

Effect of physical manipulation pulmonary rehabilitation on lung cancer patients after thoracoscopic lobectomy

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Funding information

Beijing Hospital, Grant/Award Number: 2020BJYYEC-014-03

Abstract

Background: To introduce a new postoperative pulmonary rehabilitation program named physical manipulation pulmonary rehabilitation (PMPR) and to explore the effect of perioperative management, including PMPR, on patients with non-small cell lung cancer (NSCLC) after thoracoscopic lobectomy.

Methods: A randomized controlled trial was conducted between April and June 2021 at the Department of Thoracic Surgery, Beijing Hospital. Adult patients with NSCLC who had undergone thoracoscopic lobectomy were allocated to the treatment and control groups using a random number table. The treatment group received both conventional pulmonary rehabilitation (CVPR) and 14 days of PMPR after surgery; the control group patients received CVPR only. PMPR included relaxing and exercising the intercostal muscles, thoracic costal joint and abdominal breathing muscles. Pulmonary function tests and the 6-min walk test were conducted preoperatively and 7, 14, 21 and 28 days postoperatively. The postoperative length of hospital stay, chest tube retention time and postoperative pulmonary complications were recorded. The baseline data, pulmonary function parameters and prognosis were compared with *t*- and chi-square tests between the two groups.

Results: A total of 86 patients were enrolled, and 44 patients were allocated to the treatment group. There were no significant differences in the baseline data for age, sex, body mass index, basic disease, surgical plan or preoperative pulmonary function between the two groups (all $p > 0.05$). The peak expiratory flow of patients in the treatment group was higher than that of those in the control group 21 days after surgery (316 ± 95 vs. 272 ± 103 l/min, respectively, $p = 0.043$), and forced expiratory volume in the first second on day 28 after surgery was greater than that in the control group (2.1 ± 0.2 vs. 1.9 ± 0.3 L, respectively, $p < 0.001$). There were no significant differences in forced vital capacity or 6-min walk test scores (both $p > 0.05$). There were no significant differences in the incidences of pneumonia and atelectasis between the two groups (both $p > 0.05$). The postoperative length of hospital stay (3.3 ± 1.3 vs. 3.9 ± 1.5 days, $p = 0.043$) and chest tube retention time (66 ± 30 vs. 81 ± 35 h, $p = 0.036$) in the treatment group were shorter than those in the control group.

Conclusions: We determined that PMPR could improve early lung function in patients with NSCLC after thoracoscopic lobectomy, and that chest tube retention time and length of hospital stay were shortened.

KEYWORDS

lung cancer, pulmonary rehabilitation, respiratory training, thoracoscopic surgery

INTRODUCTION

After lung tissue resection, the vast majority of patients are in a state of decreased respiratory function for a long time, and patient quality of life is heavily affected.¹ Perioperative pulmonary rehabilitation (PR) includes preoperative education, effective cough exercises and aerobic training, as well as early postoperative activities and breathing exercises, which have a certain therapeutic efficacy, but patient lung function recovery is slow, takes more than a few months, and cannot reach the preoperative level.²⁻⁴ Perioperative management, which includes physical manipulation PR (PMPR), has decreased the rates of complications and mortality after lung resection in past decades.^{5,6} In recent years, therapists have revolutionized the field of fast-track recovery with improvements in PR.^{7,8} For patients with NSCLC, there is now a requirement for postoperative PMPR based on research reports.

The purpose of this study was to investigate the effect of PMPR on lung function recovery and quality of life in postoperative patients with NSCLC.

METHODS

Patients

The patients with NSCLC in this study were admitted to the Department of Thoracic Surgery of Beijing Hospital between April and June 2021. This study was approved by the ethics committee of Beijing Hospital (Approval No: 2020BJYYEC-014-03). Informed consent was obtained from patients or their families for treatment and detection. Funding was obtained from BJ-2019-163, a hospital-level scientific research project of Beijing Hospital.

The inclusion criteria were as follows: lung cancer; lobectomy under two- or one-port thoracoscopy with or without simultaneous lymph node dissection; and age over 18 years.

The exclusion criteria were as follows: conversion to thoracotomy during the operation; postoperative complications including persistent lung leakage > 4 days, thoracic drainage > 7 days, serious arrhythmia, bronchopleural fistula, sudden increase in thoracic drainage, or active intrathoracic hemorrhage, chylothorax, or other serious adverse events; the medical students judged that the patient should not continue the test; the patient was asked to withdraw from the test; or the patient could not complete the test after discharge, treatment or follow-up.

Study design

This was a prospective randomized controlled study in which patients enrolled preoperatively were assigned to two groups using a random number table. The control group received 28 days of conventional PR (CVPR) treatment; the treatment group received 14 days of PMPR treatment as well

as CVPR treatment. The primary endpoints were peak expiratory flow rate on the 21st postoperative day and the length of postoperative hospital stay. Routine PR programme: Education, aerobic exercise and breathing exercises were started 5 to 7 days before surgery; aerobic exercise and respiratory exercises were started on the next day after surgery to gradually achieve the following training objectives: breath exercise: lip contraction breathing for 3 to 5 min, abdominal breathing for 3 to 5 min, and effective coughing for 3 to 5 min, twice a day; and aerobic exercise: upper limb exercise training, walking on the ground, treadmill exercise in bed, twice a day for 15 min. After discharge, the patients were instructed and supervised by WeChat and telephone, and the above programme was extended to 28 days after the operation.

PMPR treatment plan: A professional rehabilitation specialist formulated an individualized rehabilitation plan and issued rehabilitation prescriptions according to the patient's wound and operation type, and a nurse with a physical PR qualification certificate performed the physical manipulation treatment once a day. Before physical manipulation treatment, the following occurred: (1) The patients had an empty stomach for at least 30 min. (2) The patients were instructed to breathe deeply in a calm state whether the bilateral thoracic lobes were symmetrical during the breathing process could be evaluated. (3) The modes of breathing movement were observed: chest type, abdominal type or both. (4) The chest circumference during the inspiratory and expiratory phase was measured at the fourth intercostal level.

The main techniques include the following: (1) Intercostal muscle mobilization: the patient was placed in the supine position, and the operator's finger was placed on the patient's intercostal muscle along the direction of the intercostal muscle to avoid touching the wound site. (2) Rib mobilization: with the patient in the supine position, the operator's finger was placed on the thoracic rib joint, the skin above the ribs was pulled outward and upward during the patient's inspiratory phase, and inward and downward traction was applied in the expiratory phase; or rapid shaking of the upper and lower skin was performed at any time during patient inhalation or expiration. (3) Thoracic induction: with the patient in the supine position, the operator's palm was placed along the intercostal line close to the thoracic skin, and the thoracic skin was pulled upward and outward in the inspiratory phase and downward in the expiratory phase. (4) Induced abdominal breathing: the patient was supine, and the operator's palm was placed on the patient's abdomen. When the patient inhaled, the patient's abdomen was guided to rise upward against the weight of the palm; when the patient exhaled, the palm was pushed upward and inward to assist the diaphragm in lifting up. During manual therapy, pain assessment was carried out in real time. In the study, pain was evaluated by visual analogue scale (VAS). The analgesic target was 2-4 points, and we used an analgesic pump or intravenous injection to ease pain. The main drugs were opioids or NSAIDs. If the

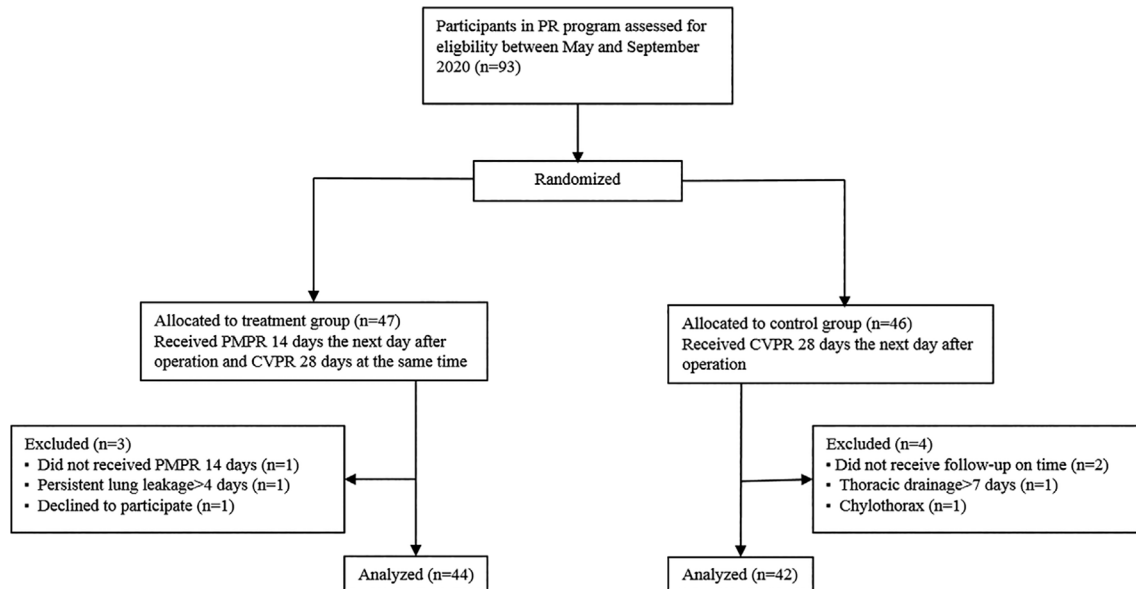


FIGURE 1 Diagram for patient selection. CVRR, conventional pulmonary rehabilitation; PMRR, physical manipulation pulmonary rehabilitation; PR, pulmonary rehabilitation

TABLE 1 Baseline data and prognosis of the two groups

	Total (n = 86)	Treatment group (n = 44)	Control group (n = 42)	t/X ²	p-value
Age (years)	61.7 ± 9.7	60.3 ± 10.1	63.2 ± 9.2	1.396	0.166
Male	49(56.9%)	26(59.1%)	23(54.8%)	0.164	0.685
BMI	23.3 ± 1.6	23.4 ± 1.7	23.3 ± 1.6	0.205	0.838
Basic diseases and smoking history					
Diabetes mellitus	7(8.1%)	4(9.1%)	3(7.1%)	0.109	0.741
Hypertension	10(11.6%)	6(13.6%)	4(9.5%)	0.008	0.931
Coronary heart disease	5(5.8%)	3(6.8%)	2(4.8%)	0.166	0.684
Chronic obstructive pulmonary disease	32(37.2%)	17(38.6%)	15(35.7%)	0.079	0.779
Chronic kidney disease	1(1.2%)	1(2.3%)	0(0%)	0.966	0.326
Liver cirrhosis	1(1.2%)	0(0%)	1(2.4%)	1.060	0.303
Cerebrovascular disease	2(2.3%)	1(2.3%)	1(2.4%)	0.001	0.973
Smoking	8(9.3%)	3(6.8%)	5(11.9%)	0.659	0.417
Previous smoking	19(22.1%)	10(22.7%)	9(21.4%)	0.021	0.885
Surgical programme					
Lobectomy	44(51.2%)	24(54.5%)	20(47.6%)	0.413	0.521
Lobectomy plus partial resection	42(48.8%)	20(45.5%)	22(52.4%)	0.413	0.521
Pathology					
Squamous cell carcinoma	48(55.8%)	26(59.1%)	22(52.4%)	0.392	0.531
Adenocarcinoma	33(38.4%)	16(36.4%)	17(40.5%)	0.154	0.695
Other	5(5.8%)	2(4.5%)	3(7.1%)	0.265	0.607
Postoperative complications					
Atelectasis	8(9.3%)	3(6.8%)	4(9.5%)	0.210	0.646
Pneumonia	5(5.8%)	2(4.5%)	3(7.1%)	0.265	0.607
Accidental disconnection	0	0	0	-	-
Chest tube retention time (h)	73 ± 33	66 ± 30	81 ± 35	2.134	0.036
Postoperative hospital stay (days)	3.5 ± 1.4	3.3 ± 1.3	3.9 ± 1.5	2.056	0.043

TABLE 2 Lung function and six-minute walk test data of the two groups

	Total	Treatment group (n = 44)	Control group (n = 42)	T	p-value
Preoperative					
FEV1 (L)	2.2 ± 0.6	2.2 ± 0.6	2.1 ± 0.7	0.368	0.714
FVC (L)	3.4 ± 0.8	3.2 ± 0.8	3.5 ± 0.9	0.766	0.446
FEV1/FVC (%)	66 ± 12	68 ± 11	64 ± 14	1.333	0.186
PEF (l/min)	351 ± 86	349 ± 86	352 ± 91	0.136	0.892
6-MWT (m)	423 ± 95	433 ± 91	414 ± 100	0.941	0.349
Borg Scale	1.7 ± 1.2	1.6 ± 1.2	2.0 ± 1.3	1.232	0.221
7 days after surgery					
FEV1 (L)	1.7 ± 0.3	1.6 ± 0.2 ^a	1.7 ± 0.4 ^a	0.577	0.565
FVC (L)	2.6 ± 0.5	2.7 ± 0.6 ^a	2.5 ± 0.5 ^a	1.484	0.142
FEV1/FVC (%)	67 ± 10	64 ± 12 ^a	68 ± 11 ^a	1.352	0.180
PEF (l/min)	262 ± 89	271 ± 90 ^a	253 ± 87 ^a	0.948	0.346
6-MWT (m)	316 ± 91	320 ± 86 ^a	312 ± 96 ^a	0.432	0.666
Borg Scale	3.5 ± 0.9	3.4 ± 1.0 ^a	3.6 ± 0.8 ^a	0.787	0.433
14 days after surgery					
FEV1 (L)	1.8 ± 0.3	1.9 ± 0.4 ^a	1.8 ± 0.3 ^a	0.516	0.607
FVC (L)	2.7 ± 0.6	2.8 ± 0.7 ^a	2.6 ± 0.6 ^a	0.931	0.345
FEV1/FVC (%)	69 ± 10	68 ± 9 ^a	70 ± 12 ^a	0.868	0.388
PEF (l/min)	283 ± 92	289 ± 87 ^a	270 ± 96 ^a	0.997	0.322
6-MWT (m)	359 ± 94	362 ± 97 ^a	357 ± 91 ^a	0.241	0.810
Borg Scale	3.5 ± 1.3	3.3 ± 1.4 ^a	3.7 ± 1.3 ^a	1.175	0.243
21 days after surgery					
FEV1 (L)	1.8 ± 0.2	1.9 ± 0.6 ^a	1.8 ± 0.2 ^a	1.301	0.197
FVC (L)	2.6 ± 0.3	2.8 ± 0.7 ^a	2.6 ± 0.3 ^a	1.357	0.178
FEV1/FVC (%)	68 ± 8	67 ± 9 ^a	68 ± 7 ^a	0.581	0.950
PEF (l/min)	296 ± 97	316 ± 95 ^a	272 ± 103 ^a	2.053	0.043
6-MWT (m)	382 ± 96	386 ± 100 ^a	378 ± 92 ^a	0.371	0.712
Borg Scale	3.3 ± 0.8	3.0 ± 0.7 ^a	3.5 ± 0.9 ^a	2.483	0.015
28 days after surgery					
FEV1 (L)	2.0 ± 0.2	2.1 ± 0.2	1.9 ± 0.3 ^a	4.452	<0.001
FVC (L)	2.9 ± 0.3	2.9 ± 0.2 ^a	2.8 ± 0.5 ^a	1.628	0.107
FEV1/FVC (%)	72 ± 8	74 ± 8 ^a	69 ± 9	2.665	0.009
PEF (l/min)	306 ± 97	331 ± 96 ^a	279 ± 92 ^a	2.546	0.013
6-MWT (m)	399 ± 93	402 ± 96 ^a	397 ± 91	0.241	0.810
Borg scale	2.9 ± 0.9	2.7 ± 1.1 ^a	3.1 ± 0.8 ^a	2.194	0.031

^ap < 0.05 versus the baseline data before surgery.

patient's analgesic score was higher than 4 points, opioids would be added on top of the analgesic pump or intravenous injection. If the visual analogue scale (VAS) score was greater than 6, the treatment was stopped immediately.

The patients in both groups were monitored with a portable pulmonary function instrument (model: UK Microlab) before the operation and on the seventh day (± 2 days), 14th day (± 2 days), 21st day (± 2 days) and 28th day (± 2 days) after the operation to obtain peak expiratory flow (PEF), forced expiratory volume in 1 s (FEV1), and forced vital capacity (FVC).

Data on patients' sex, age, height, weight, primary disease, basic disease, operation plan, chest tube retention time, postoperative hospital stay, and incidence of pneumonia and atelectasis were collected.

Statistical analysis

Sample size calculation: FEV1 was taken as the main observation index in this study. When the difference between groups was more than 10%, it was considered to be of

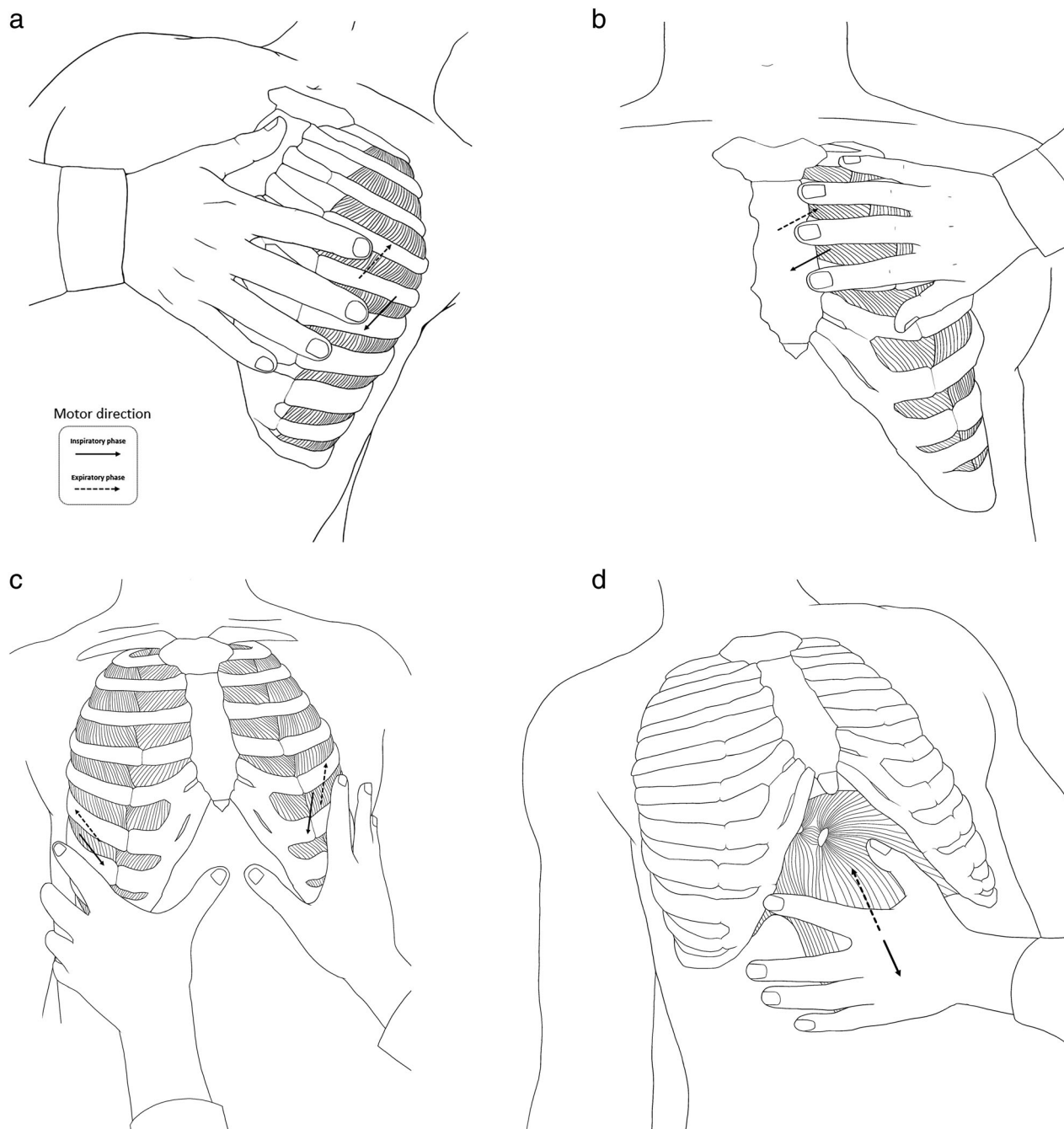


FIGURE 2 Physical manipulation used in pulmonary rehabilitation therapy

clinical significance. The level of the bilateral test was $\alpha = 0.05$, and the degree of assurance was $1 - \beta = 0.8$. The minimum sample size of each group was calculated as 26 patients.

Normally distributed data are expressed as arithmetic means (standard deviations), and comparisons between groups were conducted by two-independent sample *t* tests. The chi-square test was used to compare the rates between groups. SPSS 20.0 (IBM Corp) was used for statistical analysis, and $p < 0.05$ indicated that the difference was statistically significant.

RESULTS

A total of 93 patients entered the study, seven were excluded, and a total of 86 patients were finally included, with 44 patients in the treatment group. A diagram summarizing the flow of participants through the study is presented in Figure 1. There were no significant differences in age, sex, body mass index (BMI), underlying diseases, surgical protocol or preoperative pulmonary function between the two groups (all $p > 0.05$). There was no significant difference in the incidence of postoperative atelectasis (6.8% vs. 9.5%,

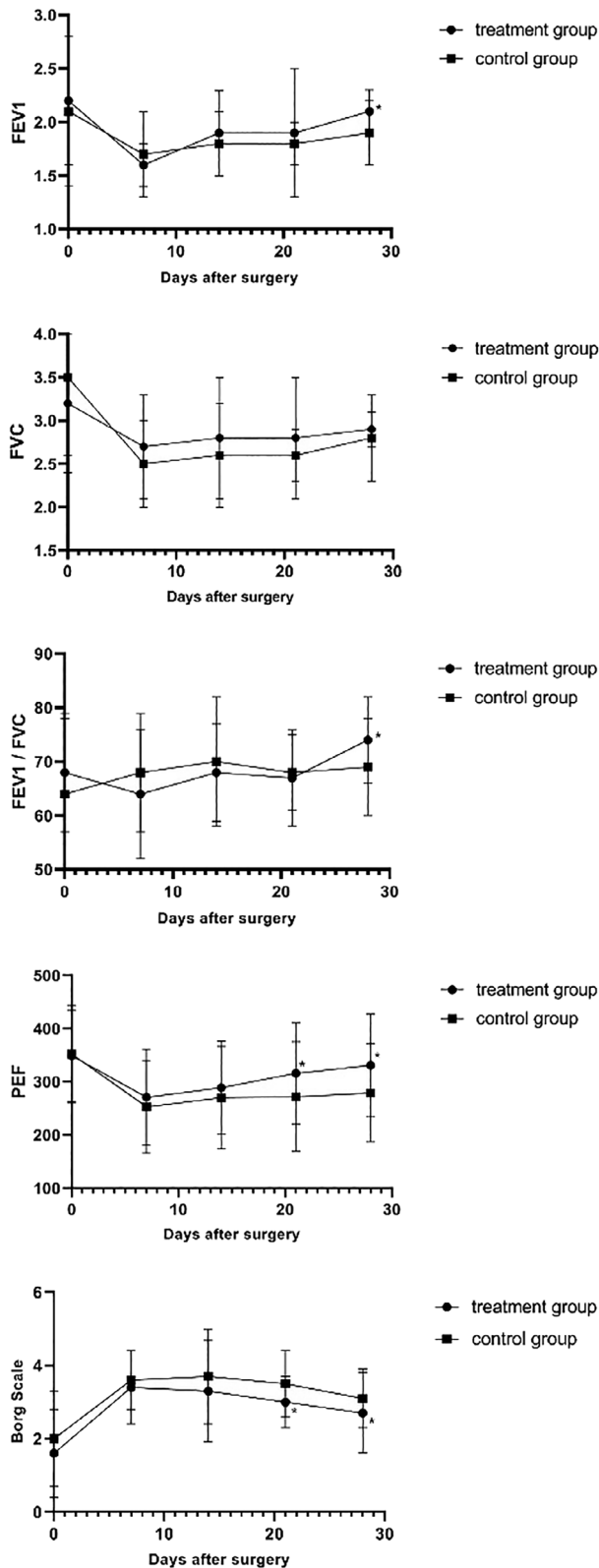


FIGURE 3 Changes in pulmonary function and Borg scale in the two groups 28 days after surgery. * $p < 0.05$ the treatment group versus the control group data at the same time

$p > 0.05$) or pneumonia (4.5% vs. 7.1%, $p > 0.05$). The postoperative hospitalization time (3.3 ± 1.3 vs. 3.9 ± 1.5 days, $p = 0.043$) and chest tube retention time (66 ± 30

vs. 81 ± 35 h, $p = 0.036$) in the treatment group were shorter than those in the control group (Table 1).

The pulmonary function of the two groups decreased after the operation. In the treatment group, the peak flow velocity during PEF 21 days after surgery (316 ± 95 vs. 272 ± 103 l/min, $p = 0.043$), FEV1 (2.1 ± 0.2 vs. 1.9 ± 0.3 L, $p < 0.001$) and FEV1/FVC ($74\% \pm 8\%$ vs. $69\% \pm 9\%$, $p = 0.009$) were greater than those of the control group, and the differences in the FVC (2.9 ± 0.2 vs. 2.8 ± 0.5 L, $p > 0.05$) and 6-min walking test outcomes (402 ± 96 vs. 397 ± 91 m, $p > 0.05$) were not statistically significant. On the 21st and 28th days after the operation, the Borg scale score of the treatment group was lower than that of the control group (all $p > 0.05$) (Table 2 and Figure 2). Lung function in both groups decreased from preoperative baseline 7 to 21 days after surgery. By 28 days after surgery, there was no significant difference between FEV1 in the treatment group and baseline value, while the control group was still lower than baseline value (Figure 3).

DISCUSSION

After thoracoscopic lobectomy, lung tissue volume decreases, and diaphragm and intercostal muscle movement dysfunction occurs in patients with lung cancer, resulting in abnormal respiratory physiological function. Postoperative lung function could be reduced by more than 20% compared with that before the operation. Perioperative PR training can be applied to lung transplantation and lung volume reduction surgery and includes preoperative and postoperative rehabilitation.⁹⁻¹² Routine postoperative rehabilitation training includes limb movement, abdominal breathing, lip retraction breathing, cough training and artificial resistance breathing training.^{10,13,14} Studies have shown that PR treatment seven days before surgery and more than four weeks after surgery can accelerate the recovery of respiratory function, reduce postoperative complications such as pneumonia and atelectasis, and shorten the duration of chest tube retention and the postoperative hospital stay.^{2,13} Even so, it usually takes more than 1 to 3 months of CVPR treatment before patients begin to recover their lung function.^{4,11} In recent years, physical manipulation lung rehabilitation therapy has achieved good therapeutic effects for severe patients.^{4,8,16} At present, there is still a lack of detailed research data on PMPR therapy in postoperative lung cancer patients both in China and abroad. In this study, individualized lung rehabilitation therapy involving physical manipulation was applied to lung cancer patients following video-assisted thoracoscopic surgery (VATS); this is a revolutionary approach in the field of postoperative rapid rehabilitation.

This study found that the PEF of patients in the treatment group was better than that of those in the control group 21 days after surgery, and the FEV1 and PEF of those in the treatment group were better than those of those in the control group 28 days after surgery. The results show that physical manipulation therapy can accelerate the recovery of

pulmonary function after surgery and can produce therapeutic effects from 3 to 4 weeks after surgery. Analysis of the causes and clinical practices found that patients often experience anxiety and pain in the early postoperative period and exhibit poor compliance with CVPR treatment. Elderly patients with a variety of basic diseases often need more than 3 to 5 days to complete an established treatment plan that includes respiratory exercise and aerobic training. Physical manipulation therapy led by a rehabilitation specialist can enable patients to complete the treatment plan passively, and bedside passive training can be effectively started on the day after surgery. By stimulating the inspiratory and respiratory muscle groups, mainly composed of the diaphragm and intercostal oblique muscles, individualized physical manipulation breathing training is helpful in promoting more effective sputum excretion, provides earlier and more effective PR training and is can shorten the chest tube retention and hospitalization times. None of the patients in the two groups received not tubes due to accidents, which shows that the training programme is safe and reliable.

After the operation, the indwelling thoracic drainage tube stimulates the intercostal nerve, the patients are often afraid of normal respiratory movement due to wound pain or fear, and the intercostal muscles are in a state of tension for a long time. Intercostal muscle mobilization and rib mobilization can relax the intercostal muscles, increase the activity of the thorax, and help patients gradually adapt to follow-up treatment. These treatments can effectively improve the thoracic range of motion by helping patients move the thoracic costal joint and the costal vertebral joint. Thoracic induction and induction of abdominal breathing can deepen and increase respiratory movements, deepen abdominal breathing, increase vital capacity and improve lung function through resistance exercise.

As stimulating the diaphragm in the process of rehabilitation may cause vomiting or stomach discomfort, having patients fast for at least 30 min before treatment could prevent discomfort. Communicating with the patient constantly and perceiving the reaction and experience of the patient during the treatment are also essential. Experiencing excessive pain and discomfort will make the patient resist the treatment and do not enable the patient to breathe easier; thus, the rehabilitation effect is not good. In the research, the treatment group had a higher pain score than the control group in the rehabilitation training. The VAS target was 2–4 in the goal-oriented analgesia treatment, in order to complete lung rehabilitation training, patients would receive higher doses of analgesics. Therefore, higher initial doses of analgesics are needed in the treatment group. If the VAS score is greater than 6, the treatment should be stopped immediately. For patients with thoracic drainage tubes after surgery, the operator should ensure that the drainage tube is fixed properly and that the drainage tube is unobstructed before treatment. During the operation, attention should be given to the color, nature and volume of the drainage fluid. If the drainage fluid suddenly becomes bloody, the volume increases suddenly, or

the gas in the drainage bottle suddenly increases, the operator should immediately stop the action and inform the doctor. During the treatment, the operator should try to avoid pulling on the wound of the patient and maintain a distance of more than 2 cm from the wound.

Previous studies have shown that routine perioperative PR training helps to reduce the incidence of complications such as pneumonia and atelectasis after surgery in patients with lung cancer.^{10,18,19} The incidence of postoperative pulmonary complications was 9.8% to 27.3% in the research by Lai et al. and Harada et al.^{13,20} The difference in incidence depends on sex, vital capacity, smoking history, surgical approach, and receipt of comprehensive preoperative PR.²⁰ In this study, the incidences of pneumonia and atelectasis in the treatment group were 4.5% and 6.8%, respectively, which were slightly lower than those in the control group, but the differences were not statistically significant. This was related to the lower incidence of postoperative complications in the patients included in this study and was lower than the incidence of pneumonia and atelectasis reported in previous domestic studies.^{18,21} The effectiveness of PMPR therapy has been confirmed in critically ill patients,^{7,8} so lung cancer patients with a higher surgical risk are more likely to benefit from physical manipulation breathing therapy immediately after surgery.^{22,23} Beijing Hospital is the national geriatric medical centre. A large number of elderly patients with lung cancer are admitted to the Thoracic Surgery Department of Beijing Hospital. The oldest patients have been up to 88 years old. They often have a combination of a variety of basic diseases. Future research can analyze these patients separately to verify the above hypothesis.

Patient compliance and postdischarge management are important influencing factors for the completion of postoperative PR treatment. Intelligent mobile devices have had a great impact on the construction of medical information platforms.²⁴ This study, through mobile phones such as smart phones, used official WeChat accounts and patient friend groups to promote peer education,^{25,26} which is conducive to improving the compliance of patients after discharge. At the same time, it also provides an information platform for patients to provide feedback on treatment effects, for medical staff to adjust treatment plans synchronously and monitor late follow-ups, for big data management, which is an exploration of modern medical information construction, etc.²⁷

The limitations of this study are as follows: (1) There was no blinding, and subjective scales such as the Borg index may have led to measurement bias. (2) Postoperative lung function was significantly lower than preoperative baseline until postoperative day 21. Twenty-eight days after surgery, FEV1 in the treatment group showed no significant difference from the preoperative baseline value, while FEV1/FVC and 6-MWT in the control group showed no significant difference from the preoperative baseline value. In order to determine the impact of the rehabilitation program on the lung function of patients, we need to investigate the functional dimension, symptom dimension and overall health level of patients in larger sample sizes and longer follow-up.

In conclusion, patients with lung cancer received individualized manual lung rehabilitation therapy soon after surgery. The recovery of lung function occurred earlier with PMPR than with conventional postoperative PR. The chest tube retention and postoperative hospital stay times were shortened.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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How to cite this article: Zhou T, Sun C. Effect of physical manipulation pulmonary rehabilitation on lung cancer patients after thoracoscopic lobectomy. *Thorac Cancer*. 2022;13:308–15. <https://doi.org/10.1111/1759-7714.14225>