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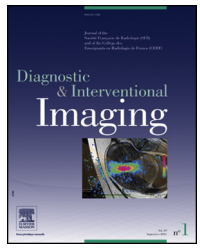

REVIEW / *Cardiovascular imaging*

Infrapopliteal arterial recanalization: A true advance for limb salvage in diabetics

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Abstract The world is facing an epidemic of diabetes; consequently in the next years, critical limb ischemia (CLI) due to diabetic arterial disease, characterized by multiple and long occlusions of below-the-knee (BTK) vessels, will become a major issue for vascular operators. Revascularization is a key therapy in these patients as restoring adequate blood supply to the wound is essential for healing, thus avoiding major amputations. Endoluminal therapy for BTK arteries is now a key part of the vascular specialist armamentarium. Tibial artery endovascular approaches have been shown to achieve high limb salvage rates with low morbidity and mortality and endovascular interventions one should now consider to be the first line treatment in the majority of CLI patients, especially in those with associated medical comorbidities. To do so, the vascular specialist requires detailed knowledge of the BTK endovascular techniques and devices. The first step decision in tibial endovascular therapy is access. In this context, the anterograde ipsilateral approach is generally preferred. The next critical decision is the choice of the vessel(s) to be approached in order to achieve successful limb salvage. Obtaining pulsatile flow to the correct portion of the foot is the paramount for ulcer healing. As such, a good understanding of the current angiosome model should enhance clinical results. The devices used should be carefully selected and optimal choice of guide wire is also extremely important and should be based on the characteristics of the lesion (location, length, and stenosis/occlusion) together with the characteristics of the guide wire itself (tip load, stiffness, hydrophilic/hydrophobic coating, flexibility, torque transmission, trackability, and pushability). Passing through chronic total occlusions can be quite challenging. The vascular interventional radiologist needs therefore to master the techniques that have been recently described: anterograde approaches, including the drilling technique, the penetrating technique, the subintimal technique and the parallel technique; subintimal arterial flossing with anterograde-retrograde procedures (Safari); the pedal-plantar loop technique and revascularization through collateral fibular artery vessels.

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Critical ischemia and diabetes: the current situation

Chronic lower limb critical ischemia (CI) causes pain in patients when they are lying down, trophic problems and gangrene following a major deterioration in foot perfusion. It differs from acute ischemia because it is longstanding, present for more than 15 days and represents stages 4 to 6 of the Rutherford classification which has been accepted since the production of the TASC2 consensus document in 2007 [1]. Distal perfusion often becomes suddenly disrupted after many years of progression of unrecognized or even undiagnosed chronic disease. The natural history of this type of resting ischemia without ''aggressive'' treatment is extremely poor, as 1 year after nocturnal pain or ulceration have developed, 50% of patients are either dead or have been amputated [2—4]. It is estimated that one million amputations are carried out annually throughout the world, i.e., one every 30 seconds, half of which are performed first line with no prior diagnostic assessment [5]. Diabetes and its comorbidities, primarily neuropathy, are the predominant risk factor for developing CI [6,7]. The disease is part of a genuine pandemic with a prevalence of 4% in France, i.e., a figure consistent with the 4 million diabetic patients recognized; 7% of these suffer or have suffered from a foot wound once in their life (between 75,000 and 150,000 annually). More than 70% of healed diabetic wounds recur within 5 years, explaining the high frequency of amputations due to this disease or between 10 and 15,000/year, half of which are estimated to be avoidable as they have been preceded by unrecognized ulceration [8,9]. Not all diabetic wounds are ischemic but compared to neuropathic or mixed ulcers, they are the ones which carry the worst prognosis with a 5-year survival of 40% (65% for neuropathic ulcers) and an amputation rate of 28% (10% in the neuropathy group) [10].

Looking for obstructive arterial lesions is therefore a fundamental stage in the optimal management of a diabetic wound, guided by clinical examination and Doppler ultrasound. One of the fundamental features of diabetic CI is the predominance of diffuse and extensive disease along the subpopliteal tibial arteries either in isolation or concomitantly with proximal femoro-popliteal obstructive lesions [11—13]. Graziani et al. [14] showed through angiography that 417 diabetic patients with ischemic trophic disorders had 2893 lesions, 55% of which were obstructive. These involved the iliac arterial system in 1% of patients but were present in 74% of patients at the asubpopliteal level, 66% of leg lesions were obstructive and 50% were over 10 cm in length. All three arterial systems were involved in 28% of patients whereas in 55%, at least one distal artery remained patent. The authors found a morphological increase in severity classification and noted that category 4 (2 obstructed arteries associated with multiple tibial-fibular and/or femoro-popliteal stenosis) was the most often recognized (36% of patients).

Calcifications are very common [15]; and are a combination of those which are relatively specific for diabetes (and chronic renal impairment), due to calcium deposition in the interstitium of media (Mönckeberg medial calcific sclerosis), which have long been the predominant lesion and spares the lumen of the artery and intimal classification which is characteristic of progression of atherosclerosis, gradually reducing the lumen of the artery. The assessment of calcifications, their severity and distribution is an important stage of the underlying thinking to decide on the method of endovascular recanalization, whether transluminal or extraluminal, as described below.

Revascularization is the only solution which reperfuses the territory of the wound and allows it to heal. Until the end of the 1990s, the only revascularization technique for distal arteries was bypass surgery [16]. The endovascular options which developed for other anatomical areas were hindered at the time by materials which were inappropriate for the morphological features of subpopliteal obstructions. From the start of the millennium, however, the technical feasibility of endovascular methods with non-specific devices has been demonstrated clearly by the pioneers Dorros et al. and Söder et al. [17,18]. In later years, technological research directed towards creating dedicated angioplasty materials has logically been accompanied by an improvement in the technical success rate and this treatment method is being used for increasingly complex lesions [19—21]. As a result, endovascular revascularization has now become the first line choice to treat tibial obstruction in diabetic patients with CI [22—25]. This strategy is based on the superior perioperative safety of results compared to surgery. Results are at least equivalent in terms of efficacy, with a limb salvage rate at 1 year similar to that of surgery [26—28]. In 2008, Romiti et al. [29] made a meta-analysis including 30 studies on infrapopliteal vessel angioplasty (2557 cases) and found a primary patency rate of 48% at 3 years, secondary patency of 62%, limb salvage of 82% and a survival rate of 63%. No significant difference was found between the subgroups in which angioplasty was only used for the distal vessels and those combined with proximal treatment and no difference was also found between endo- and subintimal intentional angioplasty. Ferraresi et al. [30], in 2009, described 101 diabetic patients with CI treated by angioplasty for exclusively subpopliteal disease and found a limb salvage rate of 91% at 3 years, 9% of patients having died at 1 year, and a restenosis rate of 42% with only 3 patients undergoing a further angioplasty because of recurrence of the CI. In 2013, Park et al. [31] described a technical success rate of 93%, a limb salvage rate of 91% at 1 year and a primary patency rate of 75% in 63 patients in a clinical population similar to that of Ferraresi.

Healing is a phenomenon which is directly related to arterial flow and the basic approach as the ideal revascularization strategy therefore aims to maximize perfusion of the foot. Until recent years, the preferred endovascular approach was to seek direct anterograde blood flow in one of the three leg arterial systems (according to the principle that one patent vessel is better than nothing), generally defined as the artery which was most technically accessible to recanalization. A second chronological stage designed to optimize limb salvage aimed to achieve as complete revascularization as possible on the basis that 3 open vessels were better than 2, which were better than one! In 2010, Peregrin et al. [32] therefore showed that complete revascularization of the leg arterial system in diabetic patients with CI had a 1 year limb salvage rate of 56% if direct patency was not obtained in at least one vessel (0 vessels open) and 73%, 80% and 83% if one, 2 or 3 vessels became patent again