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Incidence and predictors of postoperative pneumonia after cardiothoracic surgery

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ABSTRACT

Aims: The objective of this study was to examine risk factors and predictors that contribute to the development of postoperative pneumonia (POP) following cardiothoracic surgery.

Methods: This was a prospective, observational study including patients who underwent major cardiothoracic surgery and survived the initial 48 postoperative hours. POP was diagnosed based on the Centers for Disease Control and Prevention criteria. Preoperative, intraoperative, and postoperative variables were analyzed to determine their association with the occurrence of POP.

Results: A total of 278 consecutive patients (mean age: 51±22.91 years, male sex 68%) were included in the study. POP incidence was 6.87 per 1000 days of hospitalization. Significant risk factors for POP were identified as history of renal disease [odds ratio (OR) 3.9, 95% confidence interval (CI) 1.1-13.5, p=0.040)], central nervous system disorder (OR 12.8, 95% CI 4-40.5, p<0.001), postoperative aspiration (p=0.008), absence of respiratory exercise after surgery (OR 2.5, 95% CI 1-6.3, p=0.041), and presence of postoperative complications other than pneumonia (e.g. acute renal failure) (OR 7.2, 95% CI 2.3-22, p=0.002). Patients with POP had significantly longer mechanical ventilation (p<0.001), hospitalization (p<0.001), and mobilization durations (p=0.006) than those without pneumonia. Multivariate analysis revealed that prolonged postoperative mobilization duration (OR 1.8, 95% CI 1.08-2.84, p=0.022), presence of postoperative complications other than pneumonia (OR 12.7, 95% CI 1.73-92.31, p=0.012), and longer postoperative hospitalization duration (OR 1.1, 95% CI 1.02-1.19, p=0.011) were independent predictors of POP.

Conclusions: This study demonstrates that POP remains a considerable complication after cardiothoracic surgery. Pre-existing renal and neurologic disorders, postoperative aspiration, and inadequate respiratory exercises were identified as major risk factors. Prolonged postoperative mobilization duration, and longer postoperative hospitalization duration along with the presence of other postoperative complications, were identified as independent predictors of POP, highlighting the need for early risk stratification and targeted preventive strategies.

Introduction

Postoperative pneumonia (POP) is a nosocomial pneumonia or ventilator-associated pneumonia (VAP) in patients who are in the postoperative period (1). POP is one of the most frequent nosocomial infections after major surgery, which is associated with increased mortality, morbidity, and prolonged hospitalization (2). The incidence of POP differs among patients, hospitals, and types of surgery, and varies from 5% to 80% (3,4). To the best of our knowledge, there is no study regarding surveillance and risk factors of POP in our country. This study sought to identify potential risk factors for POP following cardiothoracic surgery, with the aim of reducing its incidence by targeting modifiable risks.

Methods

Patient population

This study had a prospective and observational design and was performed at the Cardiovascular Surgery and Thoracic Surgery units of Gazi University Hospital between June 2010 and May 2011. Patients who had major cardiothoracic surgery and survived the first 48 postoperative hours were consecutively included in the study. Patients who underwent minor surgical procedures and who were hospitalized for less than 48 hours were excluded from the study. The epidemiological and clinical data of the patients were recorded. Approval for the study was obtained from the Ethics Committee at the Gazi University Medical Faculty Institutional Review Board (decision number: 018, date: 02.06.2010), which stated that informed consent from participants was unnecessary due to the absence of any intervention.

Surveillance

Active prospective surveillance was performed by visiting patients every day. Patient characteristics were recorded on the POP surveillance form. The following data were included on the POP surveillance form: demographic characteristics, underlying diseases, previous surgery, survival status, risk factors for infections, invasive materials (e.g., chest tube, urinary catheter), type of surgery, surgery date, mean duration of surgery, surgical wound classification (clean, clean-contaminated, contaminated, dirty-infected), American Society of Anesthesiologists (ASA) score, the other characteristics of surgery (open or laparoscopic, emergent or elective, general or local anesthesia), prophylactic or therapeutic antibiotics, postoperative complications, infections (surgical site infections, urinary tract infections, intraabdominal infections), cultures, and antimicrobial susceptibility results. Risk factors for POP were categorized and analyzed based on the timing: preoperative, operative, and postoperative.

Prophylactic antibiotics were administered 60 minutes before the surgical incision to ensure optimal tissue concentration during surgery according to current clinical guidelines. The duration of prophylaxis did not exceed 24 hours postoperatively (1). Respiratory exercise was administered to all patients with thoracic intervention. However, patients who underwent surgery with local anesthesia or those who had peripheral vascular surgery did not receive respiratory exercise unless they had significant respiratory disease.

Nosocomial pneumonia and VAP were diagnosed according to the Center for Diseases Control (CDC) and Prevention criteria (4). According to the CDC criteria used to define nosocomial infections for the diagnosis of nosocomial pneumonia in adults, one of the following criteria must be present:

1. Rales or dullness to percussion on physical examination of chest and any of the following:
   a. New onset of purulent sputum or change in character of sputum
   b. Organism isolated from blood culture
   c. Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy.
2. Chest radiographic examination shows new or progressive infiltrate, consolidation, cavitation, or pleural effusion and any of the following:
   a. New onset of purulent sputum or change in character of sputum
   b. Organism isolated from blood culture
   c. Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy
   d. Isolation of virus or detection of viral antigen in respiratory secretions
   e. Diagnostic single antibody titer (immunoglobulin M) or fourfold increase in paired serum samples (immunoglobulin G) for pathogen
   f. Histopathologic evidence of pneumonia.

Isolation site of microorganisms were from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy and blood culture. According to our study design cultures were obteined beyond the 48 hour following surgery.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as means with standard deviations, and 95% confidence intervals (CIs) if normally distributed, or as medians with interquartile ranges when the distribution was skewed. Discrete variables were reported as percentages. Comparisons of variables were made using the chi-square test, Fisher's exact test, Mann-Whitney U test, and logistic regression (LR) analysis. LR analysis was used to identify the prognostic factors for the occurrence of POP. The Backward LR method was applied in the LR analysis. Univariate

analyses were performed before the regression model was created. Statistically significant variables in univariate analyses and significant ones in literature were added to the model. p<0.05 was considered statistically significant. The final model in the LR analysis was presented.

Results

Patient characteristics

A total of 278 patients (68% male) were included in the study. The mean age was 51±22.91 years. Of these, 200 (71.9%) were hospitalized in the cardiovascular surgery department and 78 (28.1%) in the thoracic surgery department. Demographic characteristics, underlying diseases, risk factors, and type of surgery are presented in Table 1. Perioperative antimicrobial prophylaxis was given to all patients. A single dose of intravenous prophylactic antibiotics was given within 60 minutes before the incision. Cefazolin 2 g (82.7%), ampicillin-sulbactam 3 g (10.8%), and other drugs (6.5%) were used for the antimicrobial prophylaxis. Dose adjustment was made according to creatinine clearance as recommended (1). The mean duration of the surgery was 264.75±112.75 minutes, and the mean duration of hospitalization was 13.6±12.32 days.

Nosocomial infection rate and the incidence of pneumonia

Fifty-six of 278 patients (20.1%) had a nosocomial infection after surgery. The most frequent nosocomial infection was pneumonia (26, 9.4%), followed by surgical site infection (22, 7.9%), bloodstream infection (3, 1.1%), intra-abdominal infection (2, 0.7%), and urinary tract infection (1, 0.4%). POP incidence was found to be 6.87 per 1000 hospitalization days. Eleven of the POP cases (42.3%) were diagnosed with VAP. The incidence of VAP in the mechanically ventilated population was 26 per 1000 ventilation days.

The microorganisms

The microorganisms responsible for POP in this study were *Acinetobacter baumannii* (15.4%), *Klebsiella species* (11.5%), *Escherichia coli* (11.5%), and *Pseudomonas aeruginosa* (7.7%). Gram-positive pathogens were not isolated. Culture results were negative in 53.8% of the cases.

Risk factors for postoperative pneumonia

History of renal disease [odds ratio (OR) 3.9, 95% CI 1.1-13.5, p=0.040] and central nervous system disorder (OR 12.8, 95% CI 4-40.5, p<0.001), aspiration after surgery (p=0.008), absence of respiratory exercise after surgery (OR 2.5, 95% CI 1-6.3, p=0.041), presence of postoperative complications other than pneumonia (e.g. acute renal failure) (OR 7.2, 95% CI 2.3-22, p=0.002) were significant preoperative risk factors for POP (Table 2). As shown in Table 3, patients with POP had markedly longer durations of mechanical ventilation [median 1.5 (0-30)

Table 1. Demographic characteristics (n=278)

Characteristic	n (%)
Sex, male	189 (68)
Department, cardiovascular surgery/thoracic surgery	200/78 (71.9/28.1)
Underlying diseases	
Atherosclerotic heart disease	123 (44.2)
Hypertension	101 (36.3)
Diabetes mellitus	71 (25.5)
Malignant neoplasm	68 (24.5)
Peripheral vascular disease	35 (12.6)
Hyperlipidemia	20 (7.2)
Previous myocardial infarction	18 (6.5)
Renal disease	15 (5.4)
Congestive heart failure	15 (5.4)
Central nervous system disorder	14 (5)
Respiratory failure/chronic obstructive pulmonary disease	11 (4)
Obesity	11 (4)
Pulmonary hypertension	6 (2.2)
Severe ventricular dysfunction (EF <30%)	4 (1.4)
Immunosuppression	3 (1.1)
The use of H_2 receptor blockers	186 (66.9)
The use of steroid	2 (0.7)
Smoking	85 (30.6)
Alcohol use	7 (2.5)
Hospitalization in the last 6 months	58 (20.9)
Use of antibiotics in the last 6 months	58 (20.9)
Previous surgery other than cardiac surgery	94 (33.8)
Previous cardiac surgery	19 (6.8)
Previous cardiac surgery (in the last 1 year)	2 (0.7)
Indication (surgery)	
Elective	258 (92.8)
Emergent	20 (7.2)
American Society of Anesthesiologists score	
1	2 (0.7)
2	152 (54.7)
3	120 (43.2)
4	4 (1.4)
5	-
Type of surgery	
Coronary artery surgery	104 (37.4)
Pulmonary resection	67 (24.1)
Congenital disease surgery	32 (11.5)
Valvular replacement	25 (9)
Coronary artery bypass grafting surgery	17 (6.1)
Arterial embolectomy	13 (4.7)

Table 1. Demographic characteristics (n=278)	
Characteristic	**n (%)**
Thoracic wall surgery	12 (4.3)
Aortic surgery	8 (2.9)
Surgical wound classification	
Clean	275 (98.9)
Clean-contaminated	2 (0.7)
Contaminated	1 (0.4)
Dirty-infected	-
Type of surgery	
Open	275 (98.9)
Thoracoscopic	3 (1.1)
Type of anesthesia	
General	270 (97.1)
Local	6 (2.2)
Spinal/epidural	2 (0.7)
Mortality	31 (11.2)
EF: Ejection fraction	

Table 2. Significant risk factors for postoperative pneumonia			
Variables	**OR**	**95% confidence interval**	**p-value**
History of renal failure	3.9	1.1-13.5	**0.040**
Central nervous system disorder	12.8	4-40.5	**<0.001**
Aspiration after surgery	-	-	**0.008**
Absence of respiratory exercise after surgery	2.5	1-6.3	**0.041**
Presence of postoperative complications	7.2	2.3-22	**0.002**

vs. 0 (0-38) days, p<0.001], postoperative hospitalization [15 (6-44) vs. 6 (0-52) days, p<0.001], and postoperative mobilization [4.5 (1-41) vs. 1 (0-147) days, p<0.001] than those without pneumonia. Among survivors, postoperative mobilization time also remained significantly prolonged [2 (1-10) vs. 1 (0-10) days, p=0.006].

Multivariate analysis revealed that prolonged postoperative mobilization duration (OR 1.8, 95% CI 1.08-2.84, p=0.022), presence of postoperative complications other than pneumonia (OR 12.7, 95% CI 1.73-92.31, p=0.012), and longer postoperative hospitalization duration (OR 1.1, 95% CI 1.02-1.19, p=0.011) were independent predictors of POP (Table 4).

Mortality

Overall mortality was 11.2% (31 patients). Mortality was significantly higher in patients with POP (OR 11.38, 95% CI 4.43-29.48, p<0.001) and nosocomial infections other than pneumonia (OR 3.56, 95% CI 1.29-9.64, p=0.010), and in patients who needed inotropic support (OR 2.54, 95% CI 1.02-6.22, p=0.044). A high ASA score was a significant risk factor for mortality as well (Table 5). No statistically significant relationship was identified between the type of surgery and mortality outcomes.

Discussion

According to our results, POP incidence was 6.87 per 1000 admission days and significant risk factors for POP were as follows: history of renal disease, central nervous system disorder, high ASA score, aspiration after surgery, absence of respiratory exercise after surgery, presence of postoperative complications other than pneumonia (e.g., acute renal failure), duration of mechanical ventilation, duration of postoperative hospitalization days, and duration of postoperative mobilization days. The significant risk factors for mortality were pneumonia and other nosocomial infections, the necessity of inotropic support, and a high ASA score.

POP, a type of nosocomial pneumonia, is one of the important postoperative complications after abdominal and cardiothoracic surgeries. Possible causes of POP are colonization of microorganisms at the secretion retention area, unresolved atelectasis area, or unnoticed aspiration of pathogenic microorganisms. Therefore, patients who require prolonged respiratory support and are unable to expel tracheobronchial secretions are at higher risk for the development of POP (5,6).

Pneumonia was the most frequent nosocomial infection after surgery in our study population, with 26 cases (9.4%), and 11 patients (42.3%) were diagnosed with VAP. POP incidence was 6.87 per 1,000 hospitalization days. There are few studies in the literature on the prevalence of POP, which show that the prevalence of POP after cardiac surgery varies between 1.02% and 15.3% (7-9). Some studies have reported a higher prevalence of POP compared to previous findings. Since most previous studies included patients undergoing major cardiac surgery, the prevalence may be expected to be higher. The number of POP/the patient days x1000 formula was used to calculate the incidence of POP in our study. However, “POP rate=number of POP/number of surgery x100” formula was commonly used for the incidence of POP in most of the previous studies. Therefore, as far as we know, our study is the first in which POP incidence was calculated using hospitalization days. The length of hospital stay is an important factor in the context of nosocomial infections for several reasons. The longer a patient stays in the hospital, the greater their exposure to the hospital environment, including surfaces, equipment, and healthcare workers, all of which can harbor infectious agents. This increased exposure heightens the risk of acquiring an infection. Extended hospital stays often involve prolonged use of medical devices such as catheters, ventilators, or intravenous lines, which are common sources of

Table 3. Significant postoperative time-related risk factors for the development of postoperative pneumonia

Postoperative risk factors	Pneumonia	No pneumonia	p-value
	Median (min-max)	Median (min-max)	Median (min-max)
Duration of mechanical ventilation days	1.5 (0-30)	0 (0-38)	**<0.001***
Duration of postoperative hospitalization days	15 (6-44)	6 (0-52)	**<0.001***
Duration of postoperative mobilization days	4.5 (1-41)	1 (0-147)	**<0.001***
Duration of postoperative mobilization days (survivors)	2 (1-10)	1 (0-10)	**0.006***

*Mann-Whitney U Test, min-max: Minimum-maximum

Table 4. Predictors of postoperative pneumonia

*Variables	OR	95 % confidence interval	p-value
Mobilization days	1.8	1.08-2.84	**0.022**
Presence of postoperative complications	12.7	1.73-92.31	**0.012**
Postoperative hospilization days	1.1	1.02-1.19	**0.011**

Backward logistic regression method was applied
*The model contains renal failure, central nervous system disorder, presence of aspiration after surgery, presence of respiratory exercise after surgery, presence of postoperative complications, ASA score, need for transfusion, duration of postoperative hospitalization days, duration of postoperative mobilization days
ASA: American Society of Anesthesiologists, OR: Odds ratio

nosocomial infections. The risk of infection generally increases with the duration of device use. Furthermore, longer stays involve more interactions with healthcare workers, which can increase the risk of cross-contamination, especially if infection control protocols are not strictly followed.

The incidence of POP was reported to range from 2% to 25% in previous studies (10,11). This may be justified by the presence of mixed populations with variable age groups, underlying conditions, and differences in pneumonia definitions. Clinical and radiological symptoms and signs were considered sufficient for the diagnosis of pneumonia in some studies, which reported higher rates. Considering microbiologically documented infection as a requirement for the diagnosis of pneumonia may lead to a lower incidence. When microbiologically documented infection is considered to be a necessity for the diagnosis of pneumonia, it can lead to a low incidence. Another problem in POP incidence studies is the evaluation of pneumonia and related complications (atelectasis and secretion retention) together. For these reasons, the true incidence of POP is unknown, although it is estimated to be approximately 10% (10,12).

The incidence of VAP in the mechanically ventilated patient population was 26 per 1000 ventilation days in our study population. In the study by Hortal et al. (12), the incidence of VAP was 45.9% in the patients who remained ventilated for more than 48 hours. The incidence of VAP was 7.87% in the patients undergoing cardiac surgery in the study by Bouza et al. (13). The variation in results may be attributed to the presence of patient populations with diverse underlying diseases.

Microbiological documentation of POP was made in only 46.2% of our patients. The difficulty of obtaining a culture specimen in non-VAP nosocomial pneumonias and the early empirical administration of antibiotics may reduce the percentage of microbiological documentation in these cases. The most frequently isolated microorganisms from POP were *Acinetobacter baumannii* (15.4%), *Klebsiella species* (11.5%), *Escherichia coli* (11.5%), and *Pseudomonas aeruginosa* (7.7%). Although the majority of our patients (61.5%) developed early-onset pneumonia, isolated microorganisms were mostly late-onset pneumonia pathogens in our study. Similarly, Giantsou et al. (14) showed that both early-onset and late-onset VAP were mainly caused by potentially multiresistant gram-negative bacteria and *methicillin-resistant Staphylococcus aureus*. Therefore, distinguishing between early-onset and late-onset VAP according to the isolated microorganisms is considered no longer clinically valuable (13).

Duration of mechanical ventilation and the need for blood component transfusions were found to be significant postoperative risk factors for POP in a study conducted in our country. Consistent with our findings, the use of postoperative mechanical ventilation and the duration of mechanical ventilation have been reported as the most significant risk factors for the development of POP (15). Many reported studies have commented that shortening the duration of mechanical ventilation or encouraging non-invasive mechanical ventilation would reduce the development of postoperative VAP (16,17).

There is an increased risk of aspiration in patients who have neurological dysfunction due to the affected swallowing reflex. This situation leads to the aspiration of microorganisms that colonize the oropharynx and to the development of hospital-acquired pneumonia. The presence of neurological dysfunction before the surgery was a significant risk factor for POP in Bouza et al. (13) and Leal-Noval et al. (18) studies, consistent with our study.

The incidence of postoperative complications after lung resection was 24-48% (19,20). The following postoperative complications can develop in patients undergoing cardiothoracic surgery: acute renal failure, low cardiac output syndrome, bleeding, and others. The risk of developing POP also increases

in patients who experience postoperative complications. The presence of at least one of the postoperative complications was found to be a significant risk factor for POP in our study. In the study of Lee et al. (20), the presence of postoperative complications was a significant risk factor for the development of POP, similar to our results.

A high ASA score was also significantly associated with the development of POP in our study, which is consistent with previous reports (13,21). There was a linear relationship between a high ASA score and the development of POP.

Cardiopulmonary physical therapy is frequently used to prevent and treat sputum retention, atelectasis, pneumonia, and bronchopulmonary infections. Prolonged immobilization increases the risk of atelectasis, while cardiopulmonary physical therapy helps reduce pulmonary complications and shortens the postoperative recovery period (22). The absence of respiratory exercise after surgery was a significant risk factor for the development of POP in our study (p=0.041). The presence of aspiration after surgery, prolonged postoperative hospitalization, and mobilization days were also found to be significant risk factors for POP.

The overall mortality rate in our study population was 11.2%, and this rate was significantly higher in patients with POP, nosocomial infections other than pneumonia, inotropic support requirements, and those with high ASA scores. Consistent with our results, Garibaldi et al. (23) reported that a high ASA score was an independent risk factor for the development of POP. However, it wasn't a significant risk factor for mortality. Hypotension was also reported to be associated with higher mortality in the study by Dupont et al. (24) and in our results.

Our study has several key limitations. Firstly, it is a single-center study with a relatively small patient sample. Given the limited sample size and the insufficient number of cases for each surgical category, the incidence of POP was not stratified

Table 5. The risk factors for mortality

	Non-survivors		Survivors		OR	%95 confidence interval	p-value
	n	%	n	%			
Sex							
Male	23	12.2	166	87.8	-	-	0.561*
Female	8	9.0	81	91.0			
Pneumonia	14	53.8	12	46.2	11.38	4.43-29.48	**<0.001***
Nosocomial infection	8	26.7	22	73.3	3.56	1.29-9.64	**0.010***
Atherosclerotic heart disease	11	8.9	112	91.1	-	-	0.395*
Hypertension	13	12.9	88	87.1	-	-	0.624*
Diabetes mellitus	6	8.5	65	91.5		-	0.536*
Malign neoplasm	5	7.4	63	92.6	-	-	0.356*
Need for inotropic support	10	20.4	39	79.6	2.54	1.02-6.22	**0.044***
ASA score							
1	-	-	2	100	-	-	**<0.001***
2	8	5.3	144	94.7			
3	21	17.5	99	82.5			
4	2	50.0	2	50.0			
Type of surgery							
Valvular replacement	4	16.0	21	84.0	-	-	0.081*
Coronary artery surgery	9	8.7	95	91.3			
Congenital disease surgery	8	25.0	24	75.0			
Aortic surgery	1	12.5	7	87.5			
Arterial embolectomy	3	23.1	10	76.9			
Coronary artery bypass grafting surgery	2	11.8	15	88.2			
Pulmonary resection	4	6.0	23	94.6			
Thoracic wall surgery	-	-	12	100.0			
Age, mean ± SD	51±31		51±22		-	-	0.359**

*Chi-square test, **Mann-Whitney U Test
OR: Odds ratio, ASA: American Society of Anesthesiologists, SD: Standard deviation

by surgical type. The influence of institutional experience on outcomes is undeniable, meaning these findings may not be generalizable to other centers. Several risk factors that were not evaluated in our study may contribute to the development of POP. Additional clinical studies with a prospective and randomized design are necessary to validate our findings. Despite these limitations, we believe our results highlight the need for further research.

Conclusion

In conclusion, this study demonstrates that POP remains a considerable complication after cardiothoracic surgery. Pre-existing renal and neurologic disorders, postoperative aspiration, and inadequate respiratory exercises were identified as major risk factors. Prolonged postoperative mobilization duration, and longer postoperative hospitalization duration, along with the presence of other postoperative complications, were identified as independent predictors of POP. Early identification of high-risk patients and implementation of targeted preventive strategies may reduce the incidence of POP and improve postoperative survival.

Ethics

Ethics Committee Approval: The study was approved for the study was obtained from the Ethics Committee at the Gazi University Medical Faculty Institutional Review Board (decision number: 018, date: 02.06.2010).

Informed Consent: Informed consent from participants was unnecessary due to the absence of any intervention.

Footnotes

Authorship Contributions

Surgical and Medical Practices: S.S.Y., G.T.D., M.D., Concept: S.S.Y., G.T.D., M.D., Design: S.S.Y., G.T.D., M.D., Data Collection or Processing: S.S.Y., G.T.D., E.A., M.D., Analysis or Interpretation: S.S.Y., Z.K., E.A., M.D., Literature Search: S.S.Y., Z.K., G.T.D., E.A., M.D., Writing: S.S.Y., Z.K., G.T.D., E.A., M.D.

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