Risk Factors for the Development of Nosocomial Pneumonia and Its Clinical Impact in Cardiac Surgery

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Abstract

INTRODUCTION: The development of pneumonia after cardiac surgery is a significant postoperative complication that may lead to worse clinical outcomes. We aimed to identify risk factors associated with it and determine its clinical impact in terms of in-hospital mortality and morbidity.

METHODS: This was a cross-sectional study among all adult patients who underwent cardiac surgery from 2014 to 2019 in a tertiary hospital in the Philippines. Baseline characteristics and risk factors for pneumonia were retrieved from medical records. Nosocomial pneumonia was based on the Centers for Disease Control and Prevention criteria. Odds ratios from logistic regression were computed to determine risk factors and clinical outcomes for pneumonia using STATA 15.0 (StataCorp, College Station, Texas).

RESULTS: Of 373 patients included, 104 (28%) acquired pneumonia. Most surgeries were ere coronary artery bypass grafting (71.58%). Age, sex, body mass index, diabetes, left ventricular/renal dysfunction, chronic obstructive pulmonary disease/asthma, surgical urgency, surgical time, and smoking did not show association with pneumonia development. However, preoperative stay of >2 days was associated with 92.3% increased odds of having pneumonia ($P = 0.009$). Also, every additional hour on mechanical ventilation conferred 0.8% greater odds of acquiring pneumonia ($P = 0.003$). Patients who developed pneumonia had 3.9-times odds of mortality (95% confidence interval [CI], 1.51–9.89; $P = 0.005$), 3.8-times odds of prolonged hospitalization (95% CI, 1.81–7.90; $P < 0.001$), 6.4-times odds of prolonged intensive care unit stay (95% CI, 3.59–11.35; $P < 0.001$), and 9.5-times odds of postoperative reintubation (95% CI, 3.01–29.76; $P < 0.001$).

CONCLUSION: Among adult patients undergoing cardiac surgeries, prolonged preoperative hospital stay and prolonged mechanical ventilation were associated with an increased risk of nosocomial pneumonia. Those who developed pneumonia had worse outcomes with significantly increased in-hospital mortality, prolonged hospitalization/intensive care unit stay, and increased postoperative reintubation. Clinicians should therefore minimize delays in surgery and encourage timely liberation from mechanical ventilation after surgery.

BACKGROUND

The development of nosocomial pneumonia after cardiac surgery is a significant postoperative complication that may lead to increased morbidity, mortality, and hospital cost.[1,2] Published rates of pneumonia after cardiac surgery range from 2% to 10%.[3–8] This translates to an attributable mortality rate ranging from 5% to 70%.[2,9] Limited data exist on its clinical burden in the local setting.

Some of the comorbidities of patients with cardiac diseases are also considered to be risk factors for hospital-acquired infections. These include advanced age, chronic lung disease, heart failure, and diabetes mellitus (DM).[10] Hence, cardiac surgery patients with multiple comorbidities are particularly prone to develop hospital infections such as postoperative pneumonia.

In addition, the impairment in pulmonary mechanics may result in atelectasis and pneumonia. Cardiac surgery involves the need for sternotomy and thoracotomy to access the heart. These deep incisions result in pain, hence diminishing the patients' capacity for deep breathing and coughing. Furthermore, cardiopulmonary bypass, with its release of systemic inflammatory mediators, may contribute to the development of pneumonia.[11] Prolonged mechanical ventilation after cardiac surgery may also increase the risk of pneumonia.[12]

Apart from host factors, several hospital management processes may also affect the incidence of postoperative pneumonia.[13,14] These may include level of fluid administration, antibiotic prophylaxis, mechanical ventilatory management, strictness of handwashing implementation among health care personnel, number of visitors allowed at any given time, and cardiac intensive care unit (ICU) admission protocols. However, only a few have looked into the relationship of these "processes of care" and postoperative pneumonia in the cardiac setting.[10] Cardiac patients, who often have multiple comorbidities such as chronic obstructive pulmonary disease, heart failure, and DM, may be more susceptible to pneumonia, thus posing them at a possible higher risk of morbidity and mortality.

Our aim was to determine the time course and identify risk factors of postoperative nosocomial pneumonia in adult patients undergoing cardiac surgery. Also, we aim to determine the clinical impact of pneumonia in terms of in-hospital morbidity and mortality.

METHODS

Study Design

This was a single-center cross-sectional study with an embedded cohort study conducted among consecutive adult patients 19 years or older who underwent cardiac surgeries from the period of January 1, 2014, to December 31, 2019. This study was done at a private tertiary care hospital in the Philippines. It has a coronary care unit with 11 beds. The average number of adult cardiac surgeries being done in the institution is 76 per year.

Ethical Considerations

This study was conducted in compliance with the principles of the Declaration of Helsinki (2013) and along the Guidelines of the International Conference on Harmonization-Good Clinical Practice. The clinical protocol and all relevant documents were reviewed and approved by St Luke's institutional ethics review committee (RPC-203-10-19). Patient confidentiality was respected by ensuring anonymity of patient records. Each patient document did not contain any identifying information in order to ensure confidentiality. A three-digit code number was assigned to each patient. All study data were recorded, and investigators ensured the integrity of the data, that is, accuracy, completeness, legibility, originality, timeliness, and consistency.

Study Population

Included patients were all adult patients at least 19 years old who underwent cardiac surgical interventions, regardless of urgency, type, and patient's risk of cardiac surgery. Excluded were patients who had active concomitant infections requiring systemic antibiotics at the time of surgery.

Data for the following variables were obtained from the electronic medical records of the patients as follows: demographics and comorbidities, such as age, sex, body mass index (BMI), and presence or absence of the following: hypertension, DM, dyslipidemia, renal dysfunction, history of smoking, asthma, chronic obstructive pulmonary disease, and left ventricular systolic dysfunction; and operative factors, such as type of operative procedure, urgency of procedure, bypass time, ischemic time, total surgical time, preoperative length of hospital stay, and duration of mechanical ventilatory support.

The primary clinical outcome investigated was the development of nosocomial pneumonia after the index cardiac surgery and within the hospitalization. Other clinical outcomes include in-hospital mortality and in-hospital morbidity (prolonged hospital stay, prolonged ICU stay, and postoperative reintubation). All clinical outcomes were reviewed by two independent event adjudicators (M.N., K.R.).

Operational Definitions

Cardiac Surgery: Any surgery involving the heart wherein the patient is connected to a heart-lung bypass machine or bypass pump. This may include coronary artery bypass grafting, valvular repair or replacement, repair of aortic aneurysms, and congenital heart diseases.

A. Risk Factors

Duration of mechanical ventilatory support: Duration in hours from the time of intubation to the time of extubation from mechanical ventilation.

Ischemic time: Defined as the time interval in minutes from the application of aortic cross-clamp to release of cross-clamp applied during the cardiac surgery.

Bypass time: Defined as the total time in minutes that the patient is hooked to a cardiopulmonary bypass machine.

Preoperative length of hospital stay: Number of days of hospital stay prior to undergoing the index cardiac surgery.

Length of surgery: Total length of surgical procedure in hours as documented in the operating room record.

B. Clinical Outcomes

The nosocomial pneumonia selection criteria were based on the Centers for Disease Control and Prevention guidelines.[15] It must meet one of the following criteria:

(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 showing 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

In-hospital morbidity: Defined as having any of the following:

(1) Prolonged hospital stay: Defined as having more than 8 days of total hospitalization days after index cardiac surgery.
(2) Prolonged ICU stay: Defined as having more than 5 days of total coronary care unit stay after index cardiac surgery.
(3) Postoperative reintubation: Reintubation of a cardiac surgery patient after an initial extubation postoperatively, regardless of indication of reintubation.

In-hospital mortality: Defined as patient demise during or after the index cardiac surgery and before hospital discharge, regardless of etiology.

Sample Size Estimation

A minimum of 296 patients were required for this study based on a level of significance of 5% and a power of 80%. The 30-day postoperative mortality rates were 4.2% and 13.4% for those without pneumonia and with pneumonia, respectively. These values were based on the study by Thompson et al.[16]

Statistical Analysis

Descriptive statistics was used to summarize the general and clinical characteristics of the participants. Shapiro-Wilk test was used to determine the normality of continuous variables. Frequency and proportion were used for nominal variables and interval/ratio variables. Continuous quantitative data that meet normality assumption were summarized using mean and SD, whereas those that do not were described using median and range.

Independent-sample *t* test, Mann-Whitney *U* test, and Fisher exact/χ^2 test was used to determine the differences in distributions of means, medians, and nominal data of those who had pneumonia versus those without, respectively.

Odds ratios and the corresponding 95% confidence intervals (CIs) from logistic regression were computed to determine the risk factors associated with pneumonia. Cumulative incidence and incidence density rate of pneumonia were likewise estimated.

Time-to-event (pneumonia and mortality) analysis was performed using standard Kaplan-Meier survival analysis techniques. Patients last known to be alive without an event were censored at the date of last contact (discharge).

All valid data were included in the analysis. Missing variables were neither replaced nor estimated. Null hypothesis was rejected at $\alpha = 0.05$ level of significance. STATA 15.0 (StataCorp, College Station, Texas) was used for data analysis.

RESULTS

A total of 460 patients undergoing cardiac surgery were considered for inclusion in this study. Eighty-seven patients were excluded because of the presence of active systemic infection at the time of surgery and/or they were 18 years or younger. A total of 373 patients were reviewed in the final analysis. They had a median age of 59 years (range, 19–90 years) (Table 1). Males comprised 74%. The median BMI was 26.45 kg/m^2 (range, 15.22–42.46 kg/m^2). Hypertension (74%), diabetes (46%), and dyslipidemia (27%) were the most frequent comorbidities. The smoking history of 32% indicated a median of 20 pack-years (range, 1–150 pack-years).

Most surgeries were coronary artery bypass grafting (CABG) (71.58%) (Table 2), followed by valve repair or replacement (29.76%). Almost all patients (99%) had elective cardiac surgeries. The median bypass time, ischemic time, and surgical time were 135 minutes, 113 minutes, and 5.22 hours, respectively.

Characteristics of Patients Who Developed Pneumonia

A total of 104 (28%) patients acquired pneumonia (Table 1). They were mostly males (72%), with a median age of 61 years, BMI of 26.51 kg/m^2 and had a smoking history of 20 pack-years. Most common comorbidities were hypertension (72%), DM (52%) and dyslipidemia (34%). The two groups were comparable in terms of their baseline characteristics.

Most patients (70.19%) had CABG, followed by valve repair or replacement (31.73%). (Table 2) The median bypass

Table 1. Clinicodemographic Profile of Patients Who Underwent Cardiac Surgery (n = 373)

	All (n = 373)	With Pneumonia (n = 104)	No Pneumonia (n = 269)	*P*
	Median (Range), Frequency (%), or Mean ± SD			
Age, y	59 (19–90)	61 (20–88)	58 (19–90)	0.071*
Sex				0.555†
Male	277 (74.26)	75 (72.12)	202 (75.09)	
Female	96 (25.74)	29 (27.88)	67 (24.91)	
Height, cm	164.32± 8.58	163.15± 8.51	164.78± 8.57	0.101‡
Weight, kg	72 (35–132)	72 (35–117)	72.5 (38–132)	0.908*
BMI, kg/m^2	26.45 (15.22–42.46)	26.51 (15.77–41.45)	26.4 (15.22–42.46)	0.434*
Comorbidities				
Hypertension	275 (73.73)	75 (72.12)	200 (74.35)	0.660†
Diabetes mellitus	173 (46.38)	54 (51.92)	119 (44.24)	0.182†
Dyslipidemia	101 (27.08)	35 (33.65)	66 (24.54)	0.076†
COPD or asthma	68 (18.23)	20 (19.23)	48 (17.84)	0.756†
Renal dysfunction	53 (14.21)	18 (17.31)	35 (13.01)	0.287†
LV dysfunction	44 (11.80)	10 (9.62)	34 (12.64)	0.417†
With smoking history	120 (32.17)	34 (32.69)	86 (31.97)	0.894†
Pack-years	20 (1–150)	20 (1–150)	23 (1–150)	0.595
Current smoker	18 (4.83)	3 (2.88)	15 (5.58)	0.277

BMI=body mass index; COPD=chronic obstructive pulmonary disease; LV=left ventricular.
Statistical tests used: *Mann-Whitney *U* test; †χ2 test of independence; ‡independent t test.

time, ischemic time, and surgical time were 138 minutes, 114 minutes, and 5.3 hours, respectively. Those who developed pneumonia after cardiac surgery were comparable to those who did not in terms of operative characteristics.

In contrast, patients who developed pneumonia had significantly longer median preoperative stay (3 vs 2 days, $P = 0.011$) and duration of mechanical ventilation (10.2 vs 9 hours, $P < 0.001$).

The incidence of pneumonia among post–cardiac surgery is greater than 10% at 3 days postsurgery (Table 3); it is estimated at 17.60% (95% CI, 14%–22%). This estimate increases steadily within the first 2 weeks after surgery, and by 13 days postsurgery (Figure 1), the incidence is at 31.42% (95% CI 26%–37%), which means that 3 of 10 cardiac surgery patients would have developed pneumonia within the first 2 weeks postoperatively. Patients also had pneumonia early on, with 95% of them acquiring it within 7 days postsurgery. The incidence density rate of pneumonia is at 29 patients per 1000 patient-years.

Seventeen cardiac surgery patients (4.55%) in our study population died. The mortality rates for patients with and without pneumonia were 2.7% and 1.9%, respectively. Table 4 shows the survival probability of post–cardiac surgery patients at 7, 15, and 30 days after surgery. There is a marked difference between the 30-day survival of those with and that of those without pneumonia; those with pneumonia have a survival probability of 81.70% with a 95% CI of 63% to 91.5%, which is lower than those without pneumonia, which has a survival probability of 96.51% (95% CI, 91.6%–98.6%). Figure 2 depicts the time-varying effect of pneumonia on patient survival.

On both crude and adjusted analyses, age, sex, BMI, diabetes, left ventricular dysfunction, renal dysfunction, chronic obstructive pulmonary disease or asthma, priority of surgery, surgical time, and smoking history status did not show an association with the development of postoperative pneumonia (Table 5). However, more than 2 days of preoperative hospital stay was associated with a 92.3% (95% CI, 18%–213%) increased odds of having pneumonia compared with those with shorter preoperative stay ($P = 0.009$). Also, every additional

Table 2. Operative characteristics of patients who underwent cardiac surgery (n = 373)

	All (n = 373)	With Pneumonia (n = 104)	No Pneumonia (n = 269)	*P*
	Frequency (%) or Median (Range)			
Type of surgery				
CABG	267 (71.58)	73 (70.19)	194 (72.12)	0.711*
Valve repair or replacement	111 (29.76)	33 (31.73)	78 (29)	0.604*
Aortic repair	7 (1.88)	4 (3.85)	3 (1.12)	.098†
Congenital surgery	9 (2.41)	2 (1.92)	7 (2.60)	1.00†
Others	9 (2.41)	5 (4.81)	4 (1.49)	0.123†
Priority of surgery				0.135†
Urgent	5 (1.34)	3 (2.88)	2 (0.74)	
Elective	368 (98.66)	101 (97.12)	267 (99.26)	
Bypass time, min	n = 367	n = 101	n = 266	0.326‡
	135 (48–599)	138 (64–346)	134 (48–599)	
Ischemic time, min	n = 366	n = 101	n = 265	0.987‡
	113 (0–282)	114 (12–282)	112 (0–274)	
Surgical time, h	5.22 (1.63–16.58)	5.3 (1.63–16.58)	5.17 (2.7–12.87)	0.093‡
Mechanical ventilation, hours	9 (5–516)	10.2 (7–480)	9 (5–516)	<0.001‡
Preoperative stay, d	2 (0–35)	3 (0–18)	2 (1–35)	0.011‡
≤2	220 (58.98)	51 (49.04)	169 (62.83)	
>2	153 (41.02)	53 (50.96)	100 (37.17)	

CABG=coronary artery bypass grafting.
Statistical tests used: *χ^2 test of independence; †Fisher exact test; ‡Mann-Whitney U test

Table 3. Cumulative Incidence and Incidence Density Rate of Pneumonia Among Post–Cardiac Surgery Patients

Cumulative Incidence of Pneumonia	Incidence (95% Confidence Interval)
3 d	0.1760 (0.14–0.22)
6 d	0.2669 (0.22–0.32)
9 d	0.2721 (0.23–0.32)
12 d	0.3037 (0.25–0.36)
13 d	0.3142 (0.26–0.37)
Incidence density rate (per 1000 patient-years)	28.571 (23.58–34.63)

Table 4. Survival Probabilities of Post–Cardiac Surgery Patients, With or Without Pneumonia (n = 373)

	Overall (n = 373)	Pneumonia (n = 104)	Without Pneumonia (n = 206)
	Probability of Survival (95% Confidence Interval)		
7 d	0.9784 (0.957–0.989)	0.9612 (0.900–0.985)	0.9851 (0.961–0.994)
15 d	0.9459 (0.906–0.969)	0.9078 (0.821–0.954)	0.9651 (0.916–0.986)
30 d	0.8960 (0.792–0.950)	0.8170 (0.63–0.915)	0.9651 (0.916–0.986)

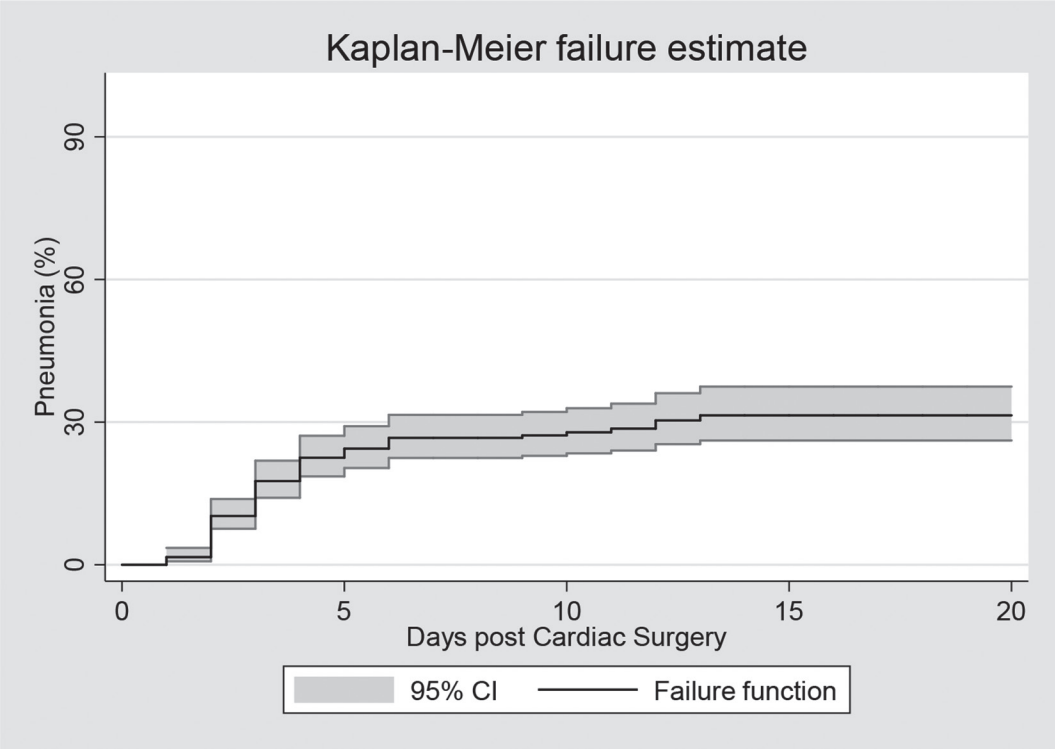

Figure 1. Cumulative incidence function with 95% confidence interval for postoperative pneumonia among cardiac surgery patients.

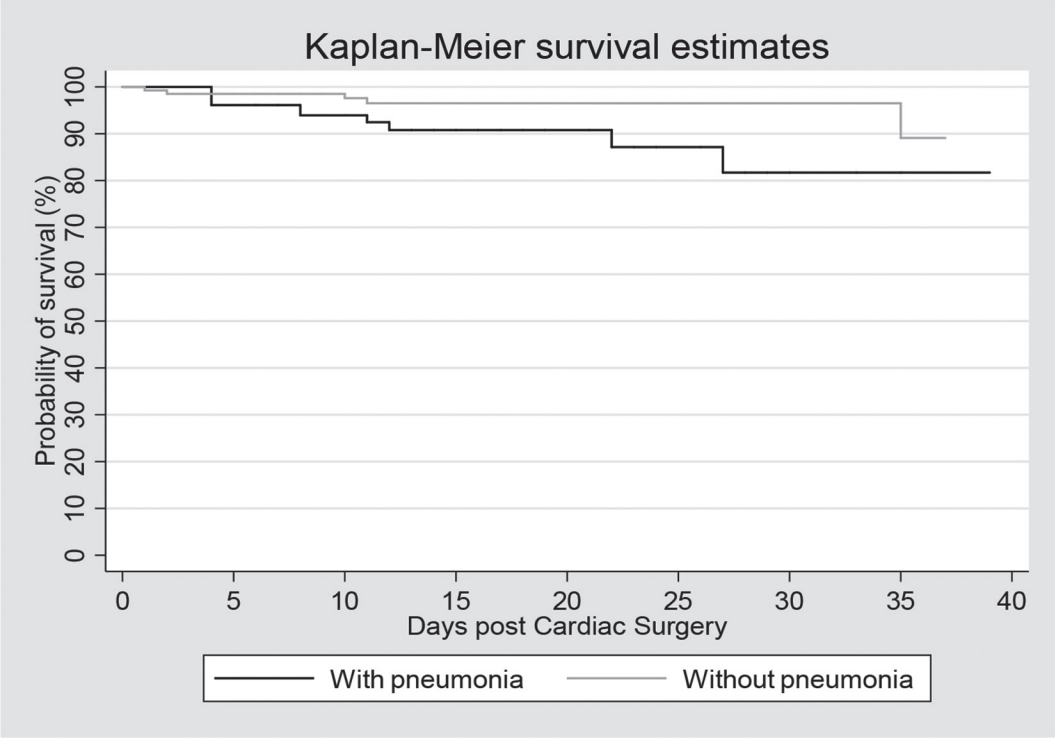

Figure 2. Kaplan-Meier curve for mortality stratified according to the presence or absence of postoperative pneumonia.

Table 5. Correlates of Pneumonia Among Patients Who Underwent Cardiac Surgery (n = 373)

	Crude Odds Ratio (95% CI)	*P*	Adjusted Odds Ratio (95% CI)	*P*
Age, y	1.015 (0.998–1.03)	0.091	1.012 (0.99–1.03)	0.229
Sex				
Male	Reference	—	Reference	—
Female	1.166 (0.70–1.94)	0.556	1.328 (0.74–2.40)	0.347
BMI, kg/m^2	1.019 (0.97–1.07)	0.431	1.013 (0.96–1.07)	0.617
Diabetes mellitus	1.361 (0.86–2.14)	0.183	1.462 (0.87–2.46)	0.154
LV dysfunction	0.735 (0.35–1.55)	0.418	0.559 (0.25–1.26)	0.160
Renal dysfunction	1.399 (0.75–2.60)	0.288	0.974 (0.49–1.93)	0.940
COPD/asthma	1.096 (0.61–1.96)	0.756	1.084 (0.57–2.05)	0.803
Preoperative stay, d				
≤2	Reference	—	Reference	—
>2	1.756 (1.11–2.77)	0.016	1.923 (1.18–3.13)	0.009
Priority of surgery				
Elective	Reference	—	Reference	—
Urgent	3.965 (0.65–24.08)	0.134	4.600 (0.70–30.13)	0.111
Surgical time, hours	1.134 (0.99–1.31)	0.079	1.078 (0.92–1.26)	0.339
Mechanical ventilation, hours	1.008 (1.003–1.01)	0.002	1.008 (1.003–1.01)	0.004
With smoking history	1.034 (0.64–1.68)	0.894	1.024 (0.57–1.83)	0.229

BMI=body mass index; CI=confidence interval; COPD=chronic obstructive pulmonary disease; LV=left ventricular.

Table 6. OR for Clinical Outcomes With Pneumonia as Exposure

	In-hospital Mortality	Prolonged Hospital Stay	Prolonged ICU Stay	Postoperative Reintubation
Crude OR	3.859	3.785	6.380	9.464
(95% CI)	(1.51–9.89)	(1.81–7.90)	(3.59–11.35)	(3.01–29.76)
P	0.005	<0.001	<0.001	<0.001

CI=confidence interval; ICU=intensive care unit; OR=odds ratio.

hour on mechanical ventilation conferred a 0.8% (95% CI, 0.3%–1%) greater odds of acquiring pneumonia (*P* = 0.003).

Patients with pneumonia demonstrated increased odds (Table 6) for undesirable outcomes in comparison with those who did not develop this complication, with the former having approximately 3.9 times the odds of mortality, 3.8 times the odds of prolonged hospitalization, 6.4 times the odds of prolonged ICU stay, and 9.5 times the odds of needing postoperative reintubation.

DISCUSSION

Incidence of Postoperative Pneumonia

Postoperative pneumonia occurred in 28% (104/373) of patients after cardiac surgeries; most occurred (95%) within 7 days postsurgery. This incidence is higher than the reported incidence in other countries, ranging from 2% to 10%.[3–8] This variation could be related to several factors such as ethnic, cultural, and economic differences of the population studied, management practices and processes of care of hospitals, epidemiological surveillance adopted per institution, and level of compliance to infection control measures.[17]

Risk Factors Associated With Pneumonia
Patients undergoing cardiac surgery have a higher risk of developing nosocomial infections. Risk factors for developing coronary artery disease, as well as various cardiac conditions, are also considered risk factors in the development of hospital infection. These include advanced age, DM, and smoking.

In our study, however, preoperative patient characteristics, such as age, sex, BMI, DM, severe left ventricular systolic dysfunction, renal dysfunction, lung diseases, and smoking, were not associated with the development of pneumonia. Likewise, other surgical factors, such as ischemic time, bypass time, total surgical time, and urgency of surgery, were not associated with pneumonia development.

In contrast, our results showed that more than 2 days of preoperative hospital stay and longer time on mechanical ventilation were both associated with an increased risk of developing pneumonia.

Prior to their cardiac surgery, these patients may be admitted to the intensive units for a variable period because of several reasons. They may present with cardiac symptoms necessitating hospital admission prior to surgery. Moreover, some patients have had acute coronary events, which would take an additional 5 to 7 days to wash out the antiplatelet agents given prior to CABG. These patients may have longer hospital stay before their scheduled operation and thus may be subjected to longer exposure to the hospital environment and possibly to pathogens.

Several studies have shown that prolonged intubation and mechanical ventilation increase the risk of postoperative pneumonia, length of hospital stay, and in-hospital complications.[12] Thus, one of the prominent focus of cardiac surgical quality improvement has been early weaning and extubation. Our study found a 0.8% increase in acquiring pneumonia for every hour delay of extubation from mechanical ventilation, hence re-emphasizing the importance of timely postoperative extubation.

Impact of Pneumonia on Clinical Outcomes
The overall in-hospital mortality observed was 4.55%, which is 17 of the 373 patients included in the study. Ten of the 17 patients who died had postoperative pneumonia. This translates to an attributable mortality rate of 58.8% among patients undergoing cardiac surgery who developed pneumonia. This is higher compared with a study done in eight European countries, which showed a mortality rate of 35%.[4] On analysis, the development of postoperative pneumonia in our study was associated with a nearly fourfold increase in in-hospital mortality.

In addition to mortality, pneumonia conferred a significant burden on patient morbidity. It is associated with a fourfold increase in prolonged hospitalization, sixfold increase in prolonged ICU stay, and a ninefold increase in postoperative reintubation.

Our study did not analyze the economic impact of pneumonia in the cardiac surgery population. However, because of the findings of prolonged hospitalization and ICU stay among patients who had pneumonia, it may be surmised that pneumonia may also incur an increased burden on resource utilization. A study by Ailawadi et al[10] among cardiac surgery patients showed that the occurrence of major hospital-acquired infection incurred an additional US $38,000 to hospital cost on an individual level.

Timing of Pneumonia and Relationship to Mortality
The median time to the onset of postoperative pneumonia was 3 days, ranging from 1 to 13 days. Ninety-five percent of patients who had pneumonia acquired it within 7 days after cardiac surgery. This is expected as the majority of pneumonia would manifest early after surgery because of the occurrence of postoperative pain and need for narcotics, both resulting in inadequate respiratory mechanics.

Our study showed that at approximately 13th postoperative day, the probability of acquiring pneumonia is at 31% (Figure 1). Given the chance of developing pneumonia even after the first week postsurgery, this emphasizes the need for continuation and maintenance of intensive postoperative pulmonary care. This may include early ambulation and progressive cardiac rehabilitation. A study done by Stolbrink et al[18] among medical inpatients showed that early ambulation significantly decreased the incidence of hospital-acquired pneumonia ($P < 0.0001$). Furthermore, a study by Ferreira et al[19] showed that an inspiratory muscle rehabilitation program significantly improved the respiratory mechanics of patients among post–cardiac surgery patients. Herdy et al[20] also demonstrated decreased incidence of postoperative pneumonia among CABG patients who had early postoperative cardiopulmonary rehabilitation compared with those who had standard care ($P = 0.004$).

The median time to mortality is 8 days (range, 1–35 days) post–cardiac surgery. The probability of survival decreases in the presence of pneumonia, with Kaplan-Meier curves beginning to diverge after approximately 3 days (Figure 2). Further, among patients who had pneumonia, the estimated 30-day survival is 81.70%. This is in contrast to a 96.51% 30-day estimated survival in those who did not acquire pneumonia (Table 4). Thus, clinicians should be aggressive in the management upon onset of nosocomial pneumonia. A study done by Luna et al[21] showed that early initiation of antibiotic therapy improves survival of patients with ventilator-associated pneumonia compared with those who had delayed initiation, with reported mortality rates of 29.2% versus 58.3%, respectively.

The study is primarily a cross-sectional study design because the main aim is to determine factors associated with the development of postoperative pneumonia (ie, an outcome). The simultaneous ascertainment of patient factors and surgical factors (exposure) and development of pneumonia (outcome) fulfill the definition of a cross-sectional study. Albeit a cross-sectional study, we feel it is practicable to label the pneumonia cases as incident cases because patients had received

pulmonary and infectious disease clearance prior to surgery. We also had used incidence density rate to standardize for varying hospital lengths of stay and estimated incidence at different time endpoints. However, we also recognized that there is an embedded cohort study within the general cross-sectional study because it was also of interest to know whether the outcomes of those who had developed pneumonia (ie, an exposure) were significantly different from those who did not develop pneumonia.

Our study has several limitations. Because the average length of stay of routine cardiac surgeries such as CABG is 5 to 7 days, the true incidence of pneumonia may be underestimated, given the retrospective nature of this study. Late-onset pneumonias, which may have occurred after hospital discharge and during readmissions, could have been missed. Also, the results and conclusions of this study are based on a single-center result, which cannot be extrapolated to other institutions. The differences in hospital preventive measures that are implemented and the level of compliance of health care professionals to infection control policies may be varied among hospitals.

Implications for Practice
Given the significantly increased in-hospital mortality and morbidity among those who acquired pneumonia, this study highlights the importance of infection control and preventive measures in the perioperative cardiac setting. Such emphases require behavioral and probably cultural changes, which may be accomplished through repeated hospital education, audit, and feedback.

We recommend the creation and implementation of a clinical pathway for patients undergoing cardiac surgeries with a goal of improving clinical outcomes and hospital cost. The pathway should aim to provide coordinated care among health professionals, with particular emphasis on infection control and preventive measures.

Implications for Research
Future studies are needed to identify the different pathogenic organisms responsible for nosocomial pneumonia, as well as to determine the role of antibiotic prophylaxis in the prevention of infection in the cardiac surgical setting. Likewise, it would also be pertinent to determine the financial impact of postoperative pneumonia with the goal of improving hospital processes of care.

CONCLUSION
Among adult patients undergoing cardiac surgeries, prolonged preoperative hospital stay and prolonged mechanical ventilation were both associated with an increased risk of nosocomial pneumonia. Those who developed pneumonia had worse outcomes, with significantly increased in-hospital mortality, prolonged hospitalization, prolonged ICU stay, and increased postoperative reintubation. Clinicians should therefore minimize delays in surgery to avoid unnecessary exposure to pathogenic organisms. We therefore recommend careful planning of cardiac surgeries with coordination of all team members as this may help avoid delays in surgery. Also, timely liberation from mechanical ventilation after surgery should be encouraged.

CONFLICT OF INTEREST
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