

2D Perfusion Angiography: A Useful Tool for CLI Treatment

Does this method have the potential to help predict clinical outcome and reduce revascularization time?

BY MARCO MANZI, MD, AND JOS C. VAN DEN BERG, MD, PhD

Endovascular therapy has become the first-choice option for patients with critical limb ischemia (CLI). Development of dedicated guidewires, crossing catheters, angioplasty balloons, and the use of distal access has made it possible to treat complex below-the-knee lesions with a high technical success rate. Most interventionists adopt an approach that aims for direct revascularization according to the angiosome concept. However, this concept remains controversial, and two recent studies came to equivocal conclusions.^{1,2} For this reason, indirect revascularization may have a place from a theoretical perspective, but perhaps even more so from a practical point of view, because it is not always possible to achieve direct revascularization.

Although outcomes may improve as more vessels are opened, extensive three-vessel revascularization may be very time consuming and induce higher cost. In addition, restoring the macrocirculation may not be sufficient, especially in diabetic patients, in whom microcirculatory problems play a significant role.³ Currently, there are no methods for periprocedurally determining whether partial (one- or two-vessel) recanalization will be sufficient to resolve rest pain or achieve wound healing. Having the ability to predict the clinical outcome in the interventional suite could potentially reduce procedure time and associated contrast medium and radiation exposure.

TWO-DIMENSIONAL PERFUSION ANGIOGRAPHY

Two-dimensional (2D) perfusion angiography is used in the assessment of the penumbra and has been

applied in evaluating foot perfusion in CLI patients.⁴ The technique is based on standard digital subtraction angiography (DSA), with an injection rate of 3 mL/sec of 12 mL of (1:1 diluted) iodinated contrast medium (iodine 150 mg/mL) and a frame rate of three images/sec. Two-dimensional perfusion images are automatically reconstructed with postprocessing software on a dedicated workstation (Allura Xper FD20 and Interventional Workspot, Philips Medical Systems).

Images are obtained before and after the revascularization procedure. Care should be taken to fully immobilize the foot. The reconstructed images can be evaluated for arrival time, time to peak, wash-in rate, width, area under the curve, and mean transit time. An operator-defined, freehand region of interest can be selected to determine a time-to-density curve, which is typically done at the level of the ulcer/wound.

CASE EXAMPLE

A 77-year-old woman was referred for necrosis of the fourth toe of the right foot. Duplex ultrasound revealed a hemodynamically significant stenosis of the popliteal artery and suspicion of below-the-knee disease (the ankle-brachial index was not measurable). The patient was scheduled for an outpatient endovascular procedure.

After an antegrade puncture of the right common femoral artery, a 4-F introducer sheath (Ultimum EV Hemostasis Introducer, St. Jude Medical) was placed. Diagnostic angiography confirmed the presence of a 75% stenosis of the P2 segment of the popliteal artery as well as multiple stenoses of the anterior tibial artery (Figure 1A). The tibioperoneal trunk was patent, but

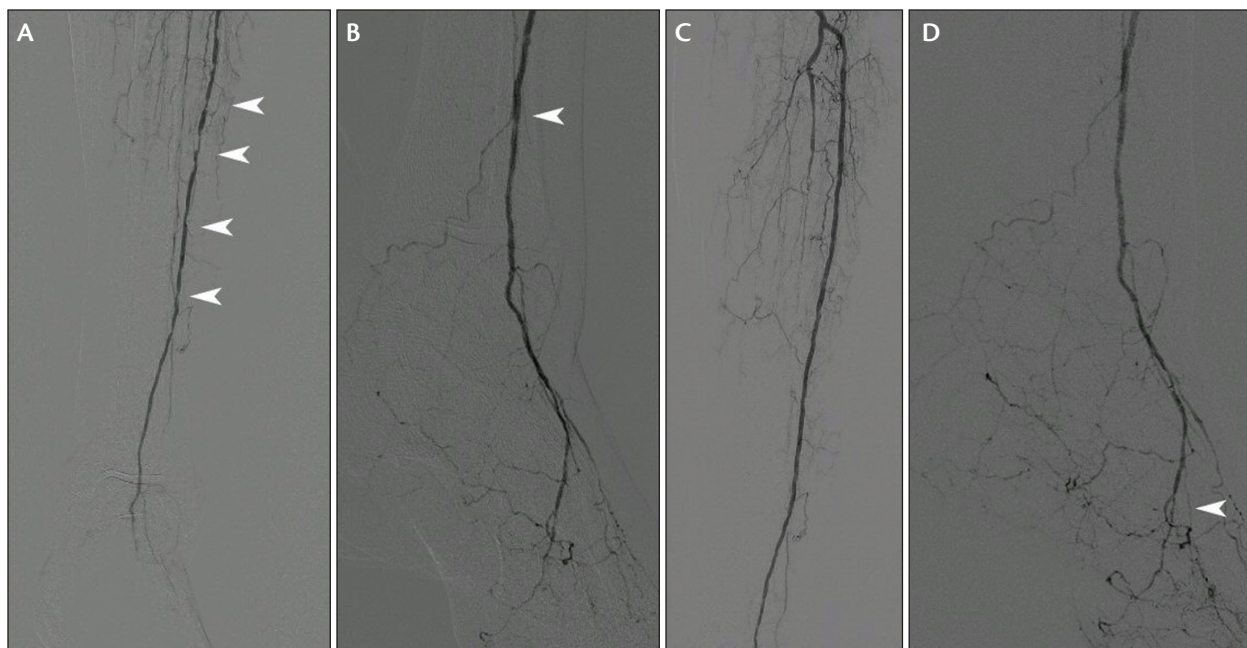


Figure 1. DSA showing multiple stenoses of the anterior tibial artery (arrowheads). Note the absence of filling of posterior tibial artery and fibular artery (A). DSA of the foot (lateral projection) demonstrating patency of the dorsalis pedis artery and distal anterior tibial artery (arrowhead) (B). DSA obtained after balloon angioplasty of the popliteal artery and anterior tibial artery, demonstrating complete luminal reconstitution (C). DSA of the foot after balloon angioplasty of the popliteal artery and tibial artery demonstrating increased peripheral flow on the forefoot; the angiographic series demonstrated an increase of flow velocity (D).

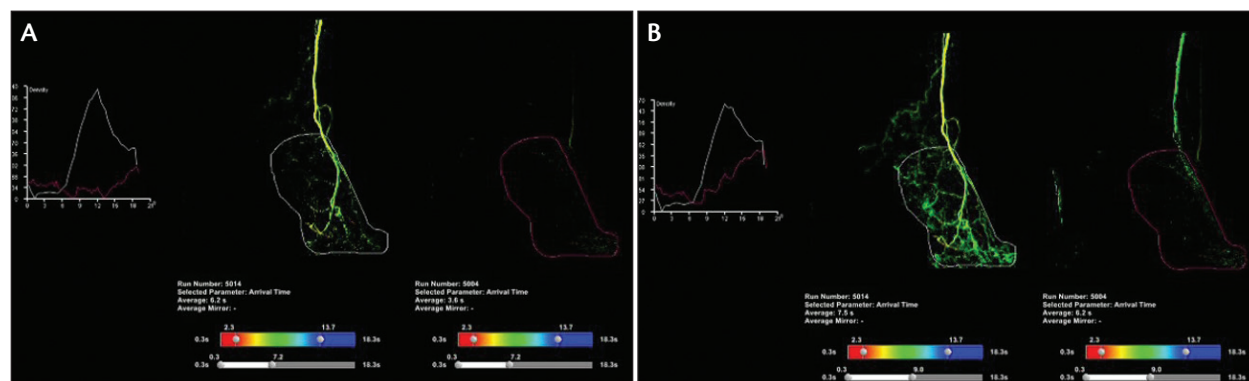


Figure 2. Two-dimensional perfusion angiogram comparing arrival time postangioplasty and at baseline at 7.2 (A) and 9 (B) seconds, respectively; an area of interest is drawn at the level of the forefoot (white and purple circle for post- and preintervention, respectively), and contrast density in the respective areas of interest is represented in the graph in the lefthand panel.

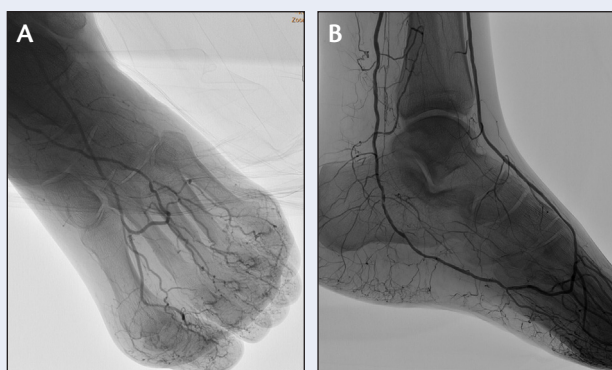
the posterior tibial artery was occluded. The fibular artery had an occlusion at the level of the mid-calf. On the level of the foot, a patent dorsalis pedis artery was seen (Figure 1B). No filling of the plantar arteries was noted.

Angioplasty of the popliteal artery stenosis was performed using a 5- X 40-mm angioplasty balloon (Pacific Plus, Medtronic, Inc.). Subsequently, the stenoses of the anterior tibial artery were crossed with a 0.014-inch guidewire (GlideWire Advantage, Terumo Interventional Systems), the proximal stenosis was dilated with a

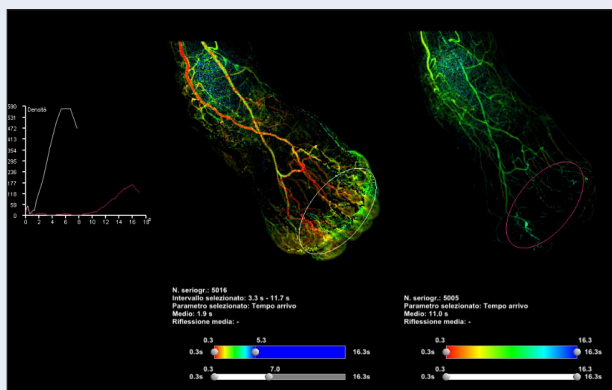
2.5- X 40-mm angioplasty balloon (Tercross, Terumo Interventional Systems), and the distal segment was dilated with a 2- X 200-mm balloon (Armada 14, Abbott Vascular). Control angiography showed an improvement of the flow toward the foot (Figure 1C and 1D). The 2D perfusion angiography, reconstructed from the lateral DSA of the foot, showed a significant improvement in arrival time and perfusion of the forefoot (Figures 2 and 3). Further recanalization of the posterior tibial artery and fibular artery was deemed unnecessary. The clinical course was uneventful, with progressive healing of the ulcer.



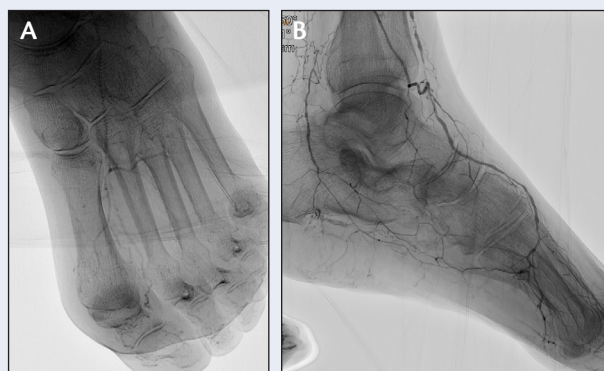
Preoperative anterior-posterior projection (A) and lateral projection (B) for a diabetic patient with Texas University Class (TUC) 3C lesions of the first and fifth toe. A stenosis of the distal posterior tibial artery, an occlusion of the lateral plantar artery, a subocclusion of the medial plantar artery, and an occlusion of the anterior tibial artery can be seen.



Anterior-posterior projection (A) and lateral projection (B) after balloon angioplasty of all the lesions showing recanalization with good caliber and flow of the posterior tibial artery, anterior tibial artery, lateral plantar artery, pedal artery, and arch; absence of flow-limiting dissections or spasm. A light blushing effect can be seen at the level of the first and fifth toe.



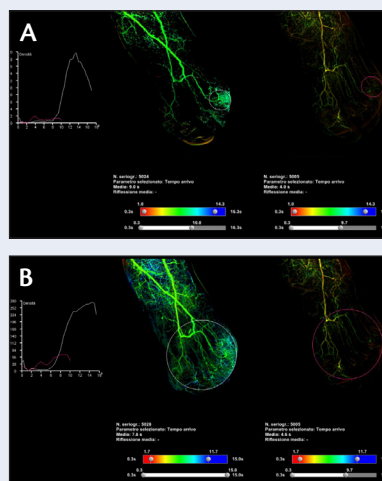
Two-dimensional perfusion angiograms after (middle panel) and before (righthand panel) endovascular revascularization. Density curve on the left panel shows increase of density and shorter arrival time (white line, postintervention; violet line preintervention).



Preoperative anterior-posterior projection (A) and lateral projection (B) for a diabetic patient with a TUC 3D lesion of the fifth toe. There was evidence of an occluded proximal and intermediate segment of the posterior tibial artery (not shown), a stenotic, suspended, distal posterior tibial artery, occlusion of the lateral plantar artery, subocclusion of the medial plantar artery, and an occlusion of the distal anterior tibial artery with a patent stenotic pedal artery and arch.



Anterior-posterior projection (A) and lateral projection (B) after balloon angioplasty of all the lesions showing recanalization with good caliber and flow of the posterior tibial artery, anterior tibial artery, lateral plantar artery, pedal artery, and arch; absence of flow-limiting dissections or spasm. A light blushing effect can be seen at the level of the fifth toe.



Two-dimensional perfusion angiograms in early phase (A) and late phase (B); images show 2D perfusion after (middle panel) and before (righthand panel) endovascular revascularization. Density curve on the left panel shows increase of density and shorter arrival time (white line, postintervention; violet line, preintervention).

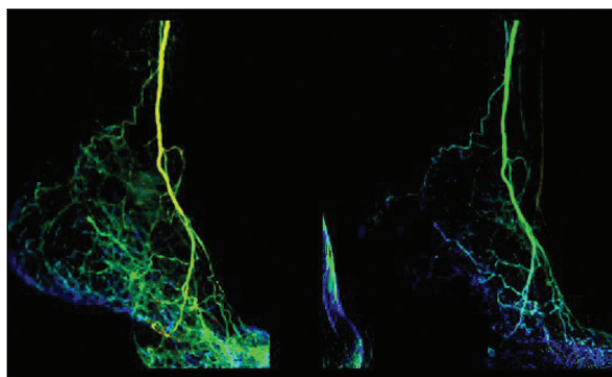


Figure 3. Two-dimensional perfusion angiogram comparing total perfusion postangioplasty (A) and at baseline (B), clearly demonstrating an overall increase in perfusion.

DISCUSSION

Endovascular treatment of CLI has been shown to be effective in preventing amputation.⁵ The goal of revascularization is not only to recanalize the vessels to the foot, but also to obtain a better wound perfusion. One of the problems interventionists face during the procedure is determining when an adequate level of revascularization has been achieved. To choose the optimal strategy, often-times the angiosome concept is used, but there are variations in infrapopliteal vessel anatomy, the presence of collateral connections, and changes in microcirculation that are not related to angiosomes. Therefore, the advantage of direct revascularization versus indirect flow restoration may not be evident in all cases.

The presence of previously absent or improvement of wound blush after endovascular therapy is associated with higher skin perfusion pressure and can be a predictor of limb salvage in patients with CLI.⁶ The wound blush concept is independent from the angiosome concept but is only a qualitative parameter; a method to quantify the blush is not yet available. The same drawback applies to current, commercially available 2D perfusion angiography, but it is likely that quantification of the perfusion will be possible in the near future.⁴ Other methods can evaluate local perfusion, such as indocyanine green fluorescence imaging and tissue oxygen saturation foot mapping.⁷⁻⁹ These methods have been demonstrated to be reliable, but all have the drawback of not being easily implemented in the interventional suite with the patient still on the angiographic table completely draped.

The initial experience with 2D perfusion angiography in the endovascular treatment of patients with CLI is promising. The technique requires additional software acquisition but does not induce additional radiation exposure or an increase in contrast dose. ■

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