Other imaging and noninvasive physiologic tests may prove important for longer-term management but are less recommended in the acute setting.

Summary of Evidence

Of the 55 references cited in the *ACR Appropriateness Criteria*[®] *Sudden Onset Cold, Painful Leg* document, 48 are categorized as diagnostic references including 11 well designed studies, 22 good quality studies, and 8 quality studies that may have design limitations. Additionally, 4 references are categorized as therapeutic references including 1 good quality study, and 2 quality studies that may have design limitations. There are 8 references that may not be useful as primary evidence. There are 3 references that are meta-analysis studies.

The 55 references cited in the *ACR Appropriateness Criteria*[®] *Sudden Onset Cold, Painful Leg* document were published from 1998-2013.

While there are references that report on studies with design limitations, 34 well designed or good quality studies provide good evidence.

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, both because of 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 to 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
○	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”.

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

- Albrecht T, Foert E, Holtkamp R, et al. 16-MDCT angiography of aortoiliac and lower extremity arteries: comparison with digital subtraction angiography. *AJR Am J Roentgenol*. 2007;189(3):702-711.
- Berg F, Bangard C, Bovenschulte H, et al. Hybrid contrast-enhanced MR angiography of pelvic and lower extremity vasculature at 3.0 T: initial experience. *Eur J Radiol*. 2009;70(1):170-176.
- Collins R, Burch J, Cranny G, et al. Duplex ultrasonography, magnetic resonance angiography, and computed tomography angiography for diagnosis and assessment of symptomatic, lower limb peripheral arterial disease: systematic review. *Bmj*. 2007;334(7606):1257.
- Heijnenbrok-Kal MH, Kock MC, Hunink MG. Lower extremity arterial disease: multidetector CT angiography meta-analysis. *Radiology*. 2007;245(2):433-439.
- Kreitner KF, Kunz RP, Herber S, Martenstein S, Dorweiler B, Dueber C. MR angiography of the pedal arteries with gadobenate dimeglumine, a contrast agent with increased relaxivity, and comparison with selective intraarterial DSA. *J Magn Reson Imaging*. 2008;27(1):78-85.
- Met R, Bipat S, Legemate DA, Reekers JA, Koelemay MJ. Diagnostic performance of computed tomography angiography in peripheral arterial disease: a systematic review and meta-analysis. *Jama*. 2009;301(4):415-424.
- Gupta R, Henneby TA. Percutaneous isolated pharmaco-mechanical thrombolysis-thrombectomy system for the management of acute arterial limb ischemia: 30-day results from a single-center experience. *Catheter Cardiovasc Interv*. 2012;80(4):636-643.
- Kuhn JP, Hoene A, Miertsch M, et al. Intraarterial recombinant tissue plasminogen activator thrombolysis of acute and semiacute lower limb arterial occlusion: quality assurance, complication management, and 12-month follow-up reinterventions. *AJR Am J Roentgenol*. 2011;196(5):1189-1193.
- Schrijver A, Vos J, Hoksbergen AW, et al. Ultrasound-accelerated thrombolysis for lower extremity ischemia: multicenter experience and literature review. *J Cardiovasc Surg (Torino)*. 2011;52(4):467-476.

10. Hentsch A, Aschauer MA, Balzer JO, et al. Gadobutrol-enhanced moving-table magnetic resonance angiography in patients with peripheral vascular disease: a prospective, multi-centre blinded comparison with digital subtraction angiography. *Eur Radiol.* 2003;13(9):2103-2114.
11. Scherthaner R, Fleischmann D, Stadler A, Scherthaner M, Lammer J, Loewe C. Value of MDCT angiography in developing treatment strategies for critical limb ischemia. *AJR Am J Roentgenol.* 2009;192(5):1416-1424.
12. Bordalo-Rodrigues M, Schweitzer M, Bergin D, Culp R, Barakat MS. Lunate chondromalacia: evaluation of routine MRI sequences. *AJR Am J Roentgenol.* 2005;184(5):1464-1469.
13. Langer S, Kramer N, Mommertz G, et al. Unmasking pedal arteries in patients with critical ischemia using time-resolved contrast-enhanced 3D MRA. *J Vasc Surg.* 2009;49(5):1196-1202.
14. Huegli RW, Aschwanden M, Bongartz G, et al. Intraarterial MR angiography and DSA in patients with peripheral arterial occlusive disease: prospective comparison. *Radiology.* 2006;239(3):901-908.
15. Swan JS, Carroll TJ, Kennell TW, et al. Time-resolved three-dimensional contrast-enhanced MR angiography of the peripheral vessels. *Radiology.* 2002;225(1):43-52.
16. Menke J, Larsen J. Meta-analysis: Accuracy of contrast-enhanced magnetic resonance angiography for assessing steno-occlusions in peripheral arterial disease. *Ann Intern Med.* 2010;153(5):325-334.
17. Burbelko M, Augsten M, Kalinowski MO, Heverhagen JT. Comparison of contrast-enhanced multi-station MR angiography and digital subtraction angiography of the lower extremity arterial disease. *J Magn Reson Imaging.* 2013;37(6):1427-1435.
18. Hahn WY, Hecht EM, Friedman B, Babb JS, Jacobowitz GR, Lee VS. Distal lower extremity imaging: prospective comparison of 2-dimensional time of flight, 3-dimensional time-resolved contrast-enhanced magnetic resonance angiography, and 3-dimensional bolus chase contrast-enhanced magnetic resonance angiography. *J Comput Assist Tomogr.* 2007;31(1):29-36.
19. Nael K, Krishnam M, Nael A, Ton A, Ruehm SG, Finn JP. Peripheral contrast-enhanced MR angiography at 3.0T, improved spatial resolution and low dose contrast: initial clinical experience. *Eur Radiol.* 2008;18(12):2893-2900.
20. Ruhl KM, Katoh M, Langer S, et al. Time-resolved 3D MR angiography of the foot at 3 T in patients with peripheral arterial disease. *AJR Am J Roentgenol.* 2008;190(6):W360-364.
21. Lim RP, Jacob JS, Hecht EM, et al. Time-resolved lower extremity MRA with temporal interpolation and stochastic spiral trajectories: preliminary clinical experience. *J Magn Reson Imaging.* 2010;31(3):663-672.
22. Menke J. Improving the image quality of contrast-enhanced MR angiography by automated image registration: a prospective study in peripheral arterial disease of the lower extremities. *Eur J Radiol.* 2010;75(3):e1-8.
23. Hadizadeh DR, Gieseke J, Lohmaier SH, et al. Peripheral MR angiography with blood pool contrast agent: prospective intraindividual comparative study of high-spatial-resolution steady-state MR angiography versus standard-resolution first-pass MR angiography and DSA. *Radiology.* 2008;249(2):701-711.
24. Ersoy H, Rybicki FJ. Biochemical safety profiles of gadolinium-based extracellular contrast agents and nephrogenic systemic fibrosis. *J Magn Reson Imaging.* 2007;26(5):1190-1197.
25. Habibi R, Krishnam MS, Lohan DG, et al. High-spatial-resolution lower extremity MR angiography at 3.0 T: contrast agent dose comparison study. *Radiology.* 2008;248(2):680-692.
26. 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.
27. Lanzman RS, Blondin D, Schmitt P, et al. Non-enhanced 3D MR angiography of the lower extremity using ECG-gated TSE imaging with non-selective refocusing pulses--initial experience. *Rofo.* 2010;182(10):861-867.
28. Lim RP, Hecht EM, Xu J, et al. 3D nongadolinium-enhanced ECG-gated MRA of the distal lower extremities: preliminary clinical experience. *J Magn Reson Imaging.* 2008;28(1):181-189.
29. Klasen J, Blondin D, Schmitt P, et al. Nonenhanced ECG-gated quiescent-interval single-shot MRA (QISS-MRA) of the lower extremities: comparison with contrast-enhanced MRA. *Clin Radiol.* 2012;67(5):441-446.
30. Mohrs OK, Petersen SE, Heidt MC, et al. High-resolution 3D non-contrast-enhanced, ECG-gated, multi-step MR angiography of the lower extremities: comparison with contrast-enhanced MR angiography. *Eur Radiol.* 2011;21(2):434-442.
31. Mihai G, Chung YC, Kariisa M, Raman SV, Simonetti OP, Rajagopalan S. Initial feasibility of a multi-station high resolution three-dimensional dark blood angiography protocol for the assessment of peripheral arterial disease. *J Magn Reson Imaging.* 2009;30(4):785-793.

32. Bonel HM, Saar B, Hoppe H, et al. MR angiography of infrapopliteal arteries in patients with peripheral arterial occlusive disease by using Gadofosveset at 3.0 T: diagnostic accuracy compared with selective DSA. *Radiology*. 2009;253(3):879-890.
33. Grijalba FU, Esandi MC. Comparison of gadofosveset-enhanced three-dimensional magnetic resonance angiography with digital subtraction angiography for lower-extremity peripheral arterial occlusive disease. *Acta Radiol*. 2010;51(3):284-289.
34. Nielsen YW, Eiberg JP, Logager VB, Just S, Schroeder TV, Thomsen HS. Whole-body magnetic resonance angiography with additional steady-state acquisition of the infragenicular arteries in patients with peripheral arterial disease. *Cardiovasc Intervent Radiol*. 2010;33(3):484-491.
35. Rapp JH, Wolff SD, Quinn SF, et al. Aortoiliac occlusive disease in patients with known or suspected peripheral vascular disease: safety and efficacy of gadofosveset-enhanced MR angiography--multicenter comparative phase III study. *Radiology*. 2005;236(1):71-78.
36. Schernthaler 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.
37. Cernic S, Pozzi Mucelli F, Pellegrin A, Pizzolato R, Cova MA. Comparison between 64-row CT angiography and digital subtraction angiography in the study of lower extremities: personal experience. *Radiol Med*. 2009;114(7):1115-1129.
38. Shareghi S, Gopal A, Gul K, et al. Diagnostic accuracy of 64 multidetector computed tomographic angiography in peripheral vascular disease. *Catheter Cardiovasc Interv*. 2010;75(1):23-31.
39. 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*. 2011;66(10):945-952.
40. Edwards AJ, Wells IP, Roobottom CA. Multidetector row CT angiography of the lower limb arteries: a prospective comparison of volume-rendered techniques and intra-arterial digital subtraction angiography. *Clin Radiol*. 2005;60(1):85-95.
41. Portugaller HR, Schoellnast H, Hausegger KA, Tiesenhausen K, Amann W, Berghold A. Multislice spiral CT angiography in peripheral arterial occlusive disease: a valuable tool in detecting significant arterial lumen narrowing? *Eur Radiol*. 2004;14(9):1681-1687.
42. Ouwendijk R, de Vries M, Stijnen T, et al. Multicenter randomized controlled trial of the costs and effects of noninvasive diagnostic imaging in patients with peripheral arterial disease: the DIPAD trial. *AJR Am J Roentgenol*. 2008;190(5):1349-1357.
43. Schertler T, Wildermuth S, Alkadhi H, Kruppa M, Marincek B, Boehm T. Sixteen-detector row CT angiography for lower-leg arterial occlusive disease: analysis of section width. *Radiology*. 2005;237(2):649-656.
44. Meyer BC, Werncke T, Hopfenmuller W, Raatschen HJ, Wolf KJ, Albrecht T. Dual energy CT of peripheral arteries: effect of automatic bone and plaque removal on image quality and grading of stenoses. *Eur J Radiol*. 2008;68(3):414-422.
45. Brockmann C, Jochum S, Sadick M, et al. Dual-energy CT angiography in peripheral arterial occlusive disease. *Cardiovasc Intervent Radiol*. 2009;32(4):630-637.
46. Huang SY, Nelson RC, Miller MJ, et al. Assessment of vascular contrast and depiction of stenoses in abdominopelvic and lower extremity vasculature: comparison of dual-energy MDCT with digital subtraction angiography. *Acad Radiol*. 2012;19(9):1149-1157.
47. Thomas C, Korn A, Ketelsen D, et al. Automatic lumen segmentation in calcified plaques: dual-energy CT versus standard reconstructions in comparison with digital subtraction angiography. *AJR Am J Roentgenol*. 2010;194(6):1590-1595.
48. Kau T, Eicher W, Reiterer C, et al. Dual-energy CT angiography in peripheral arterial occlusive disease-accuracy of maximum intensity projections in clinical routine and subgroup analysis. *Eur Radiol*. 2011;21(8):1677-1686.
49. Willmann JK, Mayer D, Banyai M, et al. Evaluation of peripheral arterial bypass grafts with multi-detector row CT angiography: comparison with duplex US and digital subtraction angiography. *Radiology*. 2003;229(2):465-474.
50. Utsunomiya D, Oda S, Funama Y, et al. Comparison of standard- and low-tube voltage MDCT angiography in patients with peripheral arterial disease. *Eur Radiol*. 2010;20(11):2758-2765.
51. Krnic A, Vucic N, Sucic Z. Duplex scanning compared with intra-arterial angiography in diagnosing peripheral arterial disease: three analytical approaches. *Vasa*. 2006;35(2):86-91.

52. Leiner T, Kessels AG, Nelemans PJ, et al. Peripheral arterial disease: comparison of color duplex US and contrast-enhanced MR angiography for diagnosis. *Radiology*. 2005;235(2):699-708.
53. Menke J, Luthje L, Kastrup A, Larsen J. Thromboembolism in atrial fibrillation. *Am J Cardiol*. 2010;105(4):502-510.
54. Gale SS, Scissons RP, Salles-Cunha SX, et al. Lower extremity arterial evaluation: are segmental arterial blood pressures worthwhile? *J Vasc Surg*. 1998;27(5):831-838; discussion 838-839.
55. Sprynger M, Fassotte C, Verhaeghe R. The ankle-brachial pressure index and a standardized questionnaire are easy and useful tools to detect peripheral arterial disease in non-claudicating patients at high risk. *Int Angiol*. 2007;26(3):239-244.

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.