Compression Hosiery and Multilayer Wraps: Proper Prescription and Usage

The effect of this therapy on venous ulcers is impressive.

BY STEVEN KRAVITZ, DPM

This article is intended as a reference for understanding the mechanism and application of compression therapy. Hosiery and multilayer (ML) wraps are the most convenient, least expensive, and the most common forms of delivery of compression.

Compression therapy is used for a host of medical conditions including but not limited to: chronic venous insufficiency, lymphedema, deep vein thrombosis, venous ulcers, venous edema, lower leg fatigue and long-term (air) travel. Dalen[1] identified reduction in the incidence of thromboses of the lower leg and related pulmonary embolism, especially when traveling with a flexed knee (economy class seating syndrome) during long-term air travel.

The effect of compression therapy on venous ulcers is impressive. Healing rates using compression therapy (with basic standard wound care) is 40% to 70%[2,3,5] within three months and 50% to 80%[2,3,5] within six months.

Basic Principles

Graduated compression: Siegel et. al.[4] (1975) demonstrated that venous proximal blood flow is greatest when the pressure applied is higher distally and decreases proximally toward the knee and then the upper thigh compared to uniform equal compression around the entire limb. The term used to describe this phenomenon is "graduated compression".[6]

For the lower extremity the standard for wound care is 40 mmHg compression at the ankle, which is then decreased by 20% at the midcalf (32 mmHg) and then decreased again by 20% at the midthigh (26 mmHg).

Interface pressure (previously known as sub-bandage pressure) is the amount of force applied to the skin beneath and directly from any compression therapeutic device. This is the compression or pressure produced between the skin and the compression device. As noted below interface pressure is directly impacted by Laplace's law.

Compression therapy is based upon two

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FIGURE 1:

Compression Ranges and Conditions for Which Hosiery Is Prescribed

15-20 mmHg
Mild edema and related venous insufficiency, early onset varicosities

20-30 mmHg
Increasing varicosities, chronic venous insufficiency, moderate edema, post-operative, *(the Medicare required compression level for three months trial prior to insurance approval for venous ablation surgery)*

30-40 mmHg
Venous ulcers, severe edema, advancing chronic insufficiency

40-50 mmHg
Venous ulcers, severe venous insufficiency and related severe edema

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laws of physics which work in tandem. These are Pascal's Law and Laplace's Law.

Pascal's Law: Pressure (compressive force) applied circumferentially around a cylinder or the (lower or upper) limb is transmitted internally in a one-to-one ratio. Applying a 4 inch wide elastic wrap with 40 mmHg around a portion of the limb causes all tissues deep to that bandage to be under 40 mmHg of pressure as well. This allows significant therapeutic effects without having to use a catheter or some form of invasive technique to apply compression forces internally.

Laplace's Law: After any compression device is placed circumferentially around the limb (elastic wrap, compression hosiery, Velcro® assisted compression device) the interface pressure will increase or decrease only if there is an increase or decrease in circumference respectively. Therefore, interface pressure under any compression device can increase ONLY if circumference increases.[6,7,8] This is impacted directly by increases or decreases in edema.

Proper Application of Compression Therapy

Compression hosiery is the most commonly utilized method of delivering this therapy. The parameters for the ranges of compression and the conditions for which hosiery is prescribed are described in the United States guidelines in Figure 1.

The proper use of compression hosiery is based upon leg measurements and selected pressure ranges prescribed by the physician. Ordering this hosiery by shoe size is not advised because it cannot provide the accurate graduated compression needed for effective edema reduction. As described above, graduated compression is the principal that allows compression hosiery to be effective. It is based on a compression level which is highest at the ankle and gradually reduced proximally up toward the knee and then, when using full length, up to the proximal thigh.

The lower extremity measurements are then matched against the fitting chart to order the appropriate garment. The ankle circumference is coordinated with the midcalf circumference to select the appropriate sizing for the patient. The leg length measurement is then used to match the fitting chart to select a garment sized as "short" or "regular". One should use the fitting chart from the company used for ordering the stockings, as there can be minor variation between different charts from different companies. Figure 3 is exemplary of a typical fitting chart.

As knee length hosiery is used most commonly, this article will concentrate on that portion of Figure 3. Remember that all prescribing is based on the pressure measurement at the ankle because the pressure decreases by 20% for each segment proximal to that. Figure 1 describes the pressure ranges utilized in the US. These are the ankle pressure ranges used to prescribe the garment: 15–20 mmHg; 20–30 mmHg; 30–40 mmHg; 40–50 mmHg.

As an example, assume one selects a therapeutic compression level of 20-30 mmHg and has measured the ankle circumference just above the malleoli to be somewhere between 8 to 9 inches. This would mean that at the smaller ankle measurement (8 inches), the amount of pressure delivered would not be less than 20 mmHg and at the highest range, the 9 inch ankle, the pressure delivered would not be greater than 30 mmHg. For the next size up, 9 inch to 10 inch ankle, the same principle applies with pressure ranges running from 20 mmHg at the 9 inch ankle to 30 mmHg at the 10 inch ankle. Then 30-40 and 40-50 is applied in the same manner. There are a number of high quality manufacturers that use these guidelines. Use only products that include ankle circumference measurement.

There will be instances where some patients will have lower extremity measurements that do not match the fitting chart. In these cases, compression stockings can still be utilized as long as there's not more than one size level difference on the fitting chart. If the calf measurement is one size larger than the ankle on the fitting chart, the sizing should be based on the measurement of the calf. If the ankle mea-

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Applying a 4 inch wide elastic wrap with 40 mmHg around a portion of the limb causes all tissues deep to that bandage to be under 40 mmHg of pressure as well.

FIGURE 2:

Appropriate Measurements[5]

Circumferential Measurements

1) Just above the ankle malleoli
2) Widest portion of the midcalf
3) Proximal thigh for full length stockings only

Length Measurements

1) Posterior proximal leg (just distal to the popliteal space) to plantar posterior heel for knee length hosiery
2) Proximal thigh to the plantar posterior heel for thigh length garments

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surement is one size larger on the fitting chart than that of the midcalf, the sizing of the garment should be based on the measurement of the ankle (see Figure 4).

If the difference is more than one size on the fitting chart in either direction the garment should not be used and custom prescribed compression wear should be utilized.

If the calf measurement is one size larger on the fitting chart then the ankle, the sizing should be based on the measurement of the calf.

Proper Fitting of Compression Hosiery

Compression around the toes should be avoided. Properly constructed hosiery should have a toolbox of non-elastic fabric. Additionally, when applying the garment it should be pulled distally at the toe box to help prevent any compression that may have been inadvertently produced during the application.

Higher compression levels (30–40 mmHg and 40–50 mmHg) can be difficult to apply to the leg, especially for compromised or elderly patients who have mobility problems, coordination difficulties and/or lack of finger strength. These garments can also be hot to wear because fabric required to create higher compression levels can be heavier than would otherwise be comfortable. *Multilayer hosiery* can be helpful in avoiding these problems. These compression systems use two garments for each limb; this is based on the principle that compression layers are additive. As 5 lbs. plus 5 lbs. equals 10 lbs., a fabric layer producing 10 mmHg applied over a layer of another fabric producing 10 mmHg provides a net total of 20 mmHg around the limb. Multilayer hosiery typically has an undergarment of 18 mmHg at the ankle. When matched with an over-stocking of 18 mmHg the compression level applied to the limb at the ankle is 35–40 mmHg. When the same undergarment is matched with a 20–30 mmHg overstocking the net compression applied to the ankle is 40–50 mmHg. The result is that the desired compression level is achieved without requiring the finger strength or manual dexterity that would otherwise be required to apply a single fabric garment with a matched level of compression. While easier to apply, these are usually also generally more comfortable and cooler to wear.

When hosiery is properly constructed, it is shaped to fit the limb and will stay in place without sliding down the leg for most patients.

Avoid compression stockings that use a tight band proximally, just below the knee for knee length and at the top of the thigh in full length garments. When hosiery is properly constructed, it is shaped to fit the limb and will stay in place without sliding down the leg for most patients. Tight proximal bands are used by some companies to help prevent slippage down the leg but they cause additional pressure at the upper end of the garment. This creates a tourniquet effect and blocks any enhanced venous return that would otherwise be obtained by the rest of the garment. The band pressure should never be higher than that of the segment directly below it. For knee length garments the band should never be at a higher pressure than that of the midcalf. For a full length stocking the upper band pressure should never be higher than that of the proximal thigh.

PANTY HOSE AND thigh length

1 Ankle	2 Calf	3 Thigh	4 Hip Standard	4 Hip Maternity	5 Length	Size	
7"-8" 18 cm - 20 cm	10"-13" 25 cm - 33 cm	16"-22" 41 cm - 56 cm	To 40" 102 cm	To 52" 132 cm	< 26" (66 cm)	Short	A
					> 26" (66 cm)	Regular	
8"-9" 20 cm - 23 cm	12"-15" 31 cm - 39 cm	19"-25" 49 cm - 64 cm	To 42" 107 cm	To 56" 142 cm	< 28" (71 cm)	Short	B
					> 28" (71 cm)	Regular	
9"-10" 23 cm - 25 cm	14"-17" 36 cm - 44 cm	22"-29" 56 cm - 74 cm	To 48" 122 cm	To 62" 157 cm	< 30" (76 cm)	Short	C
					> 30" (76 cm)	Regular	
10"-11" 25 cm - 28 cm	16"-19" 41 cm - 49 cm	24"-30" 61 cm - 73 cm	To 51" 130 cm	To 68" 173 cm	<32" (81 cm)	Regular	D
11"-12" 28 cm - 31 cm	18"-21" 46 cm - 54 cm	24"-30" 61 cm - 73 cm	To 55" 140 cm	To 72" 183 cm	<32" (81 cm)	Regular	E

knee Length sheer

1 Ankle	2 Calf	3 Length	Size	
7"-8" 18 cm - 20 cm	10"-13" 25 cm - 33 cm	< 15" (39 cm)	Short	A
		> 15" (39 cm)	Regular	
8"-9" 20 cm - 23 cm	12"-15" 31 cm - 39 cm	< 16" (41 cm)	Short	B
		> 16" (41 cm)	Regular	
9"-10" 23 cm - 25 cm	14"-17" 36 cm - 44 cm	< 17" (44 cm)	Short	C
		> 17" (44 cm)	Regular	
10"-11" 25 cm - 28 cm	16"-19" 41 cm - 49 cm	< 18" (46 cm)	Short	D
		> 18" (46 cm)	Regular	
11"-12" 28 cm - 31 cm	18"-21" 46 cm - 54 cm	< 18" (46 cm)	Short	E
		> 18" (46 cm)	Regular	
12"-13" 31 cm - 33 cm	20"-23" 51 cm - 59 cm	< 18" (46 cm)	Short	F
		> 18" (46 cm)	Regular	
13 "-14" 31 cm - 36 cm	22"-26" 56 cm - 66 cm	< 18" (46 cm)	Short	G
		> 18" (46 cm)	Regular	

Figure 3

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Latex-free is recommended and readily available through a number of manufacturers. Some manufacturers require hand washing and line drying. Others recommend their products should be machine-washed and machine-dried. Additionally, products that are recommended for machine washing and drying will perform better and be longer-lasting when the instructions are followed. At the same time it is more convenient for the patient and allows for better hygiene.

Multilayer Compression Wraps

These are packaged as two, three or four layer systems. Each layer adds compression as described above with the hosiery.[5,6] A four layer compression system where each layer applies 10 mmHg delivers a therapeutic level of 40 mmHg. Additionally, the general rule is to apply each layer of wrap with the 50% overlap, which doubles the compression level and makes that four layer system have a theoretical application of 80 mmHg. When using multilayer systems the compression from each layer must be carefully applied.

The wraps are comprised of short-stretch (inelastic) and long-stretch (elastic) bandages. Zinc oxide-impregnated bandages (e.g., Unna boot) are examples of short-stretch bandages.

Research by Kravitz, Hegarty-Craver, Grant and Reid and others have demonstrated a significant amount of compression loss with multilayer compression wraps. Very popular two-layer compression systems were shown to lose as much as 25% of their compression in only five hours while four-layer wraps lost as much as 10% of their compression in five hours.[5,6,7,8] Kravitz et al. hypothesized that this compression loss is related to a low amount of spandex, the synthetic elastic fiber, in these bandages. Nearly all the bandages on the market also have a self-adhesive layer. This helps garments remain in place and not slide down the leg. However, these bandages are also occlusive and prevent skin respiration—thus potentially increasing maceration on draining ulcers. A new vascular elastic wrap came to market about 18 months ago. This bandage is not adhesive and allows skin respiration. It also tends to wick fluid and drainage from an underlying saturated bandage, a situation which can decrease wound maceration. The degree to which a bandage loses compression is referred to as "creep".[6] The new vascular elastic wrap has been shown to provide stable compression for five hours.[5,6]

In general, multilayer wraps have not shown the degree of improved wound healing that has been demonstrated by the use of compression hosiery.

In general, multilayer wraps have not shown the degree of improved wound healing that has been demonstrated by the use of compression hosiery. There have been a number of reasons for this addressed in the literature. One is attributed to the degree of creep (loss of compression) in many of these systems; another more important consideration, however, is the inconsistency that is inherent when applying a multi-layer wrap system.[7] The amount of tension and resultant compression applied to the limb is dependent upon the provider and the amount of stretch applied to the bandage. This can vary from one provider to the next and from the same provider applying from one patient to the next. This inconsistency is a key factor in the lack of wound healing for some wraps systems used in trials. Therefore it also follows that a larger number of layers applied in various systems results in more inconsistency. Two-layer systems have a benefit in that regard over four-layer systems.

Hosiery has demonstrated better wound healing than multilayer wraps because hosiery does not have the inconsistencies described above.[6] First and foremost, the amount of compression delivered by hosiery is clearly designated on the packaging and does not vary from one provider to the next or from one session to the next. It is not provider-dependent regarding application. Additionally, unlike the multilayer wraps, higher-quality compression hosiery does not lose compression and does not have creep. Indeed, it has been shown to maintain compression level for five days, far beyond the five hours in which compression was lost in the research described above with the multilayer two-layer and four-layer wraps.

A new two-layer wrap system, rather than using two or more lay-

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FIGURE 4:

When Measurements Do Not Match the Fitting Chart: Examples

Example:	Ankle Measurement	Calf Measurement	Size Selected
Patient #1:	8.5 inches	11 inches	B
Patient #2:	10.5 inches	20 inches	E

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ers of wrap or bandage, uniquely uses a sleeve as its first layer. The sleeve delivers approximately only 5 mmHg compression. As with hosiery, a sleeve is not dependent on provider application and is consistent from one provider to the next and from one application to the next. Additionally, because the sleeve delivers only 5 mmHg, all of the therapeutic compression is developed through one outer layer, which is an elastic wrap. This one layer is dependent on the amount of tension, etc. produced during application. The entire system is improved because only one layer is provider-dependent, which enhances consistency.

Pressure Measurement

Two devices have been available for a number of years to measure interface pressure, the pressure applied to the skin beneath the bandage. The PicoPress was introduced in 1991 and the Kikuhime became available in the late 1990s. Both devices use pneumatic air bladder technology. While accurate in vitro when placed on a cylinder, these devices can have variations in pressure readings when placed on the limb.[5,7,9]

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A new device, the Carolon Smart Sleeve, that measures interface pressure will be available shortly. This new device uses a flat piezoelectric sensor rather than the air bladder used in the other older devices. It is reportedly less expensive than the older devices and promises to be more accurate as well because it is not affected as much by positioning on the limb as the two older pneumatic bladder devices.

This new technology will allow providers to measure and document mmHg pressure, which removes any inconsistency when applying multilayer compression wraps. Independent of the provider involved or when applying any wrap system from one session to the next for the same provider, compression delivered to the patient can now be consistent. It further allows the level of compression to be decreased or increased depending upon patient

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response. The degree of creep (loss of pressure)[6] from any particular wrap can now be accurately assessed and documented. If loss of compression is identified one can apply a new wrap to maintain the appropriate therapeutic compression levels and obtain maximal reduction of edema.

Observation demonstrates that there are not significant changes in circumference of the ankle or the midcalf when standing versus nonweight bearing.[8]

There have been numerous scientific articles based on a universally accepted principle known as the static stiffness index (SSI). It states "sub bandage or interface pressure standing is higher than nonweightbearing, resting interface pressure".[5,8] This concept was challenged in a series of articles using university-based research.[5,6,7,8] The authors essentially state that SSI confuses leg internal pressure, which is higher with weight bearing due to Pascal's law and muscular contraction, with interface pressure, which is related to that applied to the skin directly from the device or bandage above it.As the present article points out, interface pressure cannot increase if circumference does not increase (Laplace's law). Observation demonstrates that there are no significant changes in circumference of the ankle or the midcalf when standing versus nonweight bearing.[8] Therefore interface pressure does not change.[5,8] New devices using piezoelectric sensors, unaffected by leg positioning, could produce more accurate data for research and provide accurate clinical data for patient care.

Compression therapy can be very efficacious but only when properly prescribed. This article can hopefully serve as a resource to help achieve that objective. **PM**

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Dr. Kravitz is Assistant Professor, TUSPM; Executive Director, Academy of Physicians in Wound Healing (APWH); Executive Director, Council for Medical Education and Testing (CMET); and the Medical Director at Carolon. He is a Fellow, ACFAS and is board certified by both the ABFAS and the ABPM. Dr. Kravitz can be contacted re: this article at info@APWH.org.