The fate of bypass grafts to angiographically occult runoff vessels detected by magnetic resonance angiography

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Purpose: Magnetic resonance angiography (MRA) is a noninvasive vascular imaging technique that is more sensitive than contrast arteriography (CA) for the detection of patent distal runoff vessels. This technique has facilitated performance of MRA-directed bypass procedures for patients who were believed not to be bypass candidates because of the absence of a suitable target vessel on the preoperative CA. The fate of bypasses to these angiographically occult runoff vessels is unknown, however, and it has been proposed that patients with angiographically occult runoff may have aggressive occlusive disease, rendering bypass procedures ultimately futile.

Methods: Between April 1992 and February 1995, 212 autogenous vein infrageniculate bypasses were performed for limb-salvage indications, 22 (12%) to angiographically occult runoff vessels. Results of bypasses performed to angiographically occult vessels were compared with those of bypasses to CA-detected runoff vessels. Life-table analysis of graft-patency and limb-salvage rates was performed.

Results: The accuracy of the MRA-predicted patency of angiographically occult vessels was confirmed in every case by the operative findings. Life-table analysis revealed no significant difference in primary graft patency ($p > 0.05$) or limb-salvage ($p > 0.05$) rates between patients with bypasses to runoff vessels detected by CA compared with those to angiographically occult vessels seen by MRA alone. At 35 months after surgery, the primary graft patency rate was 68% for bypasses to CA-detected vessels and 67% for MRA-detected vessels. The limb-salvage rate was 83% for CA-detected vessel bypass patients and 78% for patients with angiographically occult runoff.

Conclusion: MRA can accurately identify patent runoff vessels not visualized by CA. Results of bypasses performed to angiographically occult runoff vessels are similar to those of bypasses performed to vessels detected by CA. MRA should be performed in patients in whom CA fails to reveal runoff vessels suitable for use in a limb-salvage procedure. The greater sensitivity of MRA may facilitate successful bypass surgery and improve the overall limb-salvage rate. (J VASC SURG 1996;23:483-9.)
sels, however, is not known. The question has been raised regarding the nature of these vessels: Do angiographically occult runoff vessels represent a severely diseased subpopulation of vessels that portend a poor prognosis for graft patency and limb-salvage? We sought to determine the fate of bypasses performed to these vessels.

METHODS

Since April 1992, preoperative MRA has routinely supplemented CA at the Hospital of the University of Pennsylvania whenever preoperative CA fails to reveal a patent runoff vessel suitable for use in a limb-salvage procedure. A retrospective review of vascular and MRA registries identified patients who underwent bypasses to angiographically occult runoff vessels. Twelve were men (55%), 10 were women (45%); the mean patient age was 66 years. Rest pain occurred in 13 (59%), gangrene in 16 (73%), and diabetes in 13 (59%). A second group of patients was identified. The patients in the second group underwent bypasses to infrageniculate runoff vessels identified by CA from April 1992 through February 1995. One hundred five were men (55%), 87 were women (45%); the mean patient age was 65 years. Rest pain occurred in 134 (70%), gangrene in 115 (59%), and diabetes in 77 (39%). All infrapopliteal autogenous bypasses performed for limb-salvage indications were analyzed. Life-table analysis of primary graft patency and limb-salvage rates was performed by the method established by the Ad-Hoc Committee on Reporting Standards, Society for Vascular Surgery/North American Chapter International Society for Cardiovascular Surgery.7

CAs were performed with the standard approach with a femoral catheter with either diatrizoate (370 mg iodine per ml; Hypaque 76) or iohexol (350 mg iodine per ml; Omnipaque 350; Winthrop Pharmaceuticals, New York). Filming was continued for 40 seconds after the end of the injection. Blood flow to the ischemic extremity was augmented with an intraarterial vasodilator (10 to 25 mg tolazoline hydrochloride) or induction of reactive hyperemia. Intraarterial digital subtraction arteriography (DSA) routinely supplemented CA. Angiographic studies were considered adequate only if one or more distal runoff vessels were identified or if an angiographic blush was seen within the soft tissues or in the very small unnamed peripheral arteries. Intraoperative CA was performed by direct arterial or bypass graft puncture with injection of 10 to 20 ml iothalate meglumine.

MRA was performed with a standard 1.5 Tesla superconducting system (Signa; General Electric Medical Systems; Milwaukee) with a transmit-receive extremity coil and commercially available pulse sequences. Only two-dimensional time-of-flight techniques were used. Inferior saturation pulses were used to suppress signal from venous blood flow. The scanning variables were a 16-cm field of view, 2-mm-thick sections, a flip angle of 60°, a repetition time of 35 to 45 milliseconds, an echo time of 7.7 milliseconds, and 128-phase encoding steps with no signal averaging. At all examinations the lower leg was imaged from at or above the level of the adductor canal to the dorsum of the foot.

RESULTS

From April 1992 to February 1995, 212 autogenous infrageniculate bypasses were performed for treatment of limb-threatening ischemia. Twenty-two of these (12%) were performed to angiographically occult runoff vessels. In every case, the patency of the angiographically occult runoff vessel was confirmed at surgery and a bypass was successfully completed (Figs. 1 and 2).

Thirty-five months after surgery no significant difference in primary graft patency or limb-salvage rates could be detected between patients whose bypass outflow was to CA-detected vessels or to angiographically occult runoff vessels detected by MRA alone (Fig. 3). The primary graft patency rate at 35 months was 68% for CA-detected vessels and 67% for MRA-detected runoff vessels (p = 0.92, NS). The limb-salvage rate was 83% for CA-detected runoff vessels and 78% for MRA-detected runoff vessels (p = 0.84, NS).

DISCUSSION

Successful peripheral bypass surgery relies on accurate preoperative vascular imaging for planning of reconstructions. Although not often necessary, blind exploration of distal runoff vessels and intraoperative CA are the traditional strategies for the patient whose preoperative CA fails to demonstrate patent distal runoff vessels suitable for use in bypass grafting. If runoff vessels are detected during blind exploration and intraoperative CA, a bypass is performed. If vessels are not identified, an amputation is usually the only alternative.

The demonstration of vessel patency by CA depends on the delivery of radiopaque contrast material to the distal runoff vessel. A proximally injected bolus of contrast material must traverse multiple segmental occlusions to reconstitute the distal vessel. In patients with severe multilevel
disease, contrast material delivery presents a great challenge even with DSA techniques. When compared with intraoperative CA, preoperative CA has been shown to fail to opacify all patent runoff vessels in 10% to 21% of calf arteries and 40% to 86% of combined calf and foot arteries. Even intraarterial DSA, which generally is believed to improve distal runoff vessel detection, fails to reveal more patent distal runoff vessels than CA. This finding reflects the inherent limitations of a contrast-based opacification technique.

Rather than relying on an injected contrast agent, MRA demonstrates vascular patency by detection of vascular flow. Even extremely slow flow can be detected. In studies that compare preoperative CA with preoperative MRA in the lower extremity, MRA detects all patent vessel segments seen on intraoperative CA and 22% to 24% more patent vessel segments than preoperative CA. This phenomenon is especially apparent in the more distal peripheral circulation, with MRA detecting 49% to 62% more tibial and pedal segments than CA.

The detection of these angiographically occult runoff vessels becomes clinically important when a patent runoff vessel suitable for use in a bypass procedure is not identified by the preoperative CA. In such cases a vessel detected by MRA can be used, which obviates the need for blind exploration of runoff vessels, with the attendant morbidity of misplaced incisions and prolonged operating time. In our report, the prevalence of bypasses to angiographically runoff vessels is 12%, a prevalence similar to previously reported occurrences of this phenomenon by others and by us. (9 of the 22 patients described were previously reported). The seemingly high incidence of bypasses performed to these vessels reflects our routine use of MRA to supplement CA.

Bypasses to angiographically occult runoff vessels result in graft patency and limb-salvage rates similar to those with bypasses performed to CA-detected runoff vessels. It would appear that what is detected is a vessel not unlike those detected by contrast techniques. The presence of angiographically occult runoff vessels does not seem to be a marker of a more highly diseased subpopulation with a worse (or better) prognosis. A patient should not be denied a limb-salvage procedure if the CA fails to reveal a runoff vessel suitable for use in a bypass if such a vessel is detected by MRA. MRA should be routinely performed in patients in whom a patent runoff vessel suitable for use in a limb-salvage procedure is not identified on the preoperative CA.

Other benefits of MRA have been noted as experience has increased. The technique is completely
Fig. 1. D, MRA revealed both posterior tibial (solid arrow) and anterior tibial (open arrow) arteries. At the ankle, DSA revealed only a diseased posterior tibial artery collateral system at level of malleolus (E, arrow), whereas MRA revealed both posterior tibial artery (F, solid arrow) and a minimally diseased anterior tibial artery continuing as dorsalis pedis artery (open arrow). A successful femoral dorsalis pedis (G, arrow) bypass graft was performed based on MRA detection of angiographically occult dorsalis pedis artery.

noninvasive and can be accomplished on an outpatient basis. Patients with poor-quality arteriograms that give adequate visualization of the proximal vessels but poor-quality views of the runoff may simply have their arteriograms supplemented with an outpatient MRA, decreasing hospital stay and providing a cost savings. The cost-effectiveness in MRA in this situation has been the subject of rigorous scrutiny, and the technique has been found to be cost-effective if MRA sensitivity and specificity remain high.12

MRAs are constructed from images obtained in a cross-sectional fashion. The axial images show the precise location in space of a patent runoff vessel segment (Fig. 2), allowing accurate placement of operative incisions and eliminating the confusion that often exists with biplanar arteriography as to the exact identification of runoff vessels.

Cortical bone, which often obscures vessels on CAs, is transparent on MRA. Lesions that may be missed by CA because they overlay cortical bone are detected by MRA and may result in an alternative choice of target vessel for bypass grafting.

Limitations of MRA include failure of patients to tolerate studies because of claustrophobia, and contraindications to magnetic resonance imaging, including patients with pacemakers or metallic foreign bodies in the eye. Because of technical inadequacies,
Fig. 2. CA and MRA from 78-year old woman with gangrenous forefoot. Preoperative CA (A) shows delivery of contrast into small unnamed collateral branches in foot (arrow), but no named runoff vessels suitable for use in limb-salvage procedure. MRA of foot and ankle (B) reveals patent distal anterior tibial artery extending into foot as dorsalis pedis artery (curved arrow) and collateral noted on CA (straight arrow). The heel (H) is labeled for orientation in lateral-projection MRA (I, inferior). Cross-sectional image taken at level of ankle (C) shows tibia (T), fibula (F), dorsalis pedis artery (curved arrow), and peroneal artery collateral (straight arrow). MRAs are reconstructed from a series of these stacked axial images reformatted by computer to show a projection arteriogram. (D) Intraoperative arteriogram at conclusion of femoral dorsalis bypass procedure. Arrow points to bypass graft.

studies may need to be repeated, which requires multiple return visits to the magnetic resonance imaging suite. Use of MRA must be validated against the gold standard of CA at individual institutions and requires a dedicated team of surgeons, angiographers, and magnetic resonance imaging radiologists.

Recently we performed peripheral vascular surgery with MRA as the sole preoperative imaging
Fig. 3. Survival curves depicting primary graft-patency (A) and limb-salvage (B) rates for patients receiving bypasses to angiographically occult runoff vessels compared with patients receiving bypasses to CA-detected runoff vessels. All bypasses were to infrageniculate outflow. Thirty-five months after surgery the primary graft patency rate was 68% for bypasses to CA-detected vessels and 67% for MRA-detected vessels. Limb-salvage rate was 83% for patients with CA-detected vessel bypass and 78% for patients with angiographically occult runoff. There were no statistically significant differences between the groups for graft patency ($p = 0.92$) or limb-salvage ($p = 0.84$) rate.

CONCLUSION

MRA is a powerful tool for preoperative imaging for patients with occlusive peripheral vascular disease. The detection of angiographically occult runoff vessels represents an important advantage of MRA over CA. Bypasses performed to angiographically occult runoff vessels yield graft patency and limb-salvage rates similar to those in other vessels. MRA should be performed in patients whose preoperative CA fails to reveal patent runoff vessels suitable for use in a limb-salvage procedure. The greater sensitivity of MRA facilitates successful bypass surgery and may improve the overall limb-salvage rate.

REFERENCES


2. Hertz SM, Baum RA, Owen RS, Holland GA, Logan DR, Carpenter JP. Comparison of magnetic resonance and contrast

method. This completely noninvasive imaging evaluation is both accurate and cost-effective when compared with preoperative CA. The elimination of the need for a short-stay unit or an additional hospital day for preoperative CA offers a significant cost savings. Cost and safety issues will continue to stimulate the search for noninvasive, outpatient, preoperative imaging methods for use in vascular surgery. As MRA continues to proliferate, the need for education and accreditation of clinicians and technologists in its proper performance and interpretation will increase.

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Submitted March 20, 1995; accepted August 10, 1995.