

Is respiratory physiotherapy effective on pulmonary complications after lobectomy for lung cancer?

Akciğer kanseri için lobektomi sonrası solunum fizyoterapisi akciğer komplikasyonlarında etkili midir?

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ABSTRACT

Background: The aim of this study was to investigate the effects of a postoperative respiratory physiotherapy program on pulmonary complications, length of hospital stay, and hospital cost after lobectomy for lung cancer.

Methods: A total of 90 patients (75 males, 15 females; mean age 63.1±10.4 years; range, 30 to 82 years) who underwent elective lobectomy through thoracotomy due to lung cancer between June 2014 and December 2019 were retrospectively analyzed. The patients were divided into two groups as Group S who received standard postoperative care (n=50) and Group P who received postoperative respiratory physiotherapy in addition to standard care (n=40). Both groups were compared in terms of postoperative pulmonary complications, 30-day mortality, length of hospital stay, and hospital cost.

Results: The preoperative and surgical characteristics of the groups were similar. Group P had a lower incidence of postoperative pulmonary complications (10% vs. 38%, respectively; p=0.002) than Group S. The median length of stay in the hospital was six (range, 4 to 12) days in Group P and seven (range, 4 to 40) days in Group S (p=0.001). The drug cost (639.70 vs. 1,211.46 Turkish Liras, respectively; p=0.001) and the total hospital cost (2,031.10 vs. 3,778.68 Turkish Liras, respectively; p=0.001) of the patients in Group P were significantly lower. The multivariate logistic regression analysis showed that respiratory physiotherapy had a protective effect on the development of postoperative pulmonary complications (odds ratio =0.063, 95% confidence interval: 0.010-0.401, p=0.003).

Conclusion: An intensive physiotherapy program focusing on respiratory exercises is a cost-effective practice which reduces the risk of development of postoperative pulmonary complications in patients undergoing lobectomy for lung cancer.

Keywords: Complication, cost, lobectomy, lung cancer, respiratory physiotherapy.

ÖZ

Amaç: Bu çalışmada, akciğer kanseri nedeniyle lobektomi sonrasında ameliyat sonrası solunum fizyoterapi programının akciğer komplikasyonları, hastanede kalış süresi ve hastane maliyeti üzerindeki etkisi araştırıldı.

Çalışma planı: Haziran 2014 - Aralık 2019 tarihleri arasında akciğer kanseri nedeniyle torakotomi ile elektif lobektomi yapılan toplam 90 hasta (75 erkek, 15 kadın; ort. yaş 63.1±10.4 yıl; dağılım, 30-82 yıl) retrospektif olarak incelendi. Hastalar standart ameliyat sonrası bakım verilen Grup S (n=50) ve standart bakıma ek olarak ameliyat sonrası solunum fizyoterapisi verilen Grup P (n=40) olarak iki gruba ayrıldı. Her iki grup, ameliyat sonrası akciğer komplikasyonları, 30 günlük mortalite, hastane kalış süresi ve hastane maliyeti açısından karşılaştırıldı.

Bulgular: Grupların ameliyat öncesi ve cerrahi özellikleri benzerdi. Grup S'ye kıyasla, Grup P'nin ameliyat sonrası akciğer komplikasyonlarının insidansı daha düşüktü (sırasıyla, %38'e karşın %10; p=0.002). Medyan hastanede kalış süresi Grup P'de altı (dağılım, 4-12) gün ve Grup S'de yedi (dağılım, 4-40) gün idi (p=0.001). Grup P'deki hastaların ilaç maliyeti (sırasıyla 1.211.46'ya karşın 639.70 Türk Lirası; p=0.001) ve toplam hastane maliyeti (sırasıyla, 3.778.68'e karşın 2.031.10 Türk Lirası; p=0.001) anlamlı düzeyde daha düşüktü. Çok değişkenli lojistik regresyon analizinde solunum fizyoterapisinin ameliyat sonrası akciğer komplikasyonlarının gelişimi üzerinde koruyucu bir etkiye sahip olduğu izlendi (olasılık oranı =0.063, %95 güven aralığı: 0.010-0.401, p=0.003).

Sonuç: Solunum egzersizlerine odaklanan yoğun bir fizyoterapi programı, akciğer kanseri için lobektomi uygulanan hastalarda ameliyat sonrası akciğer komplikasyonlarının gelişme riskini azaltan, maliyet etkin bir uygulamadır.

Anahtar sözcükler: Komplikasyon, maliyet, lobektomi, akciğer kanseri, solunum fizyoterapisi.

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Lung cancer is the most common cause of cancer-related deaths worldwide.^[1] Complete surgical resection is the most effective treatment for curative treatment of non-small cell lung cancer.^[2] Although the novelties in anesthesia and in thoracic surgery practices reduce the overall complication rate, the rate of postoperative pulmonary complications (PPCs) after lung resections is still between 7 and 36%.^[3] Reduced mucus transport by anesthesia, immobilization of the patient during surgery, postoperative pain and diaphragmatic dysfunction lead to airway collapse by reducing functional residual capacity (FRC) and effective coughing. As a result, this condition sets the scene for the occurrence of many PPCs such as sputum retention, atelectasis, hypoxemia, pulmonary infection, and respiratory depression.^[4] Since PPCs are associated with high mortality rates, long-term hospitalization, and high hospital costs,^[5] various treatment strategies and methods have been used to prevent PPCs in patients undergoing resection for lung cancer.

To date, various treatment strategies and methods such as identification and prevention of risk factors, improvement of the preoperative condition and patient education, intraoperative practices, and postoperative pulmonary care have been developed to reduce the incidence of PPCs. Of all these, postoperative respiratory physiotherapy (PRP) has been adopted as a useful practice in preventing pulmonary complications^[6,7] and recommended by the European Respiratory Society (ERS), European Society of Thoracic Surgeons (ESTS),^[8] and the American College of Chest Physicians (ACCP)^[9] to be routinely administered for its functional benefits. However, a limited number of studies and systematic reviews investigating the effect of PRP on PPCs have been published. These reviews emphasize the lack of clinical studies with strong evidence of PRP after lung resections, reporting that there is a need for more studies to design the guidelines indicating the right intervention required for each patient.^[10-12] Moreover, it has become necessary to evaluate each new medical intervention economically, before it is carried out due to the increasing costs of healthcare worldwide.^[13] As a consequence, although some clinical studies of heterogeneous patient populations have shown its positive results,^[14-16] little is known today about the physiological, clinical, and economic consequences of PRP programs.

In the present study, we aimed to investigate whether a PRP program based on respiratory exercises could reduce PPCs and shorten the length of hospital

stay in lung cancer patients undergoing lobectomy via thoracotomy and to evaluate its cost-effectiveness.

PATIENTS AND METHODS

This retrospective, cohort study was conducted at a secondary care private health institution between June 2014 and December 2019. For the study population, patients over 18 years of age who underwent oncological lobectomy through thoracotomy were evaluated. Those who received neoadjuvant therapy, extended resections such as chest wall resection, those who received an incisional pain catheter for pain management, those who were discharged with Heimlich valve without the removal of the chest tube, emergency lobectomies and re-thoracotomies were excluded. Of a total of 132 patients who underwent lobectomy through thoracotomy due to lung cancer, 90 (75 males, 15 females; mean age 63.1±10.4 years; range, 30 to 82 years) were included in the study. Data were collected from institutional database. The demographic data were obtained from the patient charts, and the clinical and radiological data were collected from the electronic medical record and image archiving system and analyzed in a quasi-experimental setting. A written informed consent was obtained from each patient. The study protocol was approved by the Medicana International Samsun Hospital Ethics Committee (No. 2019-009-7063). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The patients included in the study were divided into two groups as those undergoing standard postoperative care (Group S, n=50) in the years before the establishment of a physiotherapy unit, and those undergoing PRP in addition to standard care (Group P, n=40) after the establishment of the physiotherapy unit in 2017. The study flow chart is shown in Figure 1.

Perioperative management

All patients were operated in the same hospital by a single thoracic surgery team under the supervision of a single anesthesiologist team. Similar operative, resectability selection criteria, and anesthesia management were used in all patients. A posterolateral or lateral thoracotomy approach was adopted for all patients according to the preference of the surgeon. Preoperative antibiotic regimen consisted of a single dose of cefuroxime 1,500 mg which could be repeated 6 h later, if surgery continued. All patients were extubated in the operating room and transferred to the intensive care unit (ICU). If the patients were hemodynamically and clinically stable, they were transferred to the private ward on the first postoperative

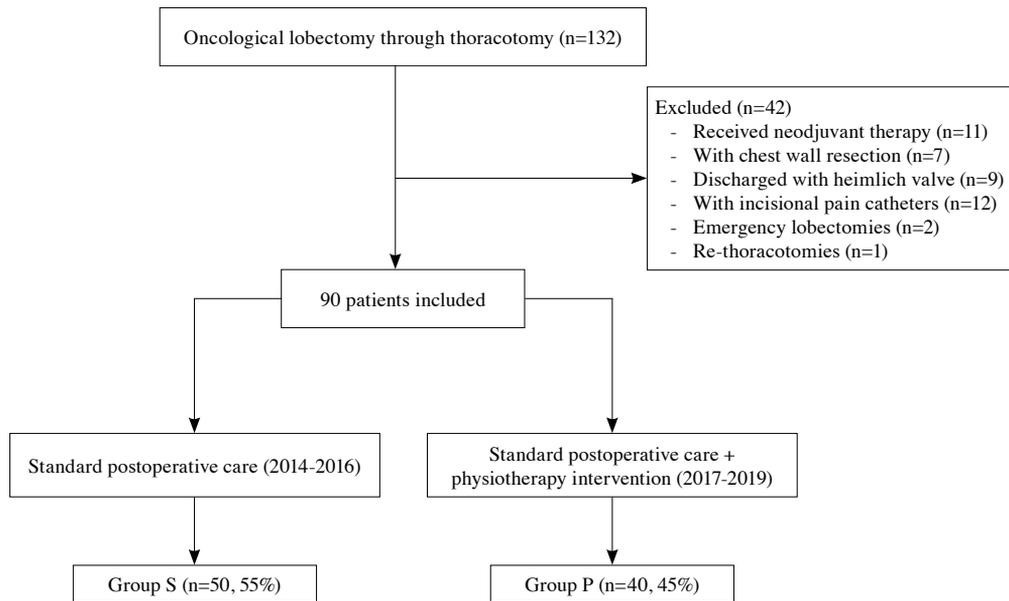


Figure 1. Study flowchart.

day. Bronchoscopy was not routinely performed in patients, unless there was a clinical requirement such as secretion retention, or atelectasis.

Intravenous tramadol hydrochloride and, if necessary, (Numeric Rating Scale [NRS] >4), intramuscular pethidine hydrochloride were administered to all patients for postoperative analgesia. Once the chest tube was removed, only non-steroidal anti-inflammatory drugs and paracetamol were given. Inflammation parameters such as C-reactive protein and white blood cells were measured daily after surgery. Chest X-ray was taken routinely within the first 4 h postoperatively, on Days 1 and 3, and after the removal of the chest tube or, additionally, in the case of a change in the clinical status of the patient. The X-rays were interpreted by a radiologist who was blinded to the group allocation. In the presence of an expansion defect on the chest X-ray, the chest tube was connected to the suction system depending on the air leak. In case that air leak from the chest tube continued for more than seven days, autologous blood pleurodesis was performed, if necessary. If there was no air leak from the chest tube and the amount of daily drainage was below 200 mL, the chest tube was removed. All patients were discharged one day after chest tubes were removed, if there were no radiological and biochemical abnormalities. There has been no economic pressure on the discharge of patients from

hospital management, which did not change during the study period.

Standard care group

Before starting the PRP program, all patients received standard medical and nursing care. In the preoperative period, the patients were shown how to perform deep inspiratory maneuvers with a moderate flow using an incentive spirometer. Postoperatively, in the ICU, the patients were asked to start the expansion maneuvers of the lung as early as possible and to continue for 10 min every hour until discharge. From the first postoperative day, bed elevation, upright position and early ambulation, and pain assessment were performed on all patients.

Physiotherapy group

Regardless of respiratory function parameters, daily targeted individual intensive respiratory physiotherapy program was administered to the patients in the physiotherapy group in the ward from the early postoperative period (from the 4th h) until discharge. The physiotherapy program included the techniques that improve ventilation such as deep breathing exercises, maximum long-term inspiration with an incentive spirometer and pursed-lip breathing; bronchial hygiene techniques such as autogenic drainage methods, effective cough training, huffing, bottle positive expiratory pressure;

early ambulation and progressive mobility exercises for shoulder girdle and thoracic cage.^[10] Each physiotherapy session took approximately 30 min. All sessions were performed under the supervision of an experienced physiotherapist in the treatment of patients with thoracic surgery. The same physiotherapist was appointed for all patients. The importance of its active role in early postoperative recovery (i.e., early ambulation, pulmonary hygiene, and extension exercises) was strongly and repetitively emphasized to the patients in each physiotherapy session. The patients were asked to repeat the techniques 10 times that improve ventilation at 1 to 2-h intervals and the bronchial hygiene techniques at 30-min intervals. Early ambulation was performed as standard on the patients with stable clinical condition and a NRS score of <4 at postoperative 4th h. The ambulation distance was gradually increased so as to be at least one turn (about 30 m). While ambulation was initially performed with help, it was performed without help the following days (according to the patient's need). It was ensured that exercises that improve shoulder, head-neck, rib cage mobility, and postural quality were given from the first postoperative day. These exercises with respiratory control were performed three-times a day with five repetitions each time. The exercises were prescribed to the patient as a home-based program in a booklet during discharge.

Variables and outcomes

Independent variables indicating that the analyzed groups were comparable, are age, sex, predicted preoperative forced expiratory volume in one second (FEV1%), predicted preoperative forced vital capacity (FVC%), body mass index (BMI), preoperative smoking habit, presence of chronic obstructive pulmonary disease (COPD), Charlson Comorbidity Index [CCI]^[17] American Society of Anesthesiologists (ASA) class, duration of anesthesia, operation side, operative procedure, mean NRS score at rest and during coughing, pathological diagnosis and stage of the tumor. The primary outcomes were the incidence of PPCs and mortality. The secondary outcomes were the length of hospital stay, surgery-related re-admissions, drug and total hospital costs.

Pain assessment

Postoperative pain was assessed using the NRS. The patients were asked to rate their pain at rest and during coughing on a scale from 0 (no pain) to 10 (intolerable pain) from the fourth postoperative hour. The mean NRS scores measured daily during hospitalization were considered.

Definitions

In the postoperative period, a new-onset progressive infiltration on chest X-ray, a body temperature of >38°C, purulent (yellow/green) sputum expectoration different from the preoperative period, a white blood cell count of 15,000/mm³, signs of positive infection in sputum microbiology, presence of dyspnea or tachypnea were considered as nosocomial pneumonia.^[18] Reporting of radiological consolidation on chest X-ray, secretion retention requiring bronchoscopic aspiration, absence of breathing sound on auscultation were considered as atelectasis. In addition to the clinical symptoms, oxygen saturation (sPO₂) <90% in room air and partial pressure of oxygen (PaO₂) <60 mmHg in arterial blood gas analysis, re-admission to ICU for non-invasive or invasive mechanical ventilation or prolonged stay (>48 h) in ICU were evaluated as acute respiratory failure. The presence of air in the subcutaneous tissue, which has become significant by covering at least one hemithorax and is crepitating on palpation, was defined as subcutaneous emphysema, an air leak from the chest tube lasting longer than seven days, was defined as prolonged air leak, the removal of chest tube with no air leak from the chest tube without obtaining full expansion on chest X-ray, although all interventions was defined as aseptic space. The development of fatal complications within 30 days after surgery or death before discharge was defined as mortality. The time from the date of operation until discharge was evaluated as the length of hospital stay.

Cost calculation

Since the fees of preoperative routine tests and examinations and surgical interventions and materials used in the operating room were considered same in each case, they were not taken into account while calculating the cost. The costs of bed occupation, procedures and examinations performed, medical materials, drugs used, and consultations during the hospitalization period were included in the cost calculation. Daily physiotherapist cost was also added to the physiotherapy group. The current fees of all factors included in the cost evaluation were obtained from the hospital's purchasing department and the hospital's pharmacy department. To prevent the change in prices during the study period from affecting the result of the study, the comparison was based on current fees.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 24.0 software (IBM Corp.,

Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical variables were expressed in number and frequency. The normality of the data was tested using the Shapiro-Wilk test, while the Student t-test was used for the comparison of normally distributed variables between two independent groups and the Mann-Whitney U test was used for the comparison of non-normally distributed variables

between two independent groups. The correlation analysis of the categorical variables in two independent groups was performed using the Pearson's chi-square test. A multivariate risk factor analysis was performed for PPCs using the logistic regression method. Following the physiotherapy program, age, presence of COPD, CCI score, BMI, current smoking status, preoperative FEV1%, sex, duration of anesthesia, and tumor stage were evaluated as possible risk factors and

Table 1. Baseline and demographic characteristics of patients

	Grup S (n=50)			Grup P (n=40)			p
	n	%	Mean±SD	n	%	Mean±SD	
Age (year)			64±10			62±11	0.304
Sex							0.448
Male	43	86		32	80		
Female	7	14		8	20		
Forced expiratory volume in one sec (%)			83.3±11.7			85.9±21.0	0.454
Forced vital capacity (%)			87.7±17.4			92.2±20.1	0.263
Body mass index (kg/m ²)			26.4±4.5			26.5±3.4	0.869
Smoking status							0.585
Current	9	18.0		12	30.0		0.585
Ex-smoker <6 weeks	6	12.0		5	12.5		
Ex-smoker >6 weeks	16	32.0		11	27.5		
Non-smoker	19	38.0		12	30.0		
Chronic obstructive pulmonary disease	15	30.0		14	35.0		0.614
Charlson Comorbidity Index			1.1±1.1			1.1±1.1	0.866
American Society of Anesthesiologists Score							0.701
2	32	64		24	60		
3	18	36		16	36		
Duration of anaesthesia (min)			196.8±46.6			192.9±34.5	0.658
Operation side							0.502
Right	31	62.0		22	55.0		
Left	19	38.0		18	45.0		
Operative procedure							0.568
Upper lobectomy	30	60.0		20	50.0		
Middle lobectomy	2	4.0		3	7.5		
Lower lobectomy	18	36.0		17	42.5		
Numeric Rating Scale-rest			2.0±0.8			1.9±0.9	0.732
Numeric Rating Scale-coughing			4.9±0.8			4.8±1.1	0.681
Pathological diagnosis							0.817
Squamous carcinoma	28	56.0		19	47.5		
Adenocarcinoma	19	38.0		17	42.5		
Adenosquamous carcinoma	1	2.0		1	2.5		
Carcinoid tumor	2	4.0		3	7.5		
Pathological stage							0.386
Stage I	29	58.0		21	52.5		
Stage II	11	22.0		13	32.5		
Stage III	10	20.0		5	12.5		
Stage IV	0	0		1	2.5		

SD: Standard deviation.

Table 2. Frequency and type of the PPCs in standard and physiotherapy groups

	Grup S (n=50)		Grup P (n=40)		p
	n	%	n	%	
Pulmonary complications	19	38	4	10	0.002*
Pneumonia	12	24.0	3	7.5	0.037*
Atelectasis	12	24.0	1	2.5	0.004*
Respiratory failure	6	12.0	1	2.5	0.094
Prolonged air leak	13	26.0	4	10.0	0.054
Subcutaneous emphysema	6	12.0	4	10.0	0.764
Aseptic space	9	18.0	1	2.5	0.02*
Mortality	4	8.0	0	0	0.067

* Indicates a significant difference between two groups. PPCs: Postoperative pulmonary complications.

added to the model as predictors. A *p* value of <0.05 was considered statistically significant.

RESULTS

Table 1 shows the baseline and demographic characteristics of the patients included in the study. Patients in both groups were similar in terms of age, sex, preoperative FEV1%, FVC%, BMI, smoking status, presence of COPD, CCI, ASA class, duration of anesthesia, operation side, lobectomy type, mean NRS score during at rest and coughing, pathological diagnosis, and stage.

Table 2 shows the type and frequency of PPCs in the standard and physiotherapy groups. The rate of patients with at least one PPC was significantly lower in the physiotherapy group (38% vs. 10%, respectively; *p*=0.002). There was a significant difference between the groups in terms of pneumonia (24% vs. 7.5%, respectively; *p*=0.037), atelectasis (24% vs. 2.5%, respectively; *p*=0.004), and aseptic space (18% vs. 2.5%, respectively; *p*=0.02) in favor of Group P. Although other PPCs such as respiratory failure, prolonged air leak, and subcutaneous emphysema were less frequent in the physiotherapy group, there was no significant difference between the groups.

In addition, no mortality was seen in the physiotherapy group, while the rate of mortality was 8% (n=4) in the Group S, while indicating no statistically significant difference (*p*=0.067).

The median LOS was six (range, 4 to 12) days in the physiotherapy group and seven (range, 4 to 40) days in the standard group (*p*=0.001). When the surgery-related re-admission rates of the physiotherapy and standard groups were compared, there was no significant difference between the two groups (5% vs. 8%, respectively; *p*=0.571). The drug (639.70 vs. 1,211.46 Turkish Liras (₺), respectively; *p*=0.001) and total hospital cost (2,031.10 vs. 3,778.68 ₺, respectively; *p*=0.001) of the patients in the physiotherapy group was significantly lower (Table 3).

Of all the patients included in the study, 25.5% (n=23) postoperatively developed respiratory complications. According to the multivariate logistic regression analysis carried out to determine the independent risk factors on respiratory complication-dependent variable, the physiotherapy program (odds ratio [OR]=0.063, 95% confidence interval [CI]: 0.010-0.401, *p*=0.003) and the presence of COPD (OR=4.722, 95% CI: 1.212-18.396, *p*=0.025) were found to be significant in the model (Table 4).

Table 3. Length of hospital stay and in-hospital expenses of standard and physiotherapy groups

	Grup S (n=50)					Grup P (n=40)					p
	n	%	Mean±SD	Median	Range	n	%	Mean±SD	Median	Range	
Length of hospital stay (day)				7	4-40				6	4-12	0.001*
Surgery related readmission	4	8				2	5				0.571
Drug cost (₺)			1,211.5±1,074.6					639.7±248.4			0.001*
Total hospital cost (₺)			3,778.7±2,509.8					2,031.1±536.4			0.001*

* Indicates a significant difference between two groups.; ₺ Turkish Lira.

Table 4. Multivariate logistic regression analysis for the risk of postoperative pulmonary complications (n=90)

Variables	OR	95% CI	<i>p</i>
Physiotherapy program	0.063	0.010-0.401	0.003*
Age	1.007	0.936-1.083	0.857
Chronic obstructive pulmonary disease	4.722	1.212-18.396	0.025*
Charlson Comorbidity Index score	1.304	0.105-16.183	0.836
Body mass index	0.937	0.775-1.133	0.499
Smoking (current)	2.758	0.281-27.028	0.384
FEV1%	0.971	0.928-1.017	0.212
Sex			
Male	1.005	0.990-1.021	0.508
Duration of anesthesia	1.008	0.993-1.022	0.308
Tumor stage	1.107	0.145-8.429	0.922

OR: Odds ratio; CI: Confidence interval; FEV₁: Forced expiratory volume in one sec; * Indicates a significant difference between two groups.

DISCUSSION

In the current study, we investigated whether a PRP program based on respiratory exercises could reduce PPCs and shorten the length of hospital stay in lung cancer patients undergoing lobectomy via thoracotomy and to evaluate its cost-effectiveness. Our results demonstrated that a PRP program was a cost-effective practice in this patient population with significantly reduced PPCs and shortened length of hospital stay. In addition, lung expansion maneuvers, bronchial hygiene techniques, and mobility exercises could be safely performed in the early postoperative period.

Physiotherapy programs are recommended to be routinely administered to patients with lung cancer after curative treatment owing to their functional benefits.^[8] In addition, patients with lung cancer undergoing parenchymal resection should rapidly be encouraged to return to the daily activities, and their quality of life should be improved. A respiratory physiotherapy program administered by experienced physiotherapists for this purpose is a significant procedure that can be easily performed in thoracic surgery units.^[19] The importance of physiotherapy is increasing every day, as new guidelines allow lung cancer surgeries to be performed on increasingly risky patients.^[8] The main goals of respiratory physiotherapy recommended to be started in the earliest postoperative period is to regulate the alveolar ventilation, increase lung volume and capacity, particularly FRC, and provide effective coughing and ventilate the atelectatic areas formed during surgery.^[20]

Patient-related factors such as age, comorbid diseases, smoking history, and respiratory and exercise capacity in patients undergoing lung resection and surgery-related factors such as type of surgery, duration, type and dose of anesthesia, and amount of removed lung parenchyma affect the risk of developing PPC.^[10,21] In our study, the baseline and demographic characteristics of the patients in both groups were similar. Also, only patients who underwent lobectomy and mediastinal lymph node dissection via thoracotomy for lung cancer under the same operative and resectability selection criteria, and similar anesthesia management by the same team were analyzed in our study. Our study provides more significant results for patients who underwent lobectomy for lung cancer compared to other studies including different causes of lobectomy^[15] or different surgical techniques.^[14] Although the use of lung resection with video-assisted thoracoscopic surgery has been increasing in recent years, according to the ESTS data,^[22] the most commonly performed surgical procedure for lung resection is lobectomy via thoracotomy. Therefore, we believe that the results of this study are valuable for the current clinical practices, and still significant for large patient populations.

Although respiratory physiotherapy is thought to be a very important tool in postoperative care after lung resection,^[23] the number of studies showing the effectiveness of its routine use is very limited. Indeed, some studies have reported that respiratory physiotherapy is administered with overindication and it is necessary to be selective and to consider

the cost while administering it.^[24] In a study, Varela *et al.*^[14] showed that a routine intensive respiratory physiotherapy program reduced PPCs after lung resection without any cost increase. A single-blind, randomized clinical trial reported that, however, respiratory physiotherapy did not contribute to the development of pulmonary complications or length of hospital stay, unless patients had COPD or low FEV1.^[25] In contrast, Novoa *et al.*^[16] reported that the nursing care provided to the patients in the control group who did not receive physiotherapy and the number of nurses per patient in this study were higher than the today's standards, and that the low complication rate in the control group might be related to this. Furthermore, in their study with a large sample size analyzed using the Propensity matching methodology (n=359 matches), they reported that a perioperative intensive respiratory physiotherapy program, similar to our study, reduced overall pulmonary morbidity in patients who underwent lobectomy for lung cancer. In a similar study, PPCs significantly decreased in patients who underwent lobectomy via thoracotomy after the administration of PRP program.^[15]

In the literature, the overall PPC rate after abdominal, cardiac, or thoracic surgery is reported to be between 2 and 40%.^[12] The reason for reporting the incidence of PPC in such a wide range is that there is no standard definition for PPCs yet, and the complications evaluated as PPCs in different studies widely vary. In our study, the PPC rate of the physiotherapy group was 10%. This result is higher than other studies evaluating only atelectasis, pneumonia, and respiratory failure as PPC and reporting the incidence of PPC between 5 and 7% in patients receiving respiratory physiotherapy.^[15,16,25] Unlike these studies, prolonged air leak, aseptic space, and subcutaneous emphysema were analyzed as PPC in our study, since they are all associated with lung expansion. We believe that our high rate of PPC is due to these additional morbidities examined in the present study.

In our study, the median length of hospital stay was six days in the physiotherapy group. This result is consistent with the results of the initial publications administering physiotherapy program based on respiratory exercises.^[25,26] However, in another recently published study comparing the efficacy of physiotherapy in patients undergoing lobectomy via thoracotomy, the length of hospital stay of the intervention group (median 12 days) was longer than that of our study and, similarly, the intervention group had significantly shorter length of hospital stay than

the control group.^[15] Moreover, readmissions due to surgery were also evaluated in this study and, similar to our study, the readmission rate of the intervention group was found to be lower, although not statistically significant.^[15]

In the current practice, to more widely adopt newly developed medical technologies and practices, it is necessary to demonstrate that they provide much benefit with low cost. The first study demonstrating that an intensive perioperative physiotherapy program provided cost saving with a shorter length of hospital stay was published by Varela *et al.*^[14] in 2006. This program based on cycling ergometry and aerobic exercise training on treadmill started a day before surgery and continued until discharge. Of note, in this program requiring new equipment cost (18,000 €), it is unclear whether costs remained constant throughout the study period. However, in our study, the current fixed prices of all factors included in the cost calculation were calculated. Therefore, a more accurate interpretation of the cost effectiveness of the program could be achieved. It is obvious that a physiotherapy program based on respiratory exercises that does not require any equipment cost other than physiotherapist expenses can be more easily administered by more thoracic surgery units, as suggested by the European Association for Cardiothoracic Surgery (EACTS)/ESTS Working Group on Structures in Thoracic Surgery.^[27] In addition, conducting cost-effectiveness studies, including the post-discharge period, would allow the benefits of physiotherapy programs to be evaluated in a wider perspective.

The presence of concomitant COPD in lung cancer patients undergoing lung resection (73% in males, 53% in females) is the most important factor increasing the rate of PPC.^[28] Loss of elasticity and increased preoperative secretion volume in COPD patients may predispose PPCs such as postoperative atelectasis and sputum retention.^[26] In a prospective observational study, the age of above 75 years, a BMI of above 30 kg/m², the ASA Class ≥ 3 , smoking and presence of COPD were found to be independent risk factors for PPC development after lung resection.^[29] In our study, the regression analysis carried out through possible risk factors showed that physiotherapy had a protective effect on PPC development, whereas the presence of COPD increased the risk of developing PPC by 4.7 times. Another study evaluating the prespecified risk factors according to bivariate analysis reported that physiotherapy program and FEV1% value had a protective effect on PPC development.^[15]

The main limitations of the present study are that it has a retrospective design with a relatively small sample size. In addition, as diffusion lung capacity for carbon monoxide or exercise capacity data were unable to be measured in many cases at the beginning of the study, these data were not used in the risk modeling of the study. Furthermore, a cost comparison made under the conditions of our country may not be fully correlated with the cost calculation of different countries (for reasons such as different currency or social security payments). Also, the cost study covering the post-discharge period could not be performed, since we do not have enough data on this subject. However, the main strength of our study is that all cases were performed by the same surgical team, in the same hospital, using the same surgical technique, and that postoperative care remained unchanged throughout the study.

In conclusion, our study results suggest that a physiotherapy program based on respiratory exercises in the early postoperative period should be administered routinely to patients undergoing lobectomy for lung cancer, considering its clinical benefits, particularly in patients with chronic obstructive pulmonary disease. In all thoracic surgery clinics, more and more importance should be given to simple, cost-effective, and low-risk physiotherapy practices that reduce health costs and increase the success of surgery. Furthermore, there is a need for multi-center, prospective studies focusing not only on the early postoperative period, but also on the late post- and preoperative periods to confirm the benefit of physiotherapy practices and to determine the ideal intervention and the patient population who benefits the most.

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