Instruction of Compression Therapy by Means of Interface Pressure Measurement

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BACKGROUND. **Compression therapy of the leg is the cornerstone in the conservative treatment of venous ulcers. The application of compression bandages, however, is largely a matter of personal experience.**

OBJECTIVE. **To evaluate the interface pressure under compression bandages and to improve the technique.**

METHODS. **Six courses on wound healing with 24–28 participants as well as individual training at our hospital were provided. Interface pressure at the distal medial calf was measured using a simple, but accurate pressure sensor that was built for this purpose (accuracy: ±3 mmHg).**

RESULTS. **During the wound healing courses, the absolute difference from the target pressure of 35–45 mmHg improved from 8.4 mmHg (95% CI 0.0–34.1) to 3.5 mmHg (95% CI 0.0–14.0) (P = .0001). After four sessions, interface pressures greater than 60 mmHg were avoided. During individual training, even nurses with everyday experience in compression therapy improved their accuracy.**

CONCLUSION. **There is a need for objective measurement of interface pressure in the teaching of compression therapy with bandages. The principles can be taught during a few exercises. However, repeated practice over a longer period of time is necessary to reach a certain accuracy.**

COMPRESSION THERAPY is the cornerstone in the conservative treatment of chronic venous insufficiency and venous ulcers. Two treatment phases are distinguished: the therapy phase and the maintenance phase. The therapy phase aims at edema reduction to allow for ulcer healing, whereas the maintenance phase aims at preventing new edema or ulcer recurrence.[1] Bandages are commonly recommended during the therapy phase and medical stockings are subsequently used to maintain the treatment result.

Medical stockings are made to exert a defined interface pressure. Most countries use their own classification of compression stockings.[2] In contrast, compression therapy with bandages is a matter of personal experience. The reported healing rates of venous ulcers varies among clinical studies, from 20 to 70% at 3 months to 40–80% at 6 months.[3,4] Apart from initial ulcer size and duration of disease, interface pressure can greatly influence different outcomes. Consequently there is a need for objective measurement of interface pressure under compression bandages in order to accurately train wound care professionals and to obtain comparable conditions in studies on leg ulcer healing. Interface pressure measurement might also help avoid the hazards of leg compression in patients with coexistent peripheral arterial disease or diabetes. In one survey, 32% of all Scottish surgeons reported severe adverse effects of compression therapy.[5]

An interface pressure of approximately 40 mmHg measured at the medial gaiter area is generally agreed to be a safe and effective target level of compression therapy.[6–9] Compression enhances the venous outflow in chronic venous insufficiency, as has been shown by foot volumetry,[8] phlebodynamometry,[1] and airplethysmography.[10–12] External compression of the leg reduces edema. It increases the interstitial pressure of soft tissues and thereby restores the filtration-diffusion equilibrium in chronic venous insufficiency.[13] The effect of interface pressures of ≥60 mmHg on venous outflow and edema reduction has hardly been investigated. However, experiments on healthy volunteers measuring radioisotope washout under external compression of the leg have demonstrated a marked reduction in subcutaneous and muscular blood flow at interface pressures greater than 50 mmHg.[14]

In conclusion, compression therapy of the leg is a valuable part of the treatment of chronic venous insufficiency, but it is not without side effects. When bandages are used during the therapy phase, the wrapping technique depends largely on personal expertise and most therapists do not have a good idea of the pres-

J. Hafner, MD, W. Lüthi, MD, H. Hänssle, MD, G. Kammerlander, and G. Burg, MD have indicated no significant interest with commercial supporters.

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ISSN: 1076-0512/00/$15.00/0 • Dermatol Surg 2000;26:481–487

sure they are applying. This prompted us to perform a study on the training of compression therapy by means of interface pressure measurement.

Materials and Methods

With the introduction of synthetic wound dressings in the local treatment of chronic wounds, there is considerable need for teaching the characteristics and use of these materials. Several companies in Switzerland give courses that are primarily attended by community and hospital nurses. One of these companies provided us with the opportunity for the present study. The participants came in groups of 24–28 and compression therapy was practiced in pairs. For this purpose we built 14 suitable pressure sensors which consisted of a rubber bag (50 mm × 30 mm × 5 mm) from baby-size sphygmomanometer cuffs and one of the connecting rubber tubes (diameter 8 mm), while the second tube was cut and sealed (Figure 1). The system was filled with silicon oil and a piezoresistive pressure transducer was connected to the far end of the tube (Figure 2). The transducers could be calibrated at 0 mmHg with the sensor suspended vertically in the air. To measure interface pressures the sensor had to be placed onto the skin at 5 cm above the medial ankle and the end of the connecting tube with the pressure transducer had to be held in a vertical fashion in order to protrude from the upper margin of the bandages. A digital manometer that could be connected to the transducers was used by the supervisor to read the pressure.

In the first phase the accuracy of the sensors was evaluated by comparison with the pressure under a sphygmoma-

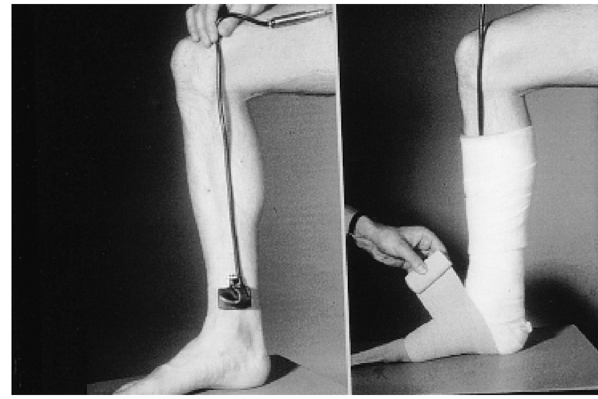

Figure 1. The interface pressure sensor in place at the distal medial calf. During measurements the connecting tube is held vertically.

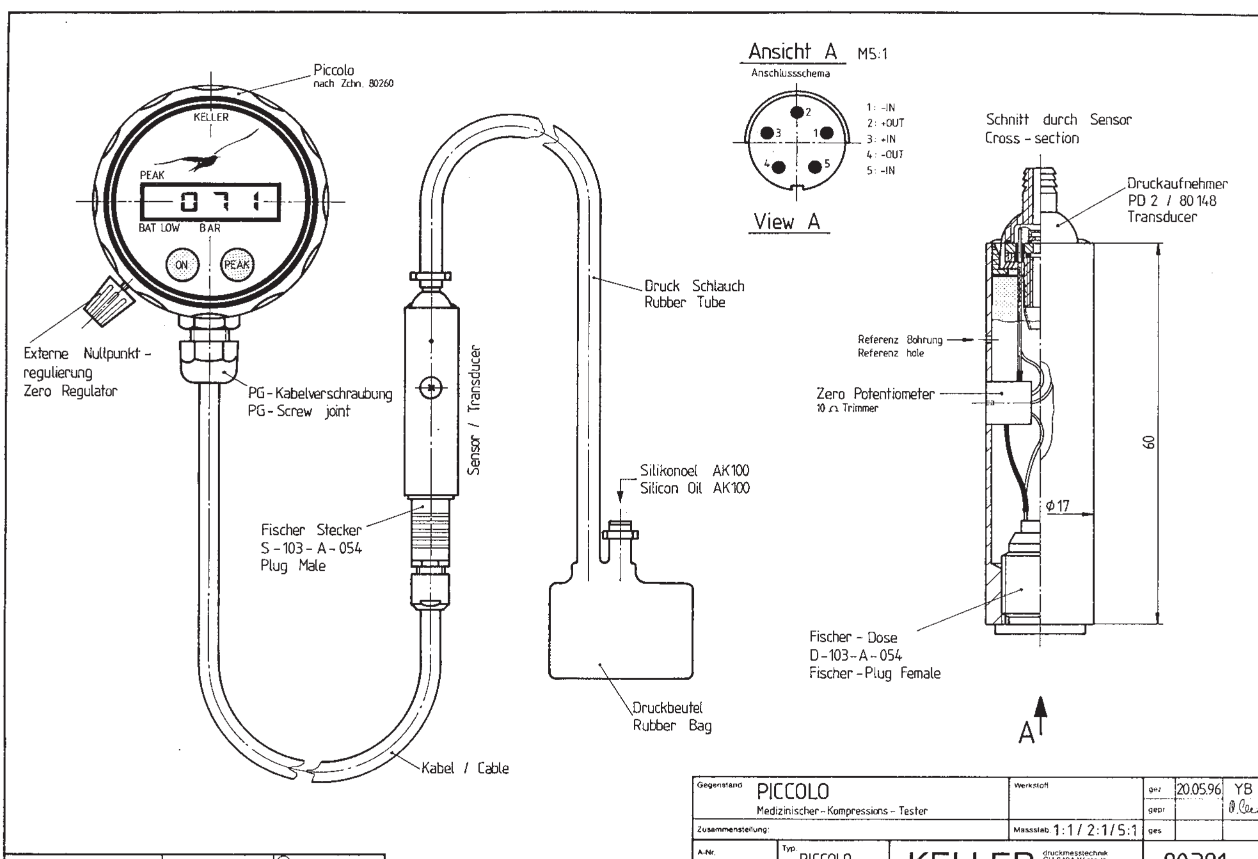

Figure 2. Technical drawing of the measuring device. On the right, a cross-section through the piezoresistive pressure transducer is shown.

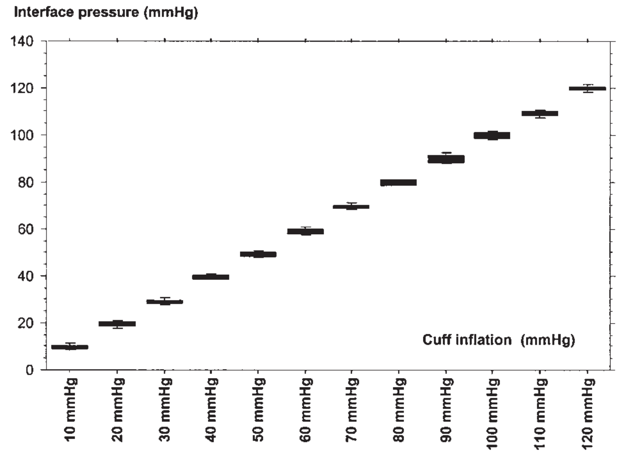

Figure 3. Accuracy of the interface pressure sensor. Fifty healthy volunteers, the sensor placed at the distal medial calf area, under a sphygmomanometer cuff. Cuff inflation in steps of 10 mmHg.

nometer cuff at the gaiter area (50 healthy persons, measurements in increments of 10 mmHg over a range of 0–120 mmHg; Figure 3) and by comparison with the compression at the gaiter area that is exerted by medical stockings (20 healthy persons, each one received a pair of class 2 and class 3 medical stockings (Figure 4).

Compression therapy of the leg was taught to a total of 156 participants during six courses on wound healing. The participants practiced in pairs. The pressure sensor was placed at the medial gaiter area, 5 cm above the medial malleolus, and readings were taken in a sitting position with the foot on the floor and the leg in a vertical position. The participants were asked to bring along their own compression bandages to evaluate their present performance in compression therapy. After a first session without any prior teaching, the compression technique according to Sigg,[15] which is widely used in Switzerland, was demonstrated. We used one padding layer of orthopedic wool and two short-stretch bandages. The orthopedic wool was applied in a spiral fashion starting at the base of the toes and ending below the knee, with a two-third overlap per circle. The short-stretch bandages were applied in circles of eight with a two-third overlap. The first bandage reached from the base of the toes to above the ankle and the second from above the ankle to below the knee. The participants had three more opportunities to practice this standard compression therapy during the remainder of the course. They tried to achieve a compression within the recommended range of 35–45 mmHg[7,9,13] and they were told to avoid interface pressures greater than 60 mmHg, which are known to be potentially dangerous in arterially compromised patients.[5,13]

Independently, 10 nurses at our institution with many years of experience in compression therapy and 10 medical students who had no previous practice participated in an inhouse compression training session. The participants practiced individually until four subsequent bandages were within the target range. Two weeks later their accuracy was retested in a single-blind fashion.

At the beginning of the study one of the authors (W.L.) was completely unaware of compression therapy. At the end of the year he was tested in performing 20 subsequent compression bandages in a single-blind fashion.

Data were expressed as median with the 95% confidence interval. Stat View 5.0 software was used for statistical calculations. The Wilcoxon signed rank test was used for comparison of continuous data in paired groups.

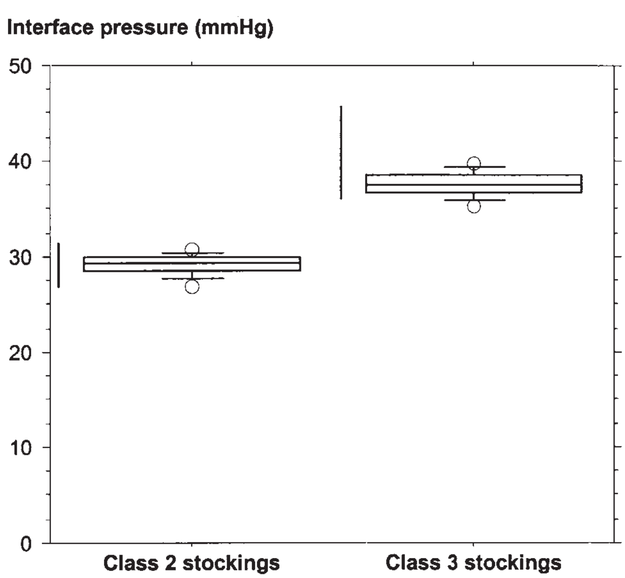

Figure 4. Accuracy of the interface pressure sensor. Twenty healthy volunteers wearing a class 2 and a class 3 medical stocking. The vertical bars indicate the pressure ranges of class 2 and class 3 stockings.

Results

The accuracy (maximum deviation) of the interface pressure under a sphygmomanometer cuff placed at the gaiter area was ±3.0 mmHg over a range of 0–120 mmHg (Figure 3). The accuracy compared to the interface pressure under a class 2 and class 3 medical stocking was 29.3 mmHg (27.0–30.8) and 37.5 mmHg (35.3–39.8), respectively. Class 2 and 3 medical stockings are knitted to exert an interface pressure of 25.1–32.1 mmHg and 36.4–46.5 mmHg, respectively, at the medial gaiter area (Figure 4).[16]

The 156 participants in the wound healing courses achieved an interface pressure of 33.8 mmHg (15.8–79.0) in the first session and 35.6 mmHg (21.0–52.5) in the fourth session (P = .6) (Figure 3a). The absolute difference from the target range (which was defined as 35–45 mmHg) was 8.4 mmHg (0.0–34.1) in the first session and 3.5 mmHg (0.0–14.0) in the fourth session (P = .0001) (Figure 5). Interface pressures ≥60 mmHg occurred in 21 instances in the first session (highest value 119 mmHg) and did not occur again.

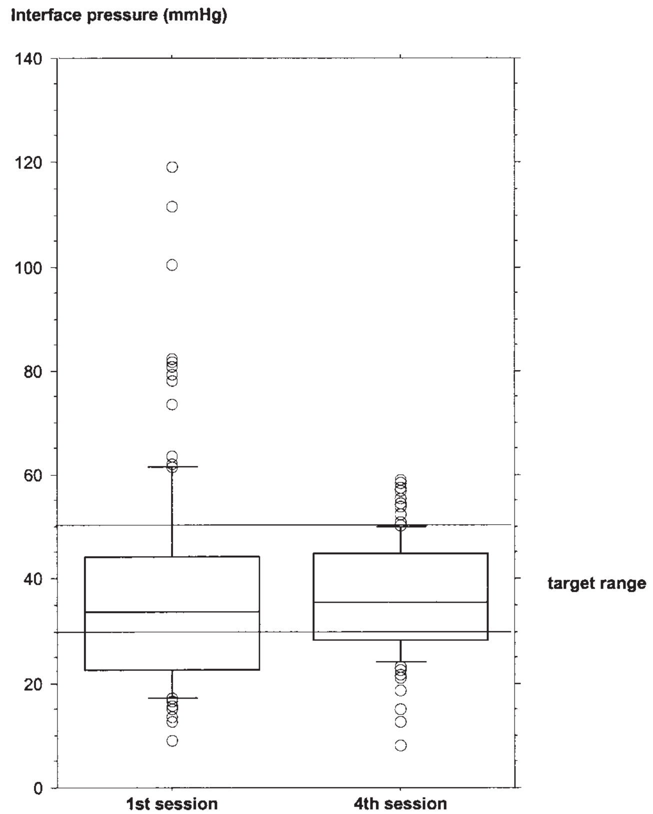

Figure 5. Training in six groups of 24–28 participants (total 156), four sessions. The median remains unchanged (P = .6). The absolute difference from the target range improves (P = .0001). After four sessions, potentially dangerous interface pressure (greater than 60 mmHg) is avoided.

The 10 nurses routinely involved in the treatment of venous ulcers achieved an interface pressure of 35.3 mmHg (13.1–62.6) on the first attempt and they continued to practice until four subsequent measurements were within the defined range of 35–45 mmHg. Two weeks later they achieved a compression of 40.5 mmHg (30.4–51.8) (two single-blind exercises) (Figure 6a).

The 10 medical students achieved an interface pressure of 41.3 mmHg (21.4–70.9) on the first attempt and they continued to practice until four subsequent measurements were within the given range. At the test 2 weeks later, they achieved a compression of 33.8 mmHg (18.8–54.8) (two single-blind exercises) (Figure 6b).

One of the supervisors (W.L.) accomplished 20 subsequent compression bandages in a single-blind fashion. All 20 bandages exerted an interface pressure within the target range, with the median at 39.4 mmHg (35.7–44.3) (Figure 6c).

Discussion

Our study shows that training effectively improves the accuracy of compression therapy with avoidance of potentially dangerous interface pressure. The ability to achieve all bandages within the target range requires daily practice, and even health care professionals can improve their accuracy by means of interface pressure measurements. Beginners require approximately 10 individual exercises in order to accomplish four consecutive bandages within the target range. The learning effect is rapidly lost if regular practice is not maintained. Nevertheless, even an absolute beginner can reach a high degree of competence after 1 year of instruction and practice.

At least 14 devices for the measurement of interface pressure in medicine have been published over the last 40 years.[4,17–29] To the best of our knowledge, currently the Oxford Pressure Monitor MK II (Talley, Romsey, UK)[24] is the only device that can be purchased, although others may become available in the near future.[12,29] For our purposes we found it more convenient to build a sufficiently accurate low-cost device that could be used for pairwise training in courses of up to 28 participants. Ideally a pressure sensor should be as flat as possible. In practice, however, a certain sensor thickness can be tolerated without influencing the accuracy of the measurements,[25] especially on flat sites such as the distal medial calf. We used the rubber bag of small sphygmomanometer cuffs because these were readily available and resistant to physical stress. Our device demonstrated an excellent accuracy of ±3 mmHg. Some of the latest prototypes[12,29] that probably will become available in the near future have a very small, flat sensor that will allow for continuous registration of interface pressure, for example, during exercise. For teaching purposes, however, static pressure measurement is sufficient.

During this study we used short-stretch bandages, which represent the mainstay of compression material in Switzerland.[15] Three categories of bandages are available based on their extensibility: short stretch (<70% extensibility), medium stretch (70–140% extensibility), and long stretch (>140% extensibility).[16] Short-stretch bandages are widely used in continental Europe.[1,12] Tight short-stretch bandages, as well as completely inelastic zinc plaster bandages (Unna boots), generate higher pressure amplitudes while walking than long-stretch bandages.[30] With short-stretch bandages the interface pressure shows a marked decrease from 40 to approximately 20 mmHg when patients lie down, whereas long-stretch bandages maintain their interface pressure in the supine position.[1,30–32] Therefore short-stretch bandages are considered to be safer in patients with peripheral arterial disease or with diabetic polyneuropathy, although this has not been formally shown in clinical trials.[4] However, short-stretch bandages lose more than half of their pressure over a wear time of several days, whereas long-stretch ban-

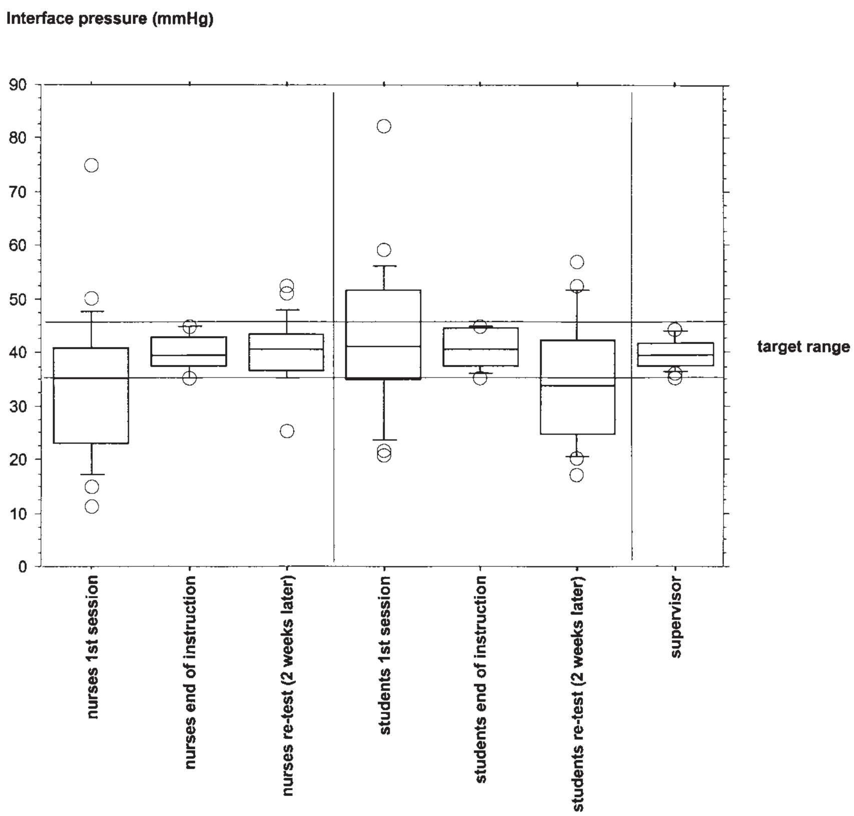

Figure 6. Individual training. Individual training until accuracy is achieved and retest 2 weeks later: Ten nurses, 10 students, and a supervisor.

dages sustain their interface pressure over a prolonged wear time.[9] The four-layer bandage, which is widely used in the United Kingdom, is a multilayer bandage composed of orthopedic wool, crepe, a long-stretch and a cohesive medium-stretch bandage.[9] It has been shown to be safe in large clinical trials where a considerable number of patients with combined venous and peripheral arterial disease (mixed venous-arterial ulcers) were enrolled.[33] Both inelastic as well as elastic multilayer bandages have yielded healing rates of 40–70% at 3 months, and currently it cannot be said which one is more effective in the treatment of venous ulcers.[3,9,33–37]

According to Laplace's law (pressure = tension/radius), the interface pressure depends on the tension of the bandage and on the radius of the limb.[16,32] In order to reach the same tension, an elastic bandage has to be stretched more than an inelastic bandage. Therefore it seems important that wound care professionals become familiar with one of the established compression techniques and that they learn to use the materials that they will work with. It might also be prudent to perform compression therapy on legs of different ankle circumferences, since edematous legs have a larger radius than slim legs. Thus in order to obtain the same amount of interface pressure, bandages need to be put on with higher tension on large legs than on slim legs. Conversely, slim legs need careful protection of the bony and tendinous prominences since interface pressure at these exposed points can reach 100 mmHg.[9,32,33]

Attention should be paid to the fact that compression is graduated, that is, the interface pressure below the knee should be approximately 70% of that above the ankle.[16] This is generally the case when the stretch is not changed while wrapping. Due to Laplace's law, interface pressure under compression bandages diminishes gradually with the increasing radius from the distal to the proximal leg. Nevertheless, training of compression therapy should include two points of interface pressure measurement, one at the medial gaiter area and one below the knee.

Leg ulcers compromise quality of life substantially.[38–40] The costs of leg ulcer care are enormous. It has been estimated that the annual direct costs come to $1 billion in the United States[38] and to £230–400 million in the United Kingdom (calculations based on 1991 prices).[39] Therefore training of compression therapy is likely to represent a good investment of time.

Acknowledgments We greatly acknowledge F. Lotto (ConvaTec Division, Bristol-Myers Squibb, Baar, Switzerland) for collaboration during the wound healing courses; M. Kägi (Beiersdorf, Münchenstein, Switzerland) for furnishing bandage material; J. Winiger (Ganzoni, St. Gallen, Switzerland) for furnishing medical compression stockings; and E. P. Scheidegger, MD (Department of Dermatology, University Hospital of Zurich, Zurich, Switzerland) for proofreading the manuscript.

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Commentary

It has been said that one cannot learn compression bandaging from a book.[1] The authors present a study in which several groups of clinicians, using short-stretch bandages for compression wrapping, were able to achieve proper pressures at the ankle level only after training, practice, and feedback about the actual interface pressures achieved. Other articles have shown similar results.[2–4] However, this study appears to have the largest number of subjects and includes the most diverse group of health care disciplines and experience levels.

As the discussion points out, proper interface pressure at the ankle level is only one part of successful bandaging. Gradient compression is generally felt to be important as well. Also, because it is unclear what one really learns with bandaging practice, that is, is a certain level of tension sensed in the bandage or is a certain amount of stretch sensed, the comments about different materials and leg sizes are important.

With acceptance of the findings in this article and others that feedback of the pressures achieved is necessary for learning proper technique, and that there is a dearth of commercially available instruments, what can one do to learn and/or demonstrate proper short-stretch bandaging technique? The authors constructed their own devices consisting of a bladder, pressure transducer, and digital readout. A less expensive instrument can be constructed from a pediatric blood pressure cuff bladder and a standard manometer of the aneroid type used for arterial blood pressure measurement (Figure 7). Using a syringe the system is filled, but not pressurized, with air. In our laboratory, such a system has shown a maximum error of 3 mmHg compared to the pressure in a limb encircling cuff using the same testing methods as described in this article. One does not have to hold the manometer at the same level as the bladder because gravitational effects are negligible on air in this system (cf., silicone used in the reported study).

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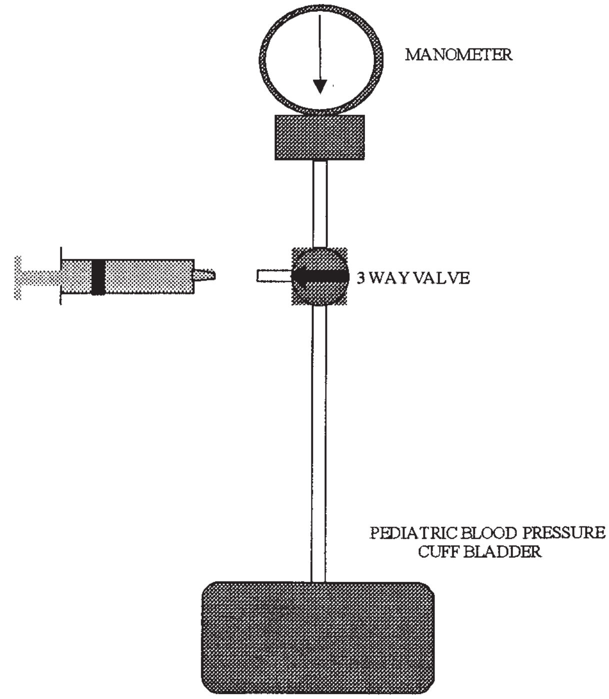

Figure 7. Measuring device to measure pressure when learning bandaging technique.

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