Journal of The Cardiovascular Thoracic Anaesthesia and Intensive Care Society

GKDA Derg 2022;28(1):15-23
DOI: 10.14744/GKDAD.2022.21704

Research Article / Araştırma

Evaluation of Risk Factors for Respiratory Complications After Lung Resection

Akciğer Rezeksiyonu Sonrası Ortaya Çıkan Solunumsal Komplikasyonlar İçin Risk Faktörlerinin Değerlendirilmesi

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ABSTRACT

Objectives: Respiratory complications are an important contributor to morbidity and mortality following lung resection. The surgical techniques used and the patient's pre-operative medical condition determine the severity of complications. The aim of this study is to evaluate the relationship between the perioperative characteristics of patients undergoing lung resection and the development of pulmonary complications (PC).

Methods: We retrospectively reviewed the records of 1186 patients who underwent lung resections between 2017 and 2020 and identified 124 patients who developed PC. A group of 215 consecutive patients who underwent surgery during the same period and did not develop complications were included as the control group. The groups were compared to evaluate risk factors for PC.

Results: The patients had a mean age of 58.9±12.1 (range, 18-83) years and 82% were men (n=278). Factors significantly associated with PC were age over 65 years, male sex, presence of chronic heart failure, coronary artery disease, and chronic obstructive pulmonary disease, undergoing pneumonectomy, intraoperative use of blood products, reoperation due to bleeding, operative time longer than 4 h, and intraoperative inotrope use. Independent variables for PC were intraoperative inotrope use, preoperative anticoagulant use, revision due to hemorrhage, high Sequential Organ Failure Assessment (SOFA) score, low Forced Expiratory Volume in the 1st s (FEV1), and low preoperative hemoglobin values.

Conclusion: This study demonstrated the presence of many risk factors for PC after lung resection. In our study, independent risk factors for PC; intraoperative inotropic use, preoperative anticoagulant use, revision due to bleeding, high SOFA score, low FEV1, and low preoperative hemoglobin values were observed.

Keywords: Lung resection, pulmonary complications, thoracotomy, video-assisted thoracoscopic surgery

ÖZ

Amaç: Solunumsal komplikasyonlar, akciğer rezeksiyonu sonrası mortalite ve morbidite insidansını artırmada önemli bir yere sahiptir. Tercih edilen cerrahi yöntemin yanı sıra hastanın ameliyat öncesi medikal durumu komplikasyonun ciddiyetini belirler. Bu çalışmanın amacı, akciğer rezeksiyonu yapılan hastaların peroperatif özellikleri ile pulmoner komplikasyon gelişimi arasındaki ilişkiyi değerlendirmektir.

Yöntem: Çalışmada, 2017-2020 yılları arasında ameliyat edilen 1186 olgu geriye dönük olarak incelendi ve pulmoner komplikasyon gelişen 124 hasta belirlendi. Aynı dönemde, komplikasyon gelişmeyen ve ardışık ameliyat edilen 215 hasta kontrol grubu olarak tanımlandı. Gruplar, pulmoner komplikasyonda risk faktörlerini değerlendirmek için karşılaştırıldı.

Bulgular: Yaş ortalaması 58,9±12,1 yıl (18-83 yıl) olan hastaların 278'i (%82) erkekti. Çalışmada 65 yaş üstü olmanın, erkek cinsiyetin, kronik kalp yetmezliği, koroner arter hastalığı ve kronik obstrüktif akciğer hastalığı varlığının, pnömonektominin, intraoperatif kan ürünleri kullanımının, kanamaya bağlı yeniden operasyonun, operasyon süresinin dört saatten fazla olmasının ve peroperatif inotrop kullanımının pulmoner komplikasyon gelişimi açısından istatistiksel olarak anlamlı olduğu görüldü. Pulmoner komplikasyon için bağımsız değişkenler; intraoperatif inotrop kullanımı, preoperatif antikoagülan kullanımı, kanamaya bağlı revizyon, yüksek "Sequential Organ Failure Assessment (SOFA)" skoru, düşük birinci saniyedeki zorlu ekspiratuvar volüm 1 (FEV1) ve düşük preoperatif hemoglobin değerleri olarak bulundu.

Sonuç: Akciğer rezeksiyonu sonrası ortaya çıkan pulmoner komplikasyonda birçok risk faktörü tanımlanmıştır. Bu çalışmada, pulmoner komplikasyon için bağımsız risk faktörleri; intraoperatif inotrop kullanımı, preoperatif antikoagülan kullanımı, kanama nedeniyle revizyon, yüksek SOFA skoru, düşük FEV1 ve düşük preoperatif hemoglobin değerleri olarak tespit edildi.

Anahtar sözcükler: Akciğer rezeksiyonu, pulmoner komplikasyon, torakotomi, video yardımlı torakoskopik cerrahi

Please cite this article as: "Özgür Y, Ulukol A. Evaluation of Risk Factors for Respiratory Complications After Lung Resection. GKDA Derg. 2022;28(1):15-23".

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Submitted Date: September 29, 2021 **Accepted Date:** December 09, 2021 **Available Online Date:** February 25, 2022

Introduction

Post-operative pulmonary complications (PC) remain a common occurrence after lung resection and can cause serious morbidity and mortality. Despite advances in surgical techniques, anesthesia, and intensive care strategies, the mortality rate is 2-12%.[1,2] The incidence of PC after lobectomy or pneumonectomy is around 50%. Common risk factors for the development of PC include age, preoperative pulmonary function, cardiovascular comorbidity, smoking, and chronic obstructive pulmonary disease (COPD).[2]

Postoperatively, patients may develop a wide range of clinically significant PC that adversely affect the patient's clinical course, such as pneumonia, atelectasis, respiratory failure, pulmonary embolism, pleural effusion, pneumothorax, and pulmonary edema.[3-5] The aim of this study was to evaluate the demographic characteristics and risk factors of patients who underwent lung resection (lobectomy and pneumonectomy) and subsequently developed PC.

Methods

Patients

We retrospectively reviewed data pertaining to 1186 patients who underwent lung resection in our institution between 2017 and 2020. Of these, 124 patients with PC were included in the study group and 215 consecutive patients who underwent surgery between May 2019 and January 2020 and did not develop any complications were included in the control group. The surgical procedure was determined according to current guidelines for pneumonectomy and lobectomy. Patients who had surgery during this period were performed in the same center and by surgical teams applying the same surgical technique. Resections were performed through thoracotomy or video-assisted thoracoscopic surgery (VATS). Emergency cases were not included in the study.

Perioperative Assessment

The patients' age, sex, body mass index (BMI), comorbid cardiovascular conditions, previous history of myocardial infarction (MI), angina pectoris, hypertension (HT), arrhythmia, cerebrovascular accident (CVA), preoperative pulmonary function test results, presence/absence of lung cancer, pre-operative chemotherapy, type of pulmonary resection, operative time, perioperative blood loss (intraoperative and first 24 h post-operative), and post-operative analgesic treatments were recorded. The patients' preoperative American Society of Anesthesiologists' scores (ASA) were calculated. Pre-operative information was given to the patients about pain management and assessment.

Antibiotic prophylaxis was administered preoperatively. All surgical procedures were performed by the same team under a similar general anesthesia protocol after premedication with midazolam. Intravenous (IV) propofol 2-3 mg/kg and fentanyl 2 µg/kg fentanyl were used for induction. As a muscle relaxant, 0.5 mg/kg IV rocuronium bromide was administered. A double-lumen endobronchial tube was placed on the right or left as appropriate and its position was confirmed by fiberoptic bronchoscopy (FBS). Anesthesia was maintained with 50% oxygen, 50% air, and 2% sevoflurane. Remifentanil IV infusion was continued throughout the operation.

The lungs were ventilated with a tidal volume (Vt) of 8 ml/kg (ideal weight), 5 cm H_2O positive final expiratory pressure (PEEP), and 40-50% fraction of inspired oxygen (FiO_2). Care was taken to maintain end-tidal carbon dioxide ($EtCO_2$) at 30-35 mmHg. During one-lung ventilation, we used Vt of 6 ml/kg (ideal weight), 5 cm H_2O PEEP, and 60-100% FiO_2 to maintain SpO_2 at 90% or higher.

At the end of surgery, the neuromuscular block was reversed systemically with IV sugammadex 2-4 mg/kg. Under normal conditions, all patients were extubated and transferred to the recovery unit after the operation. From the recovery unit, patients were transferred to the surgical intensive care unit (ICU). Post-operative pain control was achieved mainly with intercostal block and IV patient-controlled analgesia. The same analgesic protocol was applied with all patients. The patients' pain levels were assessed using a visual pain scale ranging from 0 to 10, and care was taken to keep the patients' pain level below 4.

Follow-up examinations were performed every 24 h in the surgical ICU. Patients were given nasal oxygen (1-2 L/min) or continuous positive airway pressure (CPAP) if necessary to prevent hypoxia. The target partial pressure of oxygen (PO_2) was 70-100 mmHg and target carbon dioxide (PCO_2) was 40-55 mmHg. Heart rate (HR), electrocardiogram, oxygen saturation (SpO_2), central venous arterial pressures, and arterial blood gases were monitored continuously in the ICU. Central venous pressure was monitored at regular intervals. If ventricular contraction was markedly impaired, inotropic support was provided with norepinephrine, dopamine, or dobutamine. The perioperative need for blood products was determined individually for each patient; generally, blood transfusions were performed if the hemoglobin level fell below 7 g/dL. Post-operative FBS was performed in case of lung atelectasis and to obtain bronchial secretion samples for microbiological examinations. Mechanical ventilation was initiated in case of respiratory failure. Postoperative Sequential Organ Failure Assessment (SOFA) and Acute Physiology and Chronic Health Assess-

ment II (APACHE II) scores of each patient who went to the ICU were calculated.

Postoperatively, low-molecular-weight heparin was administered for 2-4 weeks. All patients underwent an active physiotherapy program including deep breathing exercises and incentive spirometry in the preoperative and postoperative period. Early oral intake and mobilization were initiated.

Definitions of Post-operative Complications

Complications occurring within 30 days after surgery were regarded as postoperative complications. Death was analyzed as a separate complication.

PC

Nosocomial pneumonia: In patients receiving mechanical ventilation, nosocomial pneumonia was diagnosed in the presence of a new and persistent lung infiltration and purulent tracheal secretion confirmed by bacterial culture. Spontaneously breathing patients were diagnosed if the chest X-ray was consistent with the diagnosis, Gram staining showed purulent sputum, and the presence of a microorganism was confirmed by sputum culture. Acute respiratory distress: Post-operative ventilator dependency; conditions requiring intubation or CPAP for controlled ventilation. Prolonged air leak: Air leak that required post-operative chest tube drainage for 7 days or longer. Pulmonary embolism: Confirmed cases demonstrated by pulmonary angiography or probable cases supported by pulmonary ventilation/perfusion scan. Acute respiratory distress syndrome: Acute onset PaO_2/fraction of inspired oxygen lower than 200 mmHg and presence of bilateral infiltrates on posterior-anterior lung X-ray. Pneumothorax: Cases that were demonstrated on chest X-ray or computed tomography and required chest tube placement. Bronchospasm: Wheezing increased airway pressure or prolonged expiratory phase while on positive-pressure ventilation.

Other Complications

Cardiac and neurological complications and acute renal failure were recorded. Some patients developed multiple complications. Arrhythmias, HT, angina, and MI were regarded as cardiac complications. This study was approved by the Ethics Committee of Hospital. Confirmed number/date Date: 01/10/2020, No: 2020-34. All patients signed a written consent form for the study.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics® version 23.0 (IBM Corp, Armonk, NY). Mean, standard deviation (SD), minimum, and maximum values were used to summarize quantitative variables, while frequency and percentage values were given for qualitative variables. Normally distributed data were reported as mean±SD and compared between groups using Student's t-test. Qualitative variables were analyzed using Pearson's Chi-square test, or Fisher's exact test for small groups. Nonnormally distributed continuous variables were reported as median and interquartile range (25^{th}-75^{th} percentile) and compared using Mann-Whitney U test. Results with p-values lower than 0.05 were considered statistically significant. Variables were compared between patients with and without post-operative PC. Using the variables significantly associated with post-operative PC in univariate analysis, multivariate analysis was performed to identify independent risk factors for PC.

Results

The patients had a mean age of 58.9±12.1 (range, 18-83) years and most were male (82.0%, n=278). The mean BMI was 27.0±4.3 (range, 17-40) and the patients' mean pre-operative forced expiratory volume in the 1^{st} s (FEV1) was 2.26±0.64 L (range, 0.79-4.00 L). The majority of patients were ASA Class I-II (n=278, 82.0%). The patients' mean APACHE II and SOFA scores were 8.7±4.1 and 0.89±1.90, respectively. Surgery was performed due to lung cancer in 317 patients (93.5%) and bronchiectasis in 22 patients (6.5%). The most common surgical procedure was lobectomy (n=277, 81.7%). Approximately 75% of the operations were performed through thoracotomy (n=253). The demographic, preoperative, intraoperative, and post-operative data of the patients in the study are shown in Table 1. Lung cancer was more frequently located on the right side in patients with and without post-operative PC (p=0.05). Squamous cell carcinoma was the most common type of lung cancer (p=0.022). Cancer type and location were not associated with PC development.

During the 3-year study period, 124 patients developed post-operative PC (5.1%). The most common PC was pneumonia (n=61, 49.2%). Acute respiratory distress developed in 43 patients (34.6%), atelectasis in 21 (16.9%), pulmonary embolism in 11 (8.9%), subcutaneous emphysema in 11 (8.9%), prolonged air leak in 10 (8.1%), bronchospasm in 4 (3.2%), hemoptysis in 4 (3.2%), and pneumothorax in two patients (1.6%). Of the patients who developed PC, 31.5% (n=39) required invasive mechanical intervention and 40.3% (n=50) underwent CPAP. Extracorporeal membrane oxygenation was required by 3.2% of the patients who developed PC (n=4). Following PC, 45 patients underwent bronchoscopy and three required tracheostomy.

In the PC group, 64 (51.2%) patients also had other organ complications, including cardiac complications in 54 pa-

Table 1. Comparison of the patients with pre-operative demographic data and perioperative findings in terms of the development of PPC

Variables	Total (n=339)	Non-PPC (n=215)	PPC (n=124)	Odds Ratio	95% CI	p
Pre-operative, n (%)						
Age						
<65 years	223 (65.8)	153 (71.2)	70 (56.5)	1.904	1.200-3.020	0.006
≥65 years	116 (34.2)	62 (28.8)	54 (43.5)			
Gender						
Male	278 (82.0)	168 (78.1)	110 (88.7)	0.455	0.239-0.866	0.015
Female	61 (18.0)	47 (21.9)	14 (11.3)			
ASA						
I-II	278 (82.0)	188 (87.4)	90 (72.6)	2.630	1.496-4.625	0.001
III-IV	61 (18.0)	27 (12.6)	34 (27.4)			
CHF						
No	319 (94.1)	207 (96.3)	112 (90.3)	2.772	1.101-6.982	0.025
Yes	20 (5.9)	8 (3.7)	12 (9.7)			
CAD						
No	284 (83.8)	188 (87.4)	96 (77.4)	2.031	1.134-3.638	0.016
Yes	55 (16.2)	27 (12.6)	28 (22.6)			
HT						
No	112 (33.0)	76 (35.3)	36 (29.0)	1.337	0.829-2.156	0.234
Yes	227 (67.0)	139 (64.7)	88 (71.0)			
DM						
No	281 (82.9)	180 (83.7)	101 (81.5)	1.171	0.656-2.091	0.593
Yes	58 (17.1)	35 (16.3)	23 (18.5)			
COPD						
No	186 (54.9)	132 (61.4)	54 (43.5)	2.062	1.316-3.229	0.001
Yes	153 (45.1)	83 (38.6)	70 (56.5)			
MI/Angio/Bypass						
No	320 (94.4)	203 (94.4)	117 (94.4)	1.012	0.388-2.642	0.980
Yes	19 (5.6)	12 (5.6)	7 (5.6)			
Chronic venous insufficiency						
No	303 (89.4)	194 (90.2)	109 (87.9)	1.271	0.629-2.568	0.503
Yes	36 (10.6)	21 (9.8)	15 (12.1)			
Use of anticoagulants						
No	266 (78.5)	181 (84.2)	85 (68.5)	2.443	1.442-4.138	0.001
Yes	73 (21.5)	34 (15.8)	39 (31.5)			
Reason for surgery						
Lung cancer	317 (93.5)	195 (90.7)	112 (90.4)	0.160	0.037-0.696	0.005
Bronchiectasis	22 (6.5)	20 (9.3)	12 (9.6)			
Neo-adjuvant therapy						
No	325 (95.9)	207 (96.3)	118 (95.2)	1.316	0.446-3.883	0.618
Yes	14 (4.1)	8 (3.7)	6 (4.8)			
EF						
≥60%	262 (77.3)	173 (80.5)	89 (71.8)	1.620	0.967-2.715	0.066
<60%	77 (25.4)	42 (19.5)	35 (28.2)			
Intraoperative, n (%)						
Operation mode						
Thoracotomy	253 (74.6)	168 (78.1)	85 (68.5)	1.640	0.996-2.699	0.053
VATS	86 (25.4)	47 (21.9)	39 (31.5)			
Operation type						
LBC	277 (81.7)	188 (87.4)	89 (71.8)	2.738	1.561-4.802	<0.001
PNMC	62 (18.3)	27 (12.6)	35 (28.2)			

Table 1. Cont.

Variables	Total (n=339)	Non-PPC (n=215)	PPC (n=124)	Odds Ratio	95% CI	p
Intraoperative, n (%)						
Operation side						
Right	199 (58.7)	121 (56.3)	78 (62.9)	0.759	0.483-1.194	0.233
Left	140 (41.3)	94 (43.7)	46 (37.1)			
Intraop inotrope use						
No	321 (94.7)	214 (99.5)	107 (86.3)	34.000	4.465-258.903	<0.001
Yes	18 (5.3)	1 (0.5)	17 (13.7)			
Intraop blood transfusion						
No	303 (89.4)	206 (95.8)	97 (78.2)	6.371	2.886-14.067	<0.001
Yes	36 (10.6)	9 (4.2)	27 (21.8)			
Reoperation for bleeding						
No	320 (94.4)	214 (99.5)	106 (85.5)	36.340	4.787-275.887	<0.001
Yes	19 (5.6)	1 (0.5)	18 (14.5)			

PPC: Post-operative pulmonary complication; CI: Confidence interval; ASA: American Society of Anesthesiologists; CHF: Congestive heart failure; CAD: Coronary artery disease; HT: Hypertension; DM: Diabetes mellitus; COPD: Chronic obstructive pulmonary failure; MI: Myocardial infarction; EF: Ejection fraction; VATS: Video-assisted thoracoscopic surgery; LBC: Lobectomy; PNMC: Pneumonectomy.

tients (43.2%), acute renal failure in 10 patients (8%), and CVA in 10 patients (8%). The most common cardiac complications were arrhythmias (50%) and pulmonary edema (33.1%). Of the patients who developed PC, 88 (71%) had HT, 70 (56.5%) had COPD, and 28 (22.6%) had coronary artery disease (CAD) preoperatively. 16 (12.9%) of the patients with PC died.

When the pre-operative findings were examined, we determined that PC were significantly more frequent among patients who were over 65 years of age (p=0.006), male (p=0.01), and ASA III-IV (p=0.001); those with CHD (p=0.02), CAD (p=0.01), or COPD (p=0.001); and those who were operated for lung cancer (p=0.005) or had a history of anticoagulant use (p=0.001). In terms of intraoperative variables, the frequency of PC was statistically higher in patients who underwent pneumonectomy (p<0.001), received intraoperative inotrope (p<0.001) or intraoperative blood transfusion (p<0.001), and had revision due to hemorrhage (p<0.001). The other variables did not differ significantly between patients with and without PC (Table 1).

Evaluation of the relationship between PC and selected parameters revealed that patients with PC had significantly higher APACHE II score (p<0.001), SOFA score (p<0.001), and BMI (p=0.007) but lower FEV1 (p<0.001) and hemoglobin level (p<0.001) compared to patients without PC (Table 2). In addition, patients with PC also had significantly longer operative time, ventilation time, and intensive care length of stay (p<0.001 for all).

In the multiple logistic regression analysis including the independent variables shown to be associated with PC in Tables 1 and 2, it was found that intraoperative inotrope administration (p=0.04), revision due to hemorrhage (p=0.009), SOFA (p<0.001), FEV1 (p=0.04), and pre-operative hemoglobin level (p=0.03) were independent risk factors for the development of PC (Table 3). The distributions

Table 2. Comparison of selected parameters according to post-operative pulmonary complications (PPC)

Variables	Total (n=351)	Non-PPC	PPC	p
BMI, mean±SD	27.0±4.3	26.5±4.5	27.8±4.0	0.007
APACHE II, mean±SD	8.7±4.1	7.6±2.6	10.8±5.3	<0.001
SOFA, mean±SD	0.89±1.90	0.12±0.35	2.23±2.62	<0.001
FEV1, mean±SD	2.26±0.64	2.39±0.64	2.05±0.59	<0.001
Hg, mean±SD	12.5±1.4	12.8±1.5	11.9±1.1	<0.001
Operative time (hours), mean±SD	3.8±0.7	3.7±0.7	4.0±0.7	<0.001
Ventilation time (days), mean±SD	1.3±0.7	1.0±0.0	2.0±0.9	<0.001
ICU stay (days), mean±SD	2.5±4.3	1.0±0.0	5.1±6.4	<0.001

BMI: Body mass index; APACHE: Acute Physiology and Chronic Health Evaluation Score; SOFA: Sequential Organ Failure Assessment Score; FEV1: Forced expiratory volume in the 1st s; Hg: Hemoglobin; ICU stay: Intensive care unit stay.

Table 3. Multivariate logistic regression analysis for PPC

Variables	Odds ratio	95% CI	p
Age ≥65 years	0.762	0.293-1.794	0.489
Gender (male)	0.744	0.257-2.141	0.583
ASA (III-IV)	1.223	0.423-3.528	0.701
CHF	2.189	0.498-7.373	0.301
CAD	2.202	0.555-8.732	0.261
COPD	1.796	0.802-4.026	0.154
Use of anticoagulants	1.055	0.280-3.962	0.936
Lung cancer	0.258	0.027-3.229	0.293
Pneumonectomy	0.862	0.257-2.958	0.814
Perioperative inotrope use	16.686	1.047-265.944	0.04
Intraoperative blood transfusion	0.350	0.060-2.018	0.240
Reoperation for bleeding	43.743	2.524-752.765	0.009
BMI	1.023	0.938-1.117	0.597
APACHE II	0.905	0.775-1.057	0.207
SOFA	16.293	7.805-34.011	<0.001
FEV1	0.506	0.256-0.998	0.04
Hg	0.729	0.546-0.975	0.03
Thoracotomy	7.87	2.72-22.76	0.001

PPC: Post-operative pulmonary complication; CI: Confidence interval; ASA: American Society of Anesthesiologists; CHF: Congestive heart failure; CAD: Coronary artery disease; COPD: Chronic obstructive pulmonary failure; BMI: Body mass index; APACHE: Acute Physiology and Chronic Health Evaluation Score; SOFA: Sequential Organ Failure Assessment Score; FEV1: Forced expiratory volume in the 1st s; Hg: Hemoglobin.

of patients, surgical techniques, and complications during the study period are summarized in Table 3.

Discussion

In the literature, PC incidence rates ranging between 7% and 49% have been reported. In the present study, the incidence was 5.1%. The high number of wedge resections and the frequent use of the VATS method may have contributed to this low rate. High mortality and morbidity rates, which are associated with prolonged hospital stay and increased costs, are still an important problem. The incidence of PC-related mortality varies between 4.46% and 26.9%.[5] In our study, mortality was observed in 12.9% of patients who developed PC, consistent with the range seen in the literature.

Nosocomial pneumonia is the most common fatal PC complication. It was also the most common complication in our study, accounting for 49.7% of PCs. The presence of pneumonia is associated with prolonged hospital stay and a 19% increase in mortality. Acute respiratory failure is reported in the literature to be the third most common PC, with an incidence ranging from 2.4% to 17%. Contrary to the literature, it was the second most common complication in our study, accounting for 43.6% of PCs.

The third most common complication in our patients was atelectasis (n=21, 16.9%). Atelectasis is among the frequent complications that occur after thoracotomy and thoracic surgery. It increases in severity from post-operative day 2 to day 4. Contributing factors include post-operative reduction in lung compliance, impaired regional ventilation, and airway obstruction due to secretions.[6,7]

Of the patients in our study who developed PC, 31.5% required invasive mechanical intervention and 40.3% were supported with CPAP. Patients without complications were transferred to the ward after 1 day of intensive care follow-up, while those with PC had a mean length of ICU stay of 5.1 days. Risk factors for PC in various studies included age >70 years, ASA ≥III, BMI ≥30 kg/m^2, prolonged operative time, smoking, presence of anemia, pneumonectomy, and the presence of comorbidities such as COPD, diabetes mellitus (DM), CVA, and chronic renal failure.[8-11] In the present study, development of PC was significantly associated with age >65 years, male sex, presence of CAD, CHF, and COPD, pneumonectomy, intraoperative use of blood products, reoperation due to hemorrhage, operative time >4 h, and perioperative use of inotropes. Independent risk factors for PC were identified as intraoperative inotrope use, preoperative anticoagulant use, revision due to hemorrhage, high SOFA score, low FEV1, and low preoperative hemoglobin values.

Wang et al.[12] reported mean FEV1 values of 1.96±0.12 in patients with PC and 2.44±4.4 in those without PC. Ayed

et al.[2] determined that FEV1 <1.3 L was associated with the development of complications. In our study, the mean FEV1 was 2.05±0.59 L in the PC group and 2.39±0.64 L in the non-PC group. FEV1 appears to be an important indicator of PC after lung resection. The presence of severe COPD was reported to cause a 6-fold increase the risk of major postoperative complications.[8,11] In our study, the prevalence of COPD was significantly higher in the PC group.

Intraoperative hemorrhage is a complication that occurs as a result of surgical technique or coagulopathy.[2,9,10] It is reported in the literature at rates of 1-3%, with a lower frequency in VATS procedures compared to thoracotomy. Acute pulmonary edema due to blood transfusion is a common cause of mortality and morbidity and may occur within the first 6 hours after transfusion.[13] In the present study, the rate of PC was significantly higher in patients who underwent blood transfusion. Intraoperative blood transfusion was associated with higher mortality (3.4% vs. 1.7%), prolonged hospital stay in a study by Fernandes et al.[14] and higher rate of postoperative complications (53.3% vs. 30.5%) in a study by Whitson et al.[15] In addition, revision due to hemorrhage, which prolongs the total operation time, was found to be an independent risk factor for PC in our study. Anesthesia duration longer than 2 h increases the risk of postoperative PC.[7,9] The mean operative time among patients with PC in our study was 4.0±0.7 h, and extended operative time was one of the variables identified as risk factors.

Non-pulmonary disease such as CAD, DM, and HT may contribute to PC development.[14-16] In our study, the presence of CHF and CAD was found to be associated with the development of complications, but contrary to the literature, no significant relationship was observed for DM or HT. We observed that pulmonary edema was the second most common cardiac complication after arrhythmia in this study. Pulmonary edema occurs in 5-14% of patients with PC. Risk factors include advanced age, prolonged operative time, right pneumonectomy, infection, and comorbidity. Factors contributing to the development of edema include decreased left ventricular function and fluid overload exceeding the lymphatic capacity of the lungs. Pulmonary infiltrations may appear between 12 h and 5 days postoperatively.[1,3] Consistent with the literature, anticoagulant drug use due to CAD was more common in the PC group. In our study, we detected a strong association between PC and the use of inotropes due to heart failure.

Various scoring systems are used for perioperative risk assessment. The SOFA and APACHE II scores are often the most commonly used evaluation systems for mortality and morbidity assessment in non-surgical ICUs. The APACHE II score was also found to be useful in predicting post-ICU mortality, hospitalization, and re-hospitalization in postoperative patients.[17,18] For the patients in our study, pre-operative ASA scores and post-operative APACHE II and SOFA scores were determined. SOFA score was observed to be an independent risk factor for PC. The mean APACHE II score was higher among patients with PC (10.8±5.3) compared to those without. Y. Ozgur et al.[19] found that APACHE II and SOFA scores of patients after lung resection can be used in the estimation of postoperative mortality and morbidity. Another study in which cardiac surgery patients were evaluated using SOFA, Euroscore, and BNP scores showed that SOFA score was useful in the prediction of mortality.[20-23] In a study of lung transplant patients, comparison of nonsurvivors (n=28) and survivors (n=244) revealed that the non-surviving patients had higher mean SOFA (7.1 vs. 4.9) and APACHE II scores (24.2 vs. 17.4).[21] In our study, the mean SOFA score in the PC group was 2.23.

Lung resections are performed either by thoracotomy or VATS. VATS is often preferred over thoracotomy for early-stage cancers because it is a minimally invasive surgical technique. Advantages of the VATS approach over thoracotomy are the lower infection rate, rapid recovery, less muscle and bone damage, and lower need for analgesia. The incidence of PC after VATS varies between 10% and 40%. Agostini et al.[17] found this rate to be 7% in patients who underwent VATS lobectomy. In our study, PC were observed in 3.7% of VATS lobectomy patients and 8.3% in thoracotomy patients. The difference in PC rate between thoracotomy and VATS patients was statistically significant. In contrast, Lugg et al.[24] did not observe a significant difference between VATS and thoracotomy in terms of the rate of PC development in their study of 670 patients.

Conclusion

Post-operative PCs continue to be one of the main causes of increased morbidity, mortality, and length of hospital stay in patients undergoing surgical interventions that require anesthesia. In this study, we examined the comorbidities and perioperative characteristics of patients with PC and determined that the development of PC was significantly associated with age >65 years, male sex, presence of CAD, CHF, and COPD, pneumonectomy, intraoperative use of blood products and inotropes, reoperation due to hemorrhage, and operative time >4 h. Independent risk factors for PC were identified as intraoperative inotrope use, pre-operative anticoagulant use, revision due to hemorrhage, high SOFA score, low FEV1, and low pre-operative hemoglobin values. Early detection of patients at high risk of post-operative complications and appropriate operative management may reduce the risk of post-operative mortality and morbidity.

Disclosures

Ethics Committee Approval: The study was approved by The Istanbul Yedikule Chest Diseases and Thoracic Surgery Training and Research Hospital Clinical Research Ethics Committee (Date: 01/10/2020, No: 2020-34).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Financial Disclosure: The authors declared that this study has received no financial support.

Authorship Contributions: Concept – Y.Ö.; Design – Y.Ö.; Supervision – A.U.; Fundings – Y.Ö., A.U.; Materials – A.U.; Data collection &/or processing – Y.Ö.; Analysis and/or interpretation – Y.Ö.; Literature search – Y.Ö., A.U.; Writing – Y.Ö.; Critical review – Y.Ö.

Etik Kurul Onayı: Çalışma İstanbul Yedikule Göğüs Hastalıkları ve Göğüs Cerrahisi Eğitim ve Araştırma Hastanesi Klinik Araştırmalar Etik Kurulu tarafından onaylandı (Tarih: 01/10/2020, Numara: 2020-34).

Hasta Onamı: Hastalardan yazılı onam alınmıştır.

Hakem değerlendirmesi: Dışarıdan hakemli.

Çıkar Çatışması: Çıkar çatışması bulunmamaktadır.

Finansal Destek: Yazarlar bu çalışmanın herhangi bir finansal destek almadığını beyan etmişlerdir.

Yazarlık Katkıları: Fikir – Y.Ö.; Tasarım – Y.Ö.; Denetmeler – A.U.; Kaynaklar – Y.Ö., A.U.; Malzemeler – A.U.; Veri Toplanması ve/veya İşlemesi – Y.Ö.; Analiz ve/veya Yorum – Y.Ö.; Literatür Taraması – Y.Ö., A.U.; Yazıyı Yazan – Y.Ö.; Eleştirel İnceleme – Y.Ö.

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