Compression Therapy

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Compression Therapy

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BACKGROUND. Compression therapy is the standard care for venous insufficiency ulcers. It reverses some of the underlying pathologies and restores a functional calf pump unit.

OBJECTIVES. To review the pathophysiology of venous ulcers and the different types of compression devices available.

RESULTS. The choice of a compression device should be individualized and tailored to the need of the patient. It should be applied by skilled nurses or physicians.


Hippocrates (460–377 BCE) was the first to mention leg ulcers and to recognize some relationship between leg ulcers and venous disorders. Later, the Roman physicians Aurelius Celsus (25 BCE–AD 50), Claudius Galen (AD 130–200), and Aetios Amida (AD 502–574) encouraged the use of plasters and linen bandages in the treatment of these ulcers.1

The first efforts to provide extrinsic calf compression were made in the seventeenth century, by Richard Wiseman (1676), using rigid lace-up stockings applied over the lower calf in an attempt to heal leg ulcers.2 The nonelastic zinc paste bandage, Unna’s boot, which carried its inventor’s name, Paul Gerson Unna, was introduced in 1885 and is still in present day use.

Vander Molen had the idea of graduated the level of elastic compression, an idea that was developed later on by Sigg and Ganzoni in the form of a graduated compression stockings.3 Six years later, Steenue calculated that an external pressure of 35–40 mm Hg was needed at the ankle to prevent capillary transudation in legs with severe venous disease.4 In 1950 Brush and Beninson described their first commercially available “Jobst” stocking.5,6

Intermittent compression therapy can be considered to have originated during the 1930s, when Landis and Hermann described their system of alternate suction and pressure for the treatment of peripheral vascular diseases.7,8 The instrument was named after the engineer Gondred Jobst. This instrument provides an evenly graduated pressure to the leg, maximal at the foot and approaching zero at the thigh. The sequential pressure equipment presented by Sampson and Kirby in 1955, the Vaso-Pneumatic, was a 14-part sleeve.3 Each chamber of the sleeve is sequentially filled, beginning proximally. The device repeated the pressure pulses 20 times per minute.

More sophisticated devices that provide ventilation for the extremities, or repeat the compression cycles with a frequency of 30–120 Hz, synchronously with the heart rate are available nowadays.10,11

Pathophysiology of Venous Ulcers

The venous system of the lower extremities consist of deep, communicating, and superficial veins whose one-way valves direct blood from the superficial to the deep venous system in the presence of pressure differential between the superficial and deep venous systems.12 Upon ambulation or leg exercise, the contraction of the calf pump causes a drop in the deep venous pressure, thus allowing blood to flow through the communicating veins from the superficial venous system.

A dysfunctional calf pump unit can result from insufficiency of the deep, perforator or superficial veins, arteriovenous fistulas, neuromuscular dysfunction, or a combination of these factors, thus inhibiting the predicted fall in venous pressure upon ambulation or leg exercise.12 Under normal physiologic conditions, venous distention leads to venous stretch receptors stimulation, resulting in arteriolar vasodilatation via the sympathetic spinal reflex.17 In case of venous insufficiency, the continuing venous distention is not relieved by exercise, maintains the arteriolar vasodilatator impulse, and perpetuates skin hypoxia, which is only abolished by leg elevation or effective external compression.18

The relationship between calf pump failure and leg ulceration has been described by Browse et al.13 An ambulatory venous pressure exceeding 45 mm Hg increases the incidence of ulceration.14 At the microvascular level, venous hypertension is transmitted back to the dermis, leading to capillary bed vasodilatation and leakage of macromolecules, particularly fibrinogen, from the blood.15,16 Pericapillary fibrin cuff has been postulated to act as a barrier to the diffusion of oxygen and other nutrients, rendering the skin more vulnerable to ulceration and prolonging the healing process.12
Several other theories on the possible mechanism of ulceration have been advanced. Thomas et al described the white cell trapping hypothesis within the vasculature of the leg. When subjects are sitting, the white cells decrease the capillary perfusion by plugging the microcirculation and inducing the release of inflammatory mediators, which increase vascular permeability, possibly resulting in tissue damage.

Impaired lymphatic function is associated with venous insufficiency. Lymphatic dysfunction probably plays a significant role in edema formation, which in turn may predispose to infection, impaired wound healing, and fibrosis.

Compression therapy helps to reverse some of these abnormalities by trying to restore a functional calf pump unit. A variety of compression devices are available.

Types of Compression

Types of compression include graduated compression stockings, elastic and inelastic bandages, orthotic devices, and compression pumps. Each device can be tailored to meet individual needs and partially restore some defective physiologic functions. Whether elastic or inelastic compression is preferable is controversial, and several combinations of combined elastic and inelastic compression have been described.

Graduated Compression Stockings

Graduated compression stockings (Figure 1) underwent important developments in design and manufacture in recent years. Each garment has a standard compression value graduated up the stocking, from a maximum at the ankle to a minimum at the thigh. The effects of graduated compression stockings on physiologic tests of venous function in legs with chronic venous disease have been studied. A fall in the ambulatory venous pressure has been detected along with a rise in the expelled calf volume upon exercise.

There are four classes of compression stockings based on the compression exerted at the ankle. Compression class one is 20-30 mm Hg, recommended for simple varicose veins, light edema, or patients complaining of leg fatigue. Compression class two is 30-40 mm Hg, prescribed for patients suffering from moderate edema, severe varicosities, and moderate venous insufficiency. Compression classes three (40-50 mm Hg) and four (60+ mm Hg) are reserved for severe

<table>
<thead>
<tr>
<th>Vessel Type</th>
<th>Compression Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telangiectasia (nonprotuberant) not associated with reticular veins</td>
<td>Transpore tape with cotton balls for 24 hours</td>
</tr>
<tr>
<td>Telangiectasia (protuberant) associated or not associated with reticular vein</td>
<td>Graduated compression hose of 15-18 mm Hg for 1-2 weeks with Transpore tape over cotton balls. Cotton balls are removed after 24 hours.</td>
</tr>
<tr>
<td>Reticular veins up to 3 mm</td>
<td>Graduated compression hose 15-18 mm Hg for 1-2 weeks. Cotton balls with tape at injection sites are removed after 24 hours.</td>
</tr>
<tr>
<td>Larger reticular veins 4-6 mm or minor varicose veins (&lt;6 mm)</td>
<td>Graduated compression hose 20-30 mm Hg for 2 weeks. Cotton balls with tape at injection sites are removed after 24 hours.</td>
</tr>
<tr>
<td>Varicose veins (&gt; 6 mm)</td>
<td>Graduated compression hose 30-40 mm Hg for 2 weeks. Foam pads over injection site are held by short stretch bandage for 3 days.</td>
</tr>
</tbody>
</table>

cases of edema, venous insufficiency including post-thrombotic lymphatic edema, and elephantiasis.

For chronic venous insufficiency, knee-high compression stockings are usually prescribed. Compression of the calf area is important to augment calf muscle pump activity in venous insufficiency. Thigh-length stockings are prescribed less frequently because they are difficult to put on, tend to fall-down, and do not compress the thigh area well. Compression panty hose can be prescribed for mild edema, varicose veins, or leg fatigue.

Compression stockings may be difficult to apply especially for the elderly, obese, or patients with arthritis. Various devices have been introduced to facilitate stocking application. Most stocking manufacturers provide a nylon or silk sock to help slide the stockings over the foot (Figure 2). Similarly, rubber gloves are of considerable help in obtaining a good grip at the top of the stocking. Medi-Valet is a device developed in Germany, made up of a plastic covered steel frame over which the stocking is stretched, allowing the patient to slip his foot and ankle into the opening of the stocking.

Compression stockings offer the advantage of accommodating different shapes of legs and for patients with highly exudative wounds. They can be removed, the wound inspected, and the dressings changed frequently. Elasticity of these stockings decreases with time and washing, and they should be replaced at least every 6 months.
Compression stockings are frequently recommended after sclerotherapy. General guidelines are listed in Table 1.

Elastic Bandages
Another form of compression is provided by elastic wraps, such as elastic or adherent bandages and wraps made to provide ambulatory hemodynamic support (Figure 3). It is very difficult for the patient to apply these consistently to give the correct compression. The amount of compression provided may vary with each application and with the person who applies them. Some bandages have been developed that facilitate application of the appropriate tension. Printed on the bandage is a rectangle that stretches into a square when the correct amount of tension is applied (Figure 4). When compression bandages are applied, the heel should be included and the bandage should be applied from below the toes to just below the knee. Falanga advocates the use of local supplemental pressure, the addition of extra layers of gauze under the compression bandage, when the ulcer is in a depressed area, such as near the malleoli. Self-adherent wraps (Figure 5) are light weight elastic wraps that do not unravel, but can be used once only.

Unna’s Boot
Unna’s boot is an around-the-clock substitute for a failing muscle pump. It is a medicated bandage containing zinc oxide, calamine, glycerine, sorbitol, and magnesium silicate. Its inelastic consistency makes it a “pump” with the ankle joint creating the pumping force (Figure 6).

The boot produces a pressure gradient between the ankle and the calf. The mean pressure at the medial malleolus is 29.8 mm Hg (varies from 18 to 55 mm Hg according to the bandage) and decreases when approaching the knee. When compared with elastic support stockings with a gradient compression from 26 mm Hg at the ankle to 16 mm Hg at the calf in the treatment of venous leg ulcers, there was no statistical difference between their success rate in healing venous ulcers. However, the average healing time with the Unna’s boot was
3 weeks, compared with an average of 18.4 weeks for the group treated with the elastic support stocking.

Unna’s boot has been the standard medical treatment for venous ulcers for many years. Patients find them comfortable, with minimal interference with their regular activities. They protect against trauma with full maintenance of ambulatory status. However, they need to be applied by trained physicians and nurses. Sometimes a variable ankle-calf compression ratio may result depending on the person who applies them. They do not accommodate highly exudative wounds, may exacerbate wound infection, and can cause localized purpura and cyanosis of the toes if applied too tightly. They are contraindicated in patients with arterial insufficiency, where gangrene may occur.

A four-layer bandage system has been designed to maintain sustained compression in patients with venous insufficiency. The innermost layer is an orthopedic wool layer specially designed to absorb exudate, redistribute pressure around the ankle, and protect bony prominences from excessive pressure (Figure 7). The crepe layer is the second layer, which smooths the orthopedic one and increases absorptivity (Figure 8). Compression is provided by the two outer layers. The third layer is highly elastic, applied at mid-stretch in a figure-eight pattern with 50% overlap (Figure 9). For ankles measuring 18–25 cm, this layer provides a mean pressure of 17 mm Hg. The last and outermost layer is a cohesive bandage that provides an ankle pressure of 27 mm Hg and maintains the bandage in place for a full week (Figure 10).

In an attempt to compare the new four-layer bandage to the commonly used adhesive plaster bandaging system, pressure measurements were made using the Oxford Pressure monitor on 20 patients with venous leg ulcers. A sustained pressure of 40 mm Hg was achieved for 1 week by the four-layer bandage compared with a pressure of 30 mm Hg provided by an adhesive plaster bandage. The latter varied with the technique of application and dissipated rapidly after few hours.

Graduated compression has been shown to increase blood velocities in the deep veins, to reduce edema formation, and to improve the healing rate of chronic venous ulcers. Theoretically, 40 mm Hg pressure at the ankle is required to reverse chronic venous hypertension. In a study of 118 chronic venous ulcers with a mean duration of 27 months, complete ulcer healing was achieved in 74% of ulcers at 12 weeks using the four-layer bandage system. Similarly, when used in the community clinics, the bandage achieved 94% complete healing in 12 weeks in patients with venous ulcers and 88% by 21 weeks. Other authors have not achieved such high healing rates.

The pressure in a bandage system must be adjusted to the shape of each leg. For instance, very thin legs need extra padding to prevent excessive pressure over the bony prominences and the tendinous area over the dorsum of the foot, which may cause pressure necrosis. Pleating the orthopedic wool layer can protect the tibial crest and create a cushion against trauma.

It is imperative to exclude patients with arterial disease as compression bandaging may be hazardous in these patients.

Orthotic Compression Device

This is an inelastic device consisting of multiple adjustable Velcro strips around the leg from the instep to the knee. The device provides sustainable compression, is easily applied and removed, and can be adjusted for patient comfort (Figure 11). This device is helpful for patients who require compression yet need frequent dressing changes, and who find other compression bandages uncomfortable or difficult to use.

Compression Pumps

The intermittent pneumatic compression pump is designed to provide intermittent compression at varying pressures depending on the severity of the underlying pathology (Figure 12). It improves the venous return in the lower extremities and is believed to improve the fibrinolytic activity within the blood vessels, thus reducing the extravascular fibrin and surrounding capillaries in the region of venous ulceration. Intermittent compression therapy also promotes the flow through existing lymphatics and increases transcapillary exchange of extravascular protein and water into the intravascular space. To reduce lymphedematous leg, the pressure should be applied in small increments from the foot progressively up to the entire calf and thigh.

A multicompartiment, high pressure pneumatic compression device was found to be superior to a single
Table 2. Advantages and Disadvantages of Different Types of Compression

<table>
<thead>
<tr>
<th>Bandages</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic wraps</td>
<td>Inexpensive</td>
<td>Often applied incorrectly by the patients</td>
</tr>
<tr>
<td></td>
<td>Can be reused</td>
<td>Tend to unravel</td>
</tr>
<tr>
<td>Self-adherent wraps</td>
<td>Self-adherent</td>
<td>Do not maintain sustained compression</td>
</tr>
<tr>
<td></td>
<td>Maintain compression</td>
<td>Lose elasticity after washing</td>
</tr>
<tr>
<td></td>
<td>Comfortable</td>
<td>Expensive</td>
</tr>
<tr>
<td></td>
<td>Protects against trauma</td>
<td>Can not be reused</td>
</tr>
<tr>
<td></td>
<td>Full maintenance of ambulatory outpatient status</td>
<td>Pressure changes over time</td>
</tr>
<tr>
<td></td>
<td>Minimal interference with regular activities</td>
<td>Needs to be applied by trained physicians or nurses</td>
</tr>
<tr>
<td></td>
<td>Substitute for a failing pump</td>
<td>Does not accommodate highly exudative wounds</td>
</tr>
<tr>
<td>Four-layer bandage</td>
<td>Comfortable</td>
<td>Needs to be applied by well trained physicians and nurses</td>
</tr>
<tr>
<td></td>
<td>Can be left in place 7 days at a time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protects against trauma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintain a constant pressure for a week due to the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>overlap and elasticity of the bandages</td>
<td></td>
</tr>
<tr>
<td>Graduated compression stockings</td>
<td>Reduce the ambulatory venous pressure</td>
<td>Often can not monitor patients compliance</td>
</tr>
<tr>
<td></td>
<td>Increase the venous refilling time</td>
<td>Difficult to put on</td>
</tr>
<tr>
<td></td>
<td>Improve calf pump function</td>
<td></td>
</tr>
<tr>
<td>Orthotic device</td>
<td>Adjustable compression</td>
<td>Expensive</td>
</tr>
<tr>
<td></td>
<td>Sustained pressure</td>
<td>Bulky appearance</td>
</tr>
<tr>
<td></td>
<td>Easily put on and removed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Comfortable</td>
<td></td>
</tr>
<tr>
<td>Compression pump</td>
<td>Augment venous return</td>
<td>Expensive</td>
</tr>
<tr>
<td></td>
<td>Improve hemodynamics and microvascular functions</td>
<td>Requires immobility for a few hours/day</td>
</tr>
<tr>
<td></td>
<td>Enhance fibrinolytic activity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prevent postoperative thromboembolic complications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>in high-risk patients</td>
<td></td>
</tr>
</tbody>
</table>

compartmental one in reducing lymphadematous tissue.\textsuperscript{37} Large volumes of edema fluid were mobilized using a high peak pressure (100–110 mm Hg), a short cycle, and distal to proximal milking action.\textsuperscript{38}

Originally, the intermittent pneumatic compression (IPC) pump was developed for the prophylaxis of deep venous thrombosis, and later its therapeutic benefits extended to include patients with chronic venous insufficiency.\textsuperscript{39,40} A randomized study was undertaken to compare two regimens of treatment for patients with chronic venous hypertension.\textsuperscript{41} Both regimens included ulcer debridement, cleaning with nonadherent dressing application, and graduated compression stockings. In one regimen, 21 patients had a sequential gradient intermittent pneumatic compression for 4 hours each day. Ten of these patients experienced complete healing compared with one out of 24 patients in the control group. The median rate of ulcer healing in the control group was 2.1% area/week compared with 19.8% area/week in the IPC group. In an open clinical trial, three patients suffering from persistent postthrombotic leg ulcers and five from recurrent postthrombotic leg ulcers were treated with IPC therapy.\textsuperscript{42} Combined, IPC therapy and conservative treatment were found to shorten the ulcer healing time and to increase skin oxygen tension (TcPO\textsubscript{2}). The latter has been measured near the edge of the leg ulcer before and after 60 minutes of IPC at 50 mm Hg in 10 patients. The mean TcPO\textsubscript{2} was 26.2 mm Hg before treatment and increased significantly to 42.7 mm Hg after therapy (P < 0.005). The increase in tissue oxygenation may have resulted from the decrease in interstitial fluid volume. However, Nemeth et al failed to detect an increase in the oxygen tension despite a decrease in leg edema.\textsuperscript{43}

IPC therapy has been successfully applied in hospitals to treat persistent leg ulcers.\textsuperscript{44,45} Out patients can rent or buy the home model extremity pump intermittent compression unit upon prescription and after demonstration of its use. However, IPC should not be recommended during episodes of inflammatory phlebitis or any instances when increased venous or lymphatic return is undesirable.

We generally prescribe a home compression pump in patients who have not responded to other compression
Figure 12. Multicompartmental pneumatic compression pump.

modalities, particularly those with nonhealing venous ulcers and recalcitrant lymphedema.

Table 2 categorizes the different types of compression as well as summarizing their advantages and disadvantages.

Possible complications of compression devices include the following: 1) Pressure necrosis. This can occur in patients with arterial disease or vasculitis. Always check pulses and ankle brachial pressure index prior to compression therapy. 2) Skin trauma. This can occur on removing bandages, or related to friction, particularly in patients with thin legs, over bony prominences. 3) Cardiac failure. Compression may exacerbate cardiac failure with secondary edema, due to overload of venous return.

Summary

The choice of compression device needs to be tailored to the needs of the patient and extent of the disease. Although the drug therapies and operative measures for treatment of venous insufficiency are being refined and improved, compression therapy continues to constitute the foundation for the treatment of venous insufficiency.

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