Use of the intermittent pneumatic compression device in venous ulcer disease

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The intermittent pneumatic compression device is a relatively new treatment for patients with venous ulcers. With the advent of this therapy being used by the patient in the home setting, the nurse is the primary point of contact for patient questions, concerns, and patient education. Nurses need to know the optimal compression pressure, inflation time, and sequencing time cycles to advise patients in the proper use of this therapy and how to screen patients for this safe use. The major contraindication for this therapy is the presence of deep venous thrombosis. A review of the literature is presented, concluding with recommended scientific basis for optimal compression pressure, inflation time, and sequencing time cycle pattern for the intermittent pneumatic sequential compression device in the venous ulcer patient population. Patient education strategies and topics are discussed. (J Vasc Nurs 1994;12:106-11.)

Venous ulcer disease is a chronic debilitating disease. Long-term management of venous ulcer disease is complex, and ulcer recurrence is frequent. An estimated 600,000 to 800,000 Americans are afflicted with chronic venous leg ulcers. The elderly, those older than 65 years of age, develop the majority of venous leg ulcers, but occasionally ulcers develop in younger patients after trauma. Fitzpatrick estimates that 2 million workdays are lost to venous disease annually.

Deep venous thrombosis is the primary reason for the hospitalization of more than 500,000 Americans annually and is a frequent complication prolonging hospitalization for other illnesses and surgical procedures. The outcome of deep venous thrombosis is varying degrees of chronic venous insufficiency, which affects up to 20% of the United States adult population. Venous ulcers can result from deep venous thrombosis and chronic venous insufficiency.

Lower leg edema is a major component of venous ulcer disease. It has been traditionally treated with elastic leg wraps, elastic support stockings, and Unna boots. Reducing leg edema may increase tissue oxygenation, enhancing an optimal wound healing environment. Recent developments in the field have resulted in the introduction of the intermittent sequential compression device as a new compression therapy for venous ulcer disease. Intermittent pneumatic sequential compression devices mechanically increase venous return. Some studies show that the device stimulates fibrinolysis and increases skin perfusion pressure, which may assist tissue oxygenation. Traditionally the intermittent pneumatic compression device is used to decrease the incidence of deep vein thrombus in bedridden patients and reduce edema in patients with lymphedema.

Nurses monitor the efficacy of intermittent pneumatic compression therapy, select optimal pressure, inflation time, and sequencing time cycles, and provide patient education. It is important for professional nurses to know the scientific basis for this therapy to increase their problem-solving ability in care plan variances and evaluate therapy efficacy in this new patient population. This knowledge includes optimal pressure, inflation times, and cycles.

REVIEW OF THE LITERATURE

The first models of intermittent compression device were introduced with one inflatable chamber from foot to knee in a boot configuration. Later models have three chambers, excluding the knee, and newer models have a many as six inflatable chambers in a legging style. A review of the literature follows that describes varying pressure time, and sequencing cycles that have been used in studies and practice.

Using 10 patient volunteers who had normal deep veins, Nicolaides et al. compared a single-chamber boot with a six-chamber compression legging by use of five sets of pressures. The purpose of the study was to determine the cycle and pressure of the optimal stimulus that would empty the leg veins. The multichambered boot inflation began distally and moved proximally in a smooth, milking motion. Changes in blood velocity in the femoral vein were measured by use of a directional Doppler ultrasound velocity detector. Nicolaides et al. reported that the multichamber device used in a sequential pattern was more effective in emptying the veins than the single-chamber legging. Optimal pressures were reported to be 35 mm Hg for the ankle, 30 mm Hg for the calf, and 20 mm Hg for the thigh with a timing pattern of 12 seconds of compression followed by 60 seconds of relaxation to allow venous refilling between compressions. During measurement of femoral vein blood velocity, a period of 45 seconds is required for the veins to refill to the precompression value.

Three other studies reviewed involved use of the single-chamber style of compression. Dillon used 50 to...
mm Hg of compression pressure to determine the effect of single-chambered boots on patients with peripheral vascular disease. The timing of compressions was triggered by patient QRS complexes of the electrocardiogram to yield a very rapid and brief compression sequence at the end-diastolic point of cardiac contraction. Patient treatments were 40 minutes in length. Outpatients received one treatment daily during weekdays; inpatients received two to four treatments daily. Dillon and associates attributed improvement in all but one subject to stimulation of endogenous fibrinolysis and increased tissue perfusion. Patient improvement was defined as a decrease in skin induration and pigmentation and decreased palpable thrombi. Neither scientific measurement of induration and pigmentation nor how thrombi were palpated was reported. Dillon did identify his failure to control intervening variables, such as smoking, associated diseases (diabetes), obesity, and activity level (inpatients prescribed bedrest vs outpatients) in his study discussion.

As a preliminary to selecting an optimal cycle for subsequent clinical trials, Kamm et al. used radionuclide imaging on healthy volunteers to compare different pressure and timing compression sequence patterns. Their purpose was to obtain a more detailed understanding of the blood flow velocity changes with various compression cycles to determine an optimal cycle. Kamm et al. used a four-chamber ankle-to-below-the-knee compression device and reported detailed scientific measurements. A mean pressure of 45 mm Hg was used throughout the random ordered cycle patterns, with a total compression time of 10 seconds, allowing a 50-second venous refill period. An optimal graded and sequential pattern was found to be one in which the pressure is varied 5 to 10 mm Hg sequentially, with the highest pressure being at the ankle and the sequential compression rise cycle at 0.5 seconds. To achieve the single compression simulation, the four chambers were inflated simultaneously. Kamm et al. found the uniform or single-chamber compression to be partially occlusive, decreasing blood flow. Their description is likened to squeezing a toothpaste tube in the middle, rather than the desired milking flow pattern.

The purpose of Muhe's study was to determine whether pressures higher than 55 mm Hg would increase venous flow velocity. A three-chamber compression device extending from ankle to proximal thigh was used on 25 patients confined to bed. Muhe measured venous flow changes with the radionuclide xenon 133. The compression degree varied, with the highest pressure always at the ankle; the calf pressure was 20% less than the ankle, and the thigh pressure was 40 percent less than the ankle pressure. Muhe considered the resting venous flow velocity without compression to be 100% blood flow velocity. Muhe reported a 175% increase in venous blood flow velocity with a mean pressure of 55 mm Hg, a 304% velocity increase with a mean pressure of 65 mm Hg, and a 366% velocity increase with a mean pressure of 95 mm Hg. He concluded that the standard 55 mm Hg used before his study was too low to produce a very high venous flow velocity. Muhe advocated use of higher compression pressures. The optimal venous blood flow velocity in treating venous leg ulcers has not yet been established to support his conclusion.

Pekanmaki and Kolari studied seven patients by use of a segmented boot compression device with 50 mm Hg and a pressure gradient between ankle and calf of 15 mm Hg. Several possible variations of inflation/deflation rates and time patterns were described; however, the pattern(s) used in the study were not specified. An improved mean leg ulcer healing time of 6 weeks by use of the compression device versus conservative treatment with compression bandages and wet-to-dry dressings, which had a mean healing time of 16 weeks, was reported.

In another study, Pekanmaki et al. treated eight patients with leg ulcers with intermittent compression treatment and continued conservative treatment (wet-to-dry dressings with elastic bandages). The compression pattern in this study consisted of 50 mm Hg pressure with an inflation time of 12 seconds, with a sequencing of two cycles per minute. This allows an 18-second rest period between cycles. Patients used the compression boot daily for 45 minutes for the first 2 weeks of therapy, then decreased the frequency of compression therapy to two times per week. Pekanmaki et al. measured transcutaneous oxygen tension in three of the study subjects and reported an 80% increase in tissue oxygenation during intermittent compression treatment. Pretreatment skin transcutaneous oxygen tension (tcPO2) was shown on a graph as approximately 20 mm Hg, indicating the need for establishing increased blood flow to the area. Posttreatment tcPO2 was shown on the same graph as approximately 34 to 36 mm Hg for two subjects, indicating reasonable circulation, and 50 mm Hg for the third subject, indicating normal circulation. Concluding the study discussion, Pekanmaki et al. reported a mean ulcer healing time of 5 weeks with intermittent compression therapy, versus the control group's mean ulcer healing time of 13 weeks with conservative wound care treatment alone.

Mulder et al. sought to determine whether intermittent sequential pneumatic compression could expedite the healing of chronic venous ulcers. Study subjects were eight patients with chronic venous ulcers who served as their own controls in their study design. Subjects were treated with the traditional Unna's boot for 6 weeks by Mulder et al. before study entry. Only patients who were without improvement or change in ulcer size were enrolled in the study.

In this study, in addition to the traditional Unna boot therapy, the subjects used intermittent sequential pneumatic compression therapy 1 hour every morning, and 2 hours every evening for the 120-day study period, or until the ulcers healed, whichever occurred first. During weekly clinic visits, Mulder et al. reported assessing wound status by measuring leg volume dimensions and photographing the ulcers. The patients' pain was assessed with use of a numeric scale of 0 to 10. Objective recording of the amount of ulcer exudate as none, increased, decreased, or no change was performed.

The intermittent sequential compression device used in
### TABLE 1

<table>
<thead>
<tr>
<th>Author</th>
<th>Sample</th>
<th>Type device tested</th>
<th>Measurement tool</th>
<th>Reported outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicolaides</td>
<td>10 healthy</td>
<td>Single and six-chamber</td>
<td>Ultrasound velocity</td>
<td>Multichamber boot more effective than single chamber in increasing blood flow velocity</td>
</tr>
<tr>
<td>Dillon</td>
<td>Grp 1, 6 healthy; grp 2, 8 mild PVD; grp 3, 21 advanced PVD</td>
<td>Single chamber</td>
<td>Subcutaneous Po₂ levels, blood pressure, pulse volume, ultrasound velocity</td>
<td>Increased blood pressure levels, increases in ultrasound velocity</td>
</tr>
<tr>
<td>Muhe</td>
<td>25 bedridden patients</td>
<td>Three-chamber</td>
<td>Radionuclide imaging</td>
<td>Increased velocity; 175%/mean 35 mm Hg, 304%/mean 65 mm Hg, 366%/mean 95 mm Hg</td>
</tr>
<tr>
<td>Dillon</td>
<td>17 patients with PVD</td>
<td>Single-chamber boot</td>
<td>Visual observations and palpation of thrombi</td>
<td>Single-chamber partially occlusive, optimal increase in blood flow velocity with 5 to 10 mm Hg sequential pattern with highest at ankle</td>
</tr>
<tr>
<td>Kamm et al.</td>
<td>23 healthy patients</td>
<td>Single 4-chamber</td>
<td>Radionuclide imaging</td>
<td>Improved healing rate</td>
</tr>
<tr>
<td>Pekanmaki and Kolari</td>
<td>7 patients with PVD</td>
<td>Multiple-chambered</td>
<td>Healing rate</td>
<td>80% increase O₂ tension during compression, improved healing rate</td>
</tr>
<tr>
<td>Pekanmaki et al.</td>
<td>8 patients with PVD</td>
<td>Multiple-chambered</td>
<td>Healing rate transcutaneous O₂ tension</td>
<td>Reduction in ulcer size versus time with compression</td>
</tr>
<tr>
<td>Mulder et al.</td>
<td>8 patients with PVD</td>
<td>Multiple-chambered</td>
<td>Photography, pain assessment, exudate volume, segmental leg measurements</td>
<td></td>
</tr>
</tbody>
</table>

Grp, Group; PVD, peripheral vascular disease.

the study was described as a controller and thigh-length sleeves. Mulder et al. did not include the inflation pressure, inflation time, and sequencing time cycle pattern used in their study.

Using linear regression, Mulder et al. reported that the study patients demonstrated a significant reduction in ulcer wound area versus healing time with use of the intermittent compression pump. Study patients were monitored for 1 year after termination of the study. During that year, they reported that when two of the patients stopped using the compression after the ulcers healed, ulcers reappeared after 3 to 6 months. The ulcers healed a second time with resumption of the compression treatments. Mulder et al. relate the improved healing time to decreased venous blood stasis, decreased venous hypertension, and increased venous return associated with the intermittent sequential compression therapy.

**DISCUSSION**

Table 1 contains key study comparisons. All of the studies reviewed used small sample sizes. Two were conducted on a healthy, young population, which contrasts sharply with the usual profile of patients with venous ulcers. Compression levels and sequencing patterns varied widely, and there...
was little consensus regarding the optimal approach. The wide variation of inflation pressures and time and sequencing patterns used in the studies did not identify an optimal pattern for clinical use. The consistent pattern feature was the highest pressure at the ankle, with decreasing pressure gradients at the calf and thigh.

One professional publication described ulcer resolution in use of the intermittent sequential compression device in a wound healing institute and an ulcer clinic. Recommendations were peak pressures set at 45 to 60 mm Hg at the ankle. The ankle chambers inflate first; then several seconds later, the calf chambers inflate at a lower pressure (25 to 45 mm Hg). The thigh chambers inflate last, usually at a pressure of 25 to 30 mm Hg. All the chambers then remain inflated for 5.2 seconds before being deflated simultaneously. The cycle repeats every 71 seconds to allow the venous system to refill. This compression is prescribed to be used for 1 to 2 hours twice a day, morning and evening.

IMPLICATION FOR NURSING PRACTICE

The studies reviewed confirmed that multichambered compression devices and decreasing pressure gradients from ankle to thigh are far more effective in achieving the desired milking pattern than the single pressure one-chambered models. Two studies also identified the venous refilling time of approximately 45 seconds.

Mulder and Reis's recommended inflation pressure, time, and sequencing pattern use the mean 35 to 45 mm Hg pressure used in several of the previously reported study results. Their pattern follows the decreasing pressure gradients from ankle to thigh recommended by Kamm et al. and Nicolaides et al. It also allows sufficient time for venous refilling as recommended by Kamm et al. and Nicolaides et al. Although Mulder and Reis do not refer to Mulder's study report published earlier, their recommended pattern provides the best scientifically based standard for intermittent pneumatic sequential compression therapy to date.

Some of the newer intermittent sequential compression models as shown in Figure 1 have preset pressures. It is important for the nurse to be aware of model variances and to know which model the patient is using to give correct information to the patient and family members. Preset pressures and cycles should be within the recommended standard of Mulder and Reis of 45 to 60 mm Hg at the ankle, 35 to 45 mm Hg at the calf, and 25 to 35 mm Hg at the thigh. Preset pressures simplify the device for patients, but it is important for the nurse to evaluate the efficacy of the preset pressures. If the patient is not healing and the preset pressures are at the lower end of the recommended range and cannot be altered, the manual pressure selection model with higher pressure capability will need to be used.

Contraindications to therapy. The major contraindication for intermittent compression therapy is the presence of proximal deep vein thrombosis, which might be loosened and result in emboli. A sign of deep vein thrombosis is notable unilateral leg edema occurring over a 24- to 48-hour period with or without localized warmth and tenderness. Homan's sign, which is elicitation of pain with dorsiflexion of the foot, is not a reliable method to screen a patient for
TABLE II

PATIENT EDUCATION TOPICS

1. What venous insufficiency/venous hypertension is.
2. Effects of venous insufficiency/venous hypertension.
3. Frequent leg elevation.
4. Correct elastic stocking application.
5. Smoking cessation.
6. Avoidance of leg constriction.
7. Weight control.
8. Avoidance of dehydration.
9. Skin care with daily inspection.
10. Settings for intermittent sequential compression therapy.
11. Signs/symptoms of thrombi.

depth venous thrombi. Homan's sign can be falsely negative if the dorsiflexion is too gentle, or falsely positive if the dorsiflexion is too aggressive. Underhill et al. writes that sphygmomanometer readings produce a more quantitative approach than the Homan’s sign. However, the applied sphygmomanometer cuff compression could dislodge thrombi. For patients exhibiting any signs of deep venous thrombi, venous duplex imaging or iodine 125–fibrinogen leg scanning is highly recommended before intermittent compression therapy is begun.

If the patient complains of feeling pain during treatment, the nurse should recommend checking-device application for proper anatomic alignment of the chambers and pressure settings. Some patients may require the lower recommended ankle pressure of 45 mm Hg initially, with gradual increase to the higher 60 mm Hg in subsequent treatments. With continued complaints of pain, thrombophlebitis must be ruled out before continuing treatments.

Patient education. The financial, physical, and emotional stresses felt by patients and their families in dealing with chronic venous insufficiency and venous ulcers are overwhelming. People are living longer and expect to enjoy their later years without restrictions, isolation, and pain. There is no “cure” for venous insufficiency. All treatments are simply “palliative.” Patient education interventions should begin by guiding lifestyle changes to avoid aggravating factors, such as obesity, smoking, and prolonged standing.

Making lifestyle changes is very difficult. It is important for the nurse to develop an ongoing trusting, respectful, caring relationship with the patient to facilitate behavioral change. A thorough nursing assessment includes not only the physical system, but the sociologic and psychologic systems, to see the patient as a “whole person.” Collecting his patient information cues the nurse to the patients’ and families’ needs, effective therapeutic approaches, and potential barriers to interventions.

Listening to the patient’s questions and fears and answering them patiently in a positive manner let the patients know that the nurse is interested in their well being. Include family members so they can be supportive to the patient making the prescribed changes in the home environment. Give instructions in a quiet environment without interruptions, if possible. Present one concept at a time and evaluate the patient’s understanding before continuing. Audiovisals and pamphlets that the patient can take home reinforce verbal instructions. Frequent follow-up is needed throughout the behavioral change process.

The chronic nature of venous ulcer disease and the need for tenacious patient adherence to the treatment plan require a strong nurse-patient relationship. Research efforts have investigated the causes of patient nonadherence. One cause of nonadherence mentioned is the patient’s lack of understanding of the instructions. Green and Faden tell us that learners remember 20% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say, and 90% of what they say and do. The key point is that active participation and demonstration of newly learned behavior is the most effective method of teaching.

Table II lists pertinent education topics for patients with venous insufficiency. They need to understand what venous insufficiency is, how it developed, and what effect it has on the venous system. Understanding the reasons for frequent leg elevation, proper application of elastic stockings, and regular use of the intermittent pneumatic pressure device will enhance patient adherence. Patients should be instructed to continue to elevate their legs to heart level several times a day. They should avoid sitting with their legs crossed or with an acute angulation. They need to avoid standing for prolonged periods and must ambulate intermittently when taking long plane or car rides. Patients with venous insufficiency need to avoid constrictive clothing and apply their elastic stockings before getting out of bed each morning. Smoking must be eliminated because smoking delays healing. Weight control must be ongoing. Bernstein includes avoidance of significant dehydration and also notes increased risk of ulceration for women using oral contraceptives.

Once the ulcer is healed, patient education and reinforcement of the patient’s new lifestyle must continue. The rate of ulcer recurrence is about 70%. Recurrence is frequently the result of not wearing the prescribed elastic stockings, trauma to the healed ulcer area, or smoking relapse.

Skin care instructions include the need for daily cleansing and lubrication to keep skin soft and pliable. Patients should inspect their legs and feet daily for unsuspected signs of trauma. They must be warned about thermal trauma from hot water bottles and heating pads. Mechanical trauma can occur from shoes or walking barefoot. Chemical trauma can occur from drying agents in over-the-counter lotions and ointments.

Trying to make behavioral changes is frustrating for both patient and family, and sometimes, health professionals. Nurses must accept a nonadherent patient not as a failure, but as a patient who needs reinforcement, reevaluation, and support.
SUMMARY

Although the role of intermittent pneumatic sequential compression device therapy in venous ulcer treatment is relatively new, its effectiveness has been demonstrated. Despite their shortcomings, several studies reviewed in this article do indicate faster healing in treating patients with leg ulcers with compression device therapy. Nurses are the main source of information for patients and, as such, must remain current in their research-based knowledge of new therapies. Patient education is a major component in the venous ulcer disease therapy plan and must be addressed at every patient encounter to achieve lasting lifestyle changes.

REFERENCES

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