New possibilities of maximal revascularization of the foot as a limb salvage procedure in diabetics as illustrated by two case reports

G. Sauvant[1], B. Hüttenmoser [2], P. Soyka [2], S. Rüttimann[1]

[1]Medizinische Klinik, Kantonsspital Schaffhausen, Schweiz
[2]Chirurgische Klinik, Kantonsspital Schaffhausen, Schweiz

Summary
Diabetics and patients with chronic renal insufficiency often have severe peripheral arterial disease of the distal lower limbs with obstructions of crural and pedal arteries with imminent risk for critical ischemia and major amputation. Neuroischemic foot ulcers have been shown to fail to heal even after successful arterial revascularization. We report on 2 diabetic patients with neuroischemic diabetic foot syndrome and different clinical outcome after percutaneous transluminal angioplasty of chronic occluded crural arteries and discuss, whether endovascular revascularization of infrapopliteal *and* pedal arteries, if possible with complete plantar arch, could promote ulcer healing in neuroischemic diabetic foot ulcers.

Zusammenfassung
Diabetiker und Patienten mit chronischer Niereninsuffizienz leiden häufig an einer peripheren arteriellen Verschlusskrankheit der unteren Extremitäten mit Befall der Unterschenkel- und Fussarterien. Nicht selten entwickeln sie eine chronische kritische Ischämie mit Bedrohung der Extremität. Auch nach erfolgreicher Revaskularisation der Unterschenkelgefässe kann eine Abheilung neuroischämischer Fussulzera ausbleiben. Wir berichten über 2 Diabetiker mit neuroischämischem diabetischem Fusssyndrom und unterschiedlichen klinischen Verläufen nach endovaskulärer Rekanalisation chronisch verschlossener Unterschenkelgefässe und diskutieren die Bedeutung einer Revaskularisation der Fuss- und der Fussbogenarterien bei neuroischämischen diabetischen Fussulzera.

Key words: critical limb ischemia, diabetic foot syndrome, wound healing, angioplasty, infrapopliteal occlusion, plantar arch

Introduction
Diabetes mellitus and chronic renal insufficiency are associated with peripheral arterial occlusive disease favouring obstructions of distal lower limb arterial segments, including pedal arteries, representing a high risk for the development of critical limb ischemia with need of major amputation. More than fifty percent of patients with chronic renal disease are unsuitable for distal bypass grafting [5]. Recently, several studies have documented comparable short and midterm results for surgery and angioplasty regarding limb salvage in patients with critical limb ischemia [4,22,13]. Angiosome models of reperfusion have been proposed as a guide for target revascularisation of obstructed infrapopliteal vessels, depending on ischemic ulcer localisation [1].

Case reports
We present two diabetic patients suffering from critical limb ischemia and ischemic foot ulcers Wagner grade 3-4 (using the Wagner classification 1 to 4) with different management and different outcome.

Case 1:
A seventy-three-year old male with type 2 diabetes mellitus since 23 years was admitted to the hospital in June 2006 because of critical ischemia of the left leg and gangrene of the left big toe. In 2005 he had a below-knee amputation on the right side due to fulminant infection. At admission he was hemodynamically stable and had signs of peripheral neuropathy, nephropathy and angiopathy. Clinically we suspected an osteomyelitis of the left big toe (Wagner 3). The pulses of the left foot were absent, whereas the femoral and popliteal pulses were palpable. The ankle-brachial index (ABI) was 0.5. Electronic oscillography suggested occlusions of the tibio-peroneal arteries. Duplex color scan showed no hemodynamically significant stenoses of iliac, femoral and popliteal arteries. Angiography revealed long chronic occlusions of the peroneal and tibial arteries and shorter occlusions of the plantar arch (fig. 1A). In agreement with the vascular surgeons, we decided to perform an endovascular procedure and not bypass surgery. The peroneal artery was successfully recanalized, but revascularization of the posterior tibial artery failed (fig. 1B). Transphalangeal amputation of the big toe was necessary. Though the perfusion of the foot improved, suggested by oszillography and ankle

pressure, the lesion didn't heal. That's why, 3 weeks after the failed first angioplasty, we tried another percutaneous transluminal angioplasty (PTA) of the posterior tibial artery. This time the posterior tibial artery was revascularized successfully (fig. 1C). In the meantime, the patient had developed an infection of the left forefoot. Pseudomonas aeruginosa was found in tissue cultures. Despite local vacuum assisted closure therapy, antipseudomonal antibiotics, intravenous prostanoid therapy (Ilomedin) and CT-guided chemical sympatectomy a below-knee amputation became unavoidable. Thereafter the patient did well until 2008, when he died of heart failure and pericardial effusion with cardiac tamponade.

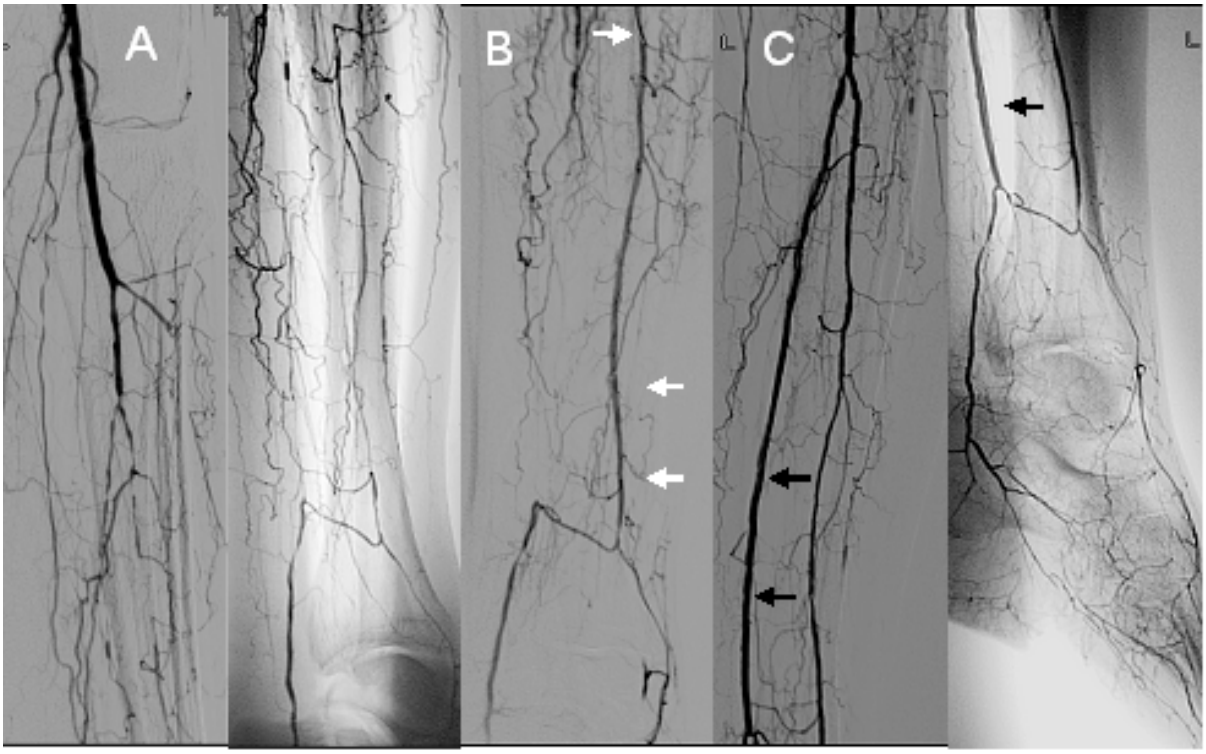

Figure 1: A. Angiography at admission: occlusions of peroneal and tibial arteries. B. After antegrade recanalization of the tibio-peroneal trunk and of the peroneal artery using a 0.018-inch hydrophilic guide wire (V18, Boston scientific) and low profile balloons (3mm/4cm Savvy, Cordis and 2.5mm/8cm Submarine, Invatec), 4F sheath, antegrade common femoral artery approach, support with 4F-multipurpose catheter. C. After angioplasty of the posterior tibial artery with a 0.018-inch hydrophilic guide wire (V18, Boston scientific) and a low profile balloon (3mm/12cm Submarine, Invatec), 4F sheath, antegrade common femoral artery approach, support with 4F multipurpose catheter

Case 2:

A sixty-three old male with hypertension and diabetic nephropathy, neuropathy, osteoarthropathy and angiopathy was repatriated from abroad and hospitalized in September 2008 because of critical limb ischemia and necrotizing fasciitis of the right foot due to an injury on the heel. He presented the clinical picture of a dominantly neuropathic rather than an angiopathic diabetic foot. In order to drain the plantar abscess he had had surgical incisions of the planta pedis 11 days earlier. Because of large extension of necrotic tissue, a below-knee amputation was taken into consideration. Five years earlier, the patient had undergone a transmetatarsal amputation of the toes I to III because of osteomyelitis and abscess of the right forefoot. Since two years before admission to our hospital, he had suffered from a malum perforans of the metatarsale I stump. At admission the vital signs were normal. The right foot showed a necrotizing plantar fasciitis and chronic malum perforans (Wagner 4). The right dorsalis pedis pulse was weak, the other foot pulses were absent. The femoral and popliteal pulses were palpable. Electronic oscillography suggested obstructions of the tibio-peroneal arteries. Laboratory tests of the anemic patient (Hb 9.6g/dl) showed signs of bacterial infection (CRP 115mg/dl, leucocytosis of 17.7x10.9/l with a shift to the left). Creatinine was elevated (135umol/l) with a calculated clearance of 53ml/min. Several blood cultures were negative. X-Rays showed signs of diabetic osteoarthropathy of the forefoot without osteolysis (fig 2A). Tissue culture grew staphylococcus aureus. The patient initially received treatment with imipenem, then according to sensitivity cotrimoxazol. Further management consisted of regular debriding of necrotic or gangrenous tissue (fig.2B), vacuum assisted closure therapy, correction of anemia and optimizing serum glucose levels by insulin treatment.

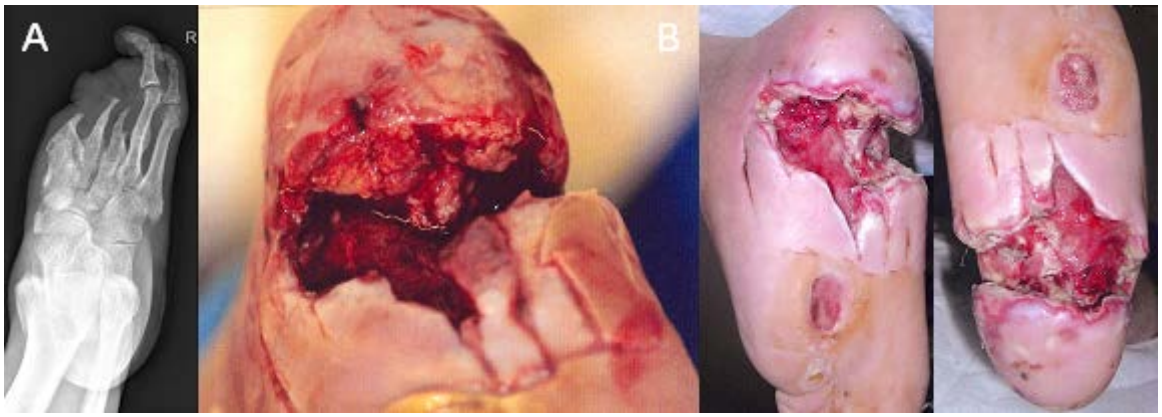

Figure 2: A. Neuropathic osteoarthropathy without osteomyelitis (DNOAP type I by Sander's). B. Lesion after debriding on day 1

Angiography showed long chronic occlusions of the peroneal, a short occlusion of the anterior tibial artery and of the distal posterior tibial artery. The plantar arch was also partially occluded (fig. 3A).

Figure 3: A. Arteriography at admission: occlusions of tibio-peroneal arteries. B. After endovascular recanalization of the anterior tibial artery (arrows) with a 0.018-inch hydrophilic guide wire (V18, Boston scientific) and a low profile balloon (2.5mm/8cm, Pacific, Invatec), 4F sheath, antegrade common femoral artery approach

An endovascular procedure was prefered to surgery. On day 6 the anterior tibial artery was revascularized. Unfortunately, the antegrade attempt to recanalize the distal posterior tibial artery failed (fig. 3B). A few days after the intervention the wound surface began to develop granulation tissue, except for the heel. To improve the plantar perfusion a retrograde approach in pedal-plantar loop technique was planned in order to recanalize the occluded distal posterior tibial artery. On day 16, the peroneal artery and the plantar arch until to the medial plantar artery were successfully recanalized (fig. 4B). The retrograde attempt to revascularize the occluded, severely calcified, distal posterior tibial artery failed.

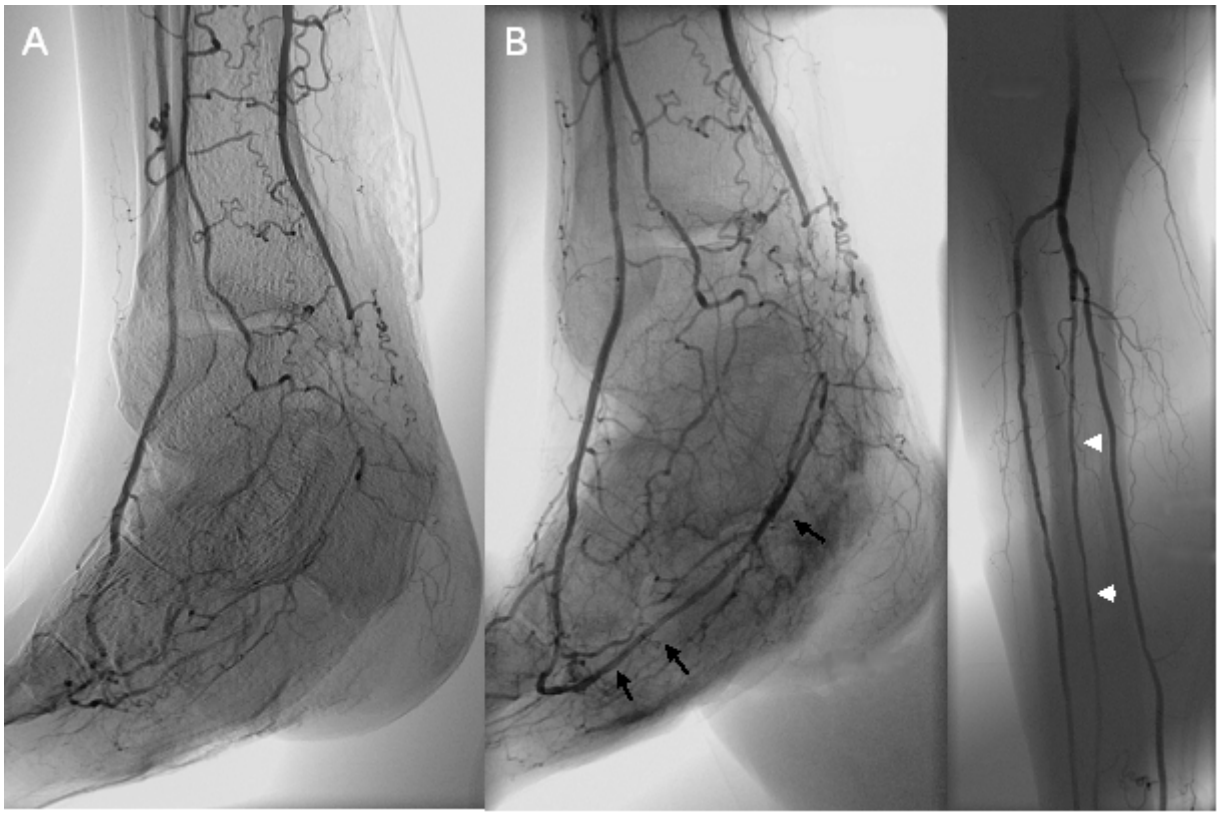

Figure 4: A. Before angioplasty. B. After successful endovascular recanalization of the peroneal artery (white arrows), of the plantar arch and medial plantar artery (black arrows) in pedal-plantar loop technique with a 0.014-inch hydrophilic guide wire (PT 2, Boston scientific) and a low profile balloon (Amphirion deep, 2mm/8cm, Invatec), long 5F sheath, antegrade common femoral artery approach, support with balloon

Although a tendency toward wound healing was observed after the intervention, an atrophic area in the depth of the heel remained. Repeated debriding of necrotic tissue had led to a cavitiy in the heel. The ultimate therapeutic option to avoid a foot (Chopart) or major amputation was to revascularize the occluded distal posterior tibial artery, in the hope, that branches of the posterior tibial artery would improve the perfusion of the lateral heel. On day 50, the plantar arch including the distal posterior tibial artery was finally successfully recanalized (fig. 6B).

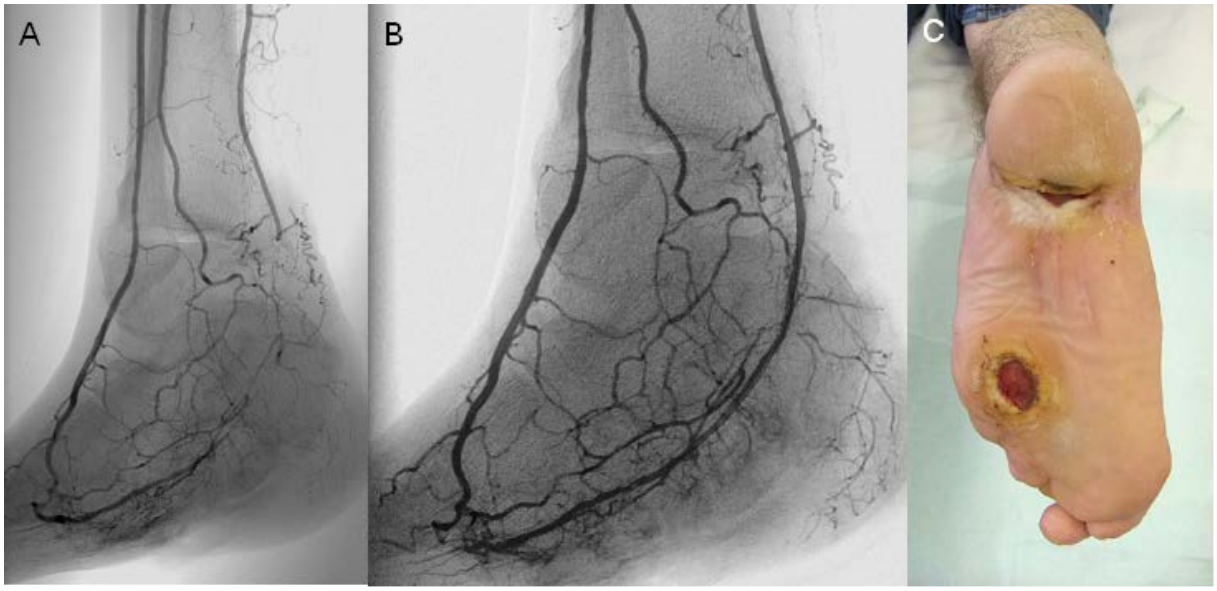

Figure 5: A. Before angioplasty. B. After endovascular recanalization of the distal posterior tibial artery with 0.018-inch hydrophilic guide wire (V18, Boston scientific) and low profile balloons (2.5mm/4cm and 2.0mm/6cm, Pacific, Invatec), 4F sheath, antegrade common femoral artery approach, support with 4F multipurpose catheter. C. Lesion after 6 months

As a result of the entire revascularization of the plantar arch the necrosis on the heel began to recover. Yet the malum perforans over the caput of metatarsale I didn't heal (fig. 6C) despite relief of mechanical load. Nevertheless, 6 months after hospitalization the patient was mobile and independent in daily activities.

Discussion

Both cases we describe suffered from longlasting type 2 diabetes mellitus with chronic limb ischemia and neuroischemic foot ulcers, which threatened the extremity. In the first case, a major amputation could not be avoided despite several endovascular interventions with revascularization of two crural arteries and permeable dorsalis pedis artery, surgical debridement, vacuum assisted closure therapy, antibiotics, optimized glucose levels, symptectomy and intravenous prostanoid therapy. At that time, we hadn't the technical skills to reopen the obstructed plantar arch. In the second case however, the lower limb was finally preserved, despite the expansive necrotic lesions of the foot with necrotizing fasciitis and ulceration of the heel. Three endovascular interventions with reconstruction of the plantar arch were necessary, before the necrotic lesions on the heel began to heal. Interestingly, the recanalization of the fibular artery and the retrograde angioplasty of the medial plantar artery in pedal-plantar loop technique did not improve the arterial perfusion enough to enable to recover the necrosis in the depth of the heel. The wound began to heal only after successful revascularization of the entire foot. Nevertheless the malum perforans persisted.

Diabetics have a 15% lifetime risk of developing a foot ulcer, of whom up to 24% will require a major amputation [16]. Even if the majority of diabetic foot ulcers are neuropathic ulcers, nearly 50% are combined neuroischemic and should be assessed for endovascular or surgical revascularization procedures aiming to improve blood flow [15]. Recently it was shown that diabetics with critical limb ischemia benefit from early and, if necessary, repeated endovascular or surgical revascularizations [4,21,7]. Angiosome analysis is helpful for the decision making for the extend of revascularisation. The limb salvage rate after infrapopliteal PTA ± stenting is about 97-98% at 1 year, and about 93% at 3 years in centers of experience [8], with a patency rate at 1 year of 68-75% [3]. A recent meta-analysis of the results after infrapopliteal angioplasty for critical lower limb ischemia showed a limb salvage rate of 91-95% at 1 year and of 79-85% at 3 years [18]. More recently, different new endovascular techniques for revascularization of infrapopliteal and pedal arteries were published [10,14,20,11]. Possibly, these new endovascular techniques, alone or in combination with bypass-surgery, may play an increasing role in the efforts to reduce major amputations. The clinical follow-up of wound progress in the second case report seems to emphasize the importance of maximal revascularization, as the lesion on the heel improved only after complete recanalization of the peroneal, tibial and pedal arteries. Of course, it is a matter of speculation, whether a below-knee amputation would have been prevented in the first case, if the pedal arteries would have been recanalized.

Neuropathy, angiopathy and an impaired immune response contribute to failure of the healing process in diabetic ulcers. A recent multi-center study identified a few negative predictive factors for healing in diabetic foot ulcers: peripheral neuropathy, end-stage renal disease, cardiac insufficiency and the inability to walk [17]. Additionally, a number of authors have demonstrated that diabetics suffering from peripheral neuropathy do not only have an impaired wound healing, but also have a higher risk of ulcer recurrence. Neuroischemic foot ulcers have been shown to relapse or fail to heal even after successful arterial revascularization, probably because the blood flow to the foot was just improved, but not completely restored [12,2,6,19]. However, it should be pointed out that at the time the mentioned studies were published, stiff coronary guide wires and low profile balloons for endovascular recanalization of the pedal arteries and the plantar arch were not in use. Nevertheless, it remains unknown whether a very distal restoration of blood flow to the foot really improves wound healing, regarding the fact that a lot of different factors influence ulcer healing in diabetics. A limitation of these new endovascular techniques is their applicability. They are challenging, expensive and time-consuming and may only be applied for selected patients, depending on individual vascular anatomy and burden of arteriosclerosis. Whether a more aggressive, but also more risky attempt to revascularize pedal arteries may contribute to enhance the limb salvage rate and to reduce ulcer recurrence, is object of further studies.

Acknowledgements: I would like to thank my teacher in endovascular techniques, Dr. Ernst Schneider, for his support and for reviewing the manuscript, G.S.

1 Alexandrescu VA, Hubermont G, Philips Y, et al. Selective primary angioplasty following an angiosome model of reperfusion in the treatment of Wagner 1-4 diabetic foot lesions: practice in a multidisciplinary diabetic limb service. J Endovasc Ther 2008; 15: 580-593.

2 Apelquist J, Larsson J, Agardh CD. Long-term prognosis for diabetic patients with foot ulcers. J Intern Med. 1993; 233: 485-491.
3 Bosiers M, Hart JP, Deloose K, et al. Endovascular therapy as the primary approach for limb salvage in patients with critical limb ischemia: experience with 443 infrapopliteal procedures. Vascular 2006; 14: 63-69.
4 Dick F, Diehm N, Galimanis A, et al. Surgical or endovascular revascularisation in patients with critical ischemia: influence of diabetes mellitus on clinical outcome. J. Vasc. Surg. 2007; 45:751-761.
5 Diehm N, Rohrer S, Baumgartner I, et al. Distribution pattern of infrageniculate arterial obstructions in patients with diabetes mellitus and renal insufficiency - implications for revascularization. VASA 2008; 37:265-273.
6 Dietzek AM, Gupta SK, Kram HB, et al. Limb loss with patent infra-inguinal bypasses. Eur J Vasc Surg. 1990; 4: 413-417.
7 Faglia E, Mantero M, Caminiti M, et al. Extensive use of peripheral angioplasty, particulary infrapopliteal, in the treatment of ischemic diabetic foot ulcers: clinical results of a multicentric study of 221 consecutive diabetic subjects. J Intern Med. 2002; 252: 225-232.
8 Ferraresi R, Centola M, Ferlini M, et al. Long-term outcomes after angioplasty of isolated, below-the-knee arteries in diabetic patients with critical limb ischemia. Eur J Vasc Endovasc Surg.2009; 37: 336-342.
9 Fusaro M, Agostini P, Biondi-Zoccai G. “Trans-collateral” angioplasty for a challenging chronic total occlusion of the tibial vessels: a novel approach to percutaneous revascularization in critical lower limb ischemia. Catheter Cardiovasc Interv..2008; 71: 268-272.
10 Fusaro M, Dalla Paola L, Biondi Zoccai G. Pedal-plantar loop technique for a challenging below-the-knee chronic total occlusion: a novel approach to percutaneus revascularisation in critical lower limb ischemia. J Invasive Cardiol. 2007; 19: E34-37.
11 Graziani L, Silvestro A, Monge L, et al. Transluminal angioplasty of peroneal artery branches in diabetics: initial technical experience. Cardiovasc Intervent Radiol. 2008; 31: 49-55.
12 Hafner J, Schaad I, Schneider E, et al. Leg ulcers in peripheral arterial disease (arterial leg ulcers): impaired wound healing above the threshold of chronic critical limb ischemia. J Am Acad Dermatol. 2000; 43:1001-1008.
13 Lazaris AM, Tsiamis AC, Fishwick G, et al. Clinical outcome of primary infrainguinal subintimal angioplasty in diabetic patients with critical lower limb ischemia. J. Endovasc Ther. 2004; 11: 447-453.
14 Montero-Baker M, Schmidt A, Bräunlich S, et al. Retrograde approach for complex popliteal and tibioperoneal occlusions. J Endovasc Ther. 2008; 15: 594-604.
15 Nelzen O, Bergqvist D, Lindhagen A. Long-term prognosis for patients with chronic leg ulcers: a prospective cohort study. Eur J Vasc Endovasc Surg. 1997; 13: 500-508.
16 Norgreen L, Hiatt WR, Dormandy JA, et al. Inter-Society Consensus for management of peripheral arterial disease (TASC II). Eur J Vasc Endovasc Surg. 2007; 33 Suppl 1: S32-55.
17 Prompers L, Schaper N, Apelqvist J, et al. Prediction of outcome in individuals with diabetic foot ulcers: focus on the differences between individuals with and without peripheral arterial disease. The EURODIALE Study. Diabetologia. 2008;23: 14-25.
18 Romiti M, Albers M, Brochado-Neto FC et al. Meta-analysis of infrapopliteal angioplasty for chronic critical limb ischemia. J Vasc Surgery 2008; 47: 975-981.
19 Soyka P, Ganzoni N. Loss of extremity despite patent vascular reconstruction. Helv Chir Acta. 1991; 58:177-180
20 Spinosa DJ, Leung DA, Harthun NL, et al. Simultaneous antegrade and retrograde access for subintimal recanalisation of peripheral arterial occlusion. J Vasc Interv Radiol. 2003; 14: 1449-1454.
21 Taylor SM, Kalbaugh CA, Blackhurst DW, et al. A comparison of percutaneus transluminal angioplasty versus amputation for critical limb ischemia in patients unsuitable for open surgery. J Vasc Surg. 2007; 45: 304-310.
22 The BASIL Trial Participants. Bypass versus angioplasty in severe ischemia of the leg (BASIL): multi-centre, randomized controlled trial. Lancet. 2005; 366: 1925-1934.

Address of correspondence:
Dr. med. Gilles Sauvant, Angiologie, Medizinische Klinik, Kantonsspital Schaffhausen, Geissbergstrasse 81, 8200 Schaffhausen, Switzerland, E-mail: gilles.sauvant@spitaeler-sh.c