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The Application Effect of Manual Lymphatic Drainage Combined with Adjustable Foam Particle Arm Sleeves in Patients with Stage I Upper Limb Lymphedema

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Abstract

Objective: To explore the application effect of manual lymphatic drainage (MLD) combined with adjustable foam particle arm sleeves in patients with stage I upper limb lymphedema following breast cancer surgery. **Methods:** A total of 52 patients with stage I upper limb lymphedema, who were treated between January and December 2023 at a tertiary tumor hospital in Guangzhou, Guangdong Province, were enrolled. Patients received MLD combined with adjustable foam particle arm sleeves. Bioelectrical impedance and body composition measurements were taken before and after treatment (one course consisting of 20 sessions) for comparison. **Results:** After one course of treatment, there was a significant reduction in arm muscle circumference, hydration rate, segmental water analysis, and segmental extracellular water ratio analysis ($p < 0.05$). Phase angle and bioelectrical impedance at 1kHz and 5kHz frequencies showed a significant increase ($p < 0.05$). **Conclusion:** MLD combined with adjustable foam particle arm sleeves effectively improves stage I upper limb lymphedema in postoperative breast cancer patients.

Keywords

Adjustable Foam Particle Arm Sleeves, Comprehensive Decongestive Therapy (CDT), Breast Cancer, Stage I Lymphedema

1. Introduction

Upper limb lymphedema is one of the most common complications following

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axillary lymph node dissection in breast cancer patients [1]. Damage to the lymphatic system causes lymph fluid accumulation, leading to an abnormal increase in tissue proteins, which, in severe cases, results in repeated infections, erysipelas, and chronic inflammation and fibrosis. The cumulative incidence of lymphedema can reach up to 41.1% over ten years [2]. According to the 2020 International Society of Lymphology (ISL) guidelines, lymphedema is classified into four stages, with stage I being reversible pitting edema, which can be completely restored through active treatment [3]. If early-stage lymphedema is not effectively treated, it may lead to subcutaneous tissue fibrosis and fat deposition, ultimately progressing to irreversible lymphedema and even disability [4], severely impacting quality of life [5]. Thus, early detection and treatment are crucial.

Currently, the ISL recommends conservative treatments for lymphedema, known as Complete Decongestive Therapy (CDT), which includes skin care, MLD, low-elasticity bandaging, and functional exercises [6]. Bandaging is a critical component of CDT [6]; however, it has several limitations: [7] 1) some patients require assistance to complete bandaging, 2) the process is time-consuming, and pressure may not be applied accurately, 3) bandaging affects daily activities, it is inconvenient to carry and clean, and the bandaging process is cumbersome, resulting in poor patient adherence and difficulty in maintaining long-term use [7]. Therefore, exploring effective treatment materials for upper limb lymphedema is essential. The development of adjustable foam particle arm sleeves may replace traditional materials for early-stage lymphedema treatment. This study aims to evaluate the decongestive effect of MLD combined with adjustable foam particle arm sleeves on post-operative stage I upper limb lymphedema patients using bioelectrical impedance and body composition analysis. The report is as follows:

2. Data and Methods

2.1. General Information

This study used a convenience sampling method to select 52 female patients with stage I upper limb lymphedema diagnosed between January and December 2023 at a lymphedema clinic of a tertiary tumor hospital in Guangzhou, Guangdong Province. The average age was (49.69 ± 9.37) years. Among them, 22 patients had lymphedema in the left limb (42.31%) and 30 in the right limb (57.69%).

Inclusion Criteria:

1) Patients with unilateral stage I upper limb lymphedema post-axillary lymph node dissection for breast cancer, as defined by the 2020 ISL guidelines [4]. No prior CDT treatment.

2) Patients committed to actively reporting symptoms during the study period.

3) Voluntary participation with signed informed consent.

Exclusion Criteria:

1) Patients with advanced breast cancer who did not undergo surgery or had significant organ disease (heart, lung, kidney).

2) Local infections, ulcers, exudate, or bleeding tendencies.

3) Untreated thrombosis.
4) Distant lymph node metastases.
5) Upper limb edema caused by other diseases.

2.2. Study Design

The study was approved by the hospital's ethics committee. MLD combined with adjustable foam particle arm sleeves was administered for one treatment course to patients with stage I upper limb lymphedema post-breast cancer surgery. Arm sleeves were selected in large, medium, and small sizes based on upper limb circumference, and pressure was adjusted according to swelling and patient tolerance to achieve treatment and maintenance effects. Before using the adjustable foam particle arm sleeves, the lymphedema therapist performed lymphatic pathway opening and MLD and instructed patients in functional exercises during sleeve application to promote lymphatic fluid return. Patients also received standard rehabilitation health education covering lymphedema risk factor prevention and precautions for wearing adjustable arm sleeves. Body composition and bioelectrical impedance were assessed and compared before and after treatment (one course consisting of 20 sessions) (**Figure 1**).

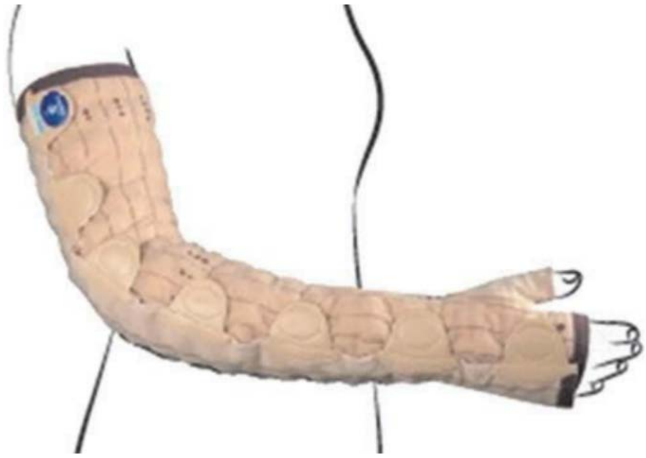

Figure 1. Foam particle-based adjustable arm sleeve.

2.2.1. Body Composition Analysis

Bioelectrical impedance and body composition analysis were performed using the InBody S10 instrument before and after treatment (one course of 20 sessions) [8] [9].

2.2.2. Statistical Method

This study used SPSS 25.0 for data analysis. Continuous data were described as mean ± standard deviation, while categorical data were described using frequency counts. Paired t-tests were used to compare bioelectrical impedance and body composition analysis of patients before and after treatment (one course consisting of 20 sessions), with a significance level set at $\alpha = 0.05$.

3. Results

3.1. Comparison of Body Composition and Bioelectrical Impedance before and after Treatment

Stage I patients accounted for 26.6%, while Stage II patients made up approximately 45%. About 43% of patients opted for total mastectomy, and 57% chose breast-conserving surgery. After one treatment course (20 sessions), the patients showed a significant reduction in muscle circumference of the upper arm, hydration rate, segmental water analysis, and segmental extracellular water ratio ($p < 0.05$). Phase angle, as well as bioelectrical impedance at 1 kHz and 5 kHz, significantly increased ($p < 0.01$). See Table 1 for details.

Table 1. Comparison of body composition analysis before and after treatment in the affected limb.

Parameter (Units)	(n = 52)		Difference	Standard Deviation	Cohen's d	t-value	p-value
	Pre-treatment	Post-treatment (20 sessions)					
Weight (Kg)	57.74 ± 7.98	57.18 ± 7.55	0.56	3.334	0.167	1.206	0.233
BMI (kg/m^2)	23.19 ± 2.95	22.97 ± 2.90	0.22	1.255	0.178	1.281	0.206
Body Fat (%)	30.80 ± 5.86	30.43 ± 5.60	0.37	3.724	0.098	0.707	0.482
Upper Arm Muscle Circumference (cm)	24.23 ± 1.62	23.98 ± 1.64	0.26	0.867	0.295	2.128	0.038*
Upper Arm Circumference (cm)	28.38 ± 2.30	28.09 ± 2.43	0.29	1.077	0.27	1.944	0.057
Hydration Rate (%)	73.50 ± 0.30	73.37 ± 0.32	0.13	0.275	0.469	3.383	0.001**
Body Water Content (L)	29.16 ± 3.10	28.95 ± 2.94	0.21	1.408	0.15	1.084	0.284
Intracellular Water (L)	17.93 ± 1.95	17.84 ± 1.85	0.1	0.89	0.108	0.779	0.439
Extracellular Water (L)	11.22 ± 1.17	11.11 ± 1.12	0.12	0.571	0.202	1.458	0.151
Extracellular Water Ratio Analysis	0.38 ± 0.01	0.38 ± 0.01	0	0.005	0.256	1.846	0.071
Segmental Water Analysis (L)	1.63 ± 0.40	1.51 ± 0.29	0.12	0.225	0.539	3.886	0.000**
Segmental Extracellular Water Ratio	0.39 ± 0.01	0.38 ± 0.01	0	0.006	0.538	3.882	0.000**
Phase Angle (˚)	4.94 ± 0.55	5.04 ± 0.47	−0.1	0.355	0.293	−2.111	0.040*
Bioelectrical Impedance 1 kHz (Z(Ω))	354.54 ± 64.19	379.56 ± 58.63	−25.03	39.912	0.627	−4.521	0.000**
Bioelectrical Impedance 5 kHz (Z(Ω))	348.99 ± 62.40	374.40 ± 57.75	−25.41	39.333	0.646	−4.659	0.000**

*$p < 0.05$; **$p < 0.01$.

3.2. Right Arm Comparison before and after Treatment

After one course of treatment (20 sessions), patients with right arm lymphedema demonstrated a significant reduction in extracellular water ratio, segmental water analysis, segmental extracellular water ratio, and hydration rate ($p < 0.05$). Phase angle and bioelectrical impedance at 1 kHz and 5 kHz significantly increased ($p < 0.01$). Details are provided in Table 2.

Table 2. Comparison of body composition analysis before and after treatment in the right limb.

Parameter (Units)	Right Limb (n = 30)		Difference	Standard Deviation of Difference	Cohen's d Value	t-value	p-value
	Pre-treatment	Post-treatment					
Weight (Kg)	56.05 ± 6.53	56.07 ± 7.06	−0.02	1.6	0.01	−0.057	0.955
BMI (kg/m²)	22.51 ± 2.61	22.51 ± 2.89	0	0.592	0.006	0.031	0.976
Body Fat (%)	29.98 ± 5.85	29.56 ± 6.06	0.42	3.393	0.124	0.678	0.503
Upper Arm Muscle Circumference (cm)	23.89 ± 1.29	23.79 ± 1.62	0.1	0.801	0.129	0.707	0.485
Upper Arm Circumference (cm)	27.95 ± 2.03	27.84 ± 2.51	0.1−1	0.962	0.114	0.626	0.536
Hydration Rate (%)	73.50 ± 0.34	73.34 ± 0.35	0.16	0.288	0.543	2.974	0.006**
Body Water Content (L)	28.71 ± 3.19	28.76 ± 2.97	−0.05	1.223	0.041	−0.224	0.824
Intracellular Water (L)	17.65 ± 1.98	17.75 ± 1.89	−0.11	0.783	0.136	−0.746	0.462
Extracellular Water (L)	11.07 ± 1.23	11.01 ± 1.10	0.06	0.481	0.118	0.645	0.524
Extracellular Water Ratio Analysis	0.39 ± 0.01	0.38 ± 0.01	0	0.005	0.471	2.579	0.015*
Right Upper Limb Segmental Water Analysis (L)	1.58 ± 0.41	1.49 ± 0.29	0.09	0.208	0.433	2.373	0.024*
Left Upper Limb Segmental Water Analysis (L)	1.35 ± 0.17	1.34 ± 0.20	0.01	0.088	0.091	0.496	0.624
Right Upper Limb Segmental Extracellular Water Ratio Analysis	0.39 ± 0.01	0.38 ± 0.01	0	0.006	0.489	2.68	0.012*
Left Upper Limb Segmental Extracellular Water Ratio Analysis	0.38 ± 0.00	0.38 ± 0.00	0	0.004	0.261	1.431	0.163
Phase Angle (˚)	4.75 ± 0.48	4.93 ± 0.43	−0.18	0.282	0.651	−3.564	0.001**
1 kHz Bioelectrical Impedance Right Upper Limb (Z(Ω))	363.75 ± 68.90	384.17 ± 63.93	−20.42	31.742	0.643	−3.523	0.001**
1 kHz Bioelectrical Impedance Left Upper Limb (Z(Ω))	420.75 ± 39.73	426.66 ± 43.75	−5.91	19.654	0.301	−1.647	0.11
5 kHz Bioelectrical Impedance Right Upper Limb (Z(Ω))	357.83 ± 67.23	379.47 ± 63.13	−21.64	32.473	0.667	−3.651	0.001**
5 kHz Bioelectrical Impedance Left Upper Limb (Z(Ω))	414.28 ± 39.92	420.54 ± 44.27	−6.26	20.128	0.311	−1.703	0.099

*p < 0.05; **p < 0.01.

3.3. Left Arm Comparison before and after Treatment

Patients with left arm lymphedema also showed significant reductions in upper arm muscle circumference, upper arm circumference, segmental water analysis, and segmental extracellular water ratio ($p < 0.05$). Bioelectrical impedance at 1 kHz and 5 kHz increased significantly ($p < 0.01$). See Table 3 for specifics.

Table 3. Comparison of body composition analysis before and after treatment in the right limb.

Parameter (Units)	Right Limb (n = 30)		Difference	Standard Deviation of Difference	Cohen's d Value	t-value	p-value
	Pre-treatment	Post-treatment					
Weight (Kg)	60.05 ± 9.29	58.70 ± 8.08	1.34	4.727	0.284	1.331	0.198
BMI (kg/m^2)	24.12 ± 3.19	23.60 ± 2.86	0.52	1.784	0.293	1.375	0.184
Body Fat (%)	31.91 ± 5.82	31.62 ± 4.79	0.29	4.217	0.069	0.324	0.749
Upper Arm Muscle Circumference (cm)	24.70 ± 1.91	24.24 ± 1.67	0.46	0.928	0.5	2.344	0.029*
Upper Arm Circumference (cm)	28.97 ± 2.55	28.43 ± 2.33	0.54	1.196	0.448	2.103	0.048*
Hydration Rate (%)	73.51 ± 0.24	73.42 ± 0.27	0.09	0.256	0.355	1.664	0.111
Body Water Content (L)	29.77 ± 2.95	29.20 ± 2.95	0.57	1.586	0.358	1.681	0.108
Intracellular Water (L)	18.33 ± 1.87	17.95 ± 1.84	0.37	0.968	0.385	1.807	0.085
Extracellular Water (L)	11.44 ± 1.09	11.25 ± 1.16	0.2	0.678	0.288	1.352	0.191
Extracellular Water Ratio Analysis	0.38 ± 0.01	0.38 ± 0.01	0	0.005	0.017	−0.081	0.936
Right Upper Limb Segmental Water Analysis (L)	1.46 ± 0.21	1.40 ± 0.23	0.06	0.132	0.474	2.224	0.057
Left Upper Limb Segmental Water Analysis (L)	1.69 ± 0.39	1.53 ± 0.28	0.16	0.245	0.669	3.136	0.005**
Right Upper Limb Segmental Extracellular Water Ratio Analysis	0.38 ± 0.01	0.38 ± 0.01	0	0.007	0.014	−0.064	0.95
Left Upper Limb Segmental Extracellular Water Ratio Analysis	0.39 ± 0.01	0.38 ± 0.01	0	0.006	0.593	2.782	0.011*
Phase Angle (˚)	5.20 ± 0.54	5.20 ± 0.50	0	0.418	0.011	0.051	0.96
1 kHz Bioelectrical Impedance Right Upper Limb (Z(Ω))	402.33 ± 40.30	415.68 ± 41.69	−13.35	42.983	0.31	−1.456	0.16
1 kHz Bioelectrical Impedance Left Upper Limb (Z(Ω))	341.97 ± 56.25	373.28 ± 51.30	−31.31	49.045	0.638	−2.994	0.007**
5 kHz Bioelectrical Impedance Right Upper Limb (Z(Ω))	395.23 ± 39.52	408.36 ± 42.00	−13.13	42.249	0.311	−1.457	0.16
5 kHz Bioelectrical Impedance Left Upper Limb (Z(Ω))	336.94 ± 54.32	367.50 ± 50.08	−30.55	47.467	0.644	−3.019	0.007**

*p < 0.05; **p < 0.01.

4. Discussion

Upper limb lymphedema is a common and severe complication following breast cancer surgery, prone to recurrence and progressive worsening with each episode [10]. Therefore, it is crucial to pay attention to the condition in its early stages to prevent further development. Current international guidelines for lymphedema management recommend skin care, MLD, multi-layer compression bandaging, pressure sleeves, intermittent pneumatic compression, functional exercises, and health education [11] [12]. Among these, multi-layer elastic bandaging plays a pivotal role. However, for stage I lymphedema patients, the symptoms may appear mild, leading to underestimation of the condition. Challenges such as difficulty in self-bandaging, activity limitations, pressure intolerance, and maintenance issues make it hard for most patients to adhere to the bandaging protocol [7], leading to condition deterioration and missed treatment opportunities. International guidelines on lymphedema management encourage the long-term and continuous use of compression garments or bandages, particularly at night. [13] Vignes *et al.* [14] indicate that patients who wear low-stretch compression materials day and night significantly reduce the risk of arm lymphedema volume recurrence. The adjustable foam particle arm sleeve allows for pressure adjustments based on patient comfort and swelling levels and can be worn both day and night, providing therapeutic and maintenance effects. In this study, comparisons of body composition and bioelectrical impedance before and after treatment (20 sessions) showed significant reductions in upper arm muscle circumference, hydration rate, segmental water analysis, and segmental extracellular water ratio. Phase angle and bioelectrical impedance at 1kHz and 5kHz significantly increased. This indicates that MLD combined with adjustable foam particle arm sleeves can effectively reduce swelling in stage I upper limb lymphedema patients post-breast cancer surgery, preventing the further development of early-stage lymphedema.

Research shows that traditional knitted arm sleeves are used to maintain the effects after intensive treatment for lymphedema and to treat early-stage lymphedema [15] [16]. Although the effectiveness of traditional knitted arm sleeves in treating lymphedema has been established, they do not act as quickly as multi-layer bandaging in clinical treatment and must be removed at night to avoid compromising blood circulation [15]-[17]. Additionally, multi-layer bandages consist of several layers of non-elastic and stretchable materials, which can reduce patient compliance and quality of life. In contrast, the adjustable foam particle arm sleeve is a novel treatment material that combines the functions of four layers of bandaging, suitable for treating patients with stage I lymphedema. [18] It is more convenient to wear than multi-layer bandaging and traditional knitted arm sleeves, and its pressure can be adjusted [18]. On the one hand, it is suitable for patients who cannot tolerate pressure, allowing them to adjust the pressure to a low level to improve comfort. The ease of wearing also means patients can take breaks every two hours, enhancing treatment adherence [18]. On the other hand, due to the poor comfort of multi-layer bandaging, most patients will stop treatment at night. However, eight hours of sleep is a critical time for treatment, and relaxation during this period can adversely affect the management of their condition. Research has demonstrated that wearing garments at night is significantly more effective than treatment during the day alone, improving treatment outcomes [18]. The adjustable foam particle arm sleeve is available in large, medium, and small sizes, meeting the varying needs of patients. Unlike traditional knitted arm sleeves, which cannot be adjusted for specific areas of swelling, the adjustable foam particle arm sleeve functions like a customized garment, allowing localized pressure adjustments based on the patient's condition. It is also reusable and washable, with a lifespan of 1 - 2 years within normal pressure ranges, which is more than twice that of knitted sleeves [18]. In this study, patients reported that after treatment (20 sessions), the adjustable sleeve was easy to wear, comfortable, and could be worn continuously at night without restriction [19]. Patients were able to operate it independently (as shown in **Figure 2**), facilitating adherence to treatment, especially for elderly patients and working individuals, extending the wearing time, and not only maintaining effectiveness but also improving treatment compliance, thereby promoting both physical and psychological recovery.

Figure 2. Self-operating foam particle arm sleeve.

Many stage I lymphedema patients experience related subjective feelings, such as heaviness, numbness, or tightness in the affected limb, before obvious swelling appears. These sensations usually improve upon waking the next day and do not significantly impact daily life and quality of life, causing patients to underestimate their condition [20]. Another portion of patients focus solely on cancer prognosis and maintain an indifferent attitude toward lymphedema. Therefore, healthcare providers should explain the occurrence and progression of lymphedema and its prognosis in detail to perioperative patients, incorporating high-risk groups for long-term follow-up to achieve the goals of early detection, early intervention, and early treatment. In this study, among the 52 patients with stage I lymphedema, two were primarily responsible for household chores at home. After one treatment course, the effects were significant. However, due to their numerous household responsibilities, these patients wore the adjustable foam particle arm sleeves for a shorter duration, averaging about 4 hours per day, which led to the recurrence of the lymphedema. After enhanced health education, re-wearing the adjustable foam particle arm sleeves resulted in the reversal of lymphedema.

5. Limitation

The limitations of this study include the observation of only one course for stage I lymphedema, lacking long-term data support. Variations in self-performed MLD techniques and foam sleeve wearing time among patients may affect consistency and do not guarantee long-term outcomes. Additionally, the sample size is small, and no further analysis was conducted regarding patient age, disease duration, severity, treatment adherence, and maintenance effects. Future research will optimize the study design, expand sample sizes, or include control groups for longer periods to assess the exact effects, providing more convincing evidence.

6. Conclusion

Standardizing lymphedema treatment requires further research, considering various factors for different populations. Selecting appropriate treatment materials is crucial for improving treatment effectiveness and patient adherence. MLD combined with adjustable foam particle arm sleeves shows significant effectiveness in treating stage I lymphedema, providing both therapeutic and maintenance benefits. This time-efficient, simple approach is well-accepted by patients with high adherence. Long-term usage does not restrict the movement of the affected limb, and the wearing time can be adjusted according to the patient's daily routine, significantly reducing physical and psychological burdens [18]. In this study, all 52 cases of stage I lymphedema were successfully controlled with no progression, supporting the recommendation of this treatment for early-stage lymphedema patients.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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