Evaluation of Longitudinal and Tubular Compression Treatment for Lower Limb Edema

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ABSTRACT

BACKGROUND: Many patients with lower limb edema do not tolerate traditional higher-pressure compression devices and require alternative devices for edema control.

METHODS: Two systems were evaluated for control of bilateral or unilateral lower limb edema: an elasticized longitudinal stockinette (ELS; EdemaWear; Compression Dynamics, Omaha, Nebraska) and an elasticized tubular bandage (ETB; Tubigrip; Mölnlycke Health Care, Norcross, Georgia). Twenty-five patients were recruited; patients with bilateral edema (n = 12) wore the ELS on one limb, and the ETB on the other. Patients with unilateral edema (n = 13) were randomized to wear either the ELS or ETB. Edema measurements, leg pain, and patient preference were recorded.

RESULTS: There were 14 females (56%) and 11 males (44%); mean age was 66 years (range, 32-88 years); and mean body mass index was 40.4 kg/m² (range, 26.1-66.9 kg/m²). Patients with bilateral edema wearing ELS had a foot-to-leg circumference of 25.5-33.9 cm pre-ELS that remained essentially unchanged at 2 weeks. The five patients with unilateral edema using ELS had a 24.3-33.7-cm circumference pre-ELS and 24.2-32.6-cm range at 2 weeks. The patients with bilateral edema using ETBs had a foot-to-leg circumference of 25.5 to 43.7 cm pre-treatment, unchanged 2 weeks later. The eight patients with unilateral edema using ETB had a 25.4- to 45.7-cm circumference pre-ETB and 24.8- to 42.0-cm range post-ETB. Mean pain levels decreased from 1.0 at week 0 to 0.5 at week 2. More patients preferred ELS (17/23, 78.3%) over ETB (5/23, 21.7%).

CONCLUSIONS: Both systems were easy to apply and provided low compression without increased pain. The ELS was preferred by more patients (78.3%) than ETB (21.7%).

KEYWORDS: compression, edema, longitudinal stockinette, lower limb, tubular bandage, wound care

INTRODUCTION

Compression therapy is a mainstay treatment of lower limb edema, especially from venous hypertension. Compression therapy needs to be modified with coexisting mild to moderate arterial disease and may be contraindicated with advanced arterial disease or critical limb ischemia. Other causes of lower limb edema may be suspected if the edema is bilateral and extends above the knees. In these cases, compression therapy must be accompanied by treating correctable causes, including low hemoglobin or albumin levels and systemic disease involving the liver, kidney, or heart.

Edema can be controlled with elastic or inelastic constrictive bandages (Table 1). Elastic systems work by exerting increased pressure at rest and lower pressure with muscle contraction. An inelastic system creates a fixed resistance, much like a plaster cast for a fractured leg or zinc oxide paste bandage to treat a venous ulcer. This type of bandage has low pressure at rest. Inelastic systems exert their pressure with muscle contraction, propelling the venous blood toward the heart and stopping any backflow from incompetent valves. These bandaging systems are designed for ambulatory patients and work best with an intact calf muscle pump as an adjunctive aid.

Adherence to compression therapy can be difficult for patients with painful leg edema, especially those with acute or subacute lipodermatosclerosis, that is, painful woody fibrosis. The application of support stockings is often difficult for individuals with irregularly shaped legs common with lymphedema and frequently misdiagnosed lipedema.1 Coexisting arterial disease can complicate...
compression therapy and is not always diagnosed; clues include the absence of a palpable pulse, an ankle brachial pressure index (ABPI) less than 0.9, or monophasic audible handheld Doppler (AHHD) results.2

There is incomplete evidence to guide optimal treatment for venous disease and lower limb edema. Critically, the literature is not definitive as to which specific compression modality is best. For patients who cannot tolerate optimal high compression because of pain, coexisting arterial disease, or irregular contours of the legs or who have difficulty applying compression devices, low compression options that can facilitate edema control may be a suitable long-term option. Elasticized tubular bandages (ETBs) on the market are available as a fabric roll or in precut formats. These bandages are cut to an appropriate length to cover the patient’s lower extremity from the base of the toes to two fingerbreadths below the knee. Each layer, when properly fitted, can deliver approximately 8-mm Hg compression. Subsequent layers (up to 4) can be applied with each upper edge often slightly shorter than the previous layer (3-5 cm above the initially applied longest bandage). Several ETB products are available, both with and without latex.

This study evaluated two elasticized systems for the control of bilateral or unilateral lower limb edema: an elasticized longitudinal stockinette (ELS; EdemaWear; Compression Dynamics, Omaha, Nebraska) and an ETB (Tubigrip; Mölnlycke Health Care, Norcross, Georgia). Local limb pain, leg circumference, and patient satisfaction with each device were the principal outcomes.

**METHODS**

**Materials**

Two different products were utilized in this study: a nonlatex spandex ELS (Figure 1) and a latex-containing ETB. The ELS has longitudinal wales that run parallel to the leg, producing furrows in the subcutaneous tissues visible on removal (Figure 2). The ETB consists of soft cotton knit interlaced with elastic threads that provide circumferential support and compression with wrinkles on the skin surface visible on removal (Figure 3).

**Study Setting and Outcomes**

This study was conducted at the Toronto Regional Wound Healing/Dermatology Clinic in Mississauga, Ontario, Canada. The primary study outcomes were edema control, pain, and patient preference. Edema reduction was measured with the following circumferences: arch of foot, above the ankle, and 10 cm below the tibial plateau. Local leg pain was measured using a 0- to 10-point numeric rating scale. Pain was measured independently in the right and left leg when different devices were used on each leg.

**Figure 1. ELS ILLUSTRATED WITH A 40-POWER PHOTOMICROGRAPH**

This material contains a knitted warp (longitudinal threads) with open space between the wales (elevated ridges on a textured woven fabric). The vertical wales are composed of wispy spiderweb-like strands of medical-grade nylon maintained under tension by horizontal medical spandex elastic yarns. Pressure is generated beneath the wales, but no pressure is generated between the wales. Spaces between the wales are open channels free of compression for unimpeded circulation (no tourniquet effect). Wales have a circular cross-section and a fuzzy faux pile surface that, when under elastic tension, generates a physiologically effective pressure gradient to move exudated fluid to deep vessels in the limb, generating visible furrows in the tissue under the wales.

**Table 1. COMPARISON OF ELASTICIZED LONGITUDINAL STOCKINETTES (ELS) AND ELASTICIZED TUBULAR BANDAGES (ETB)**

| Criterion                        | ELS                                                                 | ETB                                                                 |
|----------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|
| Application                      | Easy to apply                                                       | Easy to apply                                                       |
|                                  | Slightly harder to stretch over the foot with the first application  | May bunch at the base of the lower leg and proximal aspect of the dorsal foot |
| Compression                      | Via longitudinal ridges                                             | Via circumferential pressure from bandage structure                 |
|                                  | Equivalent to 8–15 mm Hg                                              | Equivalent to 8 mm Hg per layer                                     |
| Layers                           | Single layer                                                         | Single layer used in this study                                     |
|                                  | Can use up to 3–4 layers with staggered upper lengths                |                                                                      |
| Comfort                          | Preferred by 78.3% of participants                                   | Preferred by 21.7% of participants                                  |
| Irregularly shaped legs          | Accommodates to irregularities in leg shape (eg, fat rolls, ankle fat pad) | May have less stretch in furrows or indentations of the skin         |
| Heat                             | Breathable, cool, comfortable                                       | Occlusive                                                           |
|                                  | May be hot in summer months                                          |                                                                      |
| Footwear                         | Easy accommodation                                                   | May bunch up/crease in shoes                                       |
| Latex                            | No latex                                                            | Product in the study contained latex                               |
|                                  |                                                                      | Latex-free alternatives available                                   |

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leg. Patient preference was assessed with a survey (Supplemental Table 1; http://links.lww.com/NSW/A47).

**Inclusion and Exclusion Criteria**

Exclusion criteria included patients younger than 18 years, bilateral below the knee amputation(s) or higher, critical limb ischemia, ABPI less than 0.65 or greater than 1.3, known allergies to any of the components of either compression type, terminal illness, current use of ELS or ETB, and a lack of written informed consent.

Inclusion criteria were lower limb edema over 1 month in duration, venous disease not controlled with conventional compression, and ABPI between 0.65 and 1.3 or a biphasic/triphasic AHHD.

**Study Design**

This article reports the 2-week interval limb measurement results of an initial prospective 8-week crossover study. Participants with bilateral lower limb edema were recruited by clinic staff during routine visits.
were asked to attend five separate study visits, but because of slow recruitment, a protocol amendment was approved by the ethics committee to reduce the number of visits and include participants with unilateral edema. Accordingly, the study featured two patient groups, one with bilateral lower limb edema and the other with unilateral edema. Patients with unilateral edema were blindly randomized using a random number generator to either an ETB or ELS device and then switched devices at the 2-week follow-up visit. Patients with bilateral edema started treatment with an ETB on one limb and an ELS on the other. Bias in the clinical setting was minimized by introducing both compression systems at the same time to patients with bilateral edema or randomly selecting the first treatment for patients with unilateral edema.

Patients were educated on the use, care, and application of the devices. At subsequent visits, the product use was reviewed. A number of assessments, including AHHD, pain scores, limb and foot measurements, photographs, and wound assessments (if applicable), and a product preference survey were completed at specific study visits.

The participants in the bilateral cohort were asked at follow-up visits which product they preferred to wear. If they preferred one product over the other, this product was applied to both limbs. For the unilateral edema cohort, at visit 2 the product that was applied during randomization was switched to the comparator. At each visit, circumferences of the affected limbs, photographs, and AHHD measurements were taken.2 At the final study visit, patients chose the device they preferred and completed the device preference survey (Supplemental Table 2A, http://links.lww.com/NSW/A48; and 2B, http://links.lww.com/NSW/A49). All patients had edema measurements at week 2, and these were used for the study results with subsequent visits used for patient preference and adverse events but not comparative edema measurements that ideally should have required a no-compression washout period.

Edema measurement analysis of the bilateral cohort (n = 12) for both ELS and ETB showed a similar trend of minimal decrease in size at week 2 at all three locations. The difference was not statistically significant.

For the unilateral cohort (n = 13), 38% (n = 5) were started on ELS, and 62% (n = 8) had ETB. The unilateral ELS group showed a minimal (not statistically significant) reduction in mean measurements at the arch of foot and leg circumference at week 2. There was a mild increase in size at the ankle from 27.4 cm at baseline and 29.1 cm at week 2. For the unilateral ETB group, there was no statistically significant difference in size reduction at the arch of foot and ankle, with a greater decrease at leg circumference of 45.3 cm at baseline to 42 cm at week 2.

**Pain**

The pain levels for this patient group were low (Figures 4 and 5). Overall, mean pain scores did drop from 1/10 at first visit to 0.5/10 at the final visit. In the unilateral group, there was a 1.2-point reduction in pain for those receiving ELS (3.0 to 1.8) with a 0.4-point increase in

| Table 2. PATIENT CHARACTERISTICS |
|----------------------------------|
| Characteristics                  | n (%) |
| Male                             | 11 (44) |
| Female                           | 14 (56) |
| Mean age, y                      | 66 (range, 32–88) |
| Mean body mass index, kg/m²      | 40.4 (range, 26.1–68.9) |
| Bilateral edema                  | 12 (48) |
| Unilateral edema                 | 13 (52) |
| Edema diagnosis                  |        |
| Venous disease                   | 14 (56) |
| Lipolymphectasia                 | 3 (12)  |
| Lipedema                         | 2 (8)   |
| Venolymphectasia                 | 3 (12)  |
| Lymphedema                       | 2 (8)   |
| Mixed arterial-venous disease    | 1 (4)   |
| Comorbidities                    |        |
| Hypertension                     | 18 (64) |
| Diabetes                         | 6 (24)  |
| Dyslipidemia                     | 15 (60) |
| Peripheral vascular disease      | 1 (4)   |
| Heart disease                    | 6 (24)  |
| Renal disease                    | 1 (4)   |
| Cancer                           | 2 (8)   |
| Peripheral neuropathy            | 1 (4)   |
| Chronic obstructive pulmonary disease | 2 (8) |
| Asthma                           | 1 (1)   |

**Ethics, Data Abstraction, and Analysis**

Ethics approval and amendments were obtained from the Institutional Review Board Services (Aurora, Ontario), and written informed consent was obtained from all participants. A specific case review form was created (Supplemental Table 3, http://links.lww.com/NSW/A50) to collect data. These forms were abstracted into an SPSS (v. 23; IBM Corp, Armonk, New York) datasheet.

**RESULTS**

The patient characteristics are summarized in Table 2 and results are provided in Table 3. Twenty-five participants had edema measurements at first visit (baseline/week 0) and week 2.
the ETB group (1.1 to 1.5). The bilateral edema group noted an increase in pain scores at week 2 (right leg 1.0 to 1.8 and left leg 0.4 to 0.7). Pain scores by product were not captured for the bilateral group.

Additional data collected from the patients suggest that the majority of patients who reported pain either at baseline or at week 2 (n = 11, 44%) had a concomitant issue that caused the pain including osteoarthritis (hip, knee, ankle, feet; n = 3), diabetic neuropathy (n = 1), fibromyalgia (n = 1), ingrown toenail (n = 1), osteomyelitis (great toe; n = 1), muscle ache (n = 1), or a new wound (n = 1).

**Patient Preference**

Twenty-three of the 25 patients in the study completed the patient preference survey. The ELS was preferred by 18 (78%) surveyed participants, and 5 (22%) patients preferred ETB (Figure 6). The reasons given for preferring ELS included that it was more comfortable and breathable, easier to put on, less painful than previous compression therapies, cooler while wearing (especially in hot weather), and easier to accommodate in footwear. The reasons for preferring ETB included lower cost compared with the average compression stocking, easy application, cooler compared with previous compression therapies, and the ability to wear more than one layer.

**DISCUSSION**

Leg edema prevalence increases as populations age. Edema may occur from venous disease and other factors as mentioned in the introduction, for example, low albumin; anemia; or liver, kidney, or heart disease. In venous disease, pitting edema may be a forerunner of a leg ulcer. This edema is most prominent around the medial malleolus where the long saphenous vein is superficial and has the greatest curvature, making it most susceptible to leakage, as well as stressing the capillary system.

Traditional compression wraps (ETB) generate horizontal graduated compression because the leg has a greater circumference proximally toward the heart (Table 1). This creates less pressure toward the top of the leg to assist the venous system to direct fluid toward the deeper veins, vena cava, and the heart. The ELS provides a unique parallel longitudinal compression delivery

**Table 3. EDEMA CONTROL MEASUREMENT**

| Location                               | ELS Baseline Mean | ELS Baseline SD | ELS Baseline Range | ETB Baseline Mean | ETB Baseline SD | ETB Baseline Range | ELS 2-wk Follow-up Mean | ELS 2-wk Follow-up SD | ELS 2-wk Follow-up Range | ETB 2-wk Follow-up Mean | ETB 2-wk Follow-up SD | ETB 2-wk Follow-up Range |
|----------------------------------------|-------------------|-----------------|--------------------|-------------------|-----------------|--------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Arch of foot                           | 25.5              | 2.95            | 22.5–33.0          | 25.5              | 3.33            | 22.0–33.0          | 25.5                   | 3.15                   | 21.0–33.5              | 25.5                   | 3.28                   | 21.0–33.5              |
| Above the ankle                        | 29.8              | 4.54            | 23.5–39.0          | 29.8              | 5.33            | 20.0–40.0          | 29.8                   | 3.98                   | 23.0–38.5              | 29.8                   | 4.90                   | 20.0–40.0              |
| 10 cm below tibial plateau             | 42.9              | 7.24            | 31.0–55.5          | 42.7              | 7.17            | 32.0–56.5          | 43.7                   | 6.83                   | 32.0–55.5              | 43.7                   | 6.84                   | 32.0–55.5              |

**Unilateral cohort (ELS, n = 5; ETB, n = 8)**

| Location                               | Mean     | SD      | Range     | Mean     | SD      | Range     | Mean     | SD      | Range     | Mean     | SD      | Range     |
|----------------------------------------|----------|---------|-----------|----------|---------|-----------|----------|---------|-----------|----------|---------|-----------|
| Arch of foot                           | 24.3     | 3.05    | 22.0–29.5 | 24.2     | 3.34    | 22.0–30.0 | 25.4     | 1.65    | 23.5–29.0 | 24.8     | 2.37    | 22.0–30.0 |
| Above the ankle                        | 27.4     | 5.97    | 23.0–36.5 | 29.1     | 4.76    | 23.5–36.5 | 29.7     | 3.95    | 26.0–38.5 | 29.1     | 5.11    | 24.0–40.0 |
| 10 cm below tibial plateau             | 43.7     | 16.92   | 30.0–67.0 | 42.6     | 15.22   | 31.0–64.0 | 49.8     | 8.58    | 36.0–59.0 | 42.0     | 9.04    | 28.0–56.0 |

**Figure 4. MEAN PAIN SCORES BEFORE AND 2 WEEKS AFTER APPLICATION OF COMPRESSION**

**Figure 5. BILATERAL GROUP: MEAN PAIN SCORES NOT DIFFERENT BETWEEN BANDAGE AND STOCKINETTE; BOTH OFTEN WORN AT THE SAME TIME**
system with higher pressure under the ridges compared with ETB (Table 2).

This study revealed that both ETB and ELS may be effective for edema control when more restrictive compression therapies are not viable. The ETBs and ELSs provided low-compression alternatives to traditional bandage wraps, thromboembolic deterrent (TED) stockings, or compression hose (Table 1). The TED stockings are often used for patients on bed rest to prevent lower limb edema and blood clots. The TED stockings are low-pressure and relatively inelastic, providing an external pressure of around 8 to 15 mm Hg when properly fit. Generally, these stockings are not adequate for ambulatory patients. They are knee- to thigh-high and may be more effective for thromboembolism prevention. An open circle on the bottom allows easy inspection of the foot if there is a concern with peripheral vascular disease (although advanced disease is a contraindication to these stockings). These stockings should be used with caution in patients with severe edema, major lower limb trauma, untreated dermatitis, or other skin conditions.

Most patients in this study had an obese body mass index (average, 40.1 kg/m²), comprising the type of patients who often have problems applying traditional support stockings, especially those with high compression. Graduated compression stockings are an elastic device for ambulatory patients exerting external pressure at rest. Stockings can be purchased in knee-high, thigh-high, and pantyhose forms. They are available with compression ranges of 8 to 15 mm Hg (for mild leg edema), 15 to 20 mm Hg (for early venous disease), 20 to 30 mm Hg (for lipodermatosclerosis and advanced venous disease), 30 to 40 mm Hg (venolymphedema), and greater than 40 mm Hg for advanced lymphedema.

Table 4. COMPARISON OF VARIOUS COMPRESSION METHODS

| Type                  | Pattern                                                                 | Comment                                                                                                                                 |
|-----------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Tape/fan-shaped arrangement creates a pressure gradient | ![Diagram](image) | Differential higher pressure under the tape vs open areas forcing fluid into capillaries and venous and lymphatic system toward the heart |
| Elastic compression   | ![Diagram](image) | High pressure at rest can cause pain and discomfort if leg edema is severe or inflammation is present. Less pressure with muscle contraction |
| Inelastic compression | ![Diagram](image) | Low pressure at rest. Higher pressure with muscle contraction. Often used for patients on bed rest (thromboembolic deterrent [TED]). Flat knit for ambulatory patients often exerts less localized pressure. |
| Flat knit             | ![Diagram](image) | Vertical pressure differential to aid edema transfer into superficial capillaries, venules, and lymphatics propelling fluid toward the larger, deeper veins back to the heart. Creates vertical longitudinal furrows on the surface of the skin. |
| EdemaWear             | ![Diagram](image) | Circumferential pressure to aid edema transfer to superficial venules and deeper structures extending to subcutaneous fat. Fluid transferred to deeper veins and lymphatics. |
| Tubigrip              | ![Diagram](image) |                                                                                                                                        |

Figure 6. PATIENT PREFERENCE FOR COMPRESSION BANDAGES

![Patient Preference for Compression Bandages](image)

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The stockings may feature a grip to prevent slippage; have closed or open toes to accommodate painful, arthritic, or deformed toes; and are available in fitted or custom (more expensive) formats. The ELS and ETB systems are not a viable long-term solution for patients requiring high compression but may facilitate initial compression as a precursor to more definitive therapy.

Not all patients can benefit from compression stockings or bandaging systems. For example, individuals with disabilities such as arthritis often have difficulty putting them on and taking them off. Persons with lower limb pain may not tolerate compression. Other potential complications include bunching of stockings with foot flexion or difficulty putting on footwear.

The ETB (Table 4) has been introduced into clinical practice for individuals who cannot tolerate or apply conventional compression bandaging or support stockings. In this study, patients could apply these devices using a single layer from the base of the toes to just below the knee. This treatment option did result in microedema reduction but did not change the ankle circumference measurements for most patients. There was, however, horizontal wrinkling of the skin where the ETB bandage created wrinkles under the applied bandages (wrinkles indicate a positive action of compression).

The ELS (fuzzy wale stockinette) is a recent innovation and alternative clinical choice in the low-compression toolkit. Most patients found this device comfortable and relatively easy to apply. The fabric resulted in longitudinal ridges providing edema control in a similar mechanism to manual lymphatic drainage in physiotherapy or sports injury taping. This type of device has a more open structure providing comfort, cooling, and a less restrictive net interface with the skin surface. Initial pain levels were low because study participants did not have venous ulcers, and edema around the ankle was low or moderate. Most of the decongestion or edema control was above the ankles and concentrated on the lower legs below the knees. Both options have been made available in some healthcare systems to control leg edema.

**Limitations**

This was a relatively small study of 25 patients. Although no significant difference was observed among edema measurements, these measures are subject to variation, depending on the time of day the measurements are taken, or the length of time the stockinette or bandage is applied in the morning prior to the measurements. Other medications, medical conditions, or sodium load may also affect leg edema, along with the temperature in the examination room and seated wait time prior to the appointment.

**CONCLUSIONS**

Both ELSs and ETBs are alternatives to traditional circumferential elastic and inelastic systems for the control of leg edema, are easy to apply, and provide greater self-sufficiency for patients. These bandage systems have a relatively low cost compared with compression stockings. In this study, ELB was preferred over ETB by 72% of participants.

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