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The Science of Compression Therapy for Chronic Venous Insufficiency Edema

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Abstract One of the goals of compression therapy is to enhance healing of a venous leg ulcer. This goal is accomplished by improving venous return and reducing lower extremity edema.

At the end of the day, a person without any underlying disorders and with a reasonable circulatory status may have some lower extremity gravity-dependent edema. However, significant edema is associated with clinical pathology. Management of lower extremity edema improves patients' comfort and mobility, as well as being a key ingredient in healing lower extremity venous insufficiency ulcerations. Lower extremity edema, by inhibiting fresh oxygenated blood flow into a leg, can exacerbate ulcerations whose primary etiology is arterial insufficiency.[1]

The peripheral circulatory system has a hydrostatic pressure created by the force of the heart pump. The elastic walls of the arteries, arterioles, and arterial side of the capillaries contribute to the hydrostatic pressure. In the veins, the hydrostatic pressure depends mostly on the distance from the right atrium. The lower extremity venous system is composed of a superficial system, a perforating (connecting) system, and a deep system. Blood flows from the superficial system through the perforating system to the deep system. Valves prevent backflow and reflux of blood. Muscles, when contracting, exert a high pressure on the deep veins and pump blood toward the heart (Figure 1).[1]

Venous pressure at the ankle is higher in a person standing than in a person lying with the ankle veins at the same level as the right atrium. This is an important fact in deciding on the type of compression to be used and will be discussed later.[1,2]

The venous muscle pump is an important concept in compression therapy. When a person moves, muscles contract, which compresses adjacent veins and forces venous blood flow back to the heart (Figure 2). When these muscles relax, the emptied veins fill up again. One-way valves prevent backflow, and the muscles, combined with the one-way valves, constitute the so-called venous muscle pump. The most important venous pump is the calf muscle pump. The venous muscle pump works only with motion (eg, ambulation, muscle contraction), with unobstructed veins, and with intact venous valves. If any of these three factors fail, venous pressure in the lower extremity rises. Over time, this pressure increase could lead to chronic venous hypertension.[1,2]

As venous pressure increases, hydrostatic pressure of blood increases in the superficial and deep venous systems. Higher hydrostatic pressure in the capillaries leads to greater filtration of fluid from the capillaries to the interstitial spaces. Compounding this process is the fact that increased tissue pressure in interstitial spaces attracts more

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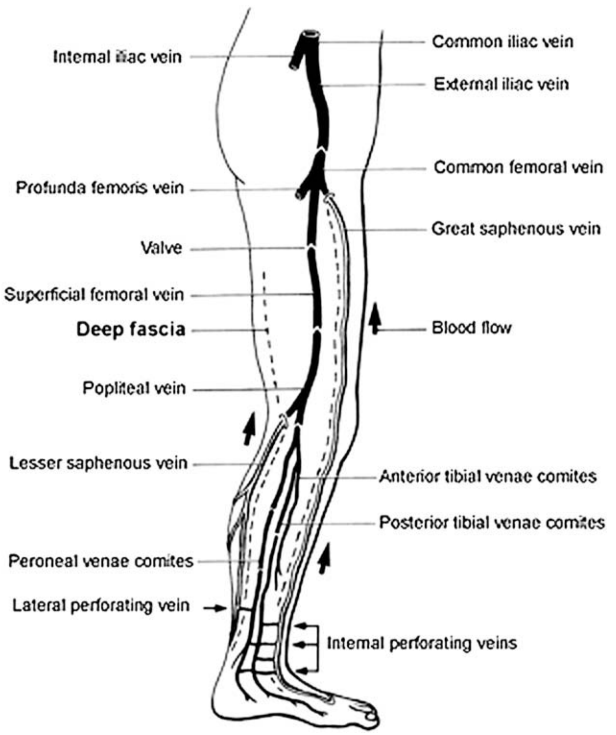


Figure 1 Lower Extremity Venous System.

fluid to the area. The end result of this process is the creation of edema in the lower extremity.[1,2]

Oncotic pressure (the force that moves fluids from a concentrated to a less concentrated environment) also affects edema formation. The fluid that filters through the capillaries to the interstitial spaces contains dissolved proteins, electrolytes, salts, cells, and metabolic by-products. As this volume of fluid increases, oncotic pressure increases in the interstitial spaces, which results in another force contributing to the accumulation of fluid (edema) within the interstitial tissues of the lower extremity. As inflammation increases in the lower extremity, capillary permeability changes, and proteins, cells, and electrolytes can diffuse from the capillaries into the interstitial spaces. Over time, this can lead to fibrotic changes in the tissues.[1,2]

Clearly, there are many elements to be considered, not to mention the lymphatic system, when one is evaluating lower extremity edema.

Two methods are used in compression therapy (Figure 3). The first method involves compressing the leg during sedentary periods. The second method involves increasing the calf and foot pumps during active periods.[3]

Standard Compression Versus Support

There is a difference between standard compression and support systems. Standard compression is an elastic system with a high pressure at rest and a slightly lower pressure during activity or muscle contraction. A support system is a relatively rigid and inelastic system that offers very little pressure at rest but offers high pressure with muscle contraction against a fixed resistance.[3]

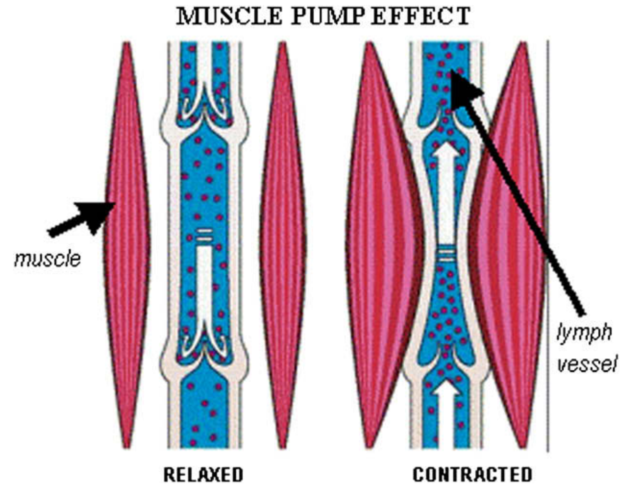


Figure 2 Venous Muscle Pump and Valves. This figure is used, with permission, from The Lymphoedema Support Group of NWS, http://www.lymphoedemasupport.com/muscle.php.

The factors in compression therapy can be understood by examining the modified Laplace's law.[3,4] This law states that the subbandage pressure is determined by the number of layers of bandage applied, times the tension by which the bandages are applied, times a constant, all divided by the circumference of the limb times the bandage width.[3,4] In other words,

$$\text{subbandage pressure} = \frac{(\text{tension})\ (\#\text{ of layers})\ (\text{constant})}{(\text{circumference of limb})\ (\text{bandage width})}$$

Increasing any factor in the denominator of this equation decreases the subbandage pressure.[4] For example,

1. Increasing the circumference of the limb decreases the subbandage pressure. The same bandage with 25-45 mm Hg pressure on a thin leg will give only 15-20 mm Hg pressure on a leg with a larger circumference.
2. Increasing the bandage width decreases the subbandage pressure. A 4-inch (10.16-cm)-wide bandage will apply less pressure than a 2-inch (5.08-cm)-wide bandage.

Increasing any factor in the numerator of this equation increases the subbandage pressure.[4] For example,

1. Increasing the bandage tension increases the subbandage pressure.
2. The more layers present, the greater the compression.

Graduated Compression

Another important concept in wound care is graduated compression. Subbandage pressure is directly proportional

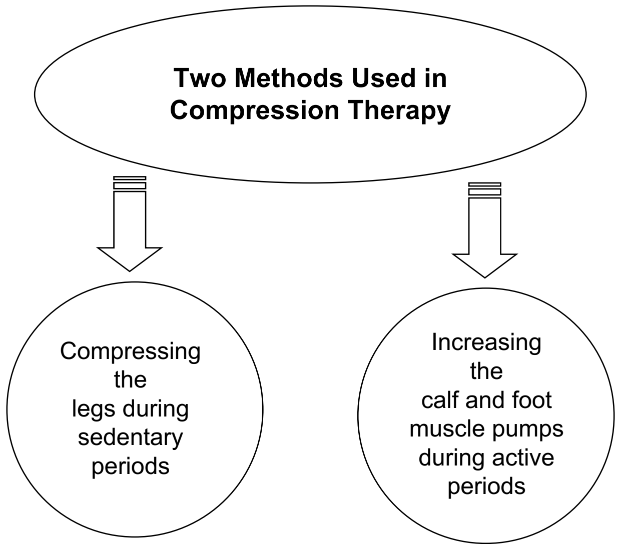


Figure 3 Two Methods of Compression Therapy.

to bandage tension but is inversely proportional to the radius of curvature of the limb to which it is applied. This means that a bandage applied with constant tension to a limb of normal proportions will automatically produce a gradient of compression, with the highest pressure at the ankle. This pressure will gradually decrease up the extremity as the circumference increases.[3,4]

Most extremities are not circular in cross section. Consequentially, the pressure applied by a bandage will vary significantly around the circumference at any given point on the leg. Particularly large variations in pressure will be found over bony prominences such as the malleolus and the tibial crest. For this reason, it is recommended that prior to application of a compression bandage, adequate padding should be applied to the leg to prevent localized areas of excessively high pressure. This padding should not be simply wrapped around the leg but should be applied in strips around or along bony prominences or protruding areas.[3,4,5] The aim of a compression bandage should be to impart to the leg a circular cross-sectional profile in order to achieve constant levels of compression.[3]

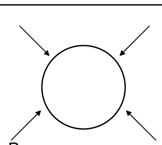
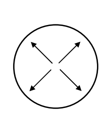
	Compression	Support
System Type	Elastic	Nonelastic
System at Rest Rest	 High Pressure	 Low pressure
At Muscle contraction	High pressure but less than with support	High pressure
Low Compression	Single Layer Elastic Bandage	Unna's Boot
High Compression	Long Stretch four layer	Short stretch Modified Unna's boot

Figure 4 Compression Versus Support[3].

Vascular Assessment

A thorough vascular assessment should be performed before a method of compression therapy is chosen. An ankle brachial index (ABI) determined with a Doppler can help identify coexisting arterial disease.[6] An ABI value between 0.8 and 1.0 indicates that the diagnosis is primarily venous and high compression can be used. An ABI value between 0.5 and 0.8 indicates that the diagnosis may be mixed arterial and venous pathology, and compression must be modified because of its effect on arterial inflow. An ABI value below 0.5 indicates possible severe arterial disease, and compression should be delayed until the arterial insufficiency is investigated.[3,7,11]

Take caution and thoroughly evaluate whether the edema is a sign of congestive right heart failure.[11] The possible sources of bilateral edema include congestive heart failure, systemic and metabolic abnormalities, endocrine dysfunction, lipedema, and pregnancy.[8] Possible causes of unilateral lower extremity swelling include venous and arterial abnormalities, lymphedema, infection, trauma, and neoplasms.[8]

Types of Compression Systems

There are four basic types of compression systems: inelastic, elastic, single component, and multicomponent. Inelastic systems have low resting pressure and high working pressure. These are safer and more appropriate for venous insufficiency complicated by arterial disease (Figure 4). There is a rapid loss of compression over time. An elastic system has a high resting pressure (Figure 4) and a high working pressure. Elastic systems are not safe for coexisting arterial disease. Little pressure is lost over time. A single-layer system delivers constant pressure whereas a multicomponent system can deliver graded compression.[2,3,5]

Compression choices can also be divided into high-compression systems, support systems, and low-compressions systems.[2,3,5]

High-Compression Systems

High-compression systems are multicomponent systems and long-stretch bandages. Support systems are short-stretch bandages and modified Unna's boot (paste bandages). Low-compression systems include single-component elastic bandages and short-stretch systems without an underlayer.

High-Compression, Multicomponent Systems

Multicomponent high-compression systems are bandaging systems using 4 layers, or components. These systems can apply a subbandage pressure of 40 mm Hg at the ankle. Pressure is gradually reduced to 17 mm Hg at the knee. The components consist of natural padding; a light, comfortable bandage; a light compression bandage; and a flexible

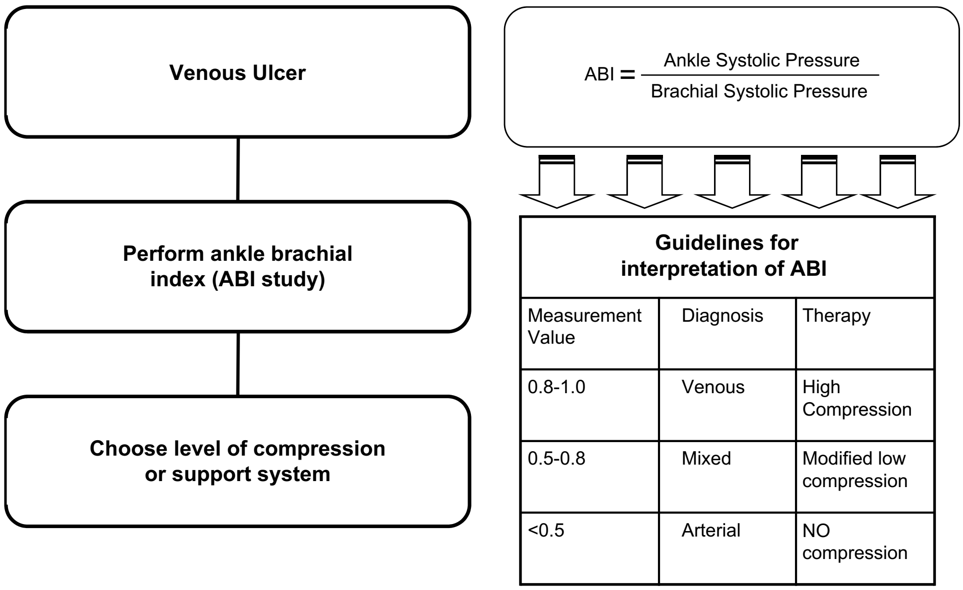


Figure 5 Algorithm for Choosing Level of Compression[3].

cohesive bandage. Note that this bandage system should not be used with coexisting arterial disease (Doppler ABI $<$ 0.80).[2,3,5]

High-Compression, Long-Stretch Bandages

Long-stretch bandages consist of an orthopedic wool undercomponent and a long-stretch elastic bandage. Long-stretch means a long stopping distance or maximum extensibility compared with the relaxed state. Some long-stretch bandages have shapes imprinted on them that change to indicate when proper stretch has been reached. The advantages of high compression with long-stretch bandages are that the elastic layer can be laundered and reused, they are less bulky than 4-component systems, and they allow for frequent inspections. The disadvantage is that this type of bandaging has a propensity to slip.

Support Systems

Support Systems With Short-Stretch Bandages

Short-stretch bandages are relatively inelastic and work on the deep venous system by providing a fixed resistance against the leg muscles when they contract. Since the muscle cannot expand outward because of the fixed resistance of the bandage, the squeeze is within the leg, and this pushes venous blood toward the heart. This system has very little elastic energy; it acts mostly as a support system.

Inelastic bandages provide a low resting pressure but a high working pressure. Inelastic bandages are tolerated in recumbent positions and at night, even by patients with mild arterial vascular disease. Note that with inelastic support bandages, pressure is increased with narrower bandages and with increased overlap of bandages. Pressure

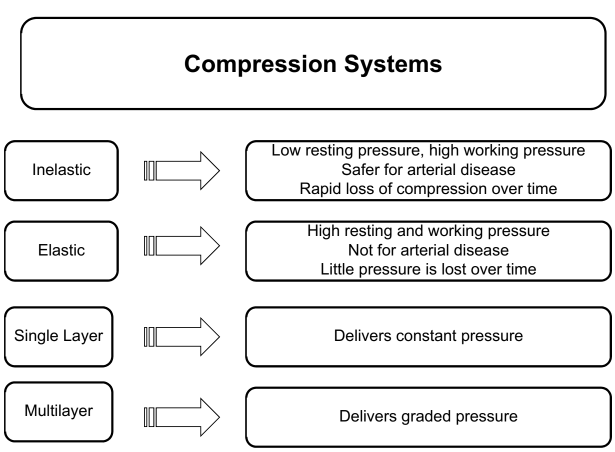


Figure 6 Compression Systems.

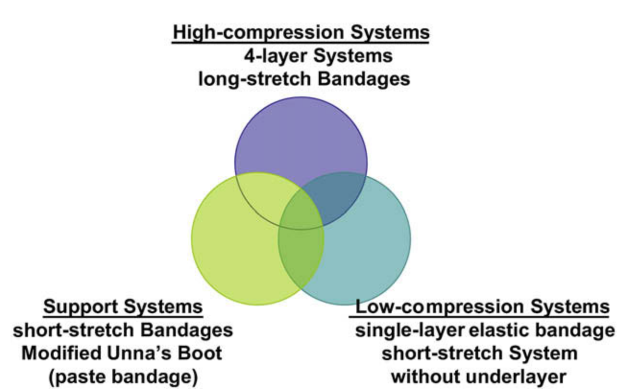


Figure 7 Compression Choices.

is decreased with wider bandages and less overlap. A paste bandage of 4 inches (10.16 cm) with few overlaps provides significantly less subbandage pressure than a paste bandage of 2 inches (5.08 cm) when applied with many overlaps.

Modified Unna's Boot

A modified Unna's boot (paste bandage) is a type of support system. It consists of either a rigid or an elastic gauze fabric coated with a zinc-oxide gel composition. A self-adhesive wrap is sometimes applied over this paste bandage for added sustained compression. When the paste dries, a semirigid cast forms, applying resistance to muscle contraction. During exercise, the calf pumping action within the cast increases blood flow velocity and venous return, and interstitial edema is reduced. A duke boot is a paste bandage with a hydrocolloid wafer over a wound.[3]

Low-Compression Systems

Low-compression systems are used for patients with an ABI between 0.6 and 0.8 who have mixed arterial and venous disease. Edema control must be balanced against further impedance of arterial circulation. Decreasing perfusion can lead to critical ischemia and must be avoided. Local pain can be a sign of arterial compromise and must be distinguished from bandage discomfort. A single-component elastic bandage or short-stretch system without an underlying component gives safe compression.

Another concept important to understand is localized supplemental pressure. An ulcer may not be receiving sufficient pressure to promote healing. Adding gauze or felt pads (or other types of material) to the secondary dressing over the wound before applying compression bandaging increases the pressure at the wound site. Enhanced local compression can improve healing rates of venous ulcers.[3]

An external pneumatic compression pump is a garment with sequential compression chambers. It is placed over the foot and leg and connected to an electric pump. The chambers are sequentially inflated from distal to proximal, causing a wave of compression that moves edema fluid into the lymphatic system and propels venous blood proximally. The pneumatic compression pump is useful if compression bandaging is not tolerated or if the edema is not adequately controlled by compression bandaging. The pumping action stimulates normal circulatory action by promoting extracellular drainage and fluid clearance. Intermittent compression stimulates venous foot and calf muscle function.[9,10]

Conclusion

A thorough understanding of the science behind compression will enable the health care provider to select the appropriate management options to address the specific needs of the patient safely and effectively.

Figure 8 External Pneumatic Compression Pump. This figure is adapted from LymphaCare, http://www.lymphacare.com/?gclid=CNPUyKXz6pUCFQpxHgodpG1Zew, with permission.

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