American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Follow-up of Lower Extremity Arterial Bypass Surgery**

Variant 1: **Claudication/suprainguinal graft.**

Radiologic Procedure	Rating	Comments	RRL*
Physiologic noninvasive tests	9		None
US lower extremity arterial duplex Doppler with color	8	Color Doppler with waveform evaluation of entire graft.	None
INV arteriography lower extremity	8	Indicated if noninvasive studies are abnormal. Not for screening.	Low
MRA lower extremity	6		None
CTA lower extremity	5	Although not yet supported by studies, MDCTA is emerging as a widely used and reliable non-invasive study in this clinical setting.	Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 2: **Claudication/infrainguinal vein graft.**

Radiologic Procedure	Rating	Comments	RRL*
Physiologic noninvasive tests	9		None
US lower extremity arterial duplex Doppler with color	8	Color Doppler with waveform evaluation of entire graft.	None
INV arteriography lower extremity	8	Indicated if noninvasive studies are abnormal. Not for screening.	Low
MRA lower extremity	6		None
CTA lower extremity	5	Although not yet supported by studies, MDCTA is emerging as a widely used and reliable non-invasive study in this clinical setting.	Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Follow-up of Lower Extremity Arterial Bypass Surgery**

Variant 3: **Claudication/infrainguinal prosthetic graft.**

Radiologic Procedure	Rating	Comments	RRL*
Physiologic noninvasive tests	9		None
US lower extremity arterial duplex Doppler with color	8	Color Doppler with waveform evaluation of entire graft.	None
INV arteriography lower extremity	8	Indicated if noninvasive studies are abnormal. Not for screening.	Low
MRA lower extremity	6		None
CTA lower extremity	5	Although not yet supported by studies, MDCTA is emerging as a widely used and reliable non-invasive study in this clinical setting.	Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 4: **Threatened limb/suprainguinal graft.**

Radiologic Procedure	Rating	Comments	RRL*
Ankle-brachial indices	9		None
INV arteriography lower extremity	9	Indicated if noninvasive studies are abnormal. Not for screening.	Low
US lower extremity arterial duplex Doppler with color	8	Color Doppler with waveform evaluation of entire graft.	None
Physiologic noninvasive tests	4		None
MRA lower extremity	4		None
CTA lower extremity	3		Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 5: **Threatened limb/infrainguinal vein graft.**

Radiologic Procedure	Rating	Comments	RRL*
Ankle-brachial indices	9		None
INV arteriography lower extremity	9	Indicated if noninvasive studies are abnormal. Not for screening.	Low
US lower extremity arterial duplex Doppler with color	8	Color Doppler with waveform evaluation of entire graft.	None
MRA lower extremity	6	In selected cases, to determine patency of distal vessels.	None
Physiologic noninvasive tests	4		None
CTA lower extremity	2		Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Follow-up of Lower Extremity Arterial Bypass Surgery**

Variant 6: **Threatened limb/infrainguinal prosthetic graft.**

Radiologic Procedure	Rating	Comments	RRL*
Ankle-brachial indices	9		None
INV arteriography lower extremity	9	Indicated if noninvasive studies are abnormal. Not for screening.	Low
US lower extremity arterial duplex Doppler with color	8	Color Doppler with waveform evaluation of entire graft.	None
MRA lower extremity	6	In selected cases, to determine patency of distal vessels.	None
Physiologic noninvasive tests	4		None
CTA lower extremity	2		Med
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 7: **Asymptomatic/infrainguinal vein graft.**

Radiologic Procedure	Rating	Comments	RRL*
Physiologic noninvasive tests	8		None
US lower extremity arterial duplex Doppler with color	8	Color Doppler with waveform evaluation of entire graft.	None
CTA lower extremity	5	Although not yet supported by studies, MDCTA is emerging as a widely used and reliable non-invasive study in this clinical setting. No artifact problem.	Med
MRA lower extremity	4	Limited data available. Inherent limitations caused by artifact clips.	None
INV arteriography lower extremity	3	Indicated if noninvasive studies are abnormal. Not for screening.	Low
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Expert Panel on Vascular Imaging: Thomas Casciani, MD[1]; Michael A. Bettmann, MD[2]; Antoinette S. Gomes, MD[3]; Julius H. Grollman, MD[4]; Stephen R. Holtzman, MD[5]; Joseph F. Polak, MD, MPH[6]; David Sacks, MD[7]; Joseph Schoepf, MD[8]; William Stanford, MD[9]; Michael Jaff, MD[10]; Gregory L. Moneta, MD.[11]

Summary of Literature Review

Lower extremity arterial bypass surgery can be broadly categorized as suprainguinal or infrainguinal, and when infrainguinal as autologous vein, or artificial graft. The postsurgical evaluation previously was limited to clinical observation of recurring symptoms and measurement of ankle-brachial indices (ABI) and segmental volume recordings [1,2]. Over the past two decades, routine duplex ultrasound (US) for asymptomatic patients following infrainguinal bypass has gained much acceptance. Regardless of the category of bypass, symptoms recur or an asymptomatic stenosis is detected, further imaging may be warranted prior to open surgical or endovascular intervention. Conventional (catheter) angiography and, more recently, magnetic resonance angiography (MRA) and computerized tomography angiography (CTA) may provide needed information regarding the severity and character of stenoses and the quality of the native vessels proximal and distal to the graft. Even in the setting of an acutely threatened limb after bypass graft failure, these studies may be warranted prior to rapid intervention.

The natural history of lower extremity bypass surgery with vein conduit is the development of stenoses within or adjacent to the graft and ultimately thrombosis [3,4]. Early failures are usually secondary to a technical imperfection such as a retained valve or a kink in the conduit during tunneling. Late failures are usually due to intimal hyperplasia within the graft or at either anastomosis, or progression of atherosclerosis in the inflow or outflow arteries. During the first postoperative year, up to 30% of venous grafts develop stenoses [5]. There is evidence suggesting that repair of these stenoses, by either surgical or endovascular means, extends the patency of venous bypass grafts [6-11]. In addition, patency following revision of a thrombosed vein graft is inferior to patency following of revision of a stenotic graft prior to thrombosis.

Duplex US has been used as a method of vein graft surveillance for more than 20 years [12-14]. The technique involves the sequential study of a graft from proximal to distal anastomosis, with measurement of peak systolic flow velocity (PSFV) and comparison of areas of increased velocity to nearby regions of low velocity to create a peak systolic flow velocity ratio (PSFVR). There is evidence to suggest that the PSFVR is the most sensitive indicator of a graft stenosis [15-17]. A PSFVR of more than 2.5 is often considered representative of a significant stenosis, although there are reports suggesting a higher value of 3.0 or 3.5 as the appropriate threshold for intervention. Another value that may signify a significant stenosis is a PSFV >200 cm/sec at any point in the graft. A midgraft PSFV <45 cm/sec may indicate high resistance, suggesting stenosis in the outflow arteries. However, low PSFV may be seen normally in large caliber vein grafts.

There have been two prospective randomized trials comparing duplex US surveillance versus clinical follow-up of lower extremity bypass grafts with opposite conclusions. The study by Ihlberg et al showed no difference in assisted primary or secondary patency for 185 vein grafts at 1 year [18]. The study of 165 grafts by Lundell et al did show a significant benefit in assisted primary and secondary patency for vein grafts at 3 years, but no benefit in patency for the surveillance of polytetrafluoroethylene (PTFE) grafts [19]. A European randomized control trial of 1,200 patients is pending [20]. A nonrandomized study of 615 bypasses found significant improvement in secondary patency and limb salvage for grafts followed by duplex US and ankle-brachial index compared to clinical surveillance (return of preoperative symptoms) [21].

Arguments against the use of duplex US surveillance include the expense of the machine and the technologist and the lack of a definitive study showing that detectable stenosis will lead to graft failure. However, there is evidence as to the cost effectiveness of such surveillance [5].

There is strong evidence that using duplex US during the creation of the graft reduces early graft failures [5,22]. In fact, the most sensitive predictor of subsequent graft stenosis formation was an abnormal duplex US during initial surgery [10].

Regardless of the indications for re-intervention in a bypass graft, many surgeons obtain arteriography before repair, mainly for evaluating the inflow and outflow vessels [23,24]. In recent years, MRA, specifically

[1]Review Author, Indiana University Hospital, Indianapolis, Ind; [2]Panel Chair, Wake Forest University School of Medicine Radiology, Winston-Salem, NC; [3]UCLA School of Medicine, Los Angeles, Calif; [4]Little Company of Mary Hospital, Torrance, Calif; [5]Radiology Associates of San Luis Obispo, San Luis Obispo, Calif; [6]New England Medical Center, Boston, Mass; [7]West Reading Radiology Associates, West Reading, Pa; [8]Medical University of South Carolina, Charleston, SC; [9]University of Iowa Hospital & Clinics, Iowa City, Iowa; [10]Massachusetts General Hospital, Boston, Mass, American College of Cardiology; [11]Oregon Health Sciences University, Portland, Ore, Society for Vascular Surgery.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

contrast-enhanced MRA, has shown increasing ability to properly evaluate inflow and outflow vessels, as well as bypass grafts [25-28]. Though less well-studied, CTA with multislice scanner technology has begun to emerge as another alternative to conventional arteriography [29,30].

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. 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	**Effective Dose Estimate Range**
None	0
Minimal	< 0.1 mSv
Low	0.1-1 mSv
Medium	1-10 mSv
High	10-100 mSv

References

1. Barnes RW, Thompson BW, MacDonald CM, et al. Serial noninvasive studies do not herald postoperative failure of femoropopliteal or femorotibial bypass grafts. *Ann Surg* 1989; 210(4):486-493; discussion 493-484.
2. Berkowitz HD, Greenstein SM. Improved patency in reversed femoral-infrapopliteal autogenous vein grafts by early detection and treatment of the failing graft. *J Vasc Surg* 1987; 5(5):755-761.
3. Gupta AK, Bandyk DF, Cheanvechai D, Johnson BL. Natural history of infrainguinal vein graft stenosis relative to bypass grafting technique. *J Vasc Surg* 1997; 25(2):211-220; discussion 220-215.
4. Idu MM, Buth J, Hop WC, Cuypers P, van de Pavoordt ED, Tordoir JM. Factors influencing the development of vein-graft stenosis and their significance for clinical management. *Eur J Vasc Endovasc Surg* 1999; 17(1):15-21.
5. Wixon CL, Mills JL, Westerband A, Hughes JD, Ihnat DM. An economic appraisal of lower extremity bypass graft maintenance. *J Vasc Surg* 2000; 32(1):1-12.
6. Avino AJ, Bandyk DF, Gonsalves AJ, et al. Surgical and endovascular intervention for infrainguinal vein graft stenosis. *J Vasc Surg* 1999; 29(1):60-70; discussion 70-61.
7. Berkowitz HD, Fox AD, Deaton DH. Reversed vein graft stenosis: early diagnosis and management. *J Vasc Surg* 1992; 15(1):130-141; discussion 141-132.
8. Dougherty MJ, Calligaro KD, DeLaurentis DA. Revision of failing lower extremity bypass grafts. *Am J Surg* 1998; 176(2):126-130.
9. Landry GJ, Moneta GL, Taylor LM, Jr., Edwards JM, Yeager RA, Porter JM. Long-term outcome of revised lower-extremity bypass grafts. *J Vasc Surg* 2002; 35(1):56-62; discussion 62-53.
10. MacKenzie KS, Hill AB, Steinmetz OK. The predictive value of intraoperative duplex for early vein graft patency in lower extremity revascularization. *Ann Vasc Surg* 1999; 13(3):275-283.
11. Mills JL, Harris EJ, Taylor LM, Jr., Beckett WC, Porter JM. The importance of routine surveillance of distal bypass grafts with duplex scanning: a study of 379 reversed vein grafts. *J Vasc Surg* 1990; 12(4):379-386; discussion 387-379.
12. Bandyk DF, Cato RF, Towne JB. A low flow velocity predicts failure of femoropopliteal and femorotibial bypass grafts. *Surgery* 1985; 98(4):799-809.
13. Bandyk DF, Kaebnick HW, Bergamini TM, Moldenhauer P, Towne JB. Hemodynamics of in situ saphenous vein arterial bypass. *Arch Surg* 1988; 123(4):477-482.
14. Bandyk DF, Kaebnick HW, Stewart GW, Towne JB. Durability of the in situ saphenous vein arterial bypass: a comparison of primary and secondary patency. *J Vasc Surg* 1987; 5(2):256-268.
15. Belkin M, Schwartz LB, Donaldson MC, Mannick JA, Whittemore AD. Hemodynamic impact of vein graft stenoses and their prediction in the vascular laboratory. *J Vasc Surg* 1997; 25(6):1016-1021; discussion 1022.
16. Mills JL, Fujitani RM, Taylor SM. The characteristics and anatomic distribution of lesions that cause reversed vein graft failure: a five-year prospective study. *J Vasc Surg* 1993; 17(1):195-204; discussion 204-196.
17. Treiman GS, Lawrence PF, Bhirangi K, Gazak CE. Effect of outflow level and maximum graft diameter on the velocity parameters of reversed vein bypass grafts. *J Vasc Surg* 1999; 30(1):16-25.
18. Ihlberg L, Luther M, Tierala E, Lepantalo M. The utility of duplex scanning in infrainguinal vein graft surveillance: results from a randomised controlled study. *Eur J Vasc Endovasc Surg* 1998; 16(1):19-27.
19. Lundell A, Lindblad B, Bergqvist D, Hansen F. Femoropopliteal-crural graft patency is improved by an intensive surveillance program: a prospective randomized study. *J Vasc Surg* 1995; 21(1):26-33; discussion 33-24.
20. Kirby PL, Brady AR, Thompson SG, Torgerson D, Davies AH. The Vein Graft Surveillance Trial: rationale, design and methods. VGST participants. *Eur J Vasc Endovasc Surg* 1999; 18(6):469-474.
21. Bergamini TM, George SM, Jr., Massey HT, et al. Intensive surveillance of femoropopliteal-tibial autogenous vein bypasses improves long-term graft patency and limb salvage. *Ann Surg* 1995; 221(5):507-515; discussion 515-506.
22. Rzucidlo EM, Walsh DB, Powell RJ, et al. Prediction of early graft failure with intraoperative completion duplex ultrasound scan. *J Vasc Surg* 2002; 36(5):975-981.
23. Landry GJ, Moneta GL, Taylor LM, Jr., et al. Duplex scanning alone is not sufficient imaging before secondary procedures after lower extremity reversed vein bypass graft. *J Vasc Surg* 1999; 29(2):270-280; discussion 280-271.
24. Toursarkissian B, D'Ayala M, Shireman PK, Schoolfield J, Sykes MT. Lower extremity bypass graft revision in diabetics. *Vasc Surg* 2001; 35(5):369-377.
25. Bendib K, Berthezene Y, Croisille P, Villard J, Douek PC. Assessment of complicated arterial bypass grafts: value of contrast-enhanced subtraction magnetic resonance angiography. *J Vasc Surg* 1997; 26(6):1036-1042.
26. Dorenbeck U, Seitz J, Volk M, et al. Evaluation of arterial bypass grafts of the pelvic and lower extremities with gadolinium-enhanced magnetic resonance angiography: comparison with digital subtraction angiography. *Invest Radiol* 2002; 37(2):60-64.
27. Loewe C, Cejna M, Lammer J, Thurnher SA. Contrast-enhanced magnetic resonance angiography in the evaluation of peripheral bypass grafts. *Eur Radiol* 2000; 10(5):725-732.
28. Loewe C, Cejna M, Schoder M, et al. Contrast material-enhanced, moving-table MR angiography versus digital subtraction angiography for surveillance of peripheral arterial bypass grafts. *J Vasc Interv Radiol* 2003; 14(9 Pt 1):1129-1137.

29. Soto JA, Munera F, Morales C, et al. Focal arterial injuries of the proximal extremities: helical CT arteriography as the initial method of diagnosis. *Radiology* 2001; 218(1):188-194.

30. 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.