Utility of direct angiosome revascularization and runoff scores in predicting outcomes in patients undergoing revascularization for critical limb ischemia

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Objective: **Both runoff scores and direct (DR) vs indirect revascularization (IR) according to pedal angiosomes have unclear impact on outcome for patients with critical limb ischemia (CLI). We compared DR vs IR and runoff scores in CLI patients undergoing infrapopliteal bypass for foot wounds.**

Methods: **Patients who had tibial/pedal bypass for a foot/ankle wound from 2005-2011 were identified and operations classified as DR or IR based on wound location and bypass target. A blinded observer reviewed angiograms for an intact pedal arch and calculated standard Society for Vascular Surgery (single tibial) and modified (composite tibial) runoff scores. Comorbidities, wound characteristics, wound healing, major amputation, and overall survival were determined.**

Results: **A total of 106 limbs were revascularized in 97 patients; 54 limbs had DR and 52 had IR, although only 36% of wounds corresponded to a single, distinct angiosome. Wound characteristics and comorbidities were similar between groups. Mean standard (7.9 vs 7.2; $P = .001$) and modified (22.2 vs 20.0; $P = .02$) runoff scores were worse (higher number indicates worse runoff) in the IR vs DR groups; 33% had a complete pedal arch. Complete wound healing (78% vs 46%; $P = .001$) and time to complete healing (99 vs 195 days; $P = .002$) were superior with DR vs IR but were not influenced by runoff score, modified runoff score or presence of complete plantar arch. In multivariate models controlling for runoff score, DR remained a significant predictor for wound healing (odds ratio, 2.9; 95% confidence interval, 1.1-7.4; $P = .028$) and reduced healing time (hazard ratio, 2.1; 95% confidence interval, 1.2-3.7; $P = .012$). Mean amputation-free survival (75 vs 71 months for DR vs IR; $P = .82$) and median survival (36 vs 33 months DR vs IR; $P = .22$) were not different for DR vs IR.**

Conclusions: **DR according to pedal angiosomes provides more efficient wound healing, but is possible in only one-half of the patients and does not affect amputation-free or overall survival. DR is associated with improved runoff scores, but current runoff scores have little clinical utility in predicting outcomes in CLI patients. (J Vasc Surg 2014;59:121-8.)**

The angiosome concept of vascular anatomy defines three-dimensional vascular territories that are fed by distinct source arteries.[1] Anatomic studies defining specific angiosomes began in the 1970s in plastic surgery as a means to optimize tissue transfer. Over the last several years, the concept has been applied to critical limb ischemia (CLI) as a means to increase the potential for limb salvage when planning distal revascularization. The central argument in favor of an angiosome-based approach is that establishing direct arterial flow to an ischemic region will provide the best chance for wound healing and limb salvage.[2]

Tibial bypass for limb salvage in CLI is not a new concept. Studies have demonstrated the benefit of bypass to the peroneal artery for pedal gangrene[3] and to the dorsalis pedis (DP) artery for heel wounds.[4] Although not specifically designed to do so, from an angiosome perspective, these target vessels represent indirect revascularization (IR). Because both studies demonstrated successful limb salvage, the findings could be used to argue against the benefits of an angiosome-based revascularization. Recent studies have examined the benefit of angiosome-oriented revascularization in both open[5-7] and endovascular procedures.[8-11] Despite extensive study, the concept has not been widely accepted. Most critics believe that regardless of which angiosome is revascularized, bypasses to any of the three crural arteries should provide adequate inflow to the entire foot because of the presence of collateral vessels.[6] Given this ongoing controversy, the primary purpose of our study was to compare rates of wound healing and limb salvage for patients undergoing direct

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revascularization (DR) vs IR. Secondary goals of the study were to examine the feasibility of angiosome-directed revascularization and to compare this approach with the Society for Vascular Surgery (SVS) runoff score to evaluate the utility of each in predicting wound healing.

METHODS

The study was approved by the Institutional Review Board at Oregon Health and Science University. We conducted a retrospective review of our prospectively maintained operative database from 2005-2011. After identifying all lower extremity bypass procedures, we included only those patients who had a bypass to the peroneal, posterior tibial (PT), anterior tibial (AT), or DP arteries. We do not use prosthetic conduit for below-knee bypasses, and thus, all procedures used the autogenous vein. Patients with distal anastomoses at a more proximal level were excluded. We then limited our cohort to those patients with foot and/or ankle wounds to identify the primary affected angiosome. Charts were reviewed for demographic information and comorbidities. Preoperative clinic notes were used to determine wound location, duration of wound prior to intervention, as well as wound dimension. Based on the documented wound location, a primary angiosome was assigned to each lesion based on published reports detailing the skin and subcutaneous tissue perfused by each source artery.[2] In addition, the presence of active infection or osteomyelitis as confirmed on pathologic specimen was noted as well.

Preop pulse examination and ankle-brachial index (ABI) were recorded as documented in the medical record. To characterize arterial inflow, all patients had an angiogram performed preoperatively. For the purposes of our study, these angiograms were reviewed by a board-certified radiologist (D.C.), who had no knowledge of the location of each individual's foot wound, nor the target artery that was ultimately used in each bypass operation. Images were scored using the SVS standards for calculating runoff score, which included assessment of whether the pedal arch was intact.[12] The runoff score is a numerical scale from 1-10 that takes into account the specific outflow vessels as well as the degree of stenosis in each vessel for any given bypass procedure, with 1 representing very little resistance and 10 representing maximal resistance to flow. In isolated tibial artery bypasses, one additional point is added for bypasses to the peroneal artery, to account for the lack of direct connection to the pedal circulation.[12] Thus, a patient with a bypass to a distally occluded peroneal artery would actually be assigned a runoff score of 11. Pedal vessels are scored according to the following scale: 3 - no primary pedal artery patent; 2.5 - partially patent or fully patent beyond critical in-line occlusive lesion; 2 - in-line continuity with patent outflow vessel, but incomplete arch (IPA); 1 - one or more subcritical stenoses but no in-line stenosis; and 0 - fully patent pedal run-off (<20% stenosis). The runoff score was calculated for each patient based on their eventual bypass target. In an attempt to determine the overall burden of vascular disease in each affected limb, we calculated a "modified runoff score" for each patient, which was essentially the sum of the occlusion scores for each of the tibial vessels (AT, PT, and peroneal) as well as their respective pedal branches (AT − DP; PT − medial calcaneal, medial plantar, lateral plantar; and peroneal − anterior perforating branch, calcaneal branch). Under this novel scheme, a limb with all tibial arteries and all subsequent terminal branches occluded would receive a maximum modified runoff score of 27, whereas a limb with fully patent tibial vessels and terminal branches would receive a score of zero. The modified runoff score was intended as a surrogate marker for collateralization. We postulated that those with lower modified runoff scores have more preserved runoff and thus increased collateral blood flow regardless of whether a DR vs IR was performed.

All patients underwent open bypass with autogenous conduit. When available, a single segment of saphenous vein was used. When saphenous vein of sufficient length and caliber was not available, composite venous conduits were created using segments of saphenous and/or arm vein (basilic or cephalic). Based on preoperative vein mapping studies, we recorded the average and minimum diameters of the conduit used in each patient. The distal target vessel was selected by the primary operating surgeon based on its angiographic appearance, the perceived quality of the target vessel, and the length of conduit available. During bypass planning, no consideration was given to whether the operation would provide DR vs IR. Our typical practice is to select the most proximal site on the target vessel that will allow for distal flow to the ischemic foot. Based on prior experience at our institution demonstrating equivalent outcomes for peroneal vs inframalleolar bypass targets for pedal gangrene,[3] we do not make exhaustive efforts to bypass to the foot unless this is the most proximal patent arterial segment.

For the purposes of our analyses, each bypass was classified as either a DR or IR based on the relationship of the target vessel to the primary wound location. Based on previously published studies, DR was defined as bypass to the artery supplying the source vessel of the primary affected angiosome[5] (Table I). For heel wounds, bypasses to either the peroneal or PT artery were both considered DR because of the dual blood supply to this region. Likewise, for isolated toe wounds, bypasses to either the DP or the PT artery were considered DRs. Other bypass target/wound combinations were considered IRs.

Wound outcome was determined by reviewing postoperative records. Primary healing as well as minor and/or major amputation date was noted. Secondary interventions, wound recurrence, and incisional complications such as dehiscence or incisional wound infection were recorded as well. Wounds were considered healed when chart review documented that the wound bed had completely re-epithelialized. Currently, we do not have a dedicated wound center outside of our clinic. In general, small wounds are treated with standard wound dressings, whereas in larger wounds we often use commercially available negative pressure wound dressings. As long as infection is controlled, we allow wounds whatever time