The effect of the position of the limb on venous impulse foot pumps

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Compression foot pumps are widely used for the prevention of postoperative venous thrombosis. We tested the efficiency of the pump in ten healthy subjects; the velocity of venous blood flow in the common femoral vein was measured in the horizontal, Trendelenberg (foot-up) and reverse-Trendelenberg (foot-down) positions.

Application of the foot pump produced an increase in the venous velocity in all subjects. The mean increase in the horizontal position was 27.2% and in the Trendelenberg position 15.4%. In the reverse-Trendelenberg position, the foot pump produced a mean increase of 102.8%.

The efficiency of the compression foot pump in increasing venous return is improved by adopting the reverse-Trendelenberg position. This may increase its thromboprophylactic effect.

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External compression foot pumps, applied to the foot and ankle, are used to increase venous flow in the lower limbs and to reduce the incidence of venous thrombosis. They are based on a physiological pump in the human foot which was first described by Gardner and Fox. This pump is activated by weight-bearing which provides sufficient driving force (vis a tergo) to return venous blood from the lower limb to the right atrium of the heart. The impulse compression foot pump was developed to mimic this physiological mechanism in non-weight-bearing patients. Based on the principles of Virchow, it has been proposed that the increased rate of venous flow in the lower limb reduces the tendency to deep-venous thrombosis.

Reports on the efficiency of these foot pumps are inconsistent. A number of authors have found a reduction in the incidence of deep-venous thrombosis compared with placebos and low-molecular-weight heparin when the devices are used, but others have not been able to confirm this. One recent report suggests that variable compliance may contribute to this apparent inconsistency.

We believed that the mechanism would be more effective when the chamber was filled with fluid, as with any pump. In the case of the impulse foot pump, increasing the volume of blood in the venous plexus of the foot by placing the feet in a dependent position, should lead to a more efficient pumping mechanism. We tested this hypothesis in a laboratory experiment which involved healthy volunteers.

Subjects and Methods

We recruited ten healthy subjects, five men and five women, with a mean age of 27 years (26 to 31). None had a history of venous disease of the lower limbs or evidence of superficial or deep-venous insufficiency.

Venous velocity was measured in the common femoral vein, 2 cm proximal to the bifurcation, using a Duplex ultrasound scanner (Acuson, Sequoia; Acuson Corporation, Mountain View, California). All measurements were carried out by one consultant radiologist under standard conditions, in a vascular laboratory. The arteriovenous (A-V) Impulse Foot Pump (Novamedix, Andover, UK) was used in a standard manner throughout the study: a pressure impulse of 200 mmHg was delivered for 3 s every 20 s.

Each volunteer had a pneumatic bootee and an A-V Impulse Pump applied to the right foot and ankle, and lay supine on a tilting couch. With the couch in the horizontal position, the peak venous velocity without the pump (PVV-P) was measured. The pump was then turned on and, after a warm-up of five minutes, the peak venous velocity with pumping (PVV+P) was measured. Values for PVV-P and PVV+P in each of three cycles of the venous pulse were noted, and the percentage increase calculated. The mean percentage increase over the three cycles was determined for each person and used in subsequent statistical analysis.


The results show that placing an individual in the 25° foot-down position consistently produces a significantly greater rise in the venous velocity when the Impulse Foot Pump is used, than in the horizontal and foot-up positions. Based on Virchow’s principles of the pathogenesis of venous thrombosis, this consistent increase in venous flow should have a greater antithrombotic effect and may enhance the other reported effects of the foot pump, such as reduction of post-traumatic foot and ankle swelling, and compartment pressures.

The A-V Impulse Foot Pump is least effective when the patient’s foot is elevated, and works best when the foot is dependent. The patient should be placed in the reverse-Trendelenberg position when the foot pump is being used.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


Table I. Mean peak venous velocity (PVV; cm/s) and the percentage difference for each of the ten subjects with limbs in the horizontal, Trendelenberg and reverse-Trendelenberg positions

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<th>Subject number</th>
<th>PVV-P</th>
<th>PVV+P</th>
<th>Difference (%)</th>
<th>PVV-P</th>
<th>PVV+P</th>
<th>Difference (%)</th>
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<th>PVV+P</th>
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</table>

*peak venous velocity without foot pumping
†peak venous velocity with pumping

Measurements of PVV-P and PVV+P were then repeated with the couch tilted into a 25° Trendelenberg (foot-up) position. The mean percentage increase over three cycles was again determined for each subject. The same procedures were repeated in a 25° reverse-Trendelenberg (foot-down) position.

The results were analysed for statistical significance using the Sigma-stat computer statistics package (SPSS, Chicago, Illinois).

Results

In the horizontal position. Application of the foot pump produced an increase in the venous velocity in all subjects (Table I) with a mean of 27.2% (2.5 to 58.3).

In the 25° Trendelenberg (foot-up) position. All ten subjects registered an increase in venous flow when the foot pump was applied (Table I) but the mean was only 15.4% (3.2 to 28.1). Although the change in velocity produced by the foot pump in this position was consistently less than in the horizontal position, this apparent difference was not significant (p = 0.06).

In the 25° reverse-Trendelenberg (foot-down) position, the increase in venous velocity was substantially greater in all cases with a mean of 102.8% (55.5 to 185.8), which was highly significant (p < 0.0001) compared with the horizontal position.

Discussion

Our laboratory study on healthy volunteers has shown that the effect of the A-V Impulse Foot Pump on venous velocity varies with the position of the foot. When the limb was horizontal, the pump produced a variable increase in the velocity of venous return in different subjects, probably because of variable filling of the plantar venous reservoir in the horizontal position. This observation may underlie the variations in the rate of deep-venous thrombosis observed by different authors. Similar variability in the efficacy of the foot pump was observed in the Trendelenberg position.