

**Vascular Claudication—Assessment for Revascularization
EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. Cafagna D, Ponte E. [Non-vascular claudication or "painful leg syndrome"]. <i>Minerva Cardioangiol.</i> 1996;44(5):229-235.	Review/Other-Dx	N/A	To evaluate the prevalence of so-called nonvascular claudication or pseudo-claudication, defined here as "painful leg syndrome", and to identify simple and low-cost clinical and instrumental parameters, which may be useful not only to the general practitioner but also to the angiologist.	A large number of patients with "false claudication" (43%) was diagnosed in this series and the most frequent cause was neurological pathology (68%). Anamnesis and an objective examination should, if correctly performed, be sufficient for a rapid diagnosis of nonvascular pathology and should therefore be useful in limiting the number of requests for Doppler tests, thus reducing waiting times and management costs.	4
2. Meijer WT, Hoes AW, Rutgers D, Bots ML, Hofman A, Grobbee DE. Peripheral arterial disease in the elderly: The Rotterdam Study. <i>Arterioscler Thromb Vasc Biol.</i> 1998;18(2):185-192.	Observational-Dx	7,715 subjects	Population-based study to assess the age and sex specific prevalence of PAD and intermittent claudication in an elderly population.	Prevalence of PAD in the elderly = 19.1%. The prevalence of intermittent claudication = 1.6%. Of those with PAD, 6.3% reported symptoms of intermittent claudication. The prevalence of PAD in the elderly is high whereas the prevalence of intermittent claudication is rather low, although both prevalence clearly increase with advancing age. The vast majority of PAD patients report no symptoms of intermittent claudication.	3
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. <i>BMC Public Health.</i> 2010;10:38.	Observational-Dx	3,786 individuals	To know the prevalence and associated risk factors of PAD in the general population.	The prevalence (95% CI) of PAD was 7.6% (6.7-8.4), (males 10.2% (9.2-11.2), females 5.3% (4.6-6.0); $P < 0.001$). Multivariate analysis showed the following risk factors: male sex [OR 1.62; 95% CI; 1.01-2.59]; age OR 2.00 per 10 years (1.64-2.44); inability to perform physical activity [OR 1.77 (1.17-2.68) for mild limitation to OR 7.08 (2.61-19.16) for breathless performing any activity]; smoking [OR 2.19 (1.34-3.58) for former smokers and OR 3.83 (2.23-6.58) for current smokers]; hypertension OR 1.85 (1.29-2.65); diabetes OR 2.01 (1.42-2.83); previous cardiovascular disease OR 2.19 (1.52-3.15); hypercholesterolemia OR 1.55 (1.11-2.18); hypertriglyceridemia OR 1.55 (1.10-2.19). Body mass index ≥ 25 Kg/m ² OR 0.57 (0.38-0.87) and walking > 7 hours/week OR 0.67 (0.49-0.94) were found as protector factors.	3

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4. Criqui MH, Fronek A, Barrett-Connor E, Klauber MR, Gabriel S, Goodman D. The prevalence of peripheral arterial disease in a defined population. <i>Circulation</i> . 1985;71(3):510-515.	Observational-Dx	613 subjects	To assess the prevalence of large vessel PAD and small vessel PAD in an older population using segmental blood pressure, Doppler US, postocclusive reactive hyperemia, and pulse reappearance half-time.	11.7% had large vessel PAD; nearly half of those with large vessel PAD also had small vessel PAD. 16% had isolated small vessel PAD. Intermittent claudication rates were 2.2% in men and 1.7% in women. Assessment of large-vessel PAD prevalence by intermittent claudication dramatically underestimated the true large-vessel PAD prevalence and assessment by peripheral pulse examination dramatically overestimated the true prevalence.	4
5. Hirsch AT, Haskal ZJ, Hertzler NR, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): 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. <i>Circulation</i> . 2006;113(11):e463-654.	Review/Other-Dx	N/A	Practice Guidelines for the management of patients with PAD (lower extremity, renal, mesenteric, and abdominal aortic).	N/A	4

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6. 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. <i>J Vasc Surg.</i> 2011;54(4):1074-1080.	Observational-Dx	51 patients	To examine the usefulness of infrared thermography in evaluating patients at high risk for lower extremity PAD, including severity, functional capacity, and quality of life.	28 subjects had abnormal ABI (ABI <1), while PAD was diagnosed in 20. No subjects had non-compressible artery (ABI >1.3). Demographic profiles and clinical parameters in PAD and non-PAD patients were similar, except for age, smoking history, and hyperlipidemia. PAD patients walked shorter distances (356 ± 102 m vs 218 ± 92 m; <i>P</i> <.001). Claudication occurred in 14 patients, while seven failed in completing the 6 minute walk test. The rest temperatures were similar in PAD and non-PAD patients. However, the post-exercise temperature dropped in the lower extremities with arterial stenosis, but was maintained or elevated slightly in the extremities with patent arteries (temperature changes at sole in PAD vs non-PAD patients: -1.25 vs -0.15°C; <i>P</i> <.001). The exercise-induced temperature changes at the sole were not only positively correlated with the 6MWD (Spearman correlation coefficient = 0.31, <i>P</i> =.03), but was also correlated with ABI (Spearman correlation coefficient = 0.48, <i>P</i> <.001) and 7-day physical activity recall scores (Spearman correlation coefficient = 0.30, <i>P</i> =.033). By detecting cutaneous temperature changes in the lower extremities, infrared thermography offers another non-invasive, contrast-free option in PAD evaluation and functional assessment.	4
7. Fowkes FG, Murray GD, Butcher I, et al. Ankle brachial index combined with Framingham Risk Score to predict cardiovascular events and mortality: a meta-analysis. <i>Jama.</i> 2008;300(2):197-208.	Review/Other-Dx	24,955 men 23,339 women 16 studies	Meta-analysis to determine if the ABI provides information on the risk of cardiovascular events and mortality independently of the Framingham risk score and can improve risk prediction.	Measurement of the ABI may improve the accuracy of cardiovascular risk prediction beyond the Framingham risk score.	4
8. Rutherford RB, Lowenstein DH, Klein MF. Combining segmental systolic pressures and plethysmography to diagnose arterial occlusive disease of the legs. <i>Am J Surg.</i> 1979;138(2):211-218.	Observational-Dx	11 volunteers and 103 patients	To evaluate the diagnostic value of segmental pressures and pulse volume recording to diagnose arterial occlusive disease of the legs.	Both tests 86% accurate when multilevel disease was present, 97% when used in combination with no errors observed in diagnosing either normal limbs or those with isolated occlusive disease.	4

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9. Van De Water JM, Laska ED, Ciniero WV. Patient and operation selectivity. The peripheral vascular laboratory. <i>Ann Surg.</i> 1979;189(2):143-146.	Review/Other-Dx	N/A	To examine data from the vascular laboratory in order to improve patient and operation selectivity in PAD of the lower extremities.	The ratio of angiograms to femoropopliteal and aortoiliac operations has been reduced from an earlier value of almost 3/1 to the present value of approximately 1/1. Laboratory has improved ability to select patient.	4

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<p>10. Dormandy J, Heeck L, Vig S. The natural history of claudication: risk to life and limb. <i>Semin Vasc Surg.</i> 1999;12(2):123-137.</p>	<p>Review/Other-Dx</p>	<p>N/A</p>	<p>To review the natural history of claudication.</p>	<p>Although a patient with intermittent claudication will fear progression to severe disease and amputation, this is a relatively rare outcome of claudication, with only 1% to 3% of claudicants ever requiring major amputation over a 5-year period. Indeed, in 1 study, 50% of claudicants became symptom free during 5 years' follow-up. All the new evidence over the last 40 years has not altered the impression that only about one-fourth of patients with intermittent claudication will ever significantly deteriorate, and that deterioration is most frequent during the first year after diagnosis (6% to 9%) compared with 2% to 3% per annum thereafter. Smoking is the most important risk factor for the progression of local disease in the legs, with an amputation rate 11 times greater in smokers than nonsmokers. Diabetes, male gender, and hypertension are also important risk factors for progression. Because cerebrovascular disease, coronary artery disease, and PAOD coexist, PAOD and intermittent claudication should be regarded as a marker for increased risk from fatal and nonfatal cardiovascular event, and 2% to 4% of claudicants have a nonfatal cardiovascular event every year. The risk is higher in the first year after developing intermittent claudication than in a long-standing stable claudicant, and the average claudicant is more likely to have a nonfatal myocardial infarction or stroke in the next year than that of ever requiring a major amputation for his leg ischemia. The mortality in claudicants is 30% at 5 years, 50% at 10 years, and 70% at 15 years, without any clear decrease in these figures over the last 30 to 40 years. The mortality of claudicants is approximately 2 and a half times that of an age-matched general population.</p>	<p>4</p>

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11. Baker WH, String ST, Hayes AC, Turner D. Diagnosis of peripheral occlusive disease: comparison of clinical evaluation and noninvasive laboratory. <i>Arch Surg.</i> 1978;113(11):1308-1310.	Observational-Dx	102 patients	To assess the accuracy of physical examination and vascular laboratory by comparison to arteriography.	The attending surgeons made a correct anatomic diagnosis in 98 patients and were at least partially correct in the other four. Surgical housestaff and students were 62% totally correct, 35% partially correct, and 3% totally wrong. The vascular laboratory results were almost identical with the attending surgeon, but two patients could not be evaluated because of calcified arteries. The operation that was eventually performed was suggested initially by the laboratory and the attending surgeon in 98% of the patients.	3
12. Feigelson HS, Criqui MH, Fronck A, Langer RD, Molgaard CA. Screening for peripheral arterial disease: the sensitivity, specificity, and predictive value of noninvasive tests in a defined population. <i>Am J Epidemiol.</i> 1994;140(6):526-534.	Observational-Dx	484 total subjects 421 normal patients and 63 with large vessel PAD	To evaluate the components of a comprehensive noninvasive vascular examination to identify the most sensitive and specific measurements for diagnosing large vessel PAD.	Measurements of posterior tibial flow showed the highest sensitivity, specificity, PPV, NPV, and overall accuracy. An absent or non-recordable posterior tibial peak forward flow, occurring in 96% of all limbs with isolated posterior tibial disease, or an ankle ratio ≤ 0.8 considered in parallel yielded a test with sensitivity of 89%, specificity of 99%, PPV of 90%, NPV of 99%, and overall accuracy of 98%. These results indicate that the vast majority of large vessel PAD cases can be detected with a single measurement using a handheld Doppler flowmeter employed at the ankle.	4
13. Goodreau JJ, Creasy JK, Flanigan P, et al. Rational approach to the differentiation of vascular and neurogenic claudication. <i>Surgery.</i> 1978;84(6):749-757.	Review/Other-Dx	52 patients	A retrospective analysis of diagnostic studies in patients with nonarterial cause of claudication to determine a rational approach to the differentiation of vascular and neurogenic claudication.	Errors in diagnosis can be avoided by using a combination of clinical evaluation, noninvasive lab and lumbar spine radiographs.	4
14. Ouriel K, Zarins CK. Doppler ankle pressure: an evaluation of three methods of expression. <i>Arch Surg.</i> 1982;117(10):1297-1300.	Observational-Dx	167 total subjects 133 patients and 34 normal volunteers	Patients with known vascular disease were studied to determine the best means for expressing ankle pressure.	ABI was 94% sensitive and 99% specific for the presence of vascular disease. Limb viability was best analyzed by absolute ankle pressure (60mmHg). The diagnostic accuracy of the three methods of expressing ankle pressure depends on the context in which they are to be used, and it appears that ankle index and gradient are most appropriate for defining the presence of disease, while absolute pressure correlates best with viability.	4

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15. Laing S, Greenhalgh RM. The detection and progression of asymptomatic peripheral arterial disease. <i>Br J Surg.</i> 1983;70(10):628-630.	Observational-Dx	100 consecutive out-patients 30 patients included in second series (19 had aortic surgery and 11 femoropopliteal surgery) 67 healthy subjects (100 legs) as control group	To determine the value of exercise testing in the detection and progression of asymptomatic PAD.	22/100 asymptomatic legs had abnormal resting tests. 32/78 limbs without symptoms and with normal resting tests had abnormal response to exercise.	4
16. Crummy AB, Rankin RS, Turnipseed WD, Berkoff HA. Biplane arteriography in ischemia of the lower extremity. <i>Radiology.</i> 1978;126(1):111-115.	Review/Other-Dx	N/A	To describe a technique for simultaneous bilateral biplane arteriography of the abdomen, pelvis, and lower extremities.	In approximately 40% of procedures, the additional view provided clinically significant information.	4
17. Beales JS, Adcock FA, Frawley JS, et al. The radiological assessment of disease of the profunda femoris artery. <i>Br J Radiol.</i> 1971;41(527):854-859.	Observational-Dx	135 patients 209 extremities	To examine radiological techniques used to obtain additional views of the origin of the profunda artery and to investigate the incidence of disease of the proximal profunda artery in patients with symptoms due to PVD.	39% of limbs showed narrowing of the origin of the profunda, 68% of these were only seen on oblique views. When the superficial femoral artery is occluded, the profunda femoris artery is the main artery supplying the lower limb, and narrowing of this vessel may be of considerable functional importance. Localized narrowing of the origin of the profunda artery is common but is often unrecognized because the artery is not adequately demonstrated by standard frontal view arteriography. Adequate arteriography is a necessary preliminary to reconstructive surgery of the profunda femoris artery.	4
18. Egglin TK, O'Moore PV, Feinstein AR, Waltman AC. Complications of peripheral arteriography: a new system to identify patients at increased risk. <i>J Vasc Surg.</i> 1995;22(6):787-794.	Observational-Dx	549 consecutive patients	To evaluate if the literature on arteriographic complications collected in the mid 1970s still remain valid and determine if patient subgroups at increased risk could be identified.	Rate of major complications 2.9%. Patients studied for claudication or limb threatening ischemia had intermediate risk (2.0%). Previous reports overestimated the risk of arteriography for trauma or aneurysm but underestimate the risk for patients with other common conditions.	4

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19. Thiele BL, Strandness DE, Jr. Accuracy of angiographic quantification of peripheral atherosclerosis. <i>Prog Cardiovasc Dis.</i> 1983;26(3):223-236.	Review/Other-Dx	N/A	A critical evaluation of arteriography as a means of quantifying PVD and its effects based on extensive literature review.	Arteriography has remained a purely morphologic study with limited usefulness in determining clinical significance of visualized lesions. The major problems are observer variability and lack of functional data.	4
20. Jager KA, Phillips DJ, Martin RL, et al. Noninvasive mapping of lower limb arterial lesions. <i>Ultrasound Med Biol.</i> 1985;11(3):515-521.	Observational-Dx	30 patients	To compare US duplex evaluation of iliac to popliteal artery to angiography.	For lesion < or > than 50%, sensitivity 77%, specificity 98%, PPV 94%, NPV 92%. These results are not significantly different from interobserver variability for angiography.	3
21. Fletcher JP, Kershaw LZ, Chan A, Lim J. Noninvasive imaging of the superficial femoral artery using ultrasound Duplex scanning. <i>J Cardiovasc Surg (Torino).</i> 1990;31(3):364-367.	Observational-Dx	28 total patients 56 extremities	To compare duplex US and angiography in superficial femoral artery disease.	Overall sensitivity for duplex scanning compared to arteriography in detecting stenotic or occlusive disease was 91%, specificity was 94%, PPV 85% and NPV 97%. Results for Duplex scanning were better in the proximal and middle segment compared to the distal third of the superficial femoral artery. The sensitivity of segmental lower extremity pressures and pulse volume recordings for predicting proximal superficial femoral artery disease compared to arteriography was 82%; specificity was 79% and accuracy 80%, all inferior to that of Duplex scanning. Duplex US is suitable for noninvasive assessment of superficial femoral artery disease.	2
22. Leng GC, Whyman MR, Donnan PT, et al. Accuracy and reproducibility of duplex ultrasonography in grading femoropopliteal stenoses. <i>J Vasc Surg.</i> 1993;17(3):510-517.	Observational-Dx	30 patients	To determine the accuracy of Doppler waveform characteristics in grading femoropopliteal stenoses.	An increase in PSV of more than 200% accurately predicted a 50% or greater reduction in luminal diameter on angiography (70% sensitivity, 96% specificity). The presence of spectral broadening and an abnormal waveform shape were found to correlate poorly with the degree of stenosis. Analysis of variance showed no significant difference between observers in velocity measurements ($P=0.78$). Although stenoses of greater than 50% can be distinguished from minor stenoses, more precise definition of the degree of narrowing is unlikely. The good repeatability of the velocity ratio makes it an excellent tool for monitoring major changes in the progression of disease.	4

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23. 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. <i>Acad Radiol.</i> 1996;3(4):361-369.	Review/Other-Dx	14 reports	To summarize and compare the diagnostic performance of duplex and color-guided duplex US in the evaluation of PAD.	The summary ROC curves demonstrated a high level of diagnostic performance for both types of duplex imaging; with color-guided duplex scanning being superior. A false-positive rate of .05 (specificity .95), the analysis predicted a true-positive rate (sensitivity) of .83 for duplex alone and .93 for color guided duplex. For aortoiliac and femoropopliteal arteries, the addition of color flow imaging to duplex scanning improves diagnostic performance in evaluating PAD.	4
24. 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. <i>J Vasc Surg.</i> 1994;19(4):650-657.	Observational-Dx	55 patients	To provide a quantitative evaluation of the effect of adjacent segment lesions on disease classification in lower limb arteries by US duplex scanning.	To recognize severe stenoses (50%–100% diameter reduction) in any arterial segment, duplex scanning had sensitivity and specificity rates of 74% and 96%. However, sensitivity and specificity rates increased to 80% and 98%, when there was no 50%–100% diameter-reducing lesion in adjacent segments, whereas they decreased to 66% and 94%, when there was at least one 50%–100% diameter-reducing lesion in adjacent segments. The results demonstrated that the presence of multiple stenoses was an important limitation of duplex scanning for the detection and quantification of lower limb arterial disease.	2
25. de Vos MS, Bol BJ, Gravereaux EC, Hamming JF, Nguyen LL. Treatment planning for peripheral arterial disease based on duplex ultrasonography and computed tomography angiography: consistency, confidence and the value of additional imaging. <i>Surgery.</i> 2014;156(2):492-502.	Observational-Dx	12 patients	To assess treatment planning based on duplex US and based on additional imaging with CTA for consistency and confidence.	Of the 36 treatment plans formulated, additional CTA confirmed 27 (75%), changed 6 (17%), and supplemented 3 (8%) plans. The approach never changed when open revascularization was selected based on duplex US (14 plans; 39%). Agreement between duplex US- and CTA-based treatment planning was substantial, with a mean kappa of 0.68, but agreement between reviewers was fair (mean kappa duplex US, 0.24; mean kappa CTA, 0.23). CTA received greater average scores than duplex US for quality (4.36 vs 3.29; $P<.0001$) and confidence (4.36 vs 3.26; $P<.0001$). Reviewers often expressed the need for additional imaging after duplex US (mean, 63%).	3

* See Last Page for Key

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26. Mewissen MW, Kinney EV, Bandyk DF, et al. The role of duplex scanning versus angiography in predicting outcome after balloon angioplasty in the femoropopliteal artery. <i>J Vasc Surg.</i> 1992;15(5):860-865; discussion 865-866.	Observational-Dx	59 patients	To assess the hemodynamics of femoropopliteal arterial sites in patients after angiographically successful percutaneous transluminal balloon angioplasty.	At 1 month, 55 limbs (86%) were hemodynamically and clinically improved by Society for Vascular Surgery/International Society for Cardiovascular Surgery (SVS/ISCVS) clinical criteria for chronic limb ischemia. Of the 55 percutaneous transluminal balloon angioplasty sites, duplex scanning had identified 40 (63%) sites with a <50% diameter-reducing stenosis and 15 (27%) sites with a >50% diameter-reducing stenosis within a week after percutaneous transluminal balloon angioplasty. The detection of a functional residual stenosis by duplex scanning did not correlate with angiographic appearance, but was predictive of clinical failure.	3
27. Sacks D, Robinson ML, Summers TA, Marinelli DL. The value of duplex sonography after peripheral artery angioplasty in predicting subacute restenosis. <i>AJR Am J Roentgenol.</i> 1994;162(1):179-183.	Observational-Dx	23 patients	To determine if abnormal findings on duplex US after peripheral artery angioplasty correlate with the subsequent recurrence of a stenosis.	34% of angioplasty sites showed recurrent stenosis before 36 months. No significant difference in patency between those patients with normal findings and those with abnormal findings on duplex US after angioplasty. Abnormal findings on duplex sonograms obtained immediately after peripheral angioplasty cannot be used to predict subacute restenosis.	3

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28. Spijkerboer AM, Nass PC, de Valois JC, et al. Iliac artery stenoses after percutaneous transluminal angioplasty: follow-up with duplex ultrasonography. <i>J Vasc Surg.</i> 1996;23(4):691-697.	Observational-Dx	61 patients	To assess iliac artery stenosis before and up to 1 year after PTA with duplex US to determine the incidence of residual and recurrent stenoses and correlate these findings to clinical outcome.	Good results with duplex US (PSV ratio 1 day and 1 year after PTA ≥ 2.5) were found in 45/70 segments (64.3%), residual stenoses (PSV ratio $>$ or $.5$ 1 day after PTA) in 15/70 segments (21.4%), and recurrent stenosis (PSV ratio 1 day after PTA < 2.5 and 1 year after PTA ≥ 2.5) in 10/70 segments (14.3%). PSV ratios of residual stenoses decreased significantly between 1 day and 1 year after PTA because some residual stenoses improved hemodynamically in time. Clinical results were significantly better in patients with a good result compared with other patients. However, the clinical outcome of patients with residual stenoses was not significantly different from the patients with good duplex US results. PSV ratios of residual stenoses decreased significantly between 1 day and 1 year after PTA. The clinical outcome of patients with residual stenoses was not significantly different from the patients with good duplex US results.	4

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29. Lowery AJ, Hynes N, Manning BJ, Mahendran M, Tawfik S, Sultan S. A prospective feasibility study of duplex ultrasound arterial mapping, digital-subtraction angiography, and magnetic resonance angiography in management of critical lower limb ischemia by endovascular revascularization. <i>Ann Vasc Surg.</i> 2007;21(4):443-451.	Observational-Dx	465 total patients referred with PAD. 199 had critical lower limb ischemia. 137 needed endovascular revascularisation	To compare clinical pragmatism, hemodynamic outcomes, and cost effectiveness when using DUAM alone compared to DSA or MRA as preoperative assessment tools for endovascular revascularisation and critical lower limb ischemia.	6-month patency rates for the DUAM group were comparable to those in the DSA group ($P=0.68$, $RR = 0.74$, 95% CI, 0.18-2.99) and superior to that in the MRA group ($P=0.022$, $RR = 0.255$, 95% CI, 0.09-0.71). Length of hospital stay was lower in the DUAM group compared with the DSA group ($P<0.0001$) and the MRA group ($P=0.0003$). The cost of DUAM is lower than that of both DSA and MRA. DUAM accurately identified the total number of target lesions for revascularization; however, MRA overestimated it. Results indicate that DUAM is outstanding when compared with other available modalities as a preoperative imaging tool in a successful endovascular revascularization program. DUAM is a minimally invasive preoperative evaluation for endovascular revascularization and offers precise consecutive data with patency and limb salvage rates comparable to endovascular revascularization based on DSA and superior to MRA.	4
30. Mandolino T, Canciglia A, D'Alfonso M, Carmignani A. Infringuinal revascularization based on duplex ultrasound arterial mapping. <i>Int Angiol.</i> 2006;25(3):256-260.	Observational-Dx	253 patients	To report the outcome of arterial revascularization procedures for chronic limb ischemia based on DUAM.	DUAM procedure time averaged 90+30 min. Proximal anastomosis was located in common femoral arteries in 202 cases, popliteal in 51. Distal anastomosis was to the tibial arteries in 144 cases and pedal arteries in 109. Primary patency was 89% and 67% at 12 and 36 months. Secondary patency was 93% and 82% at 12 and 36 months. DUAM may be a safe alternative to contrast arteriography for patients with critical lower limb ischemia. Adequate training and experience is necessary to utilize this technique as the sole preoperative imaging modality for planning infringuinal revascularization.	4

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31. 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. <i>Radiology</i> . 2006;240(2):401-410.	Experimental-Dx	352 total patients 178 in contrast-enhanced MRA group and 174 in duplex US group	Multicenter prospective randomized trial to determine the clinical and economic consequences of replacing duplex US with contrast material-enhanced MRA for the initial imaging workup of patients with PAD.	At 6 months, 352 patients (239 [68%] men, 113 [32%] women; mean age, 65 years) were analyzed. The use of contrast-enhanced MRA versus duplex US reduced the number of additional vascular imaging procedures by 42%; contrast-enhanced MRA was also associated with higher therapeutic confidence. Diagnostic costs for contrast-enhanced MRA were 167 euros (186 dollars) higher than those for duplex US ($P<.001$). No statistically significant differences were found for total cost, changes in disease severity, or changes in quality-of-life between patients examined with duplex US and those examined with contrast-enhanced MRA ($P>.05$). Replacing duplex US with contrast-enhanced MRA for the initial imaging workup of patients with PAD reduces the need for additional imaging, although diagnostic costs are higher.	3
32. 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. <i>AJR Am J Roentgenol</i> . 2008;190(5):1349-1357.	Experimental-Dx	514 randomized to MRA (n=258), DSA (n=177), CTA (n=79)	Multicenter randomized trial to evaluate DSA vs CTA vs MRA for accuracy, impact on treatment planning, cost, and quality of life.	With adjustment for potentially predictive baseline variables, the learning curve, and hospital setting, a significantly higher confidence and less additional imaging were found for MRA and CTA compared with duplex US. No statistically significant differences were found in improvement in functional patient outcomes and quality of life among the groups. The total costs were significantly higher for MRA and duplex US than for CTA. The results suggest that both CTA and MRA are clinically more useful than duplex US and that CTA leads to cost savings compared with both MRA and duplex US in the initial imaging evaluation of PAD.	3
33. Ersoy H, Rybicki FJ. Biochemical safety profiles of gadolinium-based extracellular contrast agents and nephrogenic systemic fibrosis. <i>J Magn Reson Imaging</i> . 2007;26(5):1190-1197.	Review/Other-Dx	N/A	To consolidate and update the available information on known side effects, adverse reactions, and toxicity of the gadolinium chelates, with particular emphasis on the potential mechanisms of nephrogenic systemic fibrosis.	It is necessary for radiologist to be aware of the potential side effects and adverse reactions from Gd and understand the biochemical characteristics of the extracellular Gd-chelates.	4

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34. Cambria RP, Kaufman JA, L'Italien GJ, et al. Magnetic resonance angiography in the management of lower extremity arterial occlusive disease: a prospective study. <i>J Vasc Surg.</i> 1997;25(2):380-389.	Observational-Dx	79 patients	A prospective study to clarify the clinical utility of MRA in the treatment of patients with lower extremity arterial occlusive disease.	Precise agreement (%) and the percent of major discrepancies (segment classified as normal/mild stenosis on one study and severe stenosis/occlusion on the other) between MRA and angiography for respective arterial segments was as follows: common and external iliacs (n=256) 77/3.5; superficial femoral and above-knee popliteal (n=255) 73/6.7; below-knee popliteal (n=131) 84/3.8; infrapopliteal runoff vessels (n=864) 74/12.4; pedal vessels (n=111) 69/19.8. Kappa values indicated moderate agreement (between MRA and angiography) beyond chance for all arterial segments. Treatment plans formulated by the attending surgeon, the MRA surgeon, and the angiography surgeon agreed in more than 85% of cases.	4
35. Herborn CU, Goyen M, Quick HH, et al. Whole-body 3D MR angiography of patients with peripheral arterial occlusive disease. <i>AJR Am J Roentgenol.</i> 2004;182(6):1427-1434.	Observational-Dx	51 patients	To assess the diagnostic performance of whole-body 3D contrast-enhanced MRA in comparison with DSA of the lower extremities in patients with peripheral arterial occlusive disease.	Whole-body MRA had overall sensitivities of 92.3% and 93.1% (95% CI, 78%–100%) with specificities of 89.2% and 87.6% (both CI, 84%–98%) and excellent interobserver agreement (kappa = 0.82) for the detection of high-grade stenoses. Whole-body MRA permits a rapid, noninvasive, and accurate evaluation of the lower peripheral arterial system in patients with peripheral arterial occlusive disease, and it may allow identification of additional relevant vascular disease that was previously undetected.	2
36. 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. <i>AJR Am J Roentgenol.</i> 2002;179(4):1013-1021.	Observational-Dx	106 patients	A retrospective analysis to compare contrast-enhanced moving-bed MRA and DSA in the evaluation of PAOD.	2,378 vessel segments were evaluated. In 2,156 segments, MRA and DSA were concordant for stenosis classification; in 188 segments the two modalities differed in one category, and in 24 segments they differed in two categories. MRA sensitivity 96.7%; and specificity 95.8%, for differentiating nonsignificant from hemodynamically significant stenosis (kappa = 0.91).	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
37. 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. <i>Eur Radiol.</i> 2013;23(11):3104-3114.	Meta-analysis	12 CTA, 30 contrast-enhanced MRA studies; 673 and 1,404 participants, respectively	To evaluate the diagnostic performance of CTA and contrast-enhanced MRA in detecting hemodynamically significant arterial stenosis or occlusion in patients with critical limb ischemia or intermittent claudication.	Out of 5,693 articles, 12 CTA and 30 contrast-enhanced MRA studies were included, respectively evaluating 673 and 1,404 participants. Summary estimates of sensitivity and specificity were respectively 96% (95% CI, 93%–98%) and 95% (95% CI, 92%–97%) for CTA, and 93% (95% CI, 91%–95%) and 94% (95% CI, 93%–96%) for contrast-enhanced MRA. Regression analysis showed that the prevalence of critical limb ischemia in individual studies was not an independent predictor of sensitivity and specificity for either technique. Methodological quality of studies was moderate to good.	M
38. Khilnani NM, Winchester PA, Prince MR, et al. Peripheral vascular disease: combined 3D bolus chase and dynamic 2D MR angiography compared with x-ray angiography for treatment planning. <i>Radiology.</i> 2002;224(1):63-74.	Observational-Dx	30 consecutive patients	To retrospectively compare combined 3D and 2D contrast material-enhanced MRA with x-ray angiography for planning treatment of PVD.	The three readers selected identical segments for inflow at MRA and x-ray angiography in 32, 32, and 35 of the 35 limbs evaluated (mean percentages of agreement: 91%, 91% and 95%). The readers selected identical segments for outflow in 32, 32, and 34 of the 35 limbs evaluated (mean percentages of agreement: 91%, 91% and 97%, respectively). Preliminary data support the combining of 2D MR digital subtraction angiography with 3D bolus chase MRA to extend the utility of 3D MRA in treatment planning to include patients being evaluated for limb salvage, as well as those being evaluated for claudication.	4
39. Ersoy H, Rybicki FJ. MR angiography of the lower extremities. <i>AJR Am J Roentgenol.</i> 2008;190(6):1675-1684.	Review/Other-Dx	N/A	A review of current MRI technology and post-processing tools enabling 3D contrast-enhanced MRA to evolve into a first-line non-invasive diagnostic tool to evaluate vascular disorders.	In this article, 3D MRA techniques, bolus timing issues, new IV contrast agents allowing a steady-state acquisition, principals of post processing, and unenhanced MRA techniques are reviewed and how to effectively use 3D gadolinium-enhanced MRA for peripheral arterial imaging is described.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
40. Mell M, Tefera G, Thornton F, Siepmann D, Turnipseed W. Clinical utility of time-resolved imaging of contrast kinetics (TRICKS) magnetic resonance angiography for infrageniculate arterial occlusive disease. <i>J Vasc Surg.</i> 2007;45(3):543-548; discussion 548.	Observational-Dx	150 arterial segments in 30 limbs in 27 patients	To evaluate the clinical utility and diagnostic accuracy of time-resolved imaging of contrast kinetics MRA compared with DSA in planning for percutaneous interventions of popliteal and infrapopliteal arterial occlusive disease.	Time-resolved imaging of contrast kinetics MRA correlated with DSA in 83% of the popliteal and in 88% of the infrapopliteal segments. MRA correctly identified significant disease of the popliteal artery with a sensitivity of 94% and specificity of 92%, and of the tibial arteries with a sensitivity of 100% and specificity of 84%. When used to evaluate for stenosis vs occlusion, MRA interpretation agreed with DSA 90% of the time. MRA predicted technical success 83% of the time.	3
41. 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. <i>AJR Am J Roentgenol.</i> 2008;190(6):W360-364	Observational-Dx	21 patients	To prove the feasibility and clinical relevance of fast contrast-enhanced time-resolved 3D MRA with submillimeter spatial resolution at a high magnetic field strength.	In all patients, images of diagnostic quality were obtained. Despite the known limitations regarding signal intensity measurements in images acquired with the use of parallel imaging technique, signal-to-noise ratio and contrast-to-noise ratio proved to be excellent, with mean +/- standard deviation values of 294 +/- 158 and 248 +/- 144, respectively. Although most of the patients had diabetic foot syndrome with arteriovenous shunting, the arteries and the potential vessel for bypassing could be clearly separated from the veins in each case due to the temporal information given by our study. The ability to reliably discriminate arteries from veins is of high clinical relevance in planning pedal bypass surgery.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
42. Leiner T, Kessels AG, Nelemans PJ, et al. Peripheral arterial disease: comparison of color duplex US and contrast-enhanced MR angiography for diagnosis. <i>Radiology</i> . 2005;235(2):699-708.	Observational-Dx	295 patients	To prospectively compare the diagnostic accuracies of color duplex US and contrast material-enhanced MRA and to assess interobserver agreement regarding contrast-enhanced MRA findings in patients suspected of having PAD.	249 patients had at least one hemodynamically significant stenotic lesion at contrast-enhanced MRA, duplex US, or both examinations. 152 patients underwent intra-arterial DSA. The quadratic weighted kappa for agreement regarding the presence of 50% or greater stenosis at contrast-enhanced MRA was 0.89 (95% CI: 0.87, 0.91). Sensitivity of duplex US was 76% (95% CI: 69%, 82%); specificity, 93% (95% CI: 91%, 95%); and accuracy, 89%. Sensitivity and specificity of contrast-enhanced MRA were 84% (95% CI: 78%, 89%) and 97% (95% CI: 95%, 98%), respectively; accuracy was 94%. Sensitivity ($P=.002$) and specificity ($P=.03$) of contrast-enhanced MRA were significantly higher. Results of this prospective comparison between contrast-enhanced MRA and duplex US provide evidence that contrast-enhanced MRA is more sensitive and specific for diagnosis and preintervention workup of PAD.	3
43. Leiner T, Tordoir JH, Kessels AG, et al. Comparison of treatment plans for peripheral arterial disease made with multi-station contrast medium-enhanced magnetic resonance angiography and duplex ultrasound scanning. <i>J Vasc Surg</i> . 2003;37(6):1255-1262.	Observational-Dx	100 consecutive patients	To investigate the effects of substituting multi-station total outflow contrast-enhanced MRA for color duplex US scanning on treatment planning in the diagnostic workup of patients with suspected or known peripheral arterial occlusive disease.	Duplex US scanning provided enough information for treatment planning in 46, 45, and 53 patients' vs 67, 68, and 66 patients when contrast-enhanced MRA was used. PPV and NPV of duplex US as measures of ability to discriminate between surgical and nonsurgical treatment were 0/0 (undefined) and 43/46 (93%), 1/2 (50%) and 40/43 (93%), and 5/5 (100%) and 44/48 (92%) for surgeons 1, 2, and 3, respectively. Contrast-enhanced MRA: PPV and NPV were 11/13 (85%) and 50/54 (93%), 10/12 (83%) and 51/56 (91%), and 8/13 (62%) and 48/53 (91%), respectively, for surgeons 1, 2, and 3.	3
44. Visser K, Hunink MG. Peripheral arterial disease: gadolinium-enhanced MR angiography versus color-guided duplex US--a meta-analysis. <i>Radiology</i> . 2000;216(1):67-77.	Review/Other-Dx	N/A	To summarize and compare the published data on gadolinium-enhanced MRA and color-guided duplex US for the workup for PAD.	With a random effects model, pooled sensitivity for MRA 97.5% was higher than that for duplex US 87.6%. Pooled specificities were similar: 96.2% for MRA and 94.7% for duplex US.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
45. Hay JW, Lawler E, Yucel K, et al. Cost impact of diagnostic imaging for lower extremity peripheral vascular occlusive disease. <i>Value Health</i> . 2009;12(2):262-266.	Review/Other-Dx	19,209 US veterans	To assess and compare costs associated with diagnostic imaging in PAOD.	Relative to DSA, contrast-enhanced MRA was associated with substantial treatment episode savings, beyond the US\$950 direct savings in imaging cost per procedure. Substituting contrast-enhanced MRA for DSA among those not planning or requiring any follow-up procedures within 30 days could have reduced outpatient imaging costs by up to 55%, and reduced VA system costs by US\$13.2 million over the 6-year period.	4
46. 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. <i>Eur J Vasc Endovasc Surg</i> . 2008;35(5):514-521; discussion 522-513.	Experimental-Dx	197 total patients 97 assigned to MRA 100 to DSA	A randomized controlled study to compare the diagnostic and therapeutic confidence, patient outcome and costs between MRA and DSA as the initial diagnostic imaging test, in patients with symptomatic arterial disease of the leg.	A treatment plan was determined for each included patient. Additional imaging was necessary in 11% of patients in the MRA group compared to 10% in the DSA group ($P=0.5$). 84% of the patients who received MRA judged the diagnostic workup as comfortable compared to 57% who had DSA ($P=0.013$). Within 4 months of randomization 30 patients in the MRA group compared to 34 patients in the DSA group underwent operative procedures; 39 vs 36 patients respectively underwent angioplasty. Adequate treatment can be made with MRA which is better tolerated by the patient than DSA. Costs were equivalent.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
47. Huber TS, Back MR, Ballinger RJ, et al. Utility of magnetic resonance arteriography for distal lower extremity revascularization. <i>J Vasc Surg.</i> 1997;26(3):415-423; discussion 423-414.	Observational-Dx	49 patients	To determine if MRA of the infrageniculate vessels is sufficiently accurate to replace contrast arteriography before revascularization procedures in patients with limb-threatening ischemia.	The contrast arteriography and MRA were equally effective in predicting the optimal operative plans as determined from intraoperative, prebypass arteriograms. More patent vessel segments were seen on contrast arteriography than MRA (reviewer A, 229 vs 174, kappa = 0.32; reviewer B, 321 vs 314, kappa = 0.46); a comparable number of segments were seen if the vessels of the foot were excluded. The accuracy (reviewer A, 78% vs 68%, <i>P</i> =0.003; reviewer B, 75% vs 67%, <i>P</i> =0.003) and sensitivity (reviewer A, 69% vs 51%, <i>p</i> = 0.001; reviewer B, 68% vs 46%, <i>P</i> =0.0001) of contrast arteriography relative to intraoperative, prebypass arteriograms were superior to those of MRA. Specificity was comparable. The combination of MRA and intraoperative, prebypass arteriograms would have resulted in the optimal operative plan in 51/53 cases (96%) and was comparable with contrast arteriography and intraoperative, prebypass arteriograms.	2
48. Davis CP, Schopke WD, Seifert B, Schneider E, Pfammatter T, Debatin JF. MR angiography of patients with peripheral arterial disease before and after transluminal angioplasty. <i>AJR Am J Roentgenol.</i> 1997;168(4):1027-1034.	Observational-Dx	14 patients	To evaluate the feasibility of using MRA for following up patients who have undergone interventional therapy of the infrapopliteal vascular bed.	Overall agreement between the two techniques in 110 segments (71%) and 123 segments (80%) on data obtained before and after PTA, respectively. Before PTA, interpretation of MRA overestimated 14 lesions (9%). After PTA, MRA overestimated five lesions (3%). Lesion severity was underestimated in 30 cases (19%).	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
49. Habibi R, Krishnam MS, Lohan DG, et al. High-spatial-resolution lower extremity MR angiography at 3.0 T: contrast agent dose comparison study. <i>Radiology</i> . 2008;248(2):680-692.	Observational-Dx	45 consecutive patients	To determine whether contrast material dose reduction at 3.0 T allows preserved image quality for high-spatial-resolution MRA of the lower extremities.	More than 99% of arterial segments were found to be of diagnostic image quality by both readers in all dose groups. Generalized estimating equation analysis showed a significant difference among the three groups with regard to vessel definition ($P=.019$). No significant difference was found between the high- and intermediate-dose groups; however, the low-dose group had significantly better vessel definition compared with the high-dose ($P=.034$) and intermediate-dose ($P=.015$) groups. There was no significant difference among the groups in visualization of collateral vessels. Venous contamination was seen less frequently in the low-dose group, but the difference did not achieve significance. The study showed that, compared with widely used dose strategies at 1.5 T, the contrast agent dose for 3.0-T lower extremity MRA can be reduced multifold without compromising image quality.	4
50. Rofsky NM, Johnson G, Adelman MA, Rosen RJ, Krinsky GA, Weinreb JC. Peripheral vascular disease evaluated with reduced-dose gadolinium-enhanced MR angiography. <i>Radiology</i> . 1997;205(1):163-169.	Observational-Dx	15 patients	To demonstrate the utility of low-dose gadolinium-enhanced MRA of two consecutive anatomic areas for assessment of PVD.	For distinguishing greater than 50% stenosis from 50% or less stenosis, gadolinium-enhanced MRA yielded a sensitivity of 97%, a specificity of 96%, and an accuracy of 97%. In 146 (97%) of 150 anatomic segments, there was essential or total agreement on treatments determined with MRA and DSA. In two cases (one case of vascular stent placement and one case of surgical anastomosis), extent of disease was overestimated with MRA. The MR study of one infrapopliteal area was insufficient for evaluation. Accurate gadolinium-enhanced MRA of multiple peripheral vascular areas of the lower extremities can be performed in most patients with less than 0.2 mmol/kg contrast material.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
51. Lim RP, Hecht EM, Xu J, et al. 3D nongadolinium-enhanced ECG-gated MRA of the distal lower extremities: preliminary clinical experience. <i>J Magn Reson Imaging</i> . 2008;28(1):181-189.	Observational-Dx	36 patients	A report on the authors' initial experience implementing a noncontrast-enhanced ECG gated fast spin echo MRA technique for assessment of the calf arteries.	For stenosis evaluation the noncontrast technique demonstrated accuracy 79.4% (1083/1364), sensitivity 85.4% (437/512), and specificity 75.8% (646/852). The sequence demonstrated high NPV (92.3%, 646/700). The technique had serious artifacts leading to poor diagnostic confidence in 17 patients (47.2%). These included motion (n=7) and artifacts specific to the sequence, including inaccurate trigger delays (n=5), linear artifact (n=7), and vessel blurring (n=5). When only patients in whom there was satisfactory diagnostic confidence were considered, accuracy, sensitivity, and NPV were 92.2% (661/717), 92.4% (158/171), and 97.5% (503/516), respectively. Results indicate that when technically successful, noncontrast-enhanced MRA using ECG-gated fast spin echo can provide accurate imaging of the calf and pedal arteries. However, further development and optimization are needed to improve the robustness of the technique.	3
52. 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. <i>AJR Am J Roentgenol</i> . 2011;197(6):1466-1473.	Observational-Dx	25 diabetic patients	To evaluate the accuracy of the rapid technique of quiescent-interval single-shot unenhanced MRA compared with contrast-enhanced MRA for the diagnosis in diabetic patients referred with symptomatic chronic PAD.	For this study, 775 segments were analyzed. On a per-segment basis, the mean values of the diagnostic accuracy of unenhanced MRA compared with reference contrast-enhanced MRA for 2 reviewers, reviewers 1 and 2, were as follows: sensitivity, 87.4% and 92.1%; specificity, 96.8% and 96.0%; PPV, 90.8% and 94.0%; and NPV, 95.5% and 94.6%. Substantial agreement was found when overall DSA results were compared with quiescent-interval single-shot unenhanced MRA (kappa = 0.68) and contrast-enhanced MRA (kappa = 0.63) in the subgroup of patients who also underwent DSA. There was almost perfect agreement between the 2 readers for stenosis scores, with Cohen's kappa values being >0.80 for both MRA techniques.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
53. Miyazaki M, Akahane M. Non-contrast enhanced MR angiography: Established techniques. <i>J Magn Reson Imaging</i> . 2012;35(1):1-19.	Review/Other-Dx	N/A	This article introduces other established noncontrast MRA techniques, such as ECG-gated partial Fourier fast spin echo and balanced steady-state free precession, both with and without arterial spin labeling. Then, the article focuses on two main applications: peripheral run-off and renal MRA.	Recently, both applications have achieved remarkable advancements and have become a viable clinical option as an alternative to contrast-enhanced MRA. In addition, developments on the horizon including whole body MRA applications and further advancement at 3-T are discussed.	4
54. 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. <i>J Magn Reson Imaging</i> . 2011;33(2):401-408.	Review/Other-Dx	N/A	To evaluate the signal properties of 2D time of flight, quiescent-interval single-shot, ECG-gated 3D fast spin-echo), and ungated 3D fast spin-echo ghost MRA over a range of flow velocities in a pulsatile flow phantom with a 50% diameter stenosis at 1.5T.	Time of flight and quiescent-interval single-shot signal trends was similar, but quiescent-interval single-shot exhibited the most consistent signal across velocities. At high velocities (≥ 42.4 cm/s), time of flight showed poststenotic signal loss that was not observed with quiescent-interval single-shot. Fast spin-echo and ghost signals peaked at low velocities (3.9-9.7 cm/s) without flow compensation and at high velocities (≥ 64.6 cm/s) with flow compensation. Fast spin-echo and ghost demonstrated dependence on blood flow velocity and flow compensation. Time of flight was sensitive to flow artifacts at high velocities. Quiescent-interval single-shot proved most robust for accurately depicting the normal lumen and stenosis under a wide range of flow conditions. Monophasic and triphasic flow did not appreciably affect the signal performance of any method.	4
55. Hoey ET, Ganeshan A, Puni R, Henderson J, Crowe PM. Fresh blood imaging of the peripheral vasculature: an emerging unenhanced MR technique. <i>AJR Am J Roentgenol</i> . 2010;195(6):1444-1448.	Review/Other-Dx	N/A	To describe the technical aspects of performing lower extremity MRA and illustrate some sample cases.	Fresh blood imaging is an emerging unenhanced MRA technique that has recently become commercially available. Early clinical trials appear promising and it is anticipated that fresh blood imaging will become invaluable, particularly in patients with impaired renal function. Technical refinements are still required to perfect this novel MR application, particularly for the assessment of distal calf and pedal vessels and for the evaluation of patients with arrhythmias and those with impaired cardiac function.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
56. Kumamaru KK, Hoppel BE, Mather RT, Rybicki FJ. CT angiography: current technology and clinical use. <i>Radiol Clin North Am.</i> 2010;48(2):213-235, vii.	Review/Other-Dx	N/A	Article describes CT hardware and associated software for angiography. The fundamentals of CTA physics are complemented with several clinical examples.	Catheter angiography has assumed the role of gold standard for vascular imaging, since 1958. Less invasive techniques for vascular imaging, such as CTA have been developed and have matured in conjunction with developments in catheter arteriography. In a few cases, such as imaging, the aorta and the pulmonary arteries, CTA has supplanted catheter angiography as the gold standard.	4
57. Kock MC, Dijkshoorn ML, Pattynama PM, Myriam Hunink MG. Multi-detector row computed tomography angiography of peripheral arterial disease. <i>Eur Radiol.</i> 2007;17(12):3208-3222.	Review/Other-Dx	N/A	A review to discuss the different scanning and injection protocols using 4-, 16-, and 64-detector row CT scanners, to propose effective methods to evaluate and to present large data sets, to discuss its clinical value and major limitations, and to review the literature on the validity, reliability, and cost-effectiveness of MDCT in the evaluation of PAD.	Reconstruct thins (1.5 mm of iliac and femorals), thins of below knee to minimize data sets and optimize resolution. Used volume rendered and axial images. Good CTA vs DSA results but lower accuracy for crural vessels than femorals. Cost effective. Calcifications a limitation.	4
58. 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. <i>Clin Radiol.</i> 2011;66(10):945-952.	Observational-Dx	41 consecutive patients	To assess the utility of 64 section MDCT lower-limb angiography in the evaluation of patients with critical limb ischaemia or severe intermittent claudication in grading disease before endovascular treatment.	For arterial segments with haemodynamically significant disease (stenosis $\geq 50\%$), the overall sensitivity, specificity, and accuracy of MDCT in patients with severe claudication and critical limb ischaemia was 99% (95% CI: 98%–100%), 98% (95% CI: 97%–100%) and 98% (95% CI: 97%–99%), respectively. The PPV was 97% and the NPV was 99%. MDCTA is a useful tool in the assessment of patients with severe claudication and critical limb ischaemia and can be reliably used to grade disease severity and plan treatment.	2

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59. 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. <i>Eur Radiol.</i> 2008;18(4):665-671.	Observational-Dx	50 consecutive patients	To evaluate the accuracy of MDCTA in the morphologic assessment of PAOD compared to DSA.	Mean sensitivity and specificity in the detection of significant stenoses (over 70%) were 100% and 99.5% in the iliac arteries, 97.4% and 99.0% in the femoro-popliteal arteries, and 98.3% and 99.8% in the infrapopliteal arteries, respectively. High kappa values for exact stenoses gradation (0.74-1), lesion length (0.74-1), and number of lesions (0.71-1) were reached by MDCTA, indicating high agreement with DSA. Noninvasive MDCTA is an accurate tool for the assessment of all treatment-relevant morphologic information of PAOD (gradation, length, and number of stenoses) compared to DSA.	2
60. Catalano C, Fraioli F, Laghi A, et al. Infrarenal aortic and lower-extremity arterial disease: diagnostic performance of multi-detector row CT angiography. <i>Radiology.</i> 2004;231(2):555-563.	Observational-Dx	50 patients	To compare MDCTA with DSA in evaluation of the infrarenal aorta and lower-extremity arterial system.	Sensitivity, specificity, and accuracy, based on a consensus reading of MDCTA, were 96%, 93%, and 94%. Interobserver agreement was almost perfect among the three readers for treatment recommendations based on findings at CTA and DSA. MDCTA appears consistent and accurate in the assessment of patients with peripheral arterial occlusive disease.	2
61. Fine JJ, Hall PA, Richardson JH, Butterfield LO. 64-slice peripheral computed tomography angiography: a clinical accuracy evaluation. <i>J Am Coll Cardiol.</i> 2006;47(7):1495-1496.	Observational-Dx	212 patients	To determine the accuracy of 64-slice peripheral CTA to determine if improved performance metrics offer a lower risk, more efficient, noninvasive mode of peripheral angiography, which in selected clinical situations may replace the need for catheter angiography.	Data from renal, carotid and PAD of 212 patients, 107 had PAD. Vessel to vessel analysis went from sensitivity 86%, specificity 95%, PPV 89%, and NPV 80% in iliac arteries to the popliteal arteries where sensitivity 90%, specificity 96%, PPV 82%, and NPV 98%.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
62. Heijenbrok-Kal MH, Kock MC, Hunink MG. Lower extremity arterial disease: multidetector CT angiography meta-analysis. <i>Radiology</i> . 2007;245(2):433-439.	Review/Other-Dx	436 patients from 12 studies of 9,541 arterial segments	To obtain the best available estimates of the diagnostic performance of MDCTA compared with that of DSA in the assessment of symptomatic lower extremity arterial disease and to identify the most important sources of variation in diagnostic performance between studies.	The pooled sensitivity and specificity for detecting a stenosis of at least 50% per segment were 92% (95% CI: 89%, 95%) and 93% (95% CI: 91%, 95%), respectively. Three studies provided data about the diagnostic performance of MDCTA in subdivisions of the arterial tract. The diagnostic performance of MDCTA in the infrapopliteal tract was lower than but not significantly different from that in the aortoiliac (P>.11) and femoropopliteal (P>.40) tracts. Regression analysis showed that diagnostic performance was not significantly influenced by differences in study characteristics. MDCTA is an accurate diagnostic test in the assessment of arterial disease ≥50% stenosis) of the entire lower extremity.	4
63. Martin ML, Tay KH, Flak B, et al. Multidetector CT angiography of the aortoiliac system and lower extremities: a prospective comparison with digital subtraction angiography. <i>AJR Am J Roentgenol</i> . 2003;180(4):1085-1091.	Observational-Dx	41 patients	To determine whether MDCTA is an accurate and reliable method of revealing atheroocclusive disease of the aortoiliac system and the lower extremities compared with DSA.	MDCTA sensitivity for arterial occlusions and stenoses of at least 75% were 88.6% and 97.7%, specificity 92.2% and 96.8%. MDCTA was accurate in showing arterial atheroocclusive disease with reliability similar to DSA. MDCTA showed more vascular segments than DSA, particularly within calf vessels. MDCTA was accurate in showing arterial atheroocclusive disease with reliability similar to DSA. MDCTA showed more vascular segments than DSA, particularly within calf vessels.	2
64. Ofer A, Nitecki SS, Linn S, et al. Multidetector CT angiography of peripheral vascular disease: a prospective comparison with intraarterial digital subtraction angiography. <i>AJR Am J Roentgenol</i> . 2003;180(3):719-724.	Observational-Dx	18 patients	To determine the accuracy of CTA using a multidetector scanner in the evaluation of patients with PVD when compared with DSA.	Authors found agreement for the degree of stenosis in 77.7% of the arteries and discrepancy for 22.3% of the arteries when all categories were considered. Grouping the six categories according to the threshold for treatment (categories 1 and 2 as one group and categories 3, 4, and 5 as the second group) resulted in an agreement of 91.95%. Compared with DSA, CTA yielded a sensitivity of 90.9% and a specificity of 92.4%. MDCTA is an accurate, noninvasive technique for the imaging of PVD.	3

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EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
65. Ota H, Takase K, Igarashi K, et al. MDCT compared with digital subtraction angiography for assessment of lower extremity arterial occlusive disease: importance of reviewing cross-sectional images. <i>AJR Am J Roentgenol</i> . 2004;182(1):201-209.	Observational-Dx	24 patients	To evaluate the efficacy of MDCTA in the assessment of lower limb peripheral arterial occlusive disease.	Detection of segments that had more than mild stenosis; sensitivity, specificity, and accuracy of MDCTA were 99.2%, 99.1%, and 99.1%. In the 421 noncalcified and mildly calcified segments, the sensitivity, specificity, and accuracy of MDCTA for the detection of more-than-mild stenosis were 100%, 100%, and 100%. MDCTA is a reliable method for evaluating the aortoiliac and lower extremity arteries.	2
66. Willmann JK, Baumert B, Schertler T, et al. Aortoiliac and lower extremity arteries assessed with 16-detector row CT angiography: prospective comparison with digital subtraction angiography. <i>Radiology</i> . 2005;236(3):1083-1093.	Observational-Dx	39 consecutive patients	To prospectively compare the accuracy of 16-detector row CTA with conventional DSA as the reference standard in the assessment of aortoiliac and lower extremity arteries in patients with PAD.	The sensitivity and specificity of 16-detector row CTA with regard to detection of hemodynamically significant stenosis in all 35 arterial segments were 96% and 97%, respectively, for both readers. Readers 1 and 2 overestimated arterial stenosis in 42 (3%) and 34 (2%) arterial segments, respectively, and underestimated arterial stenosis in 13 (1%) and 10 (1%) arterial segments, respectively. Interobserver agreement was excellent (kappa = 0.84-1.00). 16-detector row CTA is an accurate and reliable non-invasive alternative to conventional DSA.	1
67. 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. <i>Radiology</i> . 2003;226(3):798-811	Observational-Dx	46 consecutive patients	To compare contrast-enhanced 3D MRA and MDCTA in the same patients for assessment of the aortoiliac and renal arteries, with DSA as the standard of reference.	Sensitivity of MRA for detection of hemodynamically significant arterial stenosis was 92% for reader 1 and 93% for reader 2; specificity was 100% and 99%, respectively. Sensitivity of CTA was 91% for reader 1 and 92% for reader 2, and specificity was 99% and 99%. There is no statistically significant difference between 3D MRA and MDCTA in the detection of hemodynamically significant arterial stenosis of the aortoiliac and renal arteries.	1

Vascular Claudication—Assessment for Revascularization
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
68. 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. <i>Radiology</i> . 2003;229(2):465-474.	Observational-Dx	65 consecutive patients	To assess the technical feasibility of MDCTA in the assessment of peripheral arterial bypass grafts and to evaluate its accuracy and reliability in the detection of graft-related complications, including graft stenosis, aneurysmal changes, and arteriovenous fistulas.	Image quality was rated as good or excellent in 250 (98%) and in 252 (99%) of 255 bypass segments, respectively. There was excellent agreement both between readers and between CTA and duplex US in the detection of graft stenosis, aneurysmal changes, and arteriovenous fistulas (kappa = 0.86-0.99). CTA and duplex US were compared with conventional DSA, and there was no statistically significant difference (P>.25) in sensitivity or specificity between CTA and duplex US for both readers for detection of hemodynamically significant bypass stenosis or occlusion, aneurysmal changes, or arteriovenous fistulas. Mean CT attenuation values ranged from 232 HU in the inflow artery to 281 HU in the outflow artery of the bypass graft. MDCTA may be an accurate and reliable technique after duplex US in the assessment of peripheral arterial bypass grafts and detection of graft-related complications, including stenosis, aneurysmal changes, and arteriovenous fistulas.	2
69. 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? <i>Eur J Radiol</i> . 2012;81(3):542-546.	Observational-Dx	43 patients; 774 vessel segments	To prospectively compare the efficacy of 40-row MDCTA and duplex US to diagnose mild PAOD in lower leg and to search whether MDCTA can be used as a screening tool.	A total of 774 vessel segments were imaged by both modalities. When all arteries were considered, MDCTA detected obstructed or stenotic lesions in 16.8% of arteries, vs 11.1% compared to duplex US. When suprapopliteal arteries alone were considered, MDCTA detected lesions in 15.0% of arteries, vs 11.0% with duplex US. When infrapopliteal arteries only were considered, MDCTA detected lesions in 19.6% of arteries, vs 11.3% with duplex US. MDCTA showed 5.7% (95% CI: [3.5%, 7.9%]) more lesions than duplex US when all arteries were considered together, 8.3% (95% CI: [4.6%, 12.0%]) more lesions when only the infrapopliteal arteries were compared, and 4.0% (95% CI: [1.3%, 6.8%]) more lesions when only suprapopliteal arteries were compared (P<0.01 for all comparisons).	2

* See Last Page for Key

**Vascular Claudication—Assessment for Revascularization
EVIDENCE TABLE**

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
70. 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. <i>Radiology</i> . 2006;241(2):603-608.	Observational-Dx	145 patients	To evaluate retrospectively the effect of vessel wall calcifications on the clinical utility of MDCTA performed in patients with PAD and to identify clinical predictors for the presence of vessel wall calcifications.	The authors found that the number of calcified segments was a significant predictor of the need for additional imaging ($P=.001$) and of the confidence scores ($P<.001$). The number of calcified segments discriminated between patients who required additional imaging after CTA and those who did not (area under the ROC curve, 0.66; 95% CI: 0.54, 0.77). Age, diabetes mellitus, and cardiac disease were significant predictors of the number of calcified segments in both the univariable and multivariable analyses ($P<.05$). Vessel wall calcifications decrease the clinical utility of CTA in patients with PAD. Diabetes mellitus, cardiac disease, and elderly age (older than 84 years) are independently predictive for the presence of vessel wall calcifications.	4
71. Mostardi PM, Haider CR, Glockner JF, Young PM, Riederer SJ. High spatial and temporal resolution imaging of the arterial vasculature of the lower extremity with contrast enhanced MR angiography. <i>Clin Anat</i> . 2011;24(4):478-488.	Review/Other-Dx	N/A	To describe a recently developed 3D time-resolved contrast-enhanced MRA technique, Cartesian Acquisition with Projection Reconstruction-like sampling (CAPR), and its application to imaging of the vasculature of the lower legs and feet.	Temporal resolution of 4.9-6.5 sec and spatial resolution less than or equal to 1 mm in all directions allow for the depiction of progressive arterial filling and complex flow patterns as well as sharp visualization of vascular structure as small as the fine muscular branches. High-quality diagnostic imaging is made possible with CAPR's advanced acquisition and reconstruction techniques and the use of specialized coil arrays.	4
72. Machida H, Tanaka I, Fukui R, et al. Dual-Energy Spectral CT: Various Clinical Vascular Applications. <i>Radiographics</i> . 2016;36(4):1215-1232	Review/Other-Dx	N/A	To describe basic principles and various techniques of single-source dual-energy CT with fast kilovolt-peak switching and offer various vascular applications of single-source dual-energy CT with fast kilovolt-peak switching with illustrative clinical data and images to overcome the limitations of single-energy CT.	Single-source dual-energy CT with fast kilovolt-peak switching allows projection-based reconstruction of dual-energy CT images, which leads to substantial reduction of beam hardening, accurate reconstruction of monochromatic images obtained at 40–140 keV and material decomposition images that use various basis materials, and detailed analysis of material content by using the spectral Hounsfield unit curve and effective Z histogram.	4

Evidence Table Key

Study Quality Category Definitions

- *Category 1* The study is well-designed and accounts for common biases.
- *Category 2* The study is moderately well-designed and accounts for most common biases.
- *Category 3* There are important study design limitations.
- *Category 4* The study is not useful as primary evidence. The article may not be a clinical study or the study design is invalid, or conclusions are based on expert consensus. For example:
 - a) the study does not meet the criteria for or is not a hypothesis-based clinical study (e.g., a book chapter or case report or case series description);
 - b) the study may synthesize and draw conclusions about several studies such as a literature review article or book chapter but is not primary evidence;
 - c) the study is an expert opinion or consensus document.
- M = Meta-analysis

Dx = Diagnostic

Tx = Treatment

Abbreviations Key

ABI = Ankle brachial index

CI = Confidence interval

CTA = Computed tomography angiography

DSA = Digital subtraction angiography

DUAM = Duplex ultrasound arterial mapping

ECG = Electrocardiogram

MDCT = Multidetector computed tomography

MDCTA= Multidetector computed tomography angiography

MRA = Magnetic resonance angiography

NPV = Negative predictive value

OR = Odds ratio

PAD = Peripheral arterial disease

PAOD = Peripheral vascular occlusive disease

PPV = Positive predictive value

PSV = Peak systolic velocity

PTA = Percutaneous transluminal angioplasty

PVD = Peripheral vascular disease

ROC = Receiver-operator characteristic

RR = Relative risk

US = Ultrasound