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# Angiographic Improvement after Rapid Intermittent Compression Treatment [ArtAssist®] for Small Vessel Obstruction

*Paul van Bemmelen, MD, Daniel Char, MD, Fabio Giron, MD, and John J. Ricotta, MD, Stony Brook, New York*

A case is presented of a female ex-smoker who underwent bypass or exploration of all three below-knee arteries with failed results. Three separate arteriograms, performed at other academic institutions, demonstrated progressive, severe involvement of the pedal arteries. Therefore, the patient was prepared to undergo below-knee amputation surgery for uncontrollable rest pain and progressive necrosis of the forefoot; instead, the patient underwent 4 months of intermittent compression treatment. A fourth arteriogram, performed after 4 months of intermittent compression treatment (using rapid inflation/deflation and high-pressure cycle; ArtAssist®) demonstrated marked improvement of the posterior tibial artery runoff and development of more extensive collateral arteries in the calf. The patient's rest pain subsided and successful limb salvage was accomplished with a modified transmetatarsal amputation. This case could encourage other practitioners to repeat arteriography after compression treatments, which may redirect the treatment plan for selected patients with critical limb ischemia and nonreconstructable peripheral vascular disease.

## INTRODUCTION

Therapeutic efforts aimed at improving collateral formation may avoid some of the problems that plague both bypass and endovascular therapies, namely intimal hyperplasia and thrombotic occlusion. Previous reports[1-3] on chronic compression treatment have focused only on clinical improvement and noninvasive parameters. Compression can lead to an increase in endothelium-derived relaxing factor (EDRF, or nitric oxide) formation through both direct mechanical deformation of the vessel wall[4] and an increase in the shear-stress between the flowing blood and the endothelium. In recent animal studies,[5,6] systemic vasodilation was directly observed in arteries measuring 41-70 $\mu$m in response to distant compression. This vasodilatory effect is nitric oxide (NO) mediated as it could be blocked by *N*-monomethyl-L-arginine (L-NMMA), which is an inhibitor of NO synthethase. NO has been shown[7] to be a mediator in collateral artery development.

## CASE REPORT

The patient is a 28-year-old female, who had smoked one pack a day for 12 years, with a 2.5-year history of lower extremity rest pain and progressively necrotic toes. Her family history was positive for coronary artery disease in her father; the patient's mother had died from cancer.

After her first arteriogram on November 5, 1999, the patient underwent an anterior-tibial–to–dorsalis pedis

*Department of Surgery, Division of Vascular Surgery, State University of New York at Stony Brook, Stony Brook, NY.*

*Correspondence to: P.S. van Bemmelen, MD, Health Sciences Center, Stony Brook, NY 11794-8191, USA., E-mail: vanbemmelen.paul@northport.va.gov.*

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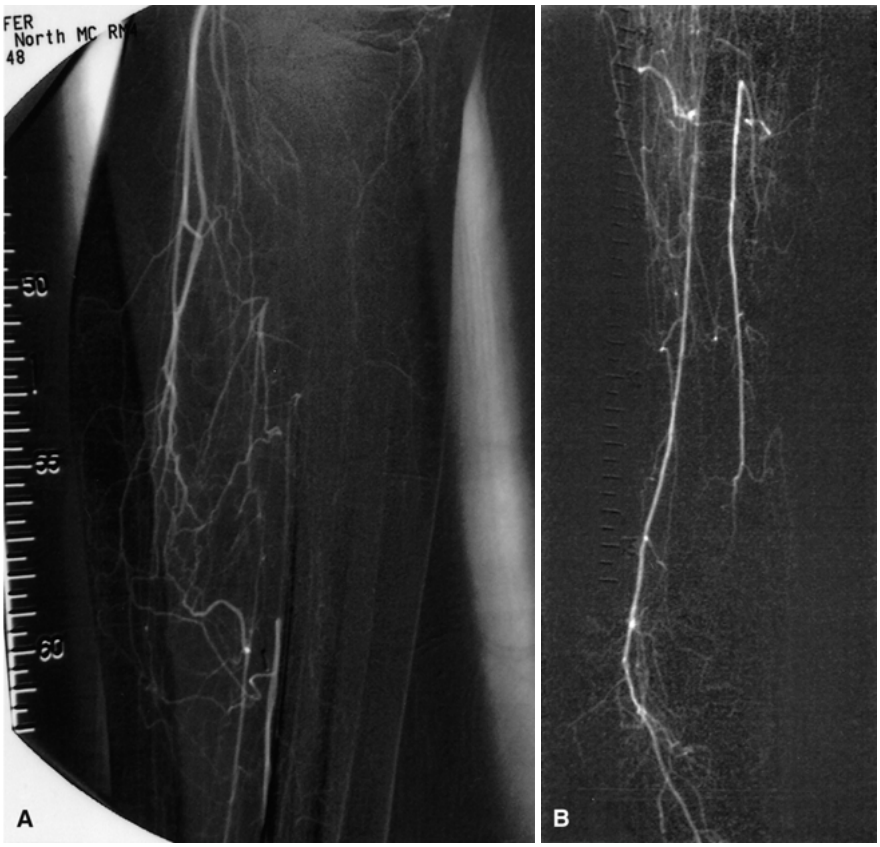


**Fig. 1. A** Angiogram 2. Lateral view of the calf on September 20, 2000: a fine pattern of collaterals is noted, and the popliteal artery is completely occluded at the knee-joint level. **B** There is reconstitution of the posterior tibial artery down to the calcaneus and a small peroneal artery is seen. The anterior tibial artery and dorsalis pedis are absent.

vein bypass (November 29, 1999) as well as exploration of the posterior tibial artery at the malleolar level. The posterior tibial artery was found to be too small for bypass. The autogenous vein graft to the dorsalis pedis artery occluded shortly after the operation.

A second arteriogram was performed on September 20, 2000 (see Fig. 1). At that time, the contralateral lower extremity was visualized and showed occlusion of the right peroneal artery, with intact pedal arteries. Thereafter, the patient underwent a left popliteal artery–to–peroneal artery bypass with saphenous vein. Again the posterior tibial artery was explored, this time at the mid-calf level. The left posterior tibial artery was found to be thin and not suitable as target vessel. Subsequently, the peroneal bypass occluded, despite coumadin and aspirin therapy.

A third arteriogram was done on February 8, 2001 (see Fig. 2). Because of the lack of suitable target vessels, the patient underwent a histologically confirmed lumbar sympathectomy the following day. The patient continued to have severe rest pain and received nifedepine (Procardia) without improvement. In addition, she required high doses of narcotics for rest pain.

The patient had previously undergone an extensive work-up for underlying disorders. Her transesophageal echocardiogram was negative for clots or vegetations, and hematological evaluation (PAI-I activity, anticardiolipin antibody, protein C and S activity, factor V Leiden mutation, cryofibrinogen, etc.) was negative. Rheumatological screening, including antinuclear antibody, was negative. Measurement of lipids showed cholesterol at 174 mg/dL (normal 100-200), and triglycerids at 163 mg/dL (normal 40-199). The patient's family history was negative for hematological and collagen disorders. She also tested negative for diabetes and homocystinuria. No vessel calcification was seen on plain X-ray films of the ankle.

Histological examination of an occluded segment of tibial artery showed sclerotic media and organizing thrombus, with no inflammatory infiltrates indicative of vasculitis or Buerger's disease. The diagnosis of occlusive disease of nonatherosclerotic origin was made.

From May 2001 to September 2001, the patient underwent intermittent compression therapy with the ArtAssist device, which was applied for 1 hr, q.i.d., at home. Pressure of 100 mmHg was applied for 3-sec periods to the calf, ankle, and foot. Prior to the treatment, the absolute ankle pressure was 40 mmHg.

Upon completion of 4 months of intermittent compression therapy, a fourth angiogram on September 10, 2001 showed a much better posterior tibial runoff, with an ankle pressure of 65 mmHg. The patient underwent another vein bypass to the distal (malleolar level) posterior tibial artery. Again this remained patent for only a few days and patient underwent a transmetatarsal am-

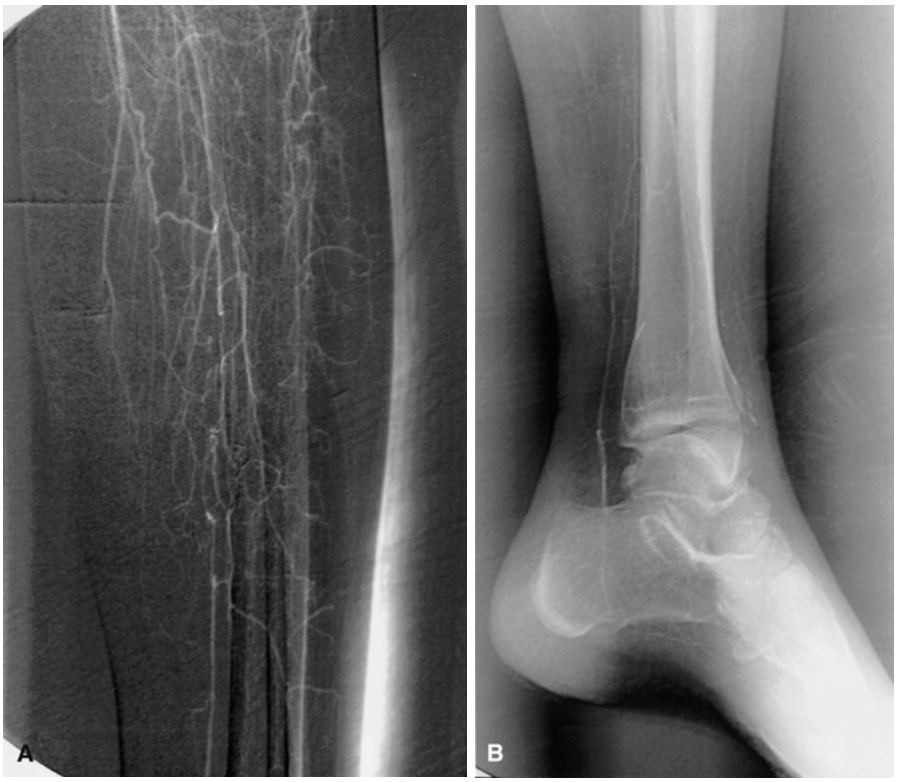


**Fig. 2. A** Angiogram 3. Same views as in Figure 1, on February 8, 2001. There is no improvement of the collaterals in the calf. **B** The posterior tibial artery appears more attenuated and there is minimal visualization of the peroneal artery.

putation, followed by an open revision. The patient resumed compression therapy, which resulted in new granulation tissue. Her pain resolved after a split skin graft was applied and the wound healed.

### Arteriographic Findings

The first angiogram demonstrated patent vessels down to the level of the trifurcation and attenuated tibial vessels in the calf. The popliteal artery was still patent and there were no visible collaterals in the proximal calf at that time. The runoff showed minimal filling of a small posterior tibial artery and occlusion of the anterior tibial artery with reconstitution of the dorsalis pedis artery. Involvement of the crural arteries in the contratlateral leg was noted at the time.

The second angiogram showed no evidence of disease in the major arteries to the level of the knee. The popliteal artery was occluded. A fine network of collateral arteries (Fig. 1A) reconsituted the posterior tibial and peroneal arteries, both of which looked attenuated (Fig. 1B).

The third angiogram showed a similar picture about 6 months later: the collateral network seen in the proximal calf remained delicate (Fig. 2A) and the reconstituted posterior tibial artery appeared more attenuated (Fig. 2B). The peroneal artery was no longer visualized.

The fourth arteriogram, after compression treatment, showed extensive collateral filling of the proximal and mid-calf level posterior tibial artery (Fig. 3A) and increased caliber of the posterior tibial artery at the ankle. More plantar branches were noted near the calcaneus. There was no improvement of the dorsalis pedis artery. Prior to the compression treatment, there was no spontaneous improvement, therefore this patient serves as her own control.

## DISCUSSION

Angiographic absence of vessels is, in itself, no proof of occlusion. Inadequate contrast volume, poor timing of exposure, and other technical factors can usually account for discrepancies between arteriogram and surgical findings at exploration. In this case, however, the poor angiographic appearance of the posterior tibial artery was confirmed by two separate surgeons upon exploration of this artery at the mid-calf level and the malleolar level. Another explanation for the reappearance of arteries that were previously not apparent is vasospastic reactions. Yet another possibility, with thrombolytic treatment, is recanalization, but this is not the usual, natural outcome of thrombotic occlusion in lower leg arteries.

### Angiography Technique

The technique of each arteriogram was carefully reviewed. Each angiogram was performed through

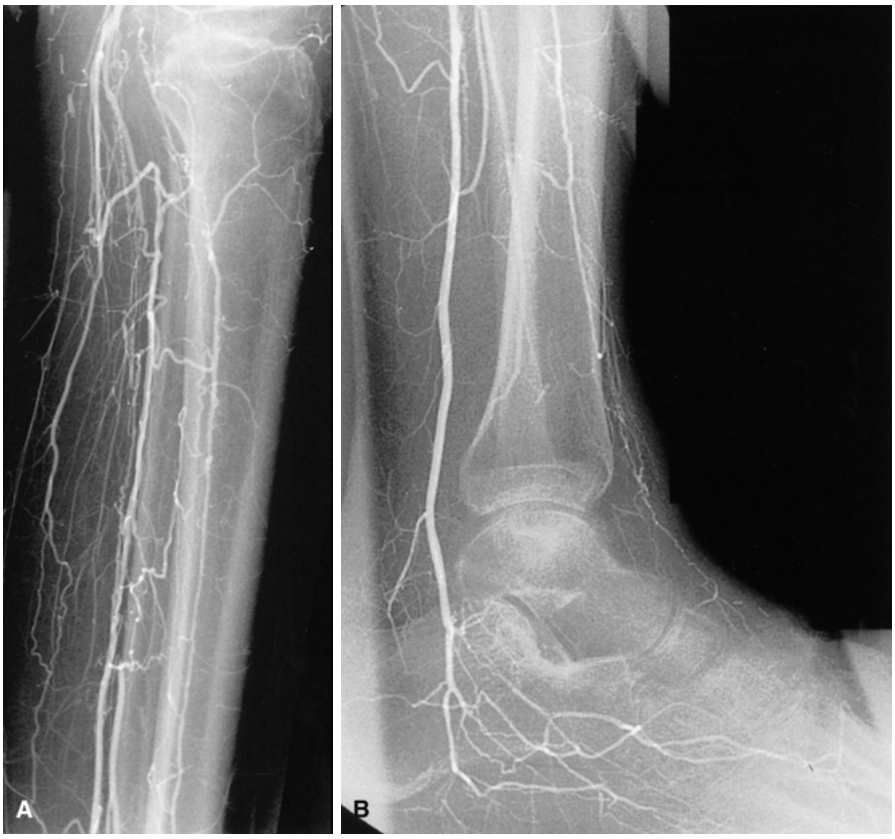


**Fig. 3. A** Angiogram 4. Same views as previous, obtained September 10, 2001, after 4 months of intermittent compression treatment. A well-developed collateral network is evident, with proximal filling of reconstituted posterior tibial artery in the calf. **B** Note the larger caliber of the posterior tibial artery and filling of multiple plantar branches. The dorsalis pedis artery remains occluded; clips mark the site of the previous dorsalis pedis bypass.

**Table I.** Angiography technique

| Angiogram no. | Date | Contrast volume (cc) | Type | Catheter tip position |
|---|---|---|---|---|
| 1 | 11-5-99 | 110 | Reno 60 | Left common femoral |
| 2 | 9-20-00 | 170 | Ultravist | Left external iliac |
| 3 | 2-8-01 | 100 | Ultravist | Left external iliac |
| 4 | 9-10-01 | 76 | Omnipaque 240 | Left external iliac |

selective ileofemoral catheter placement, from the contralateral side, with digital bolus chasing and subtraction technique. The specifics are given in Table I.

Delayed exposures were specifically mentioned at the time of angiogram 1. Furthermore, the patient received intraarterial nitroglycerin for angiogram 1.

The findings of the first three angiograms are consistent with each other and with a progressively decreasing crural and pedal vascular bed. The persistent occlusion of the dorsalis pedis artery and the histological findings argue against vasospasm. There was no indication that the collateral development in the calf was improving prior to the compression treatment.

Collateral artery development, or arteriogenesis, is the in situ development of muscular arteries stimulated by increased shear and has to be distinguished from angiogenesis (capillary sprouting), which is induced by local ischemia. Arteriogenesis can lead to an increase in size of preexisting arterioles up to 12 times their original size.[8] Takeshita et al.[9] suggested that the opening of preexisting vessels results in linear collaterals with a normal branched pattern instead of undulating (corkscrew) collaterals without branches. Diameter increase of collaterals is not due solely to vasodilation or passive enlargement. Ito et al.[10] demonstrated active proliferation of endothelial and smooth muscle cells in corkscrew collaterals, with progressive increase in diameter. With incorporation of bromodeoxy uridine, the rate of proliferation in the wall of collaterals approaches that of tumors. The ultrastructure of some collateral arteries may differ

from that of normal arteries by the persistence of a neointima.[8] Several studies with chronic intermittent compression have confirmed the functional impact of new collaterals on plethysmographic amplitude and on ankle blood pressure.[1-3,11]

In our previous paper,[11] we described our experience using intermittent compression treatment at home in elderly male patients with arteriosclerosis. Serial noninvasive studies showed an increase in the PVR amplitudes at ankle and metatarsal levels, which was, related to the number of hours that the patient received compression treatment, verified with an hour counter inside the device. None of these patients, however, had repeat arteriography once they were deemed inoperable. The current report is of a female patient with occlusive disease of nonatherosclerotic origin. Calcified arteries would not be likely to dilate with treatment, but collaterals can still be expected to enlarge with increased shear-stress.

## CONCLUSION

A well-documented (four angiograms at three different academic institutions) case is presented with angiographic improvement after 4 months of intermittent compression therapy for distal arterial obstruction. These findings led to renewed efforts at distal reconstruction and additional attempts to preserve the foot, using modified amputation. In view of these clinical implications, repeated angiography could be considered after application of arterial compression therapy. Furthermore, this case report supports the concept of intermittent compression therapy for inoperable small vessel disease.

REFERENCES

1. Dillon RS. Effect of therapy with the pneumatic end-diastolic leg compression boot on peripheral vascular tests and on the clinical course of peripheral vascular disease. Angiology 1980;31:614-638.
2. Steinberg J. Cardiosynchronous limb compression: effects on non-invasive vascular tests and clinical course of the ischemic limb. Angiology 1992;43:453-461.
3. Delis KT, Nicolaides AN, Wolfe JHN, et al. Improving walking ability and ankle brachial pressure indices in symptomatic peripheral vascular disease with intermittent pneumatic foot compression: a prospective controlled study with one-year follow-up. J Vasc Surg 2000;31:650-661.
4. Lamontagne D, Pohl U, Busse R. Mechanical deformation of vessel wall and shear stress determine the basal release of endothelium-derived relaxing factor in the intact rabbit coronary vascular bed. Circ Res 1992;70:123-130.
5. Liu K, Chen L, Saeber AV, et al. Intermittent pneumatic compression of legs increases microcirculation in distant skeletal muscle. J Orthop Res 1999;17:88-95.
6. Liu K, Chen L, Seaber AV, et al. Influences of inflation rate and duration on vasodilatory effect by intermittent pneumatic compression in distant skeletal muscle. J Orthop Res 1999;17:415-420.
7. Unthank JL, Nixon JC, Dalsing MC. Inhibition of NO synthase prevents acute collateral artery dilation in the rat hindlimb. J Surg Res 1996;61:463-468.
8. Scholz D, Ito W, Fleming I, et al. Ultrastructure and molecular histology of rabbit hind-limb collateral artery growth (arteriogenesis) Virchows Arch 2000;436:257-270.
9. Takeshita S, Ishiki T, Mori H, et al. Use of synchroton radiation microangiography to assess development of small collateral arteries in a rat model of hindlimb ischemia. Circulation 1997;95:805-808.
10. Ito WD, Arras M, Scholz D, et al. Angiogenesis but not collateral growth is associated with ischemia after femoral artery occlusion. Am J Physiol 1997;273:H1255-H1265.
11. Van Bemmelen PS, Gitlitz D, Farqui RM, et al. Limb salvage using high-pressure intermittent compression-arterial assist device in cases unsuitable for surgical revascularization. Arch Surg 2001;136:1280-1285.