All about compression: A literature review

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Lower extremity ulcers represent a significant public health problem as they frequently progress to chronicity, significantly impact daily activities and comfort, and represent a huge financial burden to the patient and the health system. The aim of this review was to discuss the best approach for venous leg ulcers (VLUs). Online searches were conducted in Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, and reference lists and official guidelines. Keywords considered for this review were VLU, leg ulcer, varicose ulcer, compressive therapy, compression, and stocking. A complete assessment of the patient's overall health should be performed by a trained practitioner, focusing on history of diabetes mellitus, hypertension, dietetic habits, medications, and practice of physical exercises, followed by a thorough assessment of both legs. Compressive therapy is the gold standard treatment for VLUs, and the ankle-brachial index should be measured in all patients before compression application. (J Vasc Nurs 2016;34:47-53)

Lower extremity ulcers represent a significant public health problem as they frequently progress to chronicity, significantly impact daily activities and comfort, and represent a huge financial burden to the patient and the health system. According to Rahman et al,[19] a leg ulcer is considered chronic when there is no healing of the wound within 6 months. In the United States, 65,000 people are affected by chronic wounds, with overall treatment expenses up to $25 billion/year, as pointed by Sen et al.[22] Agale[2] emphasizes that venous leg ulcers (VLUs) are the most common chronic wounds, representing more than 70% of all types of leg ulcers. Treatment of VLU can cost the US health system around $1.5–$3.5 billion and affect about 600,000 citizens yearly according to Hankin et al.[9] Sen et al[22] and Raffetto[20] disclosed that several patients with VLU failed to reconcile the treatment of the wound with their jobs, with consequent negative impact in income and increasing early retirement. Moreover, patients with VLU suffer with significant changes in their daily lives, overwhelming pain associated with dressing changes and wound surface, daily discomfort related to edema and odor, mobility difficulties, as well as social and family isolation.[6,8]

Studies throughout the world have been conducted to determine the best approach to the management of VLU, considering the cost and duration of therapy, topic products, technique of debridement, types of dressings and bandages, speed of healing time, recurrence prevention, and improvement of patients' quality of life.[7,20]

The pathophysiology of VLU remains unclear, yet, some theories have been proposed in an attempt to explain the pathogenesis of the ulcer. The most commonly accepted theory is that VLU is secondary to venous insufficiency. The superficial and/or deep venous systems are damaged, with valvular dysfunction leading to venous hypertension and consequent tissue hypoxia.[16] According to Casey[4] and Agale,[2] the main mechanism of valvular dysfunction is an increase in hydrostatic pressure, with consequent vein dilation, less functional valves, and considerable blood back flow. Deep vein thrombosis, pregnancy, leg fractures, phlebitis or congenital weakness of venous walls can lead to permanent damage of the superficial and/or deep venous systems, increasing hydrostatic pressure. It is also theorized that water and sodium, fibrinogen, and white and red blood cells may transudate from the vessel lumen in the presence of venous hypertension with consequential damage to the skin, clinically represented as edema, fibrin cuff formation, eczema, and hyperpigmentation of the tissue.[2] Cells might become ischemic and inactive, with the development of an extremely fragile skin tissue, susceptible to breakdown with minimal trauma. Finally, with associated impaired healing mechanisms, a chronic ulcer can develop in the long term.[4]

The most efficient way to manage venous ulcers is to address venous insufficiency in the first place, with a strong recommendation for the use of compressive therapy as the gold standard treatment for VLU. However, there is no consensus regarding the most effective compressive therapy technique.

The aim of this article was to discuss the best approach for VLU.

METHODS

A systematic search was conducted in Ovid MEDLINE, Ovid EMBASE, EBSCO CINAHL, and reference lists and official guidelines in October 2015. Keywords used for this review were venous leg ulcer, leg ulcer, varicose ulcer, compressive therapy, compression, and stocking. Documents published in English, Portuguese, or Spanish were considered.

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TABLE 1

ASSESSMENT OF THE PATIENT WITH VLU

Comorbid conditions	*Congestive heart failure, lymphedema, diabetes, thrombosis, hypertension*
Wound bed tissue	Base: ruddy red, granulation tissue present, yellow adherent or loose slough may be present. Size: variable, can be large. Depth: usually shallow. Margins: irregular, undermining or tunneling are uncommon. Exudate: moderate to heavy. Infection: not common.
Surrounding skin	Edema: Pitting or nonpitting, worsens with prolonged standing or sitting with legs dependent. Ankle flare, varicose veins, hemosiderosis (ie, brown staining), lipodermatosclerosis, atrophie blanche, maceration, temperature: normally warm to touch.
Complications	Venous dermatitis, infection/cellulitis, variceal bleeding.
Pain	Dull aching, itchy, sore, tender; severe sharp or throbbing. Note: Elevation of the limb relieves pain.
Perfusion	Capillary refill: normal (less than 3 seconds). Venous refill time: shortened (less than 20 seconds). Ankle-brachial index: within normal limits (1.0–1.3).

VLU = venous leg ulcers.
Adapted from the Wound, Ostomy and Continence Nurse Society Wound Committee.[28]

TABLE 2

ABI AND SEVERITY OF THE DISEASE

Index (mm Hg)	*Severity of the disease*
1.0 >1.3	Lower-extremity venous disease (LEVD) with no arterial disease involved
>0.8–0.95	LEVD with mild arterial disease
>0.6–0.8	Borderline for LEAD
<0.5	Severe ischemia
<0.4	Critical ischemia
Abnormally high ABI (greater than 1.3)	Vessel calcification. Toe pressure may be more useful

ABI = ankle-brachial index; LEVD = lower-extremity venous disease.
Adapted from Agale[2] and Wound, Ostomy and Continence Nurse Society Wound Committee.[28]

RESULTS AND DISCUSSION

Assessment of the patient with VLU

A complete assessment of the patient's overall health should be performed by a trained health care provider. Great emphasizes should be given to the patient's medical history including history of prior deep venous thrombosis, diabetes mellitus, hypertension, peripheral arterial disease, malnutrition, medications in use, and mobility.[23,16]

Both legs should be thoroughly assessed for signs of venous disease. Particularly, the presence of varicose veins, venous dermatitis, atrophie blanche, hemosiderin deposition, and lipodermatosclerosis.[23]

The ankle-brachial index (ABI) must be checked before the application of compressive therapy, to exclude any arterial component that could affect the healing process.[2] ABI can be obtained by measuring the systolic pressure of the affected leg (using a hand-held continuous wave Doppler ultrasound) divided by the brachial systolic pressure (the highest systolic value of both arms). The Wound, Ostomy & Continence Nurse Society (WOCN) established that all patients with VLU should be assessed thoroughly regarding comorbid conditions, wound bed tissue, surrounding skin, associated complications, pain, and limb perfusion[28] (see Table 1).

The ulcer should be re-evaluated over time, and the characteristics should be clearly described and carefully documented,

usually with detailed photography, obtained after patient's written consent. Measurement guides should be considered to calculate the area and depth of the ulcer, amount and type of exudate drainage, odor, as well as characteristics of the edges, bed tissue, and area surrounding the VLU.[16] Photography is recommended by WOCN as an adjunct to assessment documentation, provided written consent is obtained. Moreover, clear policies regarding patient's privacy, providers allowed to take pictures and proper image storage should be well established in every institution. In addition, health care providers should consult their local state board of professional regulation regarding liability on the previously mentioned issues.[27]

It is important to assess the wound for infection, and an infected ulcer has at least one or more of the following symptoms and/or signs: foul odor, purulent drainage (pus), slough (yellowish to greenish), and ongoing symptoms of inflammation (ie, fever, pain, redness, swelling, warmth).[29] All chronic wounds are colonized with bacteria and/or fungi, also known as biofilm.[3] Lack of adequate biofilm control and bacterial load implies in serious complications, such as delayed healing, cellulitis, and sepsis.[25] Removing biofilm is a major challenge for the health care provider because of its firm adherence to the surrounding tissue. Attinger and Wolcott[3] also emphasize that debridement of this hard-to-remove biofilm opens a time-dependent window (2–3 days in wounds) where topic agents might be more effective.

Treatment options

The management of VLU consists in accurate diagnosis of the ulcer, choice of topic agents, and dressings compatible with the ulcer characteristics, edema and exudate control, pain management, adequate compressive therapy, dietetic education, and tight control of diabetes mellitus and hypertension.[16]

According to the Royal College of Nursing,[21] topic agents and dressing must have low adherence, be unexpansive, and well tolerated by the patient. Moreover, dressing must be capable of absorbing exudate until the next dressing change.

Compressive therapy is recommended by the Scottish Intercollegiate Guidelines Network, WOCN, and Royal College of Nursing for appropriate edema control and faster healing of VLU. Table 2 shows ABI values and respective disease severity.

Scottish Intercollegiate Guidelines Network and WOCN emphasize that high compression multilayers would be the gold standard for VLU management. Choice of the type of compressive device must consider size and shape of the limb, patient's tolerance or preference, and the health care provider's level of expertise.

Kirsner[10] identified that application of compression on the limb can minimize or reverse venous reflux caused by valve incompetence, forcing fluid present in the interstitial spaces to return to the vascular and lymphatic systems, thus reducing tissue edema. However, this solution is temporary and would work only while the patient is wearing the compressive device, implying in the use of elastic stockings even after the ulcer has healed. In some situations, venous surgery can be performed to further manage venous insufficiency and promote wound healing, preventing recurrence of VLU. A systematic review of the literature published in 2015 concluded that surgical correction of venous insufficiency prolongs ulcer free periods and reduces recurrence rates.[5]

Types of compression

Compression therapy is identified as an essential part for the success of VLU treatment. Current studies established the efficiency of several materials and devices used for different levels of compression, with elastic or inelastic properties, providing an extensive range of choices for the health care provider. It remains unclear which type of compressive devices, techniques, and adjunct therapies are more effective, as well as the safest and most efficient ranges of compression pressure.[24]

Understanding how compressive therapy works is essential for treatment success. According to Wound International,[31] the two main principles underlying compression are "creation of an enclosed system that allows internal pressures to be evenly distributed in the leg" and "variation of interface pressures according to limb shape and tension of bandage applied." The last statement is influenced by compressive device single characteristics and the skills of the health care provider.

Compression therapy systems are designed to increase pressure in the ankle and underlying structures, to counteract the force of gravity. This therapy helps the venous and lymphatic systems to reduce tissue edema and mitigate venous hypertension.[26,31]

Before applying compression. The sub-bandage pressure and the pressure gradient should be addressed using limb shape and size in accordance with Laplace's Law

$$\text{Pressure (mm Hg)} = \frac{\text{Tension(KgF)} \times \text{number of layers} \times 4620}{\text{Circumference of ankle(cm)} \times \text{bandage width (cm)}}$$

The meaning of this formula is that augments in interface pressure are directly proportional to smaller limb circumferences, higher bandage tension, and more compressive layers with a smaller bandage width.[31] In other words, pressure is higher in smaller ankles.[11] Milic et al[13] disclosed in a clinical trial that when patients with smaller calf circumferences were exposed to higher pressures at the ankle in resting position, therapy compliance was very low secondary to discomfort caused by the applied pressure. Consequently, their group proposed a simple formula to predict the optimal pressure value, helping guide the health care provider when choosing for the best fit for an individual patient:

TABLE 3

FACTORS TO CONSIDER WHEN CHOOSING A COMPRESSIVE DEVICE

Factors to consider	*Reason*
Skin condition	Delicate friable skin can be damaged by high levels of pressure
Shape of the limb	The sub-bandage pressure and the pressure gradient will be altered by the limb shape in accordance with Laplace's Law. Skin overlying exposed bony prominences may be subject to pressure damage
Presence of cardiac failure	Rapid fluid shifts can be dangerous as it increases the preload of the heart
Presence of neuropathy	The absence of a protective response increases the risk of sub-bandage pressure damage

Adapted from Marston, Vowden. European Wound Management Association (EWMA) Position Document (2003).[12]

TABLE 4

COMPRESSION BANDAGE AND PRESSURE DELIVERED

Bandages	*Ankle pressure*
High elastic compression	40 mm Hg of pressure
Multilayers high compression	Sustained 40 mm Hg of pressure
Short stretch/inelastic compression	High pressure in activity (40 mm Hg) and low resting pressure
Light compression	Offers 20–30 mm Hg

Adapted from: Principles of compression in venous disease: a practitioner's guide to treatment and prevention of venous leg ulcers.[31]

$$\text{Sub-bandage pressure value (mm Hg)} = \text{Calf circumference} + \frac{\text{calf circumference}}{2}$$

The result obtained through this formula is supposed to offer the best balance between the required compression pressure for faster ulcer healing and tolerance and/or adherence by the patient.[13]

Milic et al[13] emphasized that an efficient compressive device provides high pressure when the patient is orthostatic, but with relatively low pressure when the patient assumes a resting position.

Factors to consider when choosing a compressive device. Patients with delicate, friable periwound skin are very vulnerable to further injury (Table 3). In these cases, it may be worthwhile applying extra padding before any compression device is installed. According to the World Union of Wound Healing Societies (WUWHS),[29] it is important to minimize complications caused by therapeutic pressure by applying extra padding over bone prominences and avoiding strong, sustained compression. Caution is advised when applying bandages with high pressure at the ankle of a slim leg to avoid pressure damage.[30]

TABLE 5

COMPRESSION STOCKING AND PRESSURE DELIVERED

Stockings	*Description*	*Ankle pressure*
Class I	Light support	20–30 mm Hg
Class II	Medium support	30–40 mm Hg
Class III	Strong support	40–50 mm Hg
Class IV	Very strong support	50–60 mm Hg

Adapted from: Principles of compression in venous disease: a practitioner's guide to treatment and prevention of venous leg ulcers.[31]

One option to entertain sustained compression is to apply an inelastic device, such as Unna's Boot. A randomized clinical trial conducted in Brazil comparing Unna's Boot with elastic bandages concluded that using inelastic material might be more effective than applying elastic ones.[1] The authors concluded that wound surface of VLU treated with Unna's Boot reduced in 69.41% of the patients, in contrast with only 42.32% in the comparison group ($P < 0.0001$). Mosti[14] reinforces that inelastic bandages are a great option for VLU treatment, if applied by skilled health care providers.

A systematic review published in 2012 concluded that compressive therapy increases ulcer healing rates, when compared with no compression.[17] In addition, multilayer bandage (with resulting higher pressures) is more effective than single layer bandage. The WOCN emphasizes that multilayer systems are better than single layer, and any compression is better than no compression.[28]

Types of compression and recommendations based on ABI. The recommended pressure according to ABI is listed in Tables 4, 5, and 6.

How to apply the compressive system

First of all, there is no definitive data on the superiority of a specific bandaging technique (spiral, figure of eight, circular, among others).[18] Table 7 shows how to apply the different types

TABLE 6

PRESSURE RECOMMENDED ACCORDING TO ABI

Index (mm Hg)	*Management*
1.0 >1.3	Apply high compression garment providing 30–42 mm Hg of compression
>0.8–0.95	Apply high compression garment providing 30–42 mm Hg of compression
>0.6–0.8	Referral to a vascular service. Use reduced compression garment providing 23–30 mm Hg
<0.5	Referral to a vascular surgeon. "Do not" apply any compressive device
<0.4	Referral to a vascular surgeon. "Do not" apply any compressive device

ABI = ankle-brachial index.

Adapted from Agale[2] and Wound, Ostomy & Continence Nurse Society Wound Committee.[28]

TABLE 7

HOW TO APPLY THE DIFFERENT TYPES OF COMPRESSIVE SYSTEMS

Type of compression	*How to apply*
Light compression bandages	Low levels of compression (class I, 20–30 mm Hg). These bandages can be applied in a spiral or a figure of eight, according to manufacturer's instructions, and can be used as a component of a layered system.
High compression bandages	These provide high sustained compression (class II, 30–40 mm Hg). These bandages are useful for bigger legs or in more active patients. They can be used over padding on their own or as part of a layered system and should be applied in a spiral, according to manufacturer's instructions.
Cohesive compression bandages	These provide light support. The cohesive bandages adhere to themselves but not to skin. They are useful as an outer layer in layered systems and to prevent slippage.
Short stretch compression bandages	These bandages have limited extensibility and should be applied at full stretch and according to manufacturer's instructions. They are applied over padding in one or two layers.
Multilayer compression systems	These are usually four-layer systems, which are commercially available as kits. Different kits are available comprising slightly different components for different ankle sizes. These should be applied according to manufacturer's instructions. Four-layer kits commonly comprise the following: A wound contact low adherent dressing; Layer 1 subcompression wadding bandage (one or two rolls depending on ankle size); Layer 2 support bandage; Layer 3 compression bandage; Layer 4 cohesive compression bandage.

Adapted from: Scottish Intercollegiate Guidelines Network (SIGN).[23]

of compressive systems. Generally, to achieve high pressures (about 40 mm Hg), all bandages should be applied from toe to knee at a 50% stretch and with 50% overlap, but manufacturer's instructions should be considered.[23,15] In addition, all bandages used in compression must be applied on top of padding to prevent pressure damage over bony prominences.[23]

CONCLUSION

Management of VLU consists of an accurate diagnosis of the ulcer in the first place. ABI measurements must be performed in all patients. Compressive therapy is the gold standard for the treatment of VLU. The amount of pressure provided and the

selection of the appropriate compressive device must be chosen based on the size and shape of the limb, the patient's tolerance or preference, and the health care providers' level of expertise. If done properly, compressive therapy can significantly change the speed of ulcer healing and aid in recurrence prevention.

Understanding how to approach a patient with VLU is essential for nurses, as they are generally the provider taking closer care and responsible for long-term follow-ups, even more for vascular nurses, for whom VLU and peripheral arterial disease are daily challenges, not infrequently seen together.

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