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ORIGINAL ARTICLE

The effect of sequential intermittent pneumatic compression of foot and calf on popliteal artery mean systolic blood flow in patients with intermittent claudication

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KEYWORDS
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Summary *Objective:* To determine the effect of intermittent pneumatic foot and calf compression on popliteal artery mean systolic blood flow in patients with intermittent claudication. The secondary objective was to determine the change in blood flow with posture.
Methods: This was a cross sectional study carried out on claudication patients at the Vascular Laboratory, Department of General Surgery, Kuala Lumpur Hospital, from January 2009 to August 2009. The effect of posture (supine to sitting to standing) and the effect of intermittent pneumatic compression (IPC) of the foot and calf on popliteal artery flow immediately and 10 minutes post compression were studied.
Results: Fifteen patients were studied. There was a consistent drop in flow from supine to sitting and to standing in all patients. Immediately after IPC application there was an increase in flow ranging from 29–335% ($p < 0.05$). Increase in flow was reduced but still sustained after 10 minutes with a flow range of 17–113 mL/minute with a median of 63 mL/minute ($p < 0.05$).
Conclusion: There is a significant reduction in popliteal artery mean systolic flow from supine to sitting and to the standing position, and popliteal artery flow is significantly increased after application of IPC and even persists after 10 minutes.

1. Introduction

As early as the 1800s, physicians have experimented with the concept of improving blood circulation by exerting external pressure on the legs. In 1934, Reid and Herrmann[1]

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proposed the use of alternating pressure and suction in what they called "PAVAEX" (passive vascular exercise) to treat various forms of lower limb arterial disease. Landis and Gibbon[2] expanded this use of pressure—suction technique to include the treatment of ischemic limb, chronic ulcers, and claudication. It has been found recently that intermittent pneumatic compression of the foot and calf can generate a hemodynamic effect similar to that produced by a postural change from sitting to supine and reducing peripheral resistance. This can directly enhance arterial calf inflow and, if used for several consecutive weeks, improve lower limb hemodynamics.

Intermittent pneumatic compression is currently thought to be an effective means of augmenting arterial volume flow in the lower limbs of patients with peripheral vascular disease. Studies report a resting popliteal artery volume flow increases more than three times on application of intermittent calf compression[3] and up to 84%[4] when intermittent foot compression is applied. More recently interest has been focused on the potential clinical benefits that intermittent pneumatic compression might provide to patients with symptomatic peripheral vascular disease. It has been shown to improve the claudication distance and peripheral hemodynamics.[5]

Our center has previously studied the effects of IPC on the normal population,[6] and as a follow up to that study, herein we have investigated the same effects on patients with intermittent claudication.

2. Patients and methods

This was a cross sectional study carried out over a period of eight months from January 2009 to August 2009 at the Vascular Laboratory of the Department of General Surgery, Kuala Lumpur Hospital. The participants were patients of all ages who presented to the Department of Vascular Surgery for treatment of intermittent claudication. Only those with stage II of Fontaine's classification were included. All patients included in the study had a patent popliteal artery, with at least two crural vessel run off as determined by recent magnetic resonance imaging (MRA), computed tomography angiogram (CTA) or angiogram and a popliteal segment that was easily insonated by Doppler ultrasound.

The exclusion criteria included patients with congestive cardiac failure, chronic venous disease, leg trauma, swelling or ulcers, morbid obesity and those on vasoactive drugs (e.g., nifedipine). Ethics approval by CRC (Clinical research centre) of Hospital Kuala Lumpur was obtained for the study.

After obtaining informed consent, history and examination findings were entered into a standard form. Each participant was considered as a single patient and, in the event of bilateral claudication, in keeping with the inclusion criteria the worse limb in terms of severity was examined.

The popliteal artery was located using the Duplex Ultrasound machine (Philips HD11XE, Philips healthcare, 30000 minuteman road, Andover, United states) with a variable linear probe (12—3 MHz). B-mode real time ultrasound imaging was used to visualize the artery. The longitudinal real time image of the popliteal artery was confirmed three times before measurements of systolic flow were obtained. The diameter of the vessel was measured using the machine's electronic calipers, after which the computerized data analysis provided by the machine's software enabled instant calculation of the peak systolic flow of the popliteal artery in mL/minute.

Baseline popliteal artery mean systolic flow in the horizontal (supine) position was measured after a resting time of 10 minutes with the knee slightly flexed and the hip slightly rotated medially. The participant was then asked to sit at the edge of the bed for 10 minutes for flow stabilization before the sitting popliteal artery mean systolic flow was measured with both legs supported in a dependent, non-weight-bearing, position with the knee flexed in a comfortable position at about 45°, which also gave easy access for the Doppler probe to identify the artery. The patient was then asked to stand at the edge of the bed, and the systolic flow was measured after a flow stabilization of 10 minutes.

The patient was then asked to sit again and the intermittent pneumatic compression device was applied to the lower limb as describe previously.[6]

Statistical analysis was achieved using SPSS version 16.0 for Windows (SPSS Inc. 233 South Wacker Drive, 11th Floor, Chicago, IL). Wilcoxon signed rank test was used to compare the systolic flow after postural change and after IPC application.

3. Results

During the study period of 8 months, 15 patients were studied. There were 12 males and 3 female patients. All patients were over 40 years old.

The popliteal artery mean systolic flow in the supine position was between 23—127 mL/minute with a median flow of 79 mL/minute. In the sitting position the popliteal mean systolic flow was between 23—98 mL/minute with a median flow of 35 mL/minute. There was a significant decrease in flow ranging from 5—68% with a mean of 32% ($p < 0.05$). In the standing position, the popliteal artery mean systolic flow was between 5—64 mL/minute with a median of 23 mL/minute. Once again there was a significant decrease in flow ranging from 17—74% with a mean of 40% ($p < 0.05$) - Figs. 1—3.

Immediately post IPC application, there was an increase in popliteal artery mean systolic flow in all 15 patients ranging from 29—335% with a median of 75%. The flow ranged from 34—146 mL/minute with a median of 90. Wilcoxon signed rank test gave a p value of < 0.05, showing that there was a significant increase in the popliteal artery blood flow between pre-application of IPC and immediately after application of IPC. At 10 minutes post IPC application, there were two patients that did not sustain a higher mean systolic flow (Fig. 4). However, the rest were above baseline. The mean systolic flow ranged from 17—113 mL/minute with a median flow of 63 mL/minute. The Wilcoxon signed rank test again showed a p value of < 0.05 (Fig. 5).

4. Discussion

Studies have documented that blood flow in the lower limbs decreases on assuming the erect position (sitting or standing).[7] Henriksen postulated that the role of