The case for intermittent pneumatic compression

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Intermittent pneumatic compression (IPC) is widely used to prevent deep vein thrombosis (DVT), yet IPC appears to have application to a broader base of lymphatic and venous disease. The intermittent nature of pulsatile external compression results in beneficial physiologic changes, including haematologic, haemodynamic, and endothelial effects. Application of IPC is a valuable adjunct to the treatment and management of patients with venous, lymphatic and arterial disease.

Key words

Compression
Lymphoedema
Ulcers
Oedema
Pharmacology

The application of external compression is the mainstay of management in patients with venous and lymphatic disease. Externally applied compression is the key to controlling oedema, which in turn controls chronic venous and lymphatic disease. Intermittent pneumatic compression (IPC) has been recognised as a valuable adjunct in the management of patients with venous, lymphatic, and arterial disease. Applying IPC to the lower extremities results in haemodynamic changes (venous velocity increase), haematological changes (fibrinolytic and intravascular coagulation), and alteration of endothelial function. This paper reviews the effects and clinical application of IPC for the management of lymphatic and venous disease.

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Venous and lymphatic flow from the lower extremities

The upright position of the human body and the force of gravity are physical factors acting against the return of venous blood from the lower extremities. Blood from the legs must be pumped against gravity towards the heart. This is mainly achieved by the muscular 'venous pump', which has two major components:

- Active contractions of leg muscles, especially in the calf
- Venous valves that prevent retrograde flow.

Failure of the venous pump (the calf muscle pump) can result from immobility, venous valvular incompetence or a combination of both (Gardner and Fox, 1989). In mobile patients with incompetent venous valves, reflux of blood in a retrograde direction prevents the drop in peripheral venous pressure that normally occurs and results in ambulatory venous hypertension. The higher the ambulatory venous pressure, the more severe are the clinical consequences of venous insufficiency. Blood can only flow normally from the capillaries and venules into the larger veins if the transport into and through larger vein segments is unimpeded. Luminal obstruction of large veins influences microcirculatory function and can result in increased leakage of fluid containing large molecules, such as proteins and blood cells. This tissue fluid will be drained by the lymphatics, which will compensate for any increase of what is called the 'lymphatic load'. However, subsequent changes in tissue resulting from proteinaceous fluid and chronic inflammation are responsible for lymphatic obstruction, leading to persistent oedema, skin changes and ulceration (Bergan et al, 2007).

Movement of the lower limbs by muscle contraction is the driving force of the venous pump and an important mechanism for lymphatic transport. Muscle contraction is important for the rhythmic opening of initial lymphatics, because of pressure changes in the tissue, and for the spontaneous contractions of the large lymph vessels, which are stimulated by contracting muscles.

Persistent oedema evolves into lymphoedema when the compensatory mechanism of increased lymph drainage is exhausted and the propelling mechanism of rhythmic stimulation on the spontaneous contraction of the lymphatics fails. The existing proteinaceous fluid, which is rich in fibrinogen, along with chronic inflammation, which stimulates the production of more fluid, leads to further oedema and induration of the skin and — when uncontrolled — the development of ulceration (Morison et al, 2007).

Lymphoedema can be broadly classified as primary or secondary. Primary lymphoedema has three categories based on the age of onset: congenital; precox (onset at puberty), and tarda (onset during adulthood). Secondary lymphoedema can be secondary to lymph node dissection, radiation, malignant obstruction or infection.

Intermittent pneumatic compression (IPC)

Intermittent pneumatic compression actively compresses the leg, mimicking the action of the leg muscle pumps. Devices may have one or more chambers and consist of a pneumatic pump that inflates air into garments wrapped around the foot, calf, thigh, or a combination of the three. Multiple-chamber devices provide sequential compression in an ascending pattern up the limb. Pumps vary in timing cycles and amount of pressure produced, ranging from low-pressure, slow-inflation to high-pressure, rapid-inflation devices. IPC is a safe and effective method frequently used to prevent deep venous thrombosis (DVT) in hospitalised patients (National Institutes of Health, 1986; Marshall, 1991; Nicolaides et al, 1997).

It has been proposed that IPC may affect two of three factors described by Rudolf Virchow (Clagett et al, 1995; Jacobs et al, 1996) — stasis and hypercoagulability. IPC functions by two mechanisms:

- The mechanical effect of IPC expels venous blood from the lower extremities, which increases the velocity of venous return and reduces stasis
- By reducing venous volume, venous pressure is reduced and the arterial-venous gradient is increased, thereby also improving arterial perfusion (Eze et al, 1996).

IPC also produces haematological alterations, which reduce the tendency for the blood to clot and enhance fibrinolytic activity (Tarnay et al, 1980; Salzman et al, 1987; Jacobs et al, 1996; Comerota et al, 1997).

A meta-analysis of more than 70 published trials of DVT prophylaxis in surgical patients showed that the use of mechanical prophylaxis reduces the rates of DVT and fatal pulmonary embolism (PE) (Marshall, 1991). The use of IPC has benefits above and beyond that of a conventional static compression bandage or elastic compression stockings.

Active compression therapy by IPC applies pulsatile external pressure, producing a pressure gradient in the leg that mimics rhythmic muscular contractions where such movements are restricted or entirely absent — this results in important benefits for patients.

Physiological effects of IPC

Researchers have shown that IPC produces numerous physiological effects. Delis et al (2000) showed that 120–140mmHg IPC applied to foot and calf with a one-second delay, and at a frequency of three to four impulses per minute produced maximal venous emptying from the leg.

IPC increases the velocity of venous return and reduces the amount of blood inside the veins at any time. Flam et al (1996) measured venous velocities in the femoral veins of 26 healthy individuals after applying IPC, and demonstrated increased venous velocities after application.

Malone et al (1999) conducted a study on 22 lower extremities from healthy volunteers and 11 lower extremities from patients with class IV to class VI post-thrombotic chronic venous insufficiency. Acute DVT was excluded before the evaluation began by using duplex ultrasound scanning. Venous velocities were monitored after the application of each IPC device, with all patients in the supine position. High-pressure rapid-inflation devices and standard low-pressure slow-inflation devices were applied in random sequence. Maximal venous velocities were obtained at the common femoral vein and the popliteal vein for all the devices and were recorded as the mean peak velocity of three compression cycles and then compared with baseline velocities.

Baseline venous velocities were higher in femoral veins than in the popliteal veins in both volunteers and post-thrombotic subjects. Standard and high-pressure, rapid-inflation compression increased both popliteal and femoral vein velocities in healthy volunteers and post-thrombotic subjects. Although the post-thrombotics group had an attenuated response at both the popliteal and femoral vein level, high-pressure, rapid-inflation compression produced significantly higher venous velocities in the popliteal and femoral veins in both healthy volunteers and the post-thrombotic group compared with standard compression. High-pressure rapid-inflation pneumatic compression may offer additional protection from thrombotic complications on the basis of an improved haemodynamic response, both in healthy volunteers and patients who are post-thrombotic.

The observations that IPC increases arterial blood flow to the limb appears to translate into improved skin perfusion, tissue oxygenation at the skin surface, and, interestingly, endothelial cell function. When laser Doppler flux was applied on subjects' big toes after application of IPC devices, the flow of blood to the skin was shown to increase by 57–66% (Abu-Own et al, 1993).

Similarly, when the transcutaneous partial pressure of oxygen ($TcPO_2$) was measured (Abu-Own et al, 1993), there was an 8% median percentage increase in patients with arterial occlusive disease as well as in healthy individuals following IPC (n=30 patients; 15 with peripheral arterial occlusive disease, 15 normal).

Kolari et al (1988) reported the results of a prospective study comparing 10 patients with post-thrombotic leg ulcers with nine patients with no evidence of peripheral arterial disease. One hour of IPC at 50mmHg was applied and the $TcPO_2$ was measured before and after compression. There was significant improvement in $TcPO_2$ after the application of IPC.

The effect of IPC on endothelial cells and their expression of nitric oxide synthase were studied by Dai et al (2002). They simulated an *in vitro* model of external limb compression with IPC devices and demonstrated a two-fold upregulation of endothelial nitric oxide (eNOS) and messenger ribonucleic acid (mRNA) expression at six hours in cultured human umbilical vein endothelial cells.

Stimulation of endogenous fibrinolysis is yet another physiological effect of IPC. Comerota et al (1997) applied IPC devices to the lower limbs of six healthy individuals and six post-thrombotic patients. Blood was drawn at baselines of 60, 120 and 180 minutes after the application of IPC devices, and global fibrinolytic activity was assessed by measuring tissue plasminogen activator (t-PA) antigen and activity, plasma activator inhibitor-1 antigen and activity, alpha-2 antiplasmin-plasmin complexes, and von Willebrand factor antigen. The results showed an increase in the fibrinolytic activity at 180 minutes using all devices in normal subjects and post-thrombotic patients.

The mechanisms of the haematological effects of IPC are yet to be clarified. It is reasonable to postulate that increased shear stress on the vessel wall is of crucial importance. Shear stresses that act on the endothelium are the result of changes in the radial velocity gradient characteristic of blood flow through a vessel. Slow flow velocities occur at the wall of a vessel, with increasing velocity reaching a maximum in the centre of the stream. IPC appears to increase the velocity of all the layers, especially at the crucial vessel wall-blood interface. An increasing body of evidence suggests that the size of blood vessels and their vascular tone are dependent on the local level of the shear stress and that endothelial cells mediate the response of the vessels to the changes in flow conditions (Eliska and Eliskova, 1995).

IPC for treatment of oedema and venous leg ulcers

IPC appears to establish a good environment for the healing of leg wounds, especially venous ulcers. Coleridge-Smith et al (1990) conducted a randomised controlled trial on 45 patients with non-healing venous ulcers. The patients were divided into two groups: group one had their ulcers debrided and cleaned and had non-adherent dressings and graduated compression stockings (30–40mmHg pressure) applied; group two received the same wound care and sustained compression as group one, but also received IPC for four hours per day. The primary endpoint of the study was ulcer healing.

Ulcer contour was measured at entry, then at weeks two, four, eight, and 12, and at four-week intervals to healing. Median ulcer size at baseline was 49.8cm^2 for the IPC group, and 17.3cm^2 for the control group. At the end of the trial, 10 of the 21 patients (48%) in the IPC group had healed, compared with one of the 24 patients (4%) in the control group.

The investigators concluded that the median healing rate in group one patients was 2.1% area per week, whereas the median healing rate for group two patients was 19.8% area per week (P=0.046), demonstrating that the use of IPC significantly improved the healing rates of venous ulcers.

Kumar et al (2002) performed a randomised controlled trial of 47 patients with non-healing venous leg ulcers. Patients were divided into two groups: group one (n=25) was treated with routine wound care and compression, whereas group two (22 patients) received wound care, compression, and IPC devices applied at 60mmHg for one hour, twice a day. The primary endpoint of the study was ulcer healing.

The patients were followed for four months. Six patients (three from each group) opted to withdraw from the trial. At the end of the trial, 23 of 25 (92%) ulcers in 22 patients from group one had healed completely. In group two, 20 of 23 (87%) ulcers in 19 patients had healed completely. In group one, the mean days to healed ulcers was 73.7 days, and the mean rate of healing was 0.05 cm^2 per day. In comparison, the mean number of days to healing in group two was 53.5 days and the mean rate of healing was 0.14 cm^2 per day. The outcomes of this randomised controlled trial demonstrated that the use of IPC can dramatically speed the healing of venous ulcers.

Nikolovska et al (2005) performed a key study evaluating the importance to clinical outcome of the speed of inflation of the IPC unit and cycle time in patients with venous leg ulcers. They conducted a randomised controlled trial in 104 patients with venous ulcers. Patients were divided into two groups of 52 patients each. Rapid-inflation, short-cycle IPC devices (inflated for 0.5 seconds, compressed for six seconds and deflated over 12 seconds) were applied to the lower extremities of the first group. Slow-inflation, long-cycle IPC devices (inflated over 60 seconds, compressed for 30 seconds, and deflated over 90 seconds) were applied to the lower extremities of the second group. Venous ulcers were re-examined at six months. In the rapid-inflation IPC group, healing was achieved in 45/52 (86%) patients. Among the slow-inflation IPC group patients, healing was achieved in 32/52 (61%) patients. The authors concluded that rapid-inflation, short-cycle IPC is associated with more rapid healing rates (0.09cm^2) when compared with slow-inflation, long-cycle IPC (0.03cm^2; p=0.0002).

The authors of a Cochrane review (Nelson et al, 2008) concluded that IPC may increase healing compared with no compression, but that more robust data from randomised controlled trials is necessary to determine whether IPC increases healing rates when added to compression bandages, or if IPC can be substituted for compression bandages.

Findings such as those discussed in this section have led the American College of Chest Physicians' (ACCP) evidence-based clinical guidelines to suggest that patients with severe oedema of the leg due to post-thrombotic syndrome undergo a course of IPC (grade 2B) (Kearon et al, 2008). Moreover, in patients with venous ulcers that are resistant to healing with wound care and compression, IPC is suggested as adjunctive therapy (grade 2B).

IPC for treatment of lymphoedema

With a strong body of evidence suggesting a therapeutic role for IPC in the management of chronic venous disease, there have been numerous studies on the effect of IPC on limb girth and volume in patients with lymphoedema.

Richmand et al (1985) performed a controlled trial on 24 patients with 25 lymphoedematous upper and/or lower limbs. Sequential pneumatic compression was applied for 6–8 hours. Limb girth and volume were measured before and after the therapy and showed absolute and relative reductions in limb girth measurements with the application of sequential pneumatic compression devices. For lower extremities, the absolute reduction in foot and calf girth averaged 8cm and the volume was reduced by about 45%.

In order to determine the long-term results of compression treatment for lymphoedema, Pappas and O'Donnell (1992) performed a prospective study on 49 patients with lymphoedematous limbs (22 patients with primary lymphoedema and 27 patients with secondary lymphoedema). All patients were hospitalised for 2–3 days and restricted to complete bed rest. Sequential compression devices were applied on the lymphoedematous limbs for 6–8 hours. After compression therapy, patients were measured for two-way stretch elastic stockings at their new post-reduction girth. Patients were followed-up at 4–6-month intervals for a period of 25 months, and limb girth measurements were made. Based on their initial response to compression therapy, patients were divided into three groups: full responders (26 patients who had a reduction in >3 of nine limb girths measured); partial responders (10 patients who had a reduction in ≤3 of nine limb girths measured); and non-responders (seven patients).

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Although at 25 months the full response group had no increase in limb girth, no additional reduction in limb girth was noted with long-term therapy. By contrast, the partial-response group had some return of fluid at the upper thigh, lower calf and instep. The degree of reduction at other levels, however, was maintained. Clinical characteristics of patients in each group were analysed. Although all patients in this study had lymphoedema for an extended period of time (50–80% for more than 10 years), the patients who were treated earlier in their disease process responded better. This consistent observation suggests that the condition of the subcutaneous tissue and possibly the degree of collateral lymphatic flow affects the response to compression therapy. This is further supported by Dennis (1993), who studied patients with post-mastectomy lymphoedema of the arm. She reported poorer responses in women who received delayed treatment and who had the most severe oedema when treatment, such as compression pumps and garments, was initiated.

The amount of pressure applied appears to correlate with outcome. In a comparative study evaluating three different IPC devices, patient response appeared to be related to the amount of compression delivered by the device and the cycle time (McLeod et al, 1991). The low-pressure (43mmHg), long-cycle time (five minutes) device resulted in the poorest result, whereas the device delivering the highest pressure (122.5mmHg) over the shortest cycle time (30 seconds) produced the greatest reduction in oedema.

Single-chamber devices have been shown to reduce girth in the oedematous limb (Raines et al, 1977); however, patients with fibrotic, subcutaneous tissue and those with more advanced disease responded poorly in this study. The single-chamber devices appear to have less effect than the multichamber, sequential compression devices that deliver high pressure. It is evident that the single-chamber devices deliver pressure in all directions; therefore, fluid can be distributed distally as well as proximally.

Zelikovski et al (1980) in an early study reported marked reduction in the size of lymphoedematous limbs following the application of a multi-compartment, high-pressure pneumatic compression device that achieved a peak pressure of 110mmHg. It had a short cycle time and compressed distally to proximally.

To date, no mechanical device has been designed to mimic the technique of manual lymphatic drainage (MLD). This would essentially consist of reverse sequential compression — compression of the proximal limb with release of pressure, followed by compression of the mid-limb with release, and then compression of the distal limb. The concept dictates that the proximal lymphatics are emptied first, allowing the fluid in the distal lymphatics to more easily drain proximally.

IPC techniques

Unfortunately, specific guidelines for IPC for either lymphoedema or venous disease have not been agreed upon. It is the authors' opinion, based upon the published data and personal experience, that the higher the pressure a patient can tolerate, the better the outcome. Eliska and Eliskova (1995) studied whether peripheral lymphatics were damaged by high-pressure manual massage, applying 70–100mmHg at 25 strokes per minute for up to 10 minutes. They found alterations in lymphatic collection suggesting damage, yet they reported translocation of interstitial fluid to the lymphatics, loosening of subcutaneous connective tissue, and release of lipid droplets that entered the lymphatics. Therefore, the alteration that occurred resulted in favourable outcomes and perhaps 'damage' is a mis-characterisation of the effect on lymphatics of high-pressure massage.

However, there is no similarity between high-pressure massage, which delivers focused pressure on tissues at 25 strokes per minute, and pneumatic IPC cuffs, which deliver pressure over an area of tissue that may be 100 or more times greater and have vastly different application times.

In individuals who have severe oedema, IPC pressures will begin at 90mmHg compression. It is recommended that patients initiate therapy in the afternoon and continue therapy in the evening and at bedtime. The longer the patient can tolerate compression, the better the clinical outcome.

The authors believe it is important to pad the dorsum of the foot. Sustained compression with elastic garments (at least 30–40mmHg ankle-gradient) should be used at all times and IPC applied over the compression garments. This appears to maximise the benefit of IPC, although data from appropriately designed trials are not available.

Partsch et al (2008) recently published a comprehensive consensus document which reviewed the indications for compression therapy for venous/lymphatic disease. This review includes information on experimental data and results of randomised controlled trials and clinical studies evaluating compression bandages, stockings and IPC. The consensus committee stated the need for future studies to address the relationship between pressure and time on the reduction of oedema (dose/response), as well as the duration of sustained and intermittent pressure. They suggested that future studies also address the mechanism of action and effects of the application of different pressure on physical and biochemical properties of tissue and blood on the various tissue compartments, and specifically on lymph drainage.

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Clinical applications of IPC

According to recent ACCP evidence-based clinical practice guidelines that are used internationally (Kearon et al, 2008), IPC has been accepted as a valid treatment of severe leg oedema and non-healing venous ulcers. The current recommendations include:

- For patients with severe oedema of the leg due to the post-thrombotic syndrome (PTS), the ACCP suggests a course of IPC (grade 2B)
- For patients with mild oedema of the leg due to PTS, ACCP suggests the use of elastic compression stockings (grade 2C)
- In patients with venous ulcers that are resistant to healing with wound care and compression, ACCP suggests the addition of IPC (grade 2B). (Grade 1 is a strong recommendation; grade 2 is a weaker recommendation. A, B, and C imply level of evidence, as in high-quality [A], moderate-quality [B], and low-quality [C].)

In addition to recommendations regarding treatment of chronic venous disease, the ACCP also recommends strategies to prevent venous thromboembolism (VTE) (Geerts et al, 2008). Current recommendations regarding VTE prophylaxis include:

- For every general hospital, ACCP recommends that a formal, active strategy addressing prevention of VTE be developed (grade 1A)
- For patients who have had minor low-risk general surgery and who have no additional thromboembolic risk factors, ACCP recommends against the use of specific thromboprophylaxis other than in early and frequent ambulation (grade 1A)
- For moderate-risk general surgery patients who are undergoing a major procedure for benign disease, the ACCP recommends thromboprophylaxis with low-molecular-weight heparin (LMWH), low-dose unfractionated heparin (LDUH), or fondaparinux (each grade 1A)
- For higher-risk general surgery patients who are undergoing a major procedure for cancer, the ACCP recommends thromboprophylaxis with LMWH, LDUH three times a day, or fondaparinux (each grade 1A)
- For general surgery patients with multiple risk factors for VTE who are thought to be at particularly high risk, ACCP recommends that a pharmacological method (e.g. LMWH, LDUH three times daily or fondaparinux) be combined with the optimal use of a mechanical method (IPC) (grade 1C)
- For general surgery patients with a high risk of bleeding, the ACCP recommends the optimal use of mechanical thromboprophylaxis with properly fitted graduated compression stockings (GCS) or IPC (grade 1A). When the high risk of bleeding decreases, ACCP recommends that pharmacological thromboprophylaxis be substituted for, or added to the mechanical thromboprophylaxis (grade 1C)
- For patients undergoing major general surgical procedures, the ACCP recommends that thromboprophylaxis should continue until discharge from hospital (grade 1A). For selected high-risk general surgery patients, including some of those who have undergone major cancer surgery or have previously had VTE, the ACCP recommends

that prophylaxis should be continued after hospital discharge with LMWH for up to 28 days (grade 2A)

- For patients receiving mechanical methods of thromboprophylaxis, ACCP recommends that careful attention be directed toward ensuring the proper use of, and optimal adherence to, these methods (grade 1A).

Other therapeutic options

Several other therapeutic options exist for patients with venous and lymphatic insufficiency of the lower extremities. The following sections provide a brief description of these options.

Manual lymph drainage (MLD) and bandaging

The Cochrane collaboration recently reported a review of physical therapies for reducing and controlling lymphoedema of the limbs (Preston et al, 2004). MLD was evaluated in a parallel group studied by Andersen et al (2000). The study focused on women with unilateral lymphoedema of the upper extremity following treatment for breast cancer. This may not reflect the results of a similar treatment for lymphoedema (primary or secondary) of the lower extremity. The investigators failed to demonstrate that MLD provided additional benefit to compression sleeves in upper extremity lymphoedema.

Badger et al (2000) performed a randomised controlled trial of bandaging plus hosiery for unilateral lymphoedema of the upper and lower extremity versus hosiery alone. The outcome measures were a reduction in volume of the extremity. There was a preponderance of upper extremity lymphoedema in women. The authors demonstrated that both groups achieved benefit; however, patients in the bandage-plus-hosiery group enjoyed greater benefit than the hosiery-alone group. These observations support the concept that the greater and more sustained the compression, the better the outcome for patients with lymphoedema.

Pharmacological agents

Diuretics

Diuretics are frequently prescribed to reduce leg oedema. Generally, however, long-term use of diuretics should be avoided — diuretics are more effective at depleting intravascular fluid than the protein-rich extravascular fluid of chronic oedema. They can also damage the physiological regulation of the renin–angiotensin mechanism, resulting in the paradoxical 'diuretic-induced' oedema (Braunwald et al, 1994).

Micronised purified flavonoid fraction

Micronised purified flavonoid fraction (MPFF) refers to the hydroxyrutosides, which are a class of flavonoid drugs produced from plant glycosides. Micronisation of the flavonoid compound improves intestinal absorption and its bioavailability (Lyseng-Williamson et al, 2003) and is thought to improve clinical effects.

The precise mechanism of action of these compounds is not entirely known, but studies suggest there is a reduction in capillary permeability, reduction in inflammation, improvement in lymphatic function, and symptomatic improvement in patients with chronic venous disease (Shoab et al, 1999).

Coleridge-Smith et al (2005) performed a meta-analysis of five trials that evaluated MPFF in the management of patients with venous ulceration who were also treated with compression. Two of the five studies incorporated placebo controls. At six months, complete ulcer healing occurred in 61% of the MPFF patients and 48% of the control patients (p=0.03). The benefit of MPFF appeared greatest in patients with ulcers ≥5cm^2 and those with ulcers of long duration (>6 months).

The above findings led the ACCP to recommend that patients with persistent venous ulcers be treated with rutosides in the form of MPFF administered orally, or sulodexide administered intramuscularly and then orally, in addition to local care and compression (grade 2B) (Kearon et al, 2008).

Pentoxifylline

Pentoxifylline modifies the red blood cell membrane, resulting in changes in the rheology of blood that lead to improvement at the microcirculatory level (Barbarino, 1992). Pentoxifylline has been studied for the management of patients with venous leg ulcers in eight randomised studies (Weitgasser, 1983; Schurman and Eberhardt, 1986; Arenas and Atoche, 1988; Colgan et al, 1990; Herdy et al, 1997; Dale et al, 1999; Falanga et al, 1999; Nikolovska et al, 2002). A combined total of 547 patients with venous leg ulcers were treated with either pentoxifylline or placebo, evaluating objective measures of wound healing. Lower leg compression was used in five of the eight studies and in three studies no compression was used. Patients treated with pentoxifylline showed improved healing rates and a greater number completely healed (risk reduction 1.5). In the studies in which compression was used, healing parameters improved by approximately 30% with pentoxifylline. In the three studies in which compression was not used, healing was also improved (risk reduction 2.4). These findings led to the ACCP recommending that pentoxifylline be used in patients with venous leg ulcers at an oral dose of 400mg three times a day, in addition to local care and compression and/or IPC (Grade 2B) (Kearon et al, 2008).

Sustained compression

Elastic compression stockings have been shown to be effective in several clinical situations (Partsch, 2004). The main indications for lighter compression stockings (20–30mmHg ankle gradient) are the prevention of leg oedema after prolonged sitting or standing and venous thromboembolism prophylaxis in bedridden patients. Higher compression stockings (30–40mmHg ankle gradient) are used for the treatment of patients with and after DVT to prevent post-thrombotic complications, after healing of venous ulcers to prevent recurrence and for the management of lymphoedema. Higher compression (50–60mmHg) may be required in patients with more chronic and severe lymphoedema.

Elastic compression stockings have been shown to be effective in preventing recurrence following the healing of venous ulcers and have also been shown to be cost-effective (Korn et al, 2002). However, patient compliance is often less than optimal. Jull et al (2004) reported that only 52% of the patients reported wearing stockings every day for the first six months after their ulcers had healed. Two factors distinguished those patients who wore stockings 75% of the time from those who did not: the belief that wearing stockings was worthwhile and the belief that stockings were uncomfortable to wear. Discomfort was found to be a leading reason why pregnant women were non-compliant with the use of elastic compression stockings (Gray and Ash, 2006). Elastic compression stockings with a pressure of more than 20mmHg may not be tolerated overnight because of the high resting pressure caused by the recoiling force of the rubber-like elastic fibres on the supine leg; since the venous pressure in the lower leg is much less in the supine position, the compression stockings should be removed before going to bed.

Experimental studies have found beneficial effects of compression stockings on leg swelling and improvement of the microcirculation of the skin. However, the pressure of most stockings is inadequate to narrow the deep veins when the patient is in the upright position (Partsch and Partsch, 2005). This is also true for the immobile patient sitting in a wheelchair with dependent legs; however, the interstitial pressure is increased by proper compression, which will help control oedema.

Conclusion

The physical application of external compression is key to the treatment and management of patients suffering from venous and lymphatic disease. Well-designed clinical studies have demonstrated that the addition of IPC to wound care and standard compression therapy, such as bandages and elastic stockings, results in improved and more rapid healing of venous ulcers. IPC produces numerous physiological effects, which appear to contribute to an enhanced environment for wound healing and it also has an important role to play in the treatment of lymphatic and venous disease. JL

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Key points

- Active compression therapy by IPC applies pulsatile external pressure, producing a pressure gradient in the leg that mimics rhythmic muscular contractions where such movements are restricted or entirely absent — this results in important benefits for patients.
- In individuals who have severe oedema, IPC pressures will begin at 90mmHg compression. It is recommended that patients initiate therapy in the afternoon and continue therapy in the evening and at bedtime.
- IPC produces numerous physiological effects, which appear to contribute to an enhanced environment for wound healing and it also has an important role to play in the treatment of lymphatic and venous disease.

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