Factors Predicting Severity of Postoperative Pulmonary Complications within the First 7 Days among Open-Heart Surgery Patients*

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Abstract

Purpose: To examine the predictors of severity of pulmonary complications within seven days after open-heart surgery, including hemoglobin levels, obstructive sleep apnea, atrial fibrillation, inotropic drug use, duration of intubation, and readiness for ventilator weaning.

Design: A cross-sectional study.

Methods: The participants were 148 open-heart surgery patients aged ≥ 18 years who were admitted to a university hospital in Bangkok, Thailand. Data were collected using the Thai version of a cognitive function assessment, a questionnaire and recording form on personal information, health status, illness, and treatment, scores for the use of inotropic and vasoactive drugs, and an assessment tool for the severity of complications. Multiple linear regression with the enter method was used to examine the predictors of the severity of pulmonary complications.

Main findings: The average age of the participants was 64.2 (SD = 10.99) years. The average severity of postoperative pulmonary complications was 17.20 (SD = 10.65) points. Significant predictors of the severity of postoperative pulmonary complications were obstructive sleep apnea (B = 9.60; 95%CI [.12, 19.08], p = .04) and duration of intubation (B = .12; 95%CI [.06, .17], p < .001). Hemoglobin level, atrial fibrillation, readiness for ventilator weaning, and the amount of inotropic drugs use were not significant predictors.

Conclusion and recommendations: Healthcare providers should assess risk factors of severity of postoperative pulmonary complications, particularly those with a history of obstructive sleep apnea and prolonged intubation. In addition, development guidelines for assessing the severity of postoperative pulmonary complications are crucial for effectively preventing these complications.

Keywords: duration of intubation, obstructive sleep apnea, open-heart surgery, postoperative pulmonary complications

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ปัจจัยทำนายความรุนแรงของภาวะแทรกซ้อนระบบหายใจหลังผ่าตัดภายใน 7 วันแรกของผู้ป่วยที่ได้รับการผ่าตัดหัวใจแบบเปิด*

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บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาปัจจัยทำนายความรุนแรงของภาวะแทรกซ้อนทางปอดภายในเจ็ดวันหลังการผ่าตัดหัวใจแบบเปิด ประกอบด้วยระดับฮีโมโกลบิน ภาวะหยุดหายใจขณะหลับ ภาวะหัวใจห้องบนเต้นผิดจังหวะชนิดสั่นพริ้ว ปริมาณการได้รับยากระตุ้นหัวใจและหลอดเลือด ระยะเวลาการใส่ท่อช่วยหายใจ และความพร้อมการหย่าเครื่องช่วยหายใจ

รูปแบบการวิจัย: การศึกษาแบบภาคตัดขวาง

วิธีดำเนินการวิจัย: การศึกษาครั้งนี้ผู้เข้าร่วมวิจัยเป็นผู้ป่วยอายุตั้งแต่ 18 ปีขึ้นไป ที่เข้ารับการรักษาด้วยการผ่าตัดหัวใจแบบเปิดที่โรงพยาบาลมหาวิทยาลัยแห่งหนึ่ง ในกรุงเทพมหานคร ประเทศไทย จำนวน 148 ราย เก็บข้อมูลโดยใช้แบบประเมินสมรรถภาพสมองฉบับภาษาไทย แบบสอบถามข้อมูลส่วนบุคคลและภาวะสุขภาพ การเจ็บป่วยและการรักษา คะแนนการได้รับยากระตุ้นหัวใจและหลอดเลือด และแบบประเมินความรุนแรงของภาวะแทรกซ้อน วิเคราะห์ข้อมูลทั่วไปโดยใช้สถิติเชิงบรรยายและวิเคราะห์ความสามารถการทำนายระหว่างตัวแปรที่ศึกษาโดยใช้สถิติการถดถอยพหุคูณ แบบนำตัวแปรเข้าทั้งหมด

ผลการวิจัย: กลุ่มตัวอย่างอายุเฉลี่ย 64.2 ปี (SD = 10.99) ความรุนแรงของภาวะแทรกซ้อนระบบหายใจหลังผ่าตัดเฉลี่ย 17.20 คะแนน (SD = 10.65) และปัจจัยที่สามารถทำนายความรุนแรงของภาวะแทรกซ้อนระบบหายใจหลังผ่าตัดหัวใจแบบเปิดภายใน 7 วันแรกได้แก่ ภาวะหยุดหายใจขณะหลับ (B = 9.60; 95%CI [.12, 19.08], p = .04) และระยะเวลาการใส่ท่อช่วยหายใจ (B = .12; 95%CI [.06, .17, p < .001) อย่างไรก็ตามระดับฮีโมโกลบิน ภาวะหัวใจห้องบนเต้นผิดจังหวะชนิดสั่นพริ้ว ความพร้อมการหย่าเครื่องช่วยหายใจ และปริมาณการได้รับยากระตุ้นหัวใจ เป็นปัจจัยที่ไม่สามารถทำนายได้

สรุปและข้อเสนอแนะ: ผู้ให้บริการทางสุขภาพควรประเมินปัจจัยเสี่ยงต่อความรุนแรงของภาวะแทรกซ้อนระบบหายใจหลังผ่าตัดหัวใจ โดยเฉพาะผู้ป่วยที่มีประวัติภาวะหยุดหายใจขณะหลับและมีระยะเวลาการใส่ท่อช่วยหายใจเป็นเวลานานและพัฒนาแนวปฏิบัติประเมินความรุนแรงภาวะแทรกซ้อนระบบหายใจหลังผ่าตัดหัวใจ

คำสำคัญ: ระยะเวลาการใส่ท่อช่วยหายใจ ภาวะหยุดหายใจขณะหลับ การผ่าตัดหัวใจแบบเปิด ภาวะแทรกซ้อนทางระบบหายใจหลังผ่าตัด

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Background and Significance

Open-heart surgery remains the primary treatment for coronary artery and heart valve diseases, with cardiopulmonary bypass (CPB) machines frequently used to maintain circulation by temporarily replacing heart and lung function during the procedure.[1] Despite its therapeutic benefits, this type of surgery is associated with notable risks, including postoperative mortality rates ranging from 0.7% to 7.9%[2] and overall complication rates as high as 66.6%.[3] Pulmonary complications occur in approximately 32% of patients within the first seven postoperative days and may include pleural effusion, respiratory failure, atelectasis, respiratory infections, and pneumothorax.[4] These complications lead to poor health outcomes, including increased patient morbidity, and higher mortality.[5] Among these complications, atelectasis is the most commonly reported, with a prevalence of 78% within the first 72 hours after surgery.[6]

In this study, the Nursing Role Effectiveness Model (NREM) was adopted to examine factors that influence nursing care quality, including structure, process, and outcome elements.[7] The NREM framework posits that a strong patient health status before surgery and effective nursing practices positively impact patient outcomes. All three components are connected and interrelated. Positive patient outcomes are often linked to good physical conditions prior to treatment and the quality of nursing care received during recovery. In this study of open-heart surgery patients, preoperative physical health varied widely. Given this variability, intensive postoperative monitoring and treatment are critical for preventing potential cardiac complications, especially the frequently observed pulmonary issues. High-quality care and treatment expedite recovery. This research thus utilizes the NREM conceptual framework.

Several preoperative factors can influence pulmonary complications.[8-9] Hemoglobin levels are associated with pneumonia rates.[10] Individuals presenting with preoperative hemoglobin levels below 10 g/dL typically exhibit compromised hemodynamic function and diminished oxygen transport to peripheral tissues. Such hematologic status is associated with an increased likelihood of requiring perioperative and postoperative blood transfusion, as well as a higher risk of developing postoperative complications following cardiac surgery.[11] Preoperative atrial fibrillation (AF) reflects underlying cardiac dysfunction, where loss of atrial contraction elevates left-sided heart pressures and promotes pulmonary congestion. These pathophysiological changes increase the risk of postoperative pulmonary complications, including pulmonary edema, infections, and prolonged mechanical ventilation.[12] Additionally, obstructive sleep apnea is strongly linked to increased

postoperative pulmonary complications.[13] Obstructive sleep apnea (OSA) is characterized by pathological obstruction of the upper airway, which can lead to episodes of hypoxemia and hypercapnia. Most patients with OSA remain undiagnosed prior to surgery. During cardiac surgery, the use of general anesthetic agents and postoperative analgesics can depress respiratory muscle activity. Patients with OSA are particularly prone to upper airway collapse and reduced pharyngeal dilator muscle tone, which increases the likelihood of airway obstruction and postoperative oxygen desaturation. These factors may contribute to prolonged endotracheal intubation and an overall increased risk of postoperative pulmonary complications following cardiac surgery.[13] The duration of intubation is also a critical factor, because prolonged intubation increases the risk of complications, Prolonged postoperative endotracheal intubation exceeding 24 hours increases the risk of postoperative infections and may lead to the development of ventilator-associated pneumonia[14] making early assessment and risk management essential.[15] The researcher recognized the importance of examining factors that have a confirmed impact on postoperative respiratory complications after open-heart surgery, particularly those that have been studied in limited numbers and that nurses can actively assess, monitor, and manage according to each patient's preoperative health condition. Nurses can monitor patients with risk factors and provide education to help them recognize the importance of their health, encouraging positive changes in self-care behaviors even before surgery. Despite preoperative preparation provided by healthcare personnel, undergoing major cardiac surgery which inherently involves cardiac injury requires close and continuous nursing care. This includes monitoring vital signs, assessing respiratory patterns, evaluating the need for mechanical ventilation, and observing any postoperative changes. Such vigilant care is essential to prevent postoperative complications, especially respiratory complications, which are commonly observed following open-heart surgery. Effective nursing care can promote faster postoperative recovery and reduce the length of hospital stay.

The role of nurses in postoperative care includes monitor changes in patients' signs and symptoms, assess their health status, and provide care in accordance with accurate and up to date treatment guidelines. This helps patients achieve better health outcomes, reduces postoperative complications, and promotes faster postoperative recovery. A review of the literature indicated that nurse led assessment of patients' readiness for ventilator weaning is a safe nursing practice. Nurses can independently perform this assessment without requiring a physician's order, and this approach has been shown to reduce the

duration of endotracheal intubation in intensive care units. Assessing ventilator weaning readiness, which has been shown to decrease intubation time, reduce pneumonia risk, and shorten ICU stay.[16] In addition, inotropic and vasoactive drug use is crucial during the postoperative phase which significantly associated with adverse postoperative outcomes. Some patients require high doses of inotropic and vasopressor medications, which are associated with the amount of fluid administered. However, in the postoperative period, it is necessary to restrict daily fluid intake and output to prevent fluid overload, which can increase the workload of the heart and lungs and lead to further complications. Liu, et al.[17] used the Vasoactive Inotropic Score (VIS) to evaluate the relationship between the amount of inotropic and vasopressor support and the occurrence of postoperative respiratory complications in patients undergoing open-heart surgery. Liu, et al.[17] and Colak, et al.[18] reported that a Vasoactive Inotropic Score (VIS) > 6 significantly increased the likelihood of respiratory failure, although there was no significant correlation between inotropic drugs and pleural effusion. Nurses are responsible for administering medications as prescribed, managing and documenting each patient's fluid intake and output to minimize fluid accumulation and prevent complications such as fluid overload, closely monitoring for any changes associated with the initiation or adjustment of inotropic and vasopressor therapy, and promptly reporting any abnormal findings to physicians to facilitate timely clinical intervention.

Most studies on postoperative pulmonary complications from open-heart surgery have reported the incidence of individual complications such as pneumonia and respiratory failure.[15,19-20] However, few studies have provided a comprehensive view of overall pulmonary complications within the initial seven days after surgery,[9,21-22] despite the increased risk of pulmonary complications following open-heart surgery compared to other surgeries.[23]

In this study, the researchers examined structural factors, which are related to preoperative health status, including hemoglobin level, obstructive sleep apnea, and atrial fibrillation with flutter. They also studied process factors, focusing on the independent role of nurses, such as readiness for ventilator weaning and nursing care according to treatment plans. Postoperative process factors included the dose of inotropic and vasopressor medications and the duration of endotracheal intubation. The aim of this study was to identify factors that can predict the severity of respiratory complications during the first seven days after open-heart surgery.

Objectives

To examine the predictors of severity of pulmonary complications within seven days after

open-heart surgery, including hemoglobin levels, obstructive sleep apnea, atrial fibrillation, inotropic drug use, duration of intubation, and readiness for ventilator weaning.

Hypothesis

At least one of hemoglobin levels, obstructive sleep apnea, atrial fibrillation, amount of vasoactive and inotropic drug use, duration of intubation, and readiness for ventilator weaning are significant predictors of the severity of pulmonary complications within the first 7 days after open-heart surgery.

Methodology

Design

A cross-sectional with predictive correlational design.

Population and sample

The study population included patients who received open-heart surgery within seven days. The study participants consisted of male and female patients aged ≥ 18 years who underwent open-heart surgery at a university hospital in Thailand. The exclusion criteria were as follows: pregnant women, patients with cognitive impairment, and patients presenting with unstable conditions such as fatigue, dyspnea, chest tightness, heart palpitations, nausea, and vomiting. The study sample was selected through convenience sampling. The data were collected between June 2023 and January 2024.

The sample size was calculated using the G*power program with a significance of .05 and linear multiple regression with a fixed model, and an R^2 deviation from zero. The power of the test was set at .95, and the effect size was set to medium (.15).[24] Therefore, a sample size of 148 participants was obtained.

Instruments

The instruments included two main parts, screening instruments and instruments for data collection.

Part 1 – Screening Instruments

The Mini-Cognitive Assessment Instrument (Mini-Cog) was used as a screening instrument. It was used to assess cognition in patients aged 60 years and older. Patients scoring less than four points indicated cognitive impairment, were excluded.

Part 2—Instruments for Data Collection

1. The demographic and clinical recording form consists of 18 questions on demographic data and 7 questions on preoperative and postoperative illness and treatment data. This form was developed by the researchers based on a review of relevant literature and academic sources. It was designed to collect baseline data and clinical variables necessary for the analysis in this study. The tool functioned primarily as a data collection worksheet, rather than as a questionnaire intended to measure participants' behaviors or attitudes. Therefore, no reliability or validity testing was conducted, as the data collected

were objective in nature, obtained through patient interviews for personal information and from medical sources such as patient histories, medical records, and clinical diagnostic results.

2. The Vasoactive Inotropic Score (VIS) was used to calculate the dosages of the vasoactive and inotropic drugs. VIS was calculated from the following equation: Inotropic score (IS) = dopamine dose (µg/kg/ min) + dobutamine dose (µg/kg/min) + 100 × epinephrine dose (µg/kg/min); and Vasoactive inotropic score (VIS) = IS + 10 × milrinone or olprinone dose (µg/kg/min) + 100 × norepinephrine dose (µg/kg/min) + 10000 × vasopressin dose (U/kg/ min). Higher scores indicate greater drug usage.[25] The Vaso-Inotropic Score is a widely accepted and commonly utilized tool in medical research and is considered a standardized instrument.[26-27] Therefore, in this study, the researcher did not conduct a content validity assessment.

3. The Comprehensive Complication Index (CCI) assesses the severity of postoperative complications. The severity of complications was calculated using the following formula: CCI = √)Σ MRVphys × MRVpat)/2. In this formula, each physician rating (MRVphys) is multiplied by the corresponding patient rating (MRVpat), the products are summed across all items, divided by 2, and then the square root is taken. Higher scores reflect greater severity, with 100 points indicating death.[28]

The researcher subsequently assessed the reliability of the CCI for evaluating postoperative complications by examining interrater consistency between two trained raters. After receiving instruction from the tool's developers, both raters independently evaluated complications in 10 patients with open-heart surgery and demonstrated complete agreement (100%). The CCI was then used to assess postoperative complications in an additional 30 open-heart surgery patients to determine its concurrent validity. The researcher obtained official permission from the tool owners before using the Mini-Cog and CCI instruments in the study. The Vaso-Inotropic Score (VIS), on the other hand, is a clinical calculation formula used to assess the dosages of inotropic/vasoactive agent administration, which is widely accepted and used in medical research,[26,29] particularly in the fields of critical care and post-cardiac surgery patient management. Therefore, the researcher did not seek formal permission from the formula's creators. However, for academic accuracy, the researcher has fully cited the original source that published the formula.

Ethical considerations

When the research proposal was approved by the Institutional Review Boards of the Faculty of Nursing and the Faculty of Medicine, Siriraj Hospital, Mahidol University (COA No. IRB-NS2023/764.2103). Participants were informed of the study's purpose,

data collection procedures, potential risks, and benefits before providing written informed consent. Participation was voluntary, and all data were kept confidential and used solely for research purposes. The study adhered to the ethical principles of respect for persons, beneficence, and justice. All participants provided written informed consent before participation.

Data collection

The first researcher collected data for a total of three times. In the first session when patients were admitted before surgery, the researcher met the samples to explain the project's information and ask for consent. When patients granted consent, the researcher used the Mini-Cognitive Assessment Instrument to assess cognition in patients aged 60 years and older. Patients who scored more than four points were considered cognitively normal. The researcher then asked questions and recorded personal and health data. Data were also collected from medical and treatment records including electronic databases, records of laboratory test results, and other special tests (if any), to obtain preoperative health factors such as hemoglobin levels, obstructive sleep apnea, and atrial fibrillation. Questionnaires and recording forms for personal, health, illness, and treatment data. In the second and third data collection sessions, the researcher collected data during the first 12 hours, focusing on the readiness-for-ventilator-weaning factor, and again on the 7th day after open-heart surgery, without directly involving the participants. The researcher collected and recorded personal, health, illness, and treatment information to capture postoperative factors, including the use of inotropic drugs, duration of intubation, and physician diagnosed pulmonary complications. Surgical and postoperative data from the first seven days were obtained from laboratory and special tests, medical and treatment records, and electronic databases, covering both preoperative and postoperative periods. In cases where participants were discharged from the hospital before completing the seven-day post-operative period, the researcher used the signed informed consent forms and hospital identification numbers to access the patients' medical and treatment records and electronic databases through the medical records department. The retrieved data were then analyzed using the vasoactive-inotropic score and the Comprehensive Complication Index (CCI), and statistical analyses were conducted using standard statistical software.

Data analysis

The obtained data were checked for completeness. Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 18. Multiple regression analysis using the enter method was performed to examine the predictors of the severity of pulmonary complications within seven days after open-heart surgery, including

hemoglobin levels, obstructive sleep apnea, atrial fibrillation, amount of inotropic drug used, duration of intubation, and readiness for ventilator weaning.

For the statistical analysis of the variables in this study, the researcher employed parametric methods, as the data met the required statistical assumptions. Prior to conducting the analysis, assumptions were tested to ensure the appropriateness of the methods used. The following assumptions were examined: 1) the dependent variable was normally distributed, as indicated by the Kolmogorov–Smirnov test, which showed $p > .05$; 2) linearity was confirmed through the Pearson's correlation, 3) multicollinearity was assessed using tolerance and Variance Inflation Factor (VIF) statistics, with VIF values less than 5 and tolerance values greater than 0.2; 4) the residuals had a mean of zero and 5) homoscedasticity (homogeneity of variance). The relationships among the studied factors were analyzed using Pearson's Product Moment Correlation Coefficient, and the predictive power of the factors was assessed in which all independent variables were entered into the model simultaneously.

Findings

Participant characteristics

The majority of participants (62.2%) were male, with a mean age of 64.2 ± 10.99 years and a mean body mass index of 19.26 ± 3.38 kilograms/meter^2. The mean ejection fraction was 57.97 ± 13.05 %. More than half of the participants (64.2%) had disease severity classified as NYHA Classification class II, indicating a slight limitation of physical activity: patients are comfortable at rest, but ordinary activity results in fatigue, palpitations, or shortness of breath. The most common comorbidities were hypertension (75%), hyperlipidemia (59.4%), diabetes (35.1%), chronic kidney disease (21.6%), atrial fibrillation (20.3%), and Obstructive Sleep apnea (2.7%). The average eGFR was 71.3 (26.4) ml/minutes/1.73 m^2, which was classified as stage 2 chronic kidney disease, and the average preoperative hemoglobin level was 12.19 ± 1.79 grams/deciliter. The majority of participants (39.9%) underwent CABG, followed by valve surgery (32.4%), and CABG with valve surgery (11.4%). The average postoperative blood loss was 186.49 ± 441.1 milliliters, and average postoperative blood transfusion was 2.27 ± 2.87 units. Participants had a mean P/F ratio of 391.18 ± 158.44 mmHg, a mean Rapid Shallow Breathing Index (RSBI) of 37.83 ± 12.56 breaths/min/L, a mean VIS of 13.51 ± 18.27, and a mean intubation time of 22.3 ± 37.4 hours as shown in table 1.

Table 1: Demographic information about the participants and clinical data (N = 148)

Characteristics	N (%)	$\bar{X}$ (SD)
Gender		
Male	92 (62.2)	
Female	56 (37.8)	
Age (Years)		64.2 (10.99)
(Min = 38, Max = 90)		
Ejection fraction (%)		57.97 (13.05)
NYHA Classification		
Class I	18 (12.2)	
Class II	95 (64.2)	
Class III	29 (19.6)	
Class IV	6 (4.0)	
Concomitant diseases		
Hypertension	111 (75.0)	
Hyperlipidemia	88 (59.4)	
Type II Diabetes Mellitus	52 (35.1)	
Chronic kidney disease	32 (21.6)	
Atrial Fibrillation	30 (20.3)	
Obstructive sleep apnea	4 (2.7)	
Preoperative laboratory		
eGFR (ml/minutes/1.73 m^2)		71.3 (26.4)
Hemoglobin (g/dl)		12.19 (1.79)
Type of surgery		
CABG	59 (39.9)	
Valve	48 (32.4)	
CABG with valve surgery	17 (11.4)	
Aortic replacement	12 (8.1)	
CABG with Aortic	5 (3.4)	
Valve with Aortic	5 (3.4)	
CABG with Valve with Aortic	2 (1.4)	
Postoperative		
Blood loss (ml)		186.49 (441.10)
Blood transfusion (Units)		2.27 (2.87)
P/F ratio (mmHg)		391 (158.44)
Rapid shallow breathing index (RSBI)		37.83 (12.56)
Vasoactive Inotropic Score (VIS)		13.51 (18.27)
Intubation time (Hours)		22.3 (37.4)
(Min = 5.08, Max = 175)		

NYHA Classification: New York Heart Association (NYHA) Classification, CABG: Coronary Artery Bypass Grafting, P/F ratio: PaO2/FIO2

Pulmonary complications within 7 days after open heart surgery

The prevalence of pulmonary complications within seven days after open-heart surgery was 94.5%. The participants presented with pulmonary complications, including pleural effusion (57.4%), atelectasis (15.5%), acute respiratory distress syndrome (9.5%), and pneumothorax (2.7%). Each subject may have had more than one postoperative pulmonary complication, as shown in Table 2.

Table 2: Pulmonary complications within 7 days after open heart surgery

Variable	N (%)
Postoperative pulmonary complication	140 (94.5)
Pleural effusion	85 (57.4)
Atelectasis	23 (15.5)
Acute Respiratory Distress Syndrome	14 (9.5)
Pneumothorax	4 (2.7)

Correlation between the studied factors and severity of pulmonary complications within 7 days among open-heart surgery patients

Inotropic drug use ($r = .36$, $p < .001$), and intubation time ($r = .47$, $p < .001$) were significantly positively associated with severity of pulmonary complications. Hemoglobin levels ($r = -.07$, $p = .39$) and readiness for ventilator weaning ($r = .10$, $p = .22$) were not significantly associated with pulmonary complications, as shown in Table 3.

Table 3: Correlation between the study factors and severity of pulmonary complications within 7 days among open-heart surgery patients

Variables	Correlation coefficient (r)						
	1	2	3	4	5	6	7
1. Severity of pulmonary complications	1						
2. Hemoglobin level	- .07	1					
3. Obstructive Sleep Apnea[1]	.14	.65	1				
4. Atrial Fibrillation[1]	.19*	.08	.02	1			
5. the amount of inotropic use	.36**	- .11	- .05	.19*	1		
6. Intubation time	.47**	- .05	- .03	.22**	.66**	1	
7. Readiness for ventilator weaning	.10	- .16*	.14	.19*	.09	- .02	1

[1] point bi-serial correlation; *p < .05, **p < .01

Predictors of pulmonary complications within 7 days among open-heart surgery patients

Multiple regression analysis was performed using the enter method to examine the predictors of pulmonary complication severity within the first seven days after heart surgery. Hemoglobin levels, obstructive sleep apnea, atrial fibrillation, the amount of inotropic use, duration of intubation, and readiness for ventilator weaning explained 26.3% of the variance in the severity of pulmonary complications (R^2 = .263).

Obstructive sleep apnea and intubation time were significant predictors of pulmonary complication severity. The severity of pulmonary complications increased by 9.60 points with one episode of sleep apnea (B = 9.60; 95%CI [.12, 19.08], p = .04) and .12 score with each 1 hour increased in the intubation time (B = .12; 95%CI [.06, .17], p < .001), as shown in Table 4.

Table 4: Predictors of pulmonary complications within 7 days among open-heart surgery patients (N = 148)

Predictive variables	B	SE	β	t	95%CI	p-value
Preoperative hemoglobin	-0.22	0.44	-0.04	-0.49	-1.08, .65	.62
Obstructive sleep apnea[1]	9.60	4.80	0.15	2.00	.12, 19.08	.04
Atrial fibrillation[1]	1.91	2.00	0.07	0.96	-2.04, 5.87	.34
The amount of inotropic use	0.04	0.06	0.07	0.77	- .07, .16	.44
Intubation times	0.12	0.03	0.41	4.19	.06, .17	< .001
Readiness to wean from ventilators	0.05	0.06	0.06	0.84	- .07, .18	.40
Constant	13.95	6.31		2.21	1.47, 26.44	.03

[1] yes/no response; R^2 = .263, Adjust R^2 = .231

Discussion

Obstructive sleep apnea (OSA) was a significant predictor of postoperative pulmonary complications. Although OSA may not show a significant bivariate correlation with complications—because such analyses consider only the direct relationship and do not account for other factors—regression analysis adjusts for the effects of multiple variables. This adjustment allows OSA to demonstrate its unique, independent contribution (partial effect) to predicting postoperative complications, even when its simple correlation appears weak. Specifically, this study demonstrated that OSA, when controlling for other variables in the equation, increased the severity of postoperative pulmonary complications by 9.60 points (B = 9.60, p = .04). This aligns with Wolf, et al.[30] who reported a 1.70-fold increased likelihood of ventilator-associated pneumonia in OSA patients. The sample population had a mean BMI of 19.26 kg/m^2 and a mean age of 64.2 years, they were middle-aged adults

with comorbidities who were undergoing open-heart surgery for the first time, and the participants had been diagnosed with obstructive sleep apnea for a considerable period prior to surgery. Other contributing factors may include anatomical characteristics (e.g., craniofacial structure, neck circumference), comorbidities (e.g., hypertension, diabetes), and lifestyle factors (e.g., alcohol use, sleep habits), which are not fully captured by age alone.[13] Therefore, OSA may still be present and can significantly predict postoperative pulmonary complications in this population. However, the findings of this study indicate that the participants were aware of their preoperative self-care, particularly in terms of diet and weight control. Therefore, the severity of postoperative respiratory complications observed may be attributed to underlying physiological pathology. During open-heart surgery, patients with pre-existing obstructive sleep apnea (OSA) may experience increased surgical complexity compared to those without OSA, due to upper airway obstruction that can lead to hypoxemia and hypercapnia.

During cardiac surgery, general anesthesia is required, and postoperative sedative medications further depress respiratory muscle function. Patients with OSA tend to have greater upper airway collapsibility and reduced pharyngeal muscle tone, which can increase airway obstruction and decrease oxygenation in the postoperative period.[13] These factors may contribute to prolonged intubation and the overall severity of postoperative respiratory complications observed in this study.

From a nursing perspective, it is essential to closely monitor patients at risk for prolonged intubation, provide pre- and postoperative respiratory care education, and implement interventions such as lung expansion exercises, early postoperative mobilization, and vigilant respiratory assessment. These nursing practices can help maintain optimal pulmonary function and reduce the likelihood of postoperative pulmonary complications following cardiac surgery.

The study found that preoperative hemoglobin levels were not a significant predictor of the severity of postoperative pulmonary complications. This lack of association can be attributed to the high quality of preoperative patient preparation provided to the participants. The rigorous preparation ensured that patients' preoperative hemoglobin levels were consistently maintained within the normal range, with only marginal instances of mild anemia observed. This finding suggests that when comprehensive strategies are implemented to optimize a patient's physical status before undergoing cardiac surgery—specifically by correcting or managing anemia to achieve optimal physical readiness—the potential negative influence of hemoglobin variability on subsequent intraoperative and postoperative outcomes

is effectively mitigated. Consequently, patients entered the surgical process in a stabilized condition, which promotes a smoother recovery course and minimizes the incidence and severity of pulmonary complications.

Although atrial fibrillation (AF) was found to be statistically correlated with postoperative pulmonary complications in the bivariate analysis, it failed to emerge as an independent predictor in the multiple regression model. This discrepancy is common and occurs because correlation analysis examines only the simple, pairwise relationship between AF and complications, without accounting for the synergistic effects of other variables. Conversely, multiple regression analysis simultaneously evaluates the unique contribution of each factor while statistically controlling for potential confounders. Therefore, while AF is associated with pulmonary complications, its predictive power is likely overshadowed by other, stronger risk factors in the model, such as intubation time or obstructive sleep apnea (OSA).

Readiness to wean from mechanical ventilation did not serve as a predictor of postoperative pulmonary complications. In this study, the mean Rapid Shallow Breathing Index (RSBI) indicated that patients were ready for extubation, and most were extubated within the first 24 hours after surgery. This was facilitated by nursing care, including assessment of respiratory patterns, monitoring of oxygen saturation, and evaluation of vital signs. Extubation was performed when patients were hemodynamically stable, showed no signs of hypoxemia, and had adequate pain control. Crucially, the routine use of an incentive spirometer (such as Tri-Flow) was consistently implemented to promote deep breathing and enhance lung expansion. These comprehensive and standardized immediate postoperative interventions ensured that any minor variations in the readiness to wean did not subsequently affect the development or severity of postoperative pulmonary complications.

The findings of this study indicate that the amount of inotropic use did not correlate with the severity of pulmonary complications. This finding suggests that the inherent risk associated with cardiovascular instability—which necessitates the use of these medications—was successfully managed and mitigated by the medical team's meticulous fluid management strategy. Typically, patients with unstable vital signs (such as significant hypotension, hypertension, or severe arrhythmias) require high doses of these drugs to optimize cardiovascular function. However, the critical concern when administering high doses of inotropes is the necessity to carefully restrict postoperative fluid administration to prevent fluid overload, which increases cardiac workload and raises the risk of respiratory complications, such as pulmonary edema or pleural effusion. In this cohort, physicians employed

specialized prescribing practices, such as increasing the concentration of the drug solution (concentrated drips), to reduce the total fluid volume administered while maintaining the required drug dose. This proactive, compensatory management approach effectively minimized the risk of fluid-related respiratory complications, thereby ensuring that the amount of inotropic drug required did not translate into a statistically significant independent risk factor for postoperative pulmonary complications.

Conclusion and Recommendations

This study underscores the significant influence of obstructive sleep apnea and intubation duration on the severity of pulmonary complications following open-heart surgery. The results point to the importance of focused preoperative screening for obstructive sleep apnea and careful postoperative surveillance of patients who are at heightened risk for more severe pulmonary complications, with the goal of improving clinical outcomes. In contrast, variables such as hemoglobin levels, atrial fibrillation, readiness for ventilator weaning, and the use of vasoactive or inotropic medications appear to be less reliable predictors in this setting.

Limitations

This study has some limitations. First, this was a cross-sectional study; therefore, researchers could not determine the causal relationship between independent and dependent variables. Second, postoperative hemoglobin levels may be influenced by blood loss and aggravate respiratory problems.

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