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Laser angioplasty of peripheral vessels: complementary procedures

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Abstract. From 1987 to 1991 we treated 167 peripheral arteries in 143 patients by laser-assisted balloon angioplasty using a Neodymium YAG laser. Embolism following or accompanying laser angioplasty was treated by aspiration and local lysis with urokinase in 10 cases. To improve long term results balloon dilatation of stenoses of the proximal vessel was performed in 36 cases (5 iliac arteries, 30 femoral arteries, 1 bypass), and of the distal vessel in 31 (16 femoropopliteal arteries, 15 crural arteries). Percutaneous transluminal angioplasty of recurrent stenosis within the recanalised segment was necessary in 11 patients. It was also possible to reopen 10 reocclusions, 6 by aspiration and local lysis and 4 by a second laser angioplasty. Both the high technical success rate (90.4%) and the good long term results (cure rate after 3 years 66.8%) are due in part to complementary procedures.

Key words: Laser angioplasty – Complications – Aspiration – Local thrombolysis

Introduction

Controlled removal of obstructive atherosclerotic plaques by laser energy applied through flexible fiber-optic catheters has been the topic of intensive investigations during recent years. Experimental work showed that fibrofatty plaque tissue can be ablated by laser energy [1–4]. The development of contact probes markedly improved the utility of intravascular lasers [5–7]. Clinical studies, some of them controlled and prospective evaluated the efficacy and safety of laser angioplasty in a large number of patients [8, 9]. Currently the question is whether laser angioplasty should be used in combination with, or as an alternative to, conventional balloon angioplasty. The aim of this study was to determine whether the use of laser angioplasty can reduce the number of other procedures, such as balloon dilatation, local thrombolysis or aspiration of clot.

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Methods

A neodymium-yttrium-aluminium-garnet (Nd-YAG) laser (Surgical Laser Technologies, Malvern) with a wavelength of 1064 nm was used in combination with a sapphire-contact-probe catheter (1.8, 2.2 or 3.0 mm in diameter). The power setting for intravascular laser recanalisation was 10–15 W in long pulses of 1 s duration. All procedures were carried out percutaneously, under fluoroscopic guidance. After arterial puncture and antegrade insertion of a catheter introducer sheath, 5000 IU heparin was given into the artery.

Primary success was defined as traversing the lesion with the laser catheter and reducing residual stenosis to less than 30% by balloon dilatation. All results were documented by means of intra-arterial digital subtraction angiography (DSA).

After successful laser recanalisation, intravenous infusion of heparin (1000 IU/h) was continued for 2 days. Most patients subsequently underwent long-term platelet inhibition therapy (300 mg acetylsalicylic acid and 75 mg of dipyridamole tds).

If any complication such as embolism or early reocclusion occurred, clot was aspirated using a thin-walled 8 F catheter, introduced via a 9 F sheath (Cordis, Brussels, Belgium). Local thrombolysis was achieved by infusion of urokinase (30000 IU/h) into the thrombus, plus heparin 1000 IU/h i.v.

If there was any significant proximal stenosis in e.g. the iliac artery balloon dilatation of this stenosis was performed in a second session before or after laser angioplasty, using catheters with balloon diameters from 7–9 mm. Haemodynamically significant distal stenoses in e.g. the crural arteries were dilated with low-profile balloon catheters of 3–5 mm diameter in the same session. These were inserted over steerable 0.020-inch guide wires with floppy tips (Schneider Shiley golden tip; Cordis platinum tip).

Follow-up was by Doppler ultrasound (ankle-brachial indexes, segmental wave form, and colour analysis) at 2 days, 6 weeks, 3 and 6 months and 1 year after the procedure and then yearly. When recurrent stenosis or occlusion was suspected or the patient's condition deteriated, intra-arterial or, in some cases, intravenous DSA was performed. Data were collected and analysed according to a modified Kaplan-Meier life table analysis.

We studied 167 recanalisations in 143 patients in Fontaine's stages II b to IV. The mean patient age was 67 years (range 41–89 years). Most cases involved occlusion of the superficial femoral artery, but in about 20% totally obstructed popliteal crural arteries were treated; we treated only a few iliac artery occlusions. The length of the occlusion was 1–20 cm (average 6.6 cm).

Results

When we failed to pass the lesion with a straight Bentson guide wire, it was possible to traverse it by means of the laser catheter in 151 of 167 cases, which represents an immediate success rate of 90.4%. Occluded segments up to 5 cm in length were traversed in 93.3%, those 5–10 cm long in 90.7%, and those 10–15 cm long in 81.8%, whereas immediate success was achieved in only half of the occlusions longer than 15 cm. In all successful procedures, the channel created by vaporisation of the target tissue was too narrow for a haemodynamically sufficient result, because the sapphire tip was only 1.8–3 mm in diameter. Therefore, it became necessary to widen the channel by conventional balloon angioplasty to achieve a satisfactory result (Fig. 1).

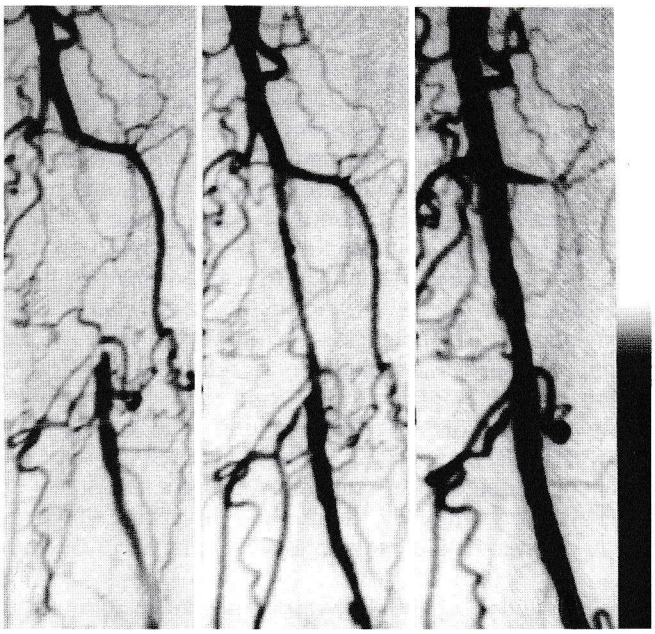


Fig. 1. *(Left)* Complete occlusion of the superficial femoral artery with some direct collateral supply. *(Centre)* Passage of the 2.2 mm diameter tip laser catheter has produced only a small, irregular channel. Only after a 6 mm diameter balloon catheter dilatation was a satisfactory result achieved *(right)*

Complications included 5 perforations and 3 dissections of the artery, all of which were treated conservatively and did not result in a deterioration of the clinical condition of the patient. The same was true for two large local haematomas and 1 retroperitoneal haematoma originating from the puncture site.

In 9 patients (5.4%), peripheral macroembolisation occurred as a consequence of laser or balloon angioplasty. Spontaneous crural embolisation occurred in 1 patient within 24 h of the diagnostic angiogram and before the planned recanalisation, the embolus presumably originating from the thromubs occluding the superficial femoral artery. Figure 2 shows an example of peripheral embolisation as a sequel to laser-assisted balloon angioplasty. The presumed causes of these embolisations were reported elsewhere [10]: in 3 cases, the probable cause was fresh thrombus on the end of an old occlusion; in 3 others, forceful mechanical recanalisation was attempted with different guide wires and catheters in addition to applying laser energy. The other cases remain unclear, but the average length of these occlusions was 8.6 cm, as against 6.6 cm in the uncomplicated cases.

In the 9 cases of laser- or balloon-induced embolus and 1 of spontaneous embolisation we used aspiration alone in 3, thrombolysis alone in 1 and a combination of the two in the remaining 6, the result in all 10 cases being satisfactory. In the patients with laser- or balloon-induced embolism, the embolic incident had no influence whatsoever on the long term results. The patient with spontaneous embolism suffered a recurrent occlusion of the superficial femoral artery 6 months after the procedure.

Four patients showed reocclusion of the recanalised segment within 48 h of treatment, accompanied in 3 by peripheral embolism, these latter patients suffering major deterioration of their condition as a result. However, both early reocclusion and the accompanying embolism could be treated by combined aspiration and lysis. One patient suffered a further occlusion 2 weeks later and a bypass operation was necessary.

It is well known that the long-term results of surgical reconstruction are dependent on the condition of the arteries on either side of the operated segment. This is true for endarterectomy as well as for vein grafts [11] and even more so for synthetic grafts [12]. A statistically significant dependence on the condition of the runoff has also been shown for the results of balloon angioplasty, this being the case for stenoses as well as occlusions [13]. Similar results were obtained in the Austrian multicenter study of laser angioplasty [9]. The 3-year patency rate for femoral artery occlusions treated by laser angioplasty was 63% where the peripheral runoff was favourable (two or three patent arteries), whereas the patency rate dropped to 52% when this was not the case. Thus, it is essential to treat not only the obviously occluded segment but also lesions in the proximal and runoff vessels [14, 15].

Of the patients included in this study 36 showed significant stenosis of the arteries supplying the segment to be treated by laser angioplasty (Fig. 3).

We carried out additional dilatation of the pelvic arteries on 5 patients undergoing laser recanalisation in the thigh. A further 30 stenoses were dilated in the femoro-

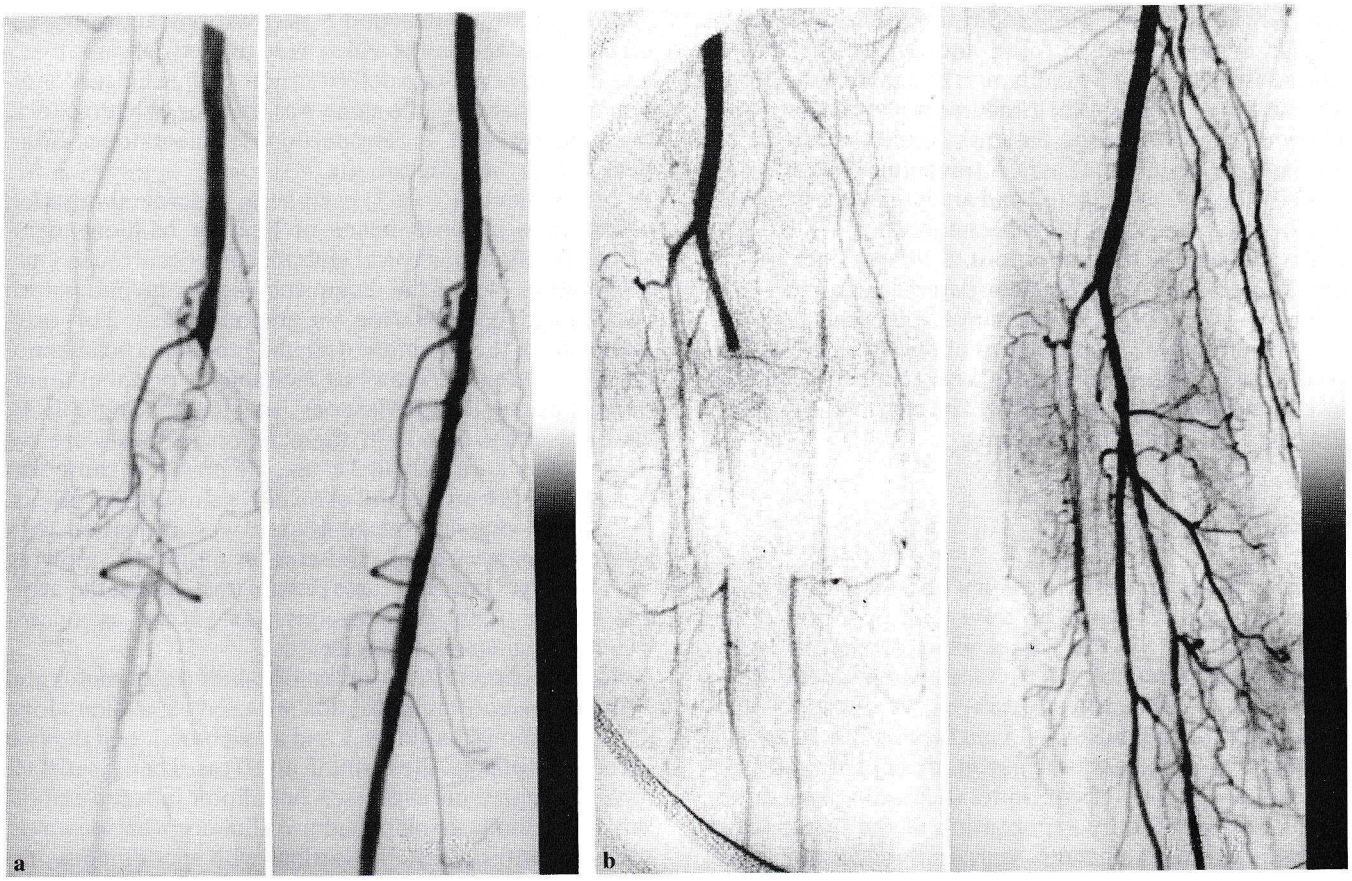


Fig. 2. **a** A 7 cm occlusion of the superficial femoral artery *(left)* was treated by laser and balloon angioplasty *(right)*. **b** An embolic occlusion of the tibiofibular trunk was noted, occlusion of the anterior tibial artery being longstanding *(left)*. After aspiration of the thrombus, the tibiofibular trunk was open, with good runoff to the posterior tibial and fibular arteries *(right)*

popliteal region and 1 within a bypass, all of which were proximal to complete occlusions.

Stenoses in the distal vessels are treated in an analogous fashion. After recanalisation of the occluded segment, a suitable balloon catheter is advanced via a guide wire and peripheral stenoses are immediately dilated. Figure 4 shows such a case. We carried out 16 such procedures, 6 in the distal superficial femoral artery and 10 in the popliteal artery.

With current equipment, treatment is not restricted to the proximal calf: very distal vessels are also accessible (Fig. 5). Thus, we treated the crural region in 15 patients and the femoropopliteal region in 16, a total of 31 dilatations distal to the occlusion. No patient showed a complication attributable to these additional measures.

The maximum follow-up time was 3 years, the average being 10.2 ± 13.9 months. During this period, 11 recurrent stenoses were seen in the recanalised segment, all of which were overcome by repeat balloon angioplasty. In 27 cases, occlusions reccured, including the 4 mentioned above. Six fresh occlusions were reopened using a combination of aspiration and lysis. In 4 cases, repeat laser angioplasty was successful. Five patients underwent bypass operations, and in 1 case an amputation of the calf was unavoidable. Eleven patients were treated conservatively.

Discussion

In recanalisation procedures, an immediate technical success rate of more than 90% – as in laser angioplasty – must be considered very high. Chronic occlusions in the femoropopliteal region, up to a length of 15 cm, are particularly suitable for laser recanalisation. With occlusions more than 15 cm in length the immediate success rate was only 50%, which we attribute to the lack of steerability of the laser catheter in its present form. The arterial perforations and dissections (in 4.8%) described here are also at least partly due to this. Technical development of the catheter system, to improve steerability is therefore mandatory.

For laser angioplasty of this kind to produce an adequate haemodynamic result, balloon dilatation is certainly necessary and probably essential. The long-term results are therefore partly dependent on the efficiency of the balloon, so that, for the method described, the term "laser-assisted balloon angioplasty" is more accurate than "laser angioplasty".

The original hope that by vaporizing the occluding material we could avoid peripheral embolism has not been fulfilled. Admittedly, the rate of embolisation of 5.4% in our patients is relatively low; Hess [16] reports macroembolism in 7% of patients undergoing local thrombolysis and Creutzig [17] noted embolism in up to 30% of elderly

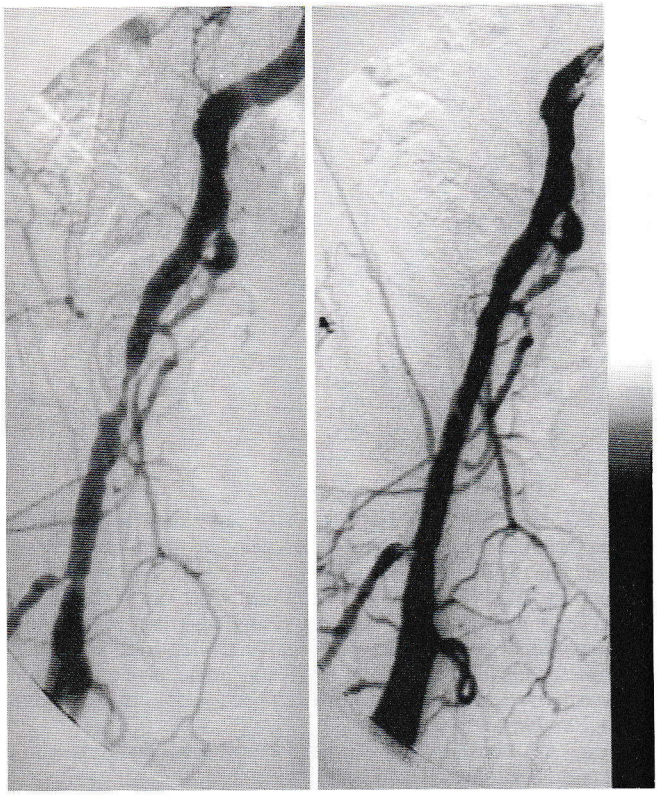


Fig. 3. *(left)* High-grade and moderate stenoses of the external iliac and common femoral arteries respectively. The superficial femoral artery (not shown) was occluded more distally and was to be treated by laser angioplasty. The stenoses were therefore dilated *(right)*, to improve inflow; in this situation this could not be carried out at the same time as laser angioplasty

patients treated by PTA. However, given the risks involved, we consider it essential to take all possible measures to prevent or treat these complications. Only occlusions known to be present for at least several months should be treated by laser angioplasty and it is advisable to minimise mechanical trauma. Nevertheless, all emboli occurring during this study were removed by local lysis and aspiration, without adverse effects on the long-term results. It is essential to master these techniques and to have the correct equipment readily available to perform successful laser angioplasty. The occasional cases of early occlusion are also suitable for treatment by these methods.

The dependence of the patency rate of arterial reconstructions on the conditions of the proximal and distal vessels has been proved in numerous studies. This is true for surgical procedures [11, 12], percutaneous angioplasty [13] and for laser angioplasty [9]. To improve the long-term results, balloon dilatation of stenoses of proximal arteries has been performed as complementary procedure in 21.6% of cases. In 18.6%, stenoses in the distal vessels rendered dilatation of these arteries necessary. Modern materials such as steerable guide wires and low-profile balloons enable dilatation of small vessels far out in the periphery [15, 18]. Overall, in more than 40% of cases, balloon dilatation was thus not limited to the segment treated by laser.

During the follow-up period, we tried to avoid reocclusion by dilating recurrent stenoses by means of balloon angioplasty, successful in 11 cases. Ten of the 27 reocclusions were reopened by local thrombolysis, aspiration, laser angioplasty or balloon dilatation. Table 1 shows these results in the form of two curves. The "uncorrelated" curve treats recurrent stenoses and occlusions as failed procedures. The "correlated" curve includes successfully treated re-

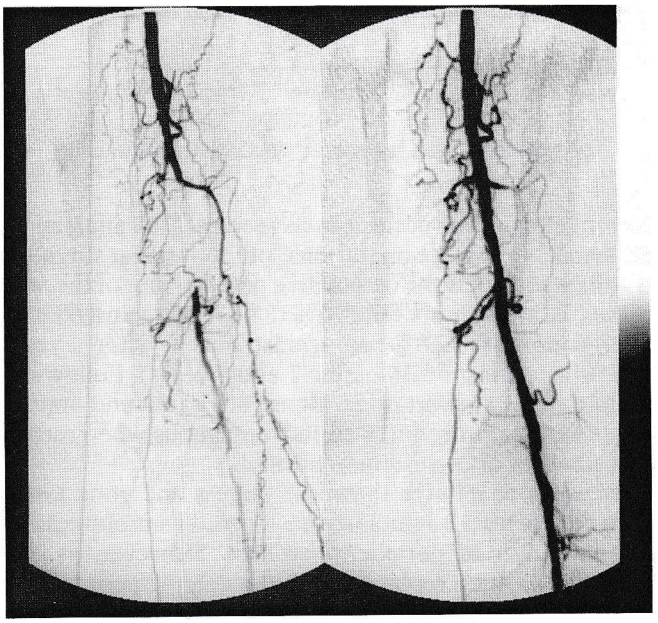


Fig. 4. *(left)* Distal to a 5 cm occlusion of the superficial femoral artery there is a narrow, irregular segment with a number of high-grade stenoses. *(right)* After recanalisation and dilatation of both the occluded and stenotic segments

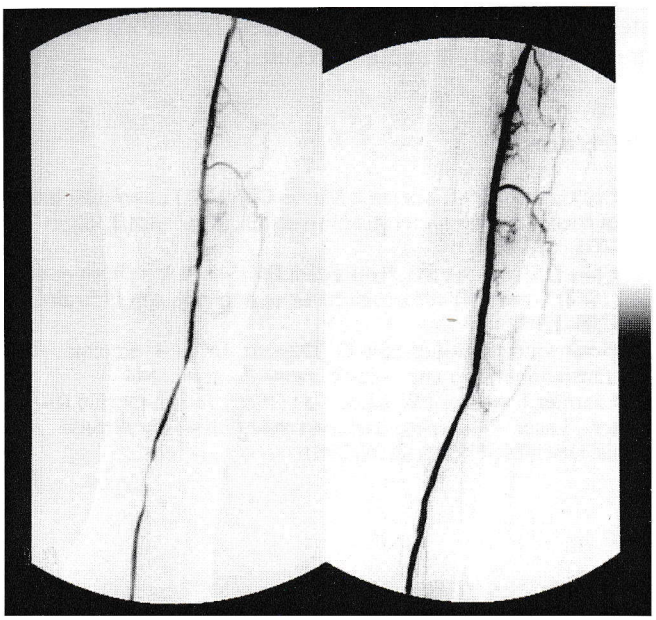
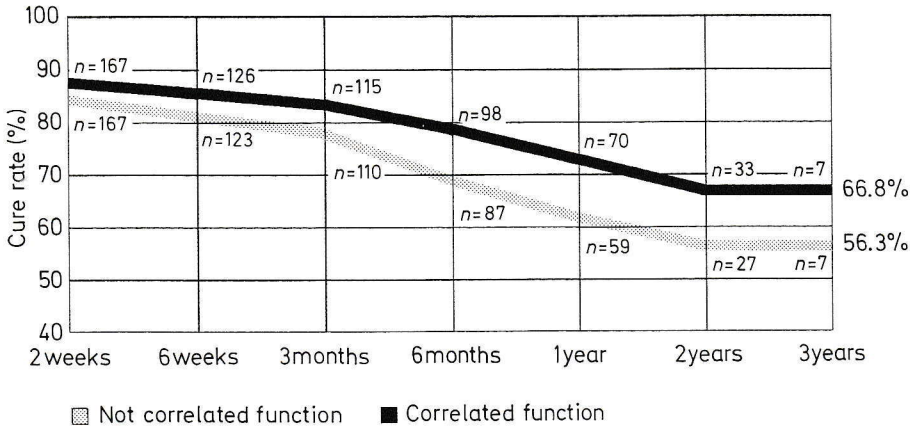


Fig. 5. *(left)* In the calf of a patient with an occluded femoral artery only the anterior tibial artery is patent: it shows multiple high-grade stenoses in the supramalleolar region. A steerable guide wire traversed these and dilatation with a low-profile balloon produced a satisfactory result *(right)*

Table 1. Life Table Analysis – Cumulative Patency Rate



current stenoses or occlusions as successes, by analogy to the so-called "service operations" of the vascular surgeon. It will be seen that the cumulative patency rate of the two curves differs by more than 10% (78.6% as against 68.9% after 6 months, 72.8% as against 61.8% after 1 year, 66.8% as against 56.3% after 2 and 3 years). Follow-up examinations at short intervals are advisable und appropriate further procedures are advantageous when recurrent stenoses or occlusions are found.

Because of its high technical success and good long-term results laser angioplasty has proved its usefulness in recanalisation of peripheral arteries. However, as described, it is not a replacement but a complement to balloon angioplasty. Indeed, increased use of balloons is necessary for treatment of proximal or distal vessels or to remove recurrent stenoses. Other methods of angioplasty, e. g. aspiration and local thrombolysis, are becoming more important for treatment of complications or recurrent occlusions. Every case calls for the adoption of the appropriate method, but only a combination of methods will produce consistently acceptable results.

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