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acute swelling of the hand is a common problem after trauma or surgery and is associated with both pain and loss of function. We describe a prospective study of 47 patients in which we assessed the effects of a pneumatic compression device (A-V impulse hand pump) on the swollen hand. The pump reduced swelling by increasing the velocity of venous return as demonstrated by Duplex scanning of the median cubital vein.

Continuous use of the pump for 48 hours gave a reduction of 78.6% in swelling of the injured hand compared with the opposite, uninjured side. Even when used intermittently, with the pump on for 12 hours out of 24, a statistically significant effect was seen.

There was a subjective reduction in pain and an objective improvement in function of the hand. Use of the pump resulted in a nearly normal hand by the time of discharge from hospital after, on average, 48 hours.

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Pneumatic compression has been shown to be effective in the control of both acute and chronic swelling of the foot and ankle after trauma and surgery.\(^1\) The incidence of deep-venous thrombosis after hemiarthroplasty for hip fractures was reduced by increasing venous return by using the A-V impulse system in the legs.\(^2\)

Gardner and Fox\(^3\) have described a physiological venous pump in the hand similar to that in the foot.\(^4\) Under normal circumstances this mechanism is activated by fist-clenching which pumps venous blood proximally.\(^5\)

We have assessed the effects of a pneumatic compression device (A-V Impulse Hand Pump; Novamedix Services Ltd, Andover, UK) on acute swelling of the adult hand.\(^4\) This system enhances the action of clenching the fist when that manoeuvre is restricted by swelling or pain or both.

Patients and Methods

Between December 1996 and June 1997, we studied prospectively 47 patients with acutely swollen hands due to a variety of causes (Fig. 1). There were 23 men and 24 women with a mean age of 61 years (18 to 78).

The A-V impulse hand pump consists of a bladder which can be inflated to 130 mmHg for two seconds every 20 seconds by an electrically-driven air compressor (Fig. 2). After wrapping the hand and wrist with a thin layer of wool the device is placed on the palm, with the thumb located in the cut-out provided. The ends of the cover are then wrapped snugly across the back of the hand and secured by fastening tabs. The wrist strap is closed across the base of the thumb and secured by another tab. A ‘cling’ bandage is finally applied over the hand to provide a firm and comfortable fit.

The effect of elevation was excluded by keeping the injured hand on a pillow beside the patient.

Measurements of hand girth were taken along the distal palmar crease using a spring-loaded tape measure, before and after using the hand pump. The mean of three measurements was recorded in millimetres.

To assess any possible effect on the normal hand the pump was applied for 48 hours to ten uninjured hands which were not swollen. Five dominant and five non-dominant hands were selected, with patients chosen from both sexes.

Measurements of girth in the normal hand before and after use of the pump confirmed that it had no effect on a normal hand. The uninjured opposite hands were therefore used as controls for all further measurements.

The velocity of venous return was measured in the injured hand using a Duplex scanner (Acuson 128XP/10 colour Doppler ultrasound system; Acuson Corporation, Mountain View, California), with a high resolution 7MHz linear probe. We assessed 15 patients as soon as practicable after injury, usually within 24 hours. With the patient...
supine, the median cubital vein was located and the baseline flow velocities, the peak flow velocities during active fist clenching and the peak flow velocity during activation of the hand pump were recorded. There was an increase of 319% over the baseline flow ($p = 0.0002$) during activation of the A-V impulse hand pump and of 77% ($p = 0.350$) during clenching of the fist alone (Figs 3 and 4).

In the clinical study, patients were divided into two groups (Fig. 1). One used the pump for 48 hours continuously (continuous group, 27 patients) and the other followed an intermittent regime of 12 hours on and 12 hours off (intermittent group, 20 patients).

In the continuous group 12 patients had a Colles’ fracture, 14 a soft-tissue swelling, and one a fracture of the forearm treated by open reduction and internal fixation.

In the intermittent group 12 patients had a Colles’ fracture, 14 a soft-tissue swelling, and one a fracture of the forearm treated by open reduction and internal fixation.

In the patients with Colles’ fractures in the continuous group dorsoradial plaster-of-Paris slabs were applied after reduction. The bladder of the hand pump was then located on the palm of the hand and the Impad strapped around the plaster slab on the dorsum. At the end of 48 hours, the Impad was removed and a below-elbow cast applied. The
14 patients with soft-tissue swelling of the hand and the one with a fracture of the forearm had volumetric analysis. The mean of three readings was taken on each occasion.

Joint function was assessed by measuring total active motion (TAM) and pulp-palm distance (PPD). Measurements were recorded before and after using the hand pump taking the mean of three recordings.

Pain was measured on a visual analogue scale (VAS), both before and after using the hand pump. All the patients tolerated the device well during the day and night.

The intermittent group comprised 20 patients who had fractures of the distal radius treated by percutaneous wiring (Fig. 1). This approach demonstrated the progressive effect of the hand pump in contrast with a physiological sequential reduction in swelling over time alone. These readings provided a measure of the ‘pump-on’ effect.

Results

Continuous group. There was a reduction in swelling of 78.6% as measured by the girth of the palm and confirmed by volumetric analysis. The mean reduction in volume was 30.2 ml (sd 3.9; p < 0.0001). The VAS showed a mean reduction in pain of 57% at the end of 48 hours. Improvement in finger movement was significant as shown by TAM (Fig. 5) and PPD (Fig. 6). The results were classified as
good according to the criteria of Buck-Gramcko et al. 

**Intermittent group.** There was a reduction in swelling of 69.4% and the ‘pump-on’ effect was seen. The reduction in swelling in the 12 hours when the pump was on was considerably greater than that in the period when the pump was off ($p < 0.0001$) (Fig. 7). These results show that the ‘pump-on’ effect was considerable.

**Discussion**

There are three independent venous systems in the hand, the superficial palmar, deep palmar and dorsal, which are activated by palm compression, isometric intrinsic muscle contraction and dorsal compression, respectively. These systems act in synergy, producing the greatest increase in velocity when activated concurrently during clenching of the fist. 

Gardner and Fox suggested that the superficial dorsal veins are venous pumps and stated that the venous hand pump “anatomically consists of a system of looping veins related to the metacarpophalangeal joints”, within the dorsal venous system. Perforating connecting veins are present in the first and fourth interosseous spaces, with valves preventing reflux of blood to the deep veins. Blood in the dorsal veins is actively pumped proximally by tension on the dorsal skin, produced by movement of the hand.

Gladback, Penning and Meyer showed a reduction in hand swelling by 65% in patients treated with an A-V pump compared with 18% in those managed by cryotherapy.

The traditional management of post-traumatic swelling of the hand has been by elevation of the limb. In our study we kept the hand in a neutral position on a pillow below the level of the right atrium to ensure that the venous plexus in the palm was constantly primed. This also contributed to the comfort and convenience of the patient.

Duplex flow studies of the median cubital vein are not possible with the limb elevated since the vein is completely collapsed in this position. We presume that drainage of the interstitial fluid by the lymphatics of the upper limb has a small role to play in reducing the swelling of an injured hand and this is now the subject of further study.

Simons et al used Duplex ultrasound in the normal hand to measure the mean volume of blood pumped through the cephalic vein during fist clenching and compared it with that when clenching was preceded by abduction of the digits. They noted a threefold increase in the velocity of the venous return in the cephalic vein and a sevenfold increase in the venae comitantes accompanying the ulnar artery during clenching.

We studied the swollen hands using a Duplex scanner and recorded an increase of 319% over the baseline venous return in the median cubital vein with the hand pump on. Also, an increase of 77% over the baseline venous return was recorded with fist clenching. When using the pump, venous return is greatly increased, in spite of the inhibiting effects of post-traumatic pain and stiffness and the restricting effect of a plaster cast.

The mechanism of action of the A-V impulse system in reducing acute oedema of the limbs was explained by Gardner and Fox who found that impulse pumping effected a sudden rise in venous pressure. This, in turn, caused a greater proportion of the venous limbs of capillary loops to open, encouraging osmotic reabsorption of interstitial fluid.

Our study explains the reduction in swelling of 78.6% of an injured hand after using the pump for 48 hours. The results in the intermittent group show a significant ‘pump-on’ effect ($p < 0.0001$) on measurements of hand girth.

Pain in a swollen hand is relieved by the A-V impulse system, probably by reducing the venous congestion and minimising the local acidosis that is thought to increase the perception of pain.

The painful swollen hand usually adopts a position with the metacarpophalangeal joints extended, so that the collateral ligaments are slack. Maintenance of this position rapidly leads to shortening of the ligaments and fibrosis, resulting in decreased function of the hand. Use of the hand pump brought about a prompt reduction in swelling which helped to improve the range of movement of the joints and fingers, thereby aiding function (Figs 5 and 6).

Some loss of reduction occurred in the first two patients with a Colles’ fracture. This was rectified by enlarging the dorsoradial slab in the remaining patients. The potential complications of chronic swelling and reflex sympathetic dystrophy were not seen. We anticipate that this early reduction of swelling and pain, together with improved movement of the fingers, may reduce the risk of both.

The study confirmed our clinical impression that the A-V impulse hand pump is an effective method for obtaining an increase in the velocity of venous return which ensures a rapid reduction of swelling and pain. This increases joint mobility and so improves function of the hand. The maximum effect is achieved if the pump is used continuously for 48 hours, but intermittent use is also worthwhile and
may be necessary in a busy ward where there are more patients in need than pumps available. The patients in our study were discharged from hospital at 48 hours with comfortable hands, satisfactory movement of the fingers, and, as a result, improved function of the hand.

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References

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