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ORIGINAL RESEARCH ARTICLE

Pressure Monitoring of Multilayer Inelastic Bandaging and the Effect of Padding in Breast Cancer–Related Lymphedema Patients

ABSTRACT

Kang Y, Jang D-H, Jeon JY, Lee SJ, Jeong SY, Shin DI, Kim HJ: Pressure monitoring of multilayer inelastic bandaging and the effect of padding in breast cancer–related lymphedema patients. Am J Phys Med Rehabil 2012;91:768–773.

Objective: This study of pressure monitoring of multilayer inelastic bandaging and the effect of padding in breast cancer–related lymphedema patients aimed to measure the resting and working sub-bandage pressures in compression therapy for lymphedema patients and to determine whether applying additional padding has an additional effect in volume reduction of the limb.

Design: Forty-eight patients with breast cancer who were beginning complex decongestive therapy for lymphedema were included. In 24 patients, padding was added to the forearm. A short-stretch bandage with or without padding was applied to the affected arm. The working pressure was measured while the patients squeezed a rubber device. The forearm limb circumference was measured before and after 2 wks of treatment.

Results: The mean (SD) of the resting pressure was 36.3 (2.2) mm Hg without padding and 49.5 (3.2) mm Hg with padding. The mean (SD) of the working pressure was 9.5 (3.7) mm Hg without padding and 24.3 (9.1) mm Hg with padding ($P < 0.05$). The volume loss after treatment was significantly greater in the group with added padding ($P < 0.05$).

Conclusions: The working pressure during exercising with a force of 50 Pa is approximately 10 mm Hg with a short-stretch bandage applied. Adding a pad increases both the resting and the working pressure and also seems to be effective in increasing volume reduction of the limb.

Key Words: Lymphedema, Breast Neoplasms, Compression Bandages, Compression Therapy

Recently, more attention has been paid to lymphedema because it has become a relatively common complication after treatment of a malignancy.[1] Treatment is targeted at eliminating the edema by reducing the interstitial fluid production and facilitating lymphatic propulsion using compression. Complex decongestive therapy is composed of manual lymph drainage, compression, exercises, and skin care.[2] For initial compression, multilayer inelastic lymphedema bandaging (MLLB), using short-stretch bandages, is the method most commonly used. Foam pads are often added underneath the bandage when increased compression is desired.

Because the main mechanism of lymphedema treatment is creating pressure for lymphatic flow, sub-bandage pressures are expected to be closely related to the treatment effect.

Working pressure is the increase in compression produced during muscle contraction. Because of multiple factors that influence the working pressure and the difficulty measuring it, most studies have focused on the measurement of the resting pressure. However, working pressure may be a more important factor for determining the therapeutic effect of bandaging.

There have been only few studies that measured the sub-bandage pressure with short-stretch bandaging, and the working pressure during remedial exercise is still unknown. The effect of padding in arm volume reduction also has not been studied. The purpose of this study was to measure the resting and working pressures with and without padding and to compare the arm volume reduction after 2 wks.

METHODS

Study Design and Patients

Female patients who visited our outpatient clinic for the evaluation and the treatment of edema of the upper limbs after breast cancer treatment and who had more than a 2-cm difference in limb circumference were enrolled in our study. Patients with acute thrombosis; arterial occlusive disease; and skin problems, such as a scar, an inflammation, or an infection, were excluded. We enrolled patients first into the no-pad group as an extension of a pilot study for sub-bandage pressure measurements, and after enrolling 24 patients, the same number of patients was sequentially enrolled into the pad group.

Both the case and control groups received complex decongestive therapy for 2 wks. Complex decongestive therapy consisted of manual lymph drainage, physical exercise, bandaging, and skin care. The no-pad group received MLLB with only short-stretch bandages, and the pad group received MLLB with short-stretch bandages and a foam pad (Swell Spots, Solaris, United States), which was placed on the forearm underneath the bandage. Written consent was obtained from all patients, and the study protocol was approved by the ethics committee of our institution.

Bandaging Techniques

All patients were treated with the same type of bandage by the same Vodder technique–certified physical therapist. Certified multilayer short-stretch bandages (Rosidal K Short Stretch Bandage, Lohmann & Rauscher, International) were used and consisted of a foam layer and three short-stretch cotton-wool bandages. The bandages started at the base of the hand and covered the arm up to the shoulder. The hand and fingers were also bandaged using elastic bandages (Mollelast, Lohmann & Rauscher, International).

Measurements and Assessments

Sub-bandage pressure was measured by an air-filled pressure transducer (Kikuhime, TT Medi Trade, Soro, Germany) applied on the muscle belly of the flexor carpi radialis (Fig. 1). The probe size was 3 × 2 cm in diameter. To ensure that the variation of

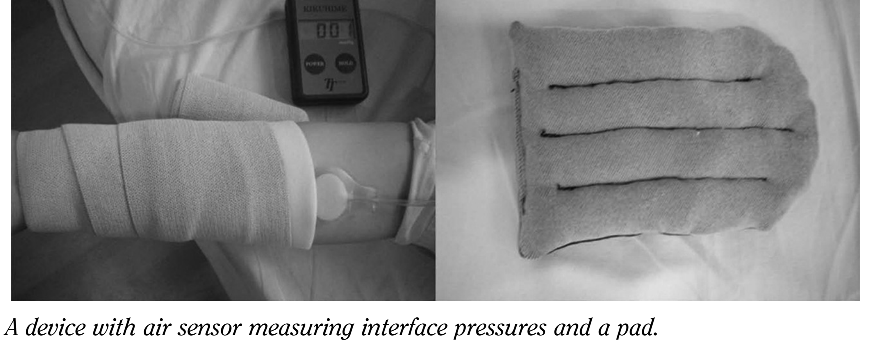

FIGURE 1 *A device with air sensor measuring interface pressures and a pad.*

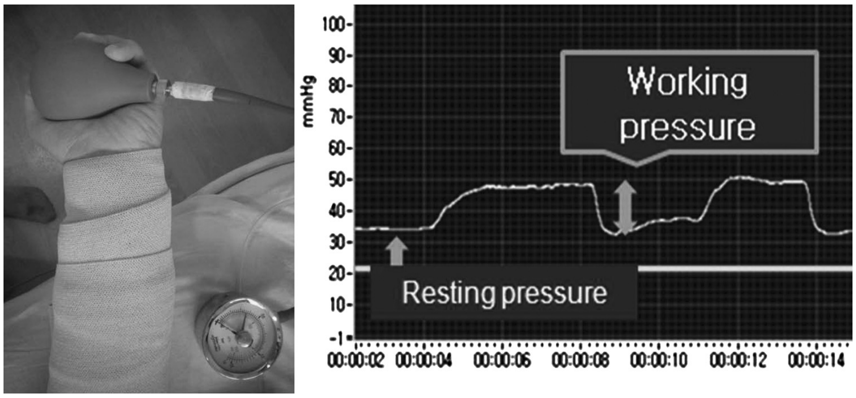

FIGURE 2 *A patient exercising with a rubber device that measures squeezing pressure. The double arrow in the pressure graph shows the working pressure.*

baseline pressure measured immediately after bandaging was minimal, a pilot study of ten patients was done. In this study, the mean (SD) of the baseline pressure was 35.7 (3.7) mm Hg without a pad and 44.4 (4.9) mm Hg with a pad.

The pressure was measured and recorded continuously while the patients were instructed to squeeze a rubber device three times with a force of 50 Pa. The working pressure was measured as the difference between the peak pressure and the resting pressure. All pressures were measured with the patient in the supine position (Fig. 2).

After measuring the pressures, the bandages were reapplied until the next treatment session the following day. The patients were encouraged to continue daily activities.

Limb volumes were calculated by measuring the circumference of the forearm every 4 cm from the wrist to the elbow, using the formula $\sum \text{Circumference}^2/\pi$.[3] The measurement was done before starting treatment and after 2 wks of treatment by the same therapist.

All patients underwent bioimpedance measurements (Inbody 720, Biospace, Seoul, South Korea), in which the body mass index and the extracellular fluid of the affected limb/total body fluid were measured. Using the International Society of Lymphology lymphedema staging classification, the lymphedema stage of the patients was assessed by one physician.

Statistical Analysis

A comparison of the resting and working pressures between the no-pad group and the pad group was made using the Student's t test. For the correlation between the loss of volume and other parameters, the Pearson correlation test was used. Statistical significance was set with type I error level at $\alpha = 0.05$. Data analysis was performed using SPSS 18.0.

RESULTS

Demographic Details

Forty-eight patients with unilateral upper limb edema were enrolled in this study. Twenty-four patients were enrolled in the no-pad group, and the remaining 24, in the pad group. The demographic data of both groups are shown in Table 1. There were no significant differences in the variables, except for the extracellular fluid of the affected limb/total body fluid between the two groups.

TABLE 1 Characteristics of study groups

	No Pad (n = 24)	Pad (n = 24)
Age, yrs	50.4 ± 8.8	49.0 ± 5.9
Side of arm (right/left)	13/11	13/11
Time of LE onset after surgery, mos	23.8 ± 24.6	17.9 ± 19.6
Mastectomy with axillary clearance (partial/total)	10/14	9/15
Received radiotherapy, %	50	54.2
ISL LE stage		
Stage I	3	5
Stage II	20	19
Stage III	1	0
BMI, kg/m^2	24.6 ± 3.7	25.0 ± 3.4
ECF/TBF, %	35.9 ± 2.2	34.5 ± 0.8
Initial forearm volume, ml	899.9 ± 109.8	994.1 ± 203.5

Values are presented as mean ± SD. There was no significant difference in any of the parameters except in the ECF/TBF.

LE, lymphedema; ISL, International Society of Lymphology; BMI, body mass index; ECF/TBF, extracellular fluid of the affected limb/total body fluid.

Sub-bandage Pressures

Sub-bandage pressure values were measured in both groups (Table 2). The working pressure, which was measured as the mean (SD) increase of pressure with the patient exerting a force of 50 Pa by squeezing a rubber device three times, was 9.5 (3.7) mm Hg when only bandaging was applied and increased to 24.3 (9.1) mm Hg in the pad group. The pressure drop after squeezing the rubber device had no significant difference between the two groups.

Limb Volume Change

The arm volumes of the patients, before and after treatment, are shown in Figures 3*A*–*B*. Both groups showed significant reductions in arm volume after 2 wks of treatment. The mean (SD) of the reduction value was significantly higher in the pad group (82.9 [27.6] ml) than in the no-pad group (55.8 [33.3] ml).

Correlation Between Volume Loss and Other Parameters

A correlation test was done using the Pearson correlation test to evaluate the parameters related to the degree of volume loss. Volume loss showed a positive correlation with working pressure (r = 0.325, $P < 0.05$), resting pressure (r = 0.319, $P < 0.05$), and peak pressure (r = 0.287, $P < 0.05$). There was no significant correlation between volume loss and body mass index or extracellular fluid of the affected limb.

DISCUSSION

This study evaluated the pressures created with short-stretch bandaging and the working pressure during remedial exercise. The sub-bandage resting pressure was approximately 36 mm Hg without a pad and 50 mm Hg with a pad. The working pressure and the peak pressure were significantly higher in the pad group, and the volume loss was greater after 2 wks. The study results also showed that volume loss was correlated with the sub-bandage pressure parameters.

TABLE 2 Sub-bandage pressures (mm Hg) measured in both groups

	No Pad	Pad
Resting pressure	36.3 ± 2.2	49.5 ± 3.2
Working pressure	9.5 ± 3.7	24.3 ± 9.1
Peak pressure	45.2 ± 3.8	72.1 ± 10.1
Loss of pressure after volition	2.2 ± 1.7	4.1 ± 1.9

Values are presented as mean ± SD.

All parameters showed significant difference ($P < 0.05$) between the two groups.

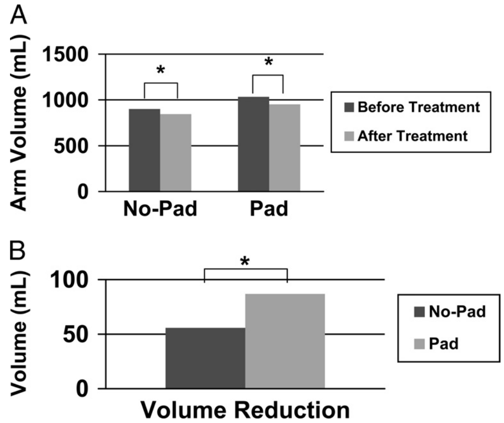

FIGURE 3 *A and B, Volume change after treatment in the no-pad group and the pad group.*

This is the first study to evaluate the working pressure in inelastic bandages applied to breast cancer–related lymphedema patients and to investigate the effect of padding on volume reduction of the affected limb.

MLLB is a key element of complex decongestive therapy, and it may be used as part of the long-term management as well as of the initial, intensive therapy.[3] Compression is considered to increase the tissue pressure and thus cause an opening of the lymph capillaries. It also enhances the contractions of lymph vessels, which spontaneously contracts with rhythmic pressure changes made under normal conditions.[4] Measuring the interface pressures is important to achieve the appropriate level of compression. The pressure applied should be enough to help to increase the propulsion of lymphatic fluids, but it also has to be tolerable to patients and should not cause any complications, such as pain or circulation problems.

In leg lymphedema, the recommended resting pressure for standard intensive therapy is approximately 45 mm Hg, and although there are no standard pressures for arm lymphedema, Partsch et al.[5] recommended compression pressures of less than 30 mm Hg. The compression needed for the arms could be expected to be lower than that for the legs because of the higher intravenous pressure in the legs when standing. In our pilot study, when the board-certified therapist applied the bandages, the sub-bandage pressures ranged between 30 and 40 mm Hg. This result was similar to that seen in previous studies that measured sub-bandage pressures using a routine technique.[6,7] When padding was added and the bandage was applied using the same method (i.e., same number of layers, similar tension) by the same trained therapist, the pressure increased to a range of 37–51 mm Hg.

MLLB uses relatively inelastic (short-stretch) bandages that apply a constant pressure to the skin when a limb is at rest and that produce high working pressure.[8,9] Applying multilayers contributes to its inelastic characteristic.[10] When muscles contract and expand during exercise, these press against the bandage, thus temporarily increasing the pressure inside. This creates a massaging effect and stimulates lymph flow.[3] Compression of the lymph vessels also triggers smooth muscle contraction within the walls of lymph transport vessels.[8] Therefore, working pressure is a key component of MLLB, and the monitoring and/or the determination of the working pressure is important in MLLB.

Hirai et al.[11] measured the interface pressure of elastic stockings and bandages during posture changes and exercise. Short-stretch bandages showed a greater pressure difference between muscle contraction and relaxation, and thus a higher working pressure, compared with long-stretch bandages and short-stretch stockings. The authors suggested that the short-stretch bandages may have more benefits for augmenting muscle pump than do other types of compression garments. Another study by King et al.[12] also supported greater volume reduction with bandaging compared with compression garments. In our study, higher working pressures correlated with greater volume reduction.

It has not been established whether higher compression pressures are more effective for volume reduction of the affected limb. In previous studies, higher pressures were associated with greater volume reduction in chronic venous edema of the lower limb, although not in upper limb edema.[13] In a study by Damstra and Partsch,[6] the interface pressure values were 30–40 mm Hg after routine bandaging. When low (20–30 mm Hg) *vs.* high (44–58 mm Hg) interface pressures were compared, there was no significant difference in the arm volume reduction after 2 and 24 hrs, and low pressure was better tolerated. Partsch et al.[5] suggested optimal compression pressures on the basis of these studies. Because low pressure after 2 hrs resulted in higher volume reduction than did high pressure, they proposed that the upper limit for upper limb compression was 30 mm Hg.[5] Because higher pressures may occlude the lymphatic vessels and hence impede lymph flow, we agree that an upper limit for compression exists. However, the limitations of the study by Partsch et al.[5] are that a short term was used to evaluate the volume loss and that the working pressure was not considered. Our study evaluated volume loss after 2 wks, which is the duration of intensive therapy for most patients before transitioning to the self-maintenance phase with bandages or compression garments and to the self-administered manual lymph drainage.

We used foam pads in our study to add pressure. The foam particles inside the pad create localized tissue stretch and pressure differentials, thus opening lymphatic gaps and encouraging reabsorption of interstitial fluids and particles. The foam particles may also help to break up tissue fibrosis. There were no complications resulting from adding a pad.

Previous studies have demonstrated a decrease of sub-bandage pressure shortly after bandaging, which was mainly attributed to volume reduction.[6,14] This loss of pressure may be another explanation why higher initial pressure is more effective in decreasing limb volume. In our study, the pressure drop after volitional exercise showed no difference in the two groups.

The limitations of this study include that only the forearm was evaluated and that the patient's discomfort level was not assessed. The patients were measured in the supine position, and pressures may be different in the upright position because of the effect of gravity on fluid. In addition, padding was placed on the same anatomical area in all subjects, although it may be more effective to apply it on areas that have more edema or fibrosis. This should be further investigated. Another fact to consider is that, although not significant, the initial forearm volume was higher in the pad group, and this may have affected the difference in volume reduction between the two groups. Further studies should also determine the effect of therapeutic exercise with a bandage applied to the affected limb because this would most likely produce massaging peak pressures similar to the hand flexor exercise used in this study.

CONCLUSIONS

The working pressure created by inelastic bandages is approximately 10 mm Hg when exerting a force of 50 Pa with the hand. The adding of pads increases both the resting and the working pressure, and the increased pressures may lead to increased volume reduction of the affected arm.

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