Increased Skin Microvascular Flow in the Leg with Mild Negative Pressure

INTRODUCTION
A major source of morbidity for patients with diabetes mellitus is a foot ulcer (1). It has been estimated that foot ulcers occur in 2.5% of diabetic patients each year. Moreover, diabetes is also the main cause of non-traumatic lower extremity amputations in orthopaedics. Surgical revascularization sometimes can not be performed for these patients due to poor peripheral circulation. Conservative treatment such as dressings and other wound-care products are only adjuncts to careful local treatment include pressure reduction for foot (crutch, wheelchair, walker), wound debridement, and infection control. Use of vasodilator drugs does not aid healing of diabetic foot ulcers (2). Hyperbaric oxygen sometimes can be effective, but raising the oxygen content of blood is of little value when the blood supply to the foot is severely impaired. Locally applied negative pressure may increase local blood flow, but this technique requires negative pressure over 100 mmHg. In fact, previous studies of local blood flow and negative pressure indicate that tight seals over the skin actually reduce venous return (3). In the present study, we employed an adjustable loose seal for the lower leg to avoid venous stasis in order to evaluate skin blood flow with locally applied negative pressure. Our long-term goal is to improve treatment of poor circulation in orthopaedic patients with diabetic ulcers.

METHODS
The right lower legs of eight healthy male subjects, aged 22-35 years, were used. Subjects were seated and laser Doppler probes were placed at: 1) the dorsum of the foot, 2) medial heel, 3) narrowest part of the ankle anterior to tibia, and 4) 5cm below lower edge of the kneecap (Fig 1). The test leg was placed in a chamber that was connected to a vacuum source and a pressure gauge. An adjustable loose seal was used to generate negative chamber pressure. The height of the seal was also adjusted at the lower edge or maximum circumference of the calf (Fig 1). After a stabilization period, a test with normal, ambient pressure until baseline values of blood flow were restored. After the seal was also adjusted at the lower edge or maximum circumference of the calf (Fig 1). The test leg was placed in a chamber that was connected to a vacuum source and a pressure gauge. An adjustable loose seal was used to generate negative chamber pressure. The height of the seal was also adjusted at the lower edge or maximum circumference of the calf (Fig 1). After a stabilization period, a test with normal, ambient pressure provided baseline, control data. The chamber pressure was set at environmental pressures of -10 and -20 mmHg for each height of the loose seal. The leg was exposed to each environmental pressure for five minutes, and the chamber was returned to normal atmospheric pressure until baseline values of blood flow were restored. After the loose seal condition, the seal was tightened against the leg, and the same procedures were performed. Data were normalized so that skin blood flow at normal ambient pressure was defined as 100%. Data points were generated by averaging the instantaneous signals over 10-second periods.

RESULTS
Figure 2 shows skin blood flow during -10 and -20 mmHg exposures with a loose seal set at maximum girth of the calf (higher seal) and at the lower aspect of the calf (lower seal). Skin blood flows at all measurement sites 1-4 were significantly increased compared to those at normal ambient pressure (100%). Blood flow on the foot dorsum and heel increased 7-17 times during -10 and -20 mmHg with both the higher and lower loose seals compared to those at normal ambient pressure. Blood flow increased up to 30 times normal at the ankle for both loose seal positions compared to that at normal ambient pressure. Outside the chamber (site 4), blood flow changes were slightly, but significant higher than those at normal ambient pressure. No significant differences were observed between the higher seal and lower seal conditions. With a tight seal, skin blood flow was not different from control value.

DISCUSSION
In the present study, we employed a loose seal to avoid disturbing local venous drainage during very mild suction pressures of -10 and -20 mmHg. With the loose seal, skin microvascular flow significantly increased to high levels at all measurement sites within the chamber. Arterial vessel distention and reflexive arterial vasoconstriction are minimal with these mild suction pressures,. In previous studies, airtight seals were used to generate negative pressure. However, airtight seals or skin contact seals likely disturb local venous drainage in skin by compressing the tissue. Thus, our new technique of locally applied negative pressure along with a loose seal greatly increases skin blood flow in normal volunteers and may hold promise for treatment of diabetic patients having impaired microcirculation and ulcers.

REFERENCES

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