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RISK FACTORS OF POSTOPERATIVE PNEUMONIA AFTER CORONARY ARTERY BYPASS GRAFT: A SCOPING REVIEW

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ABSTRACT

Postoperative pneumonia (POP) is the most common complication in patients after CABG surgery. It increases morbidity, mortality, length of stay, and hospitalization costs. This review aims to identify the factors that influence pneumonia and *the microorganisms that cause it in CABG postoperative patients. This scoping review used the framework developed by Arksey and O'Malley (2005). Primary sources of information were searched through five databases: PubMed, Scopus, Science Direct, Oxford, and EBSCO, and 2 search engines: Sage and Google Scholar. Article quality was assessed using the Joanna Briggs Institute critical appraisal checklist. A total of 8 articles with a total of 35235 participants were included in this review. The prevalence of post-CABG POP ranged from 2.4% to 18%. Dominant factors influencing postoperative pneumonia included duration of surgery, CPB time, blood transfusion, mechanical ventilation, LVAD/Tx, smoking history, chronic lung disease, and preoperative malnutrition. Meanwhile, the microorganisms that cause postoperative pneumonia are gram-positive and negative bacteria, fungi, and other bacteria. Infection prevention can be an important point in the CABG postoperative care continuum. By understanding the factors that influence POP, healthcare professionals can optimize patient outcomes, reduce complications, and improve the efficiency of postoperative care.*

Keywords: Coronary Artery Bypass Graft, Factors, Pneumonia

ABSTRAK

Pneumonia pasca operasi (POP) adalah komplikasi yang paling umum terjadi pada pasien setelah operasi CABG, yang meningkatkan morbiditas, mortalitas, peningkatan lama rawat inap, dan biaya perawatan di rumah sakit pasca operasi CABG. Review ini bertujuan untuk mengidentifikasi faktor-faktor yang mempengaruhi pneumonia dan mikroorganisme penyebab pneumonia pada pasien pasca operasi CABG. Scoping review ini menggunakan kerangka kerja yang dikembangkan oleh Arksey dan O'Malley (2005). Sumber informasi utama dicari melalui lima database: PubMed, Scopus, Science Direct, Oxford dan EBSCO serta 2 search engine: Sage dan Google Scholar. Kualitas artikel dinilai menggunakan the Joanna Briggs Institute critical appraisal checklist. Sebanyak 8 artikel dengan total 35235 partisipan dilibatkan dalam tinjauan ini. Prevalensi POP pascaoperasi CABG berkisar antara 2.4% sampai dengan 18%. Faktor dominan yang mempengaruhi pneumonia pasca operasi termasuk durasi operasi, waktu CPB, transfusi darah, ventilasi mekanis, LVAD / Tx, riwayat merokok, penyakit paru-paru kronis, dan malnutrisi sebelum operasi. Sedangkan mikroorganisme penyebab pneumonia pasca operasi adalah bakteri gram positif dan negatif, jamur, dan bakteri lainnya. Pencegahan infeksi dapat menjadi titik penting dalam rangkaian perawatan pascaoperasi CABG. Dengan memahami faktor yang mempengaruhi POP, para profesional kesehatan dapat mengoptimalkan hasil akhir pasien, mengurangi komplikasi, dan meningkatkan efisiensi perawatan pasca operasi.

Kata kunci: Cangkok Bypass Arteri Koroner, Faktor, Pneumonia

INTRODUCTION

Postoperative pneumonia (POP) is the most prevalent complication seen in patients following CABG surgery. A rapid onset characterizes it and poses a substantial risk (Zhang et al., 2023). POP is the result of infection by various microorganisms, including gram-negative and gram-positive bacteria such as acinetobacter baumannii, klebsiella pneumoniae, staphylococcus aureus, and others (Ailawadi et al., 2017; Zhang et al., 2023). Additionally, POP can be caused by polymicrobial infections, fungi, and even by the normal flora of the upper respiratory tract, such as Streptococcus viridans (Alsulami et al., 2020; D. Wang et al., 2021).

Postoperative pneumonia (POP) has a significant impact on the prognosis of patients and is linked to higher resource utilization, morbidity, and mortality following CABG surgery (Kinlin et al., 2010; Strobel et al., 2016). Additionally, postoperative pneumonia is connected to substantially increased care costs (Kilic et al., 2016). Patients who receive a diagnosis of pneumonia after CABG surgery are four times more likely to die and experience three times longer hospital stays compared to those without pneumonia (Kinlin et al., 2010). Postoperative pneumonia varies, ranging from 2.4% to 18% (Ailawadi et al., 2017; Zhang et al., 2023). Therefore, it is crucial to identify patients who are at risk of developing POP.

In a study carried out in China, it was found that 90 out of 500 patients developed POP after CABG surgery. The factors influencing this outcome were the duration of endotracheal intubation, the length of the operation, and the patient's smoking history (Zhang et al., 2023). Another study by Kilic et al.

(2016) revealed that age, chronic lung disease, peripheral vascular disease, a cardiopulmonary bypass (CPB) time exceeding 100 minutes, blood transfusion, and the use of an intra-aortic balloon pump (IABP) had a significant impact on the occurrence of POP following cardiac surgery (Kilic et al., 2016).

In 2017, a study conducted in the USA detailed patient, procedure characteristics, and management practices linked to pneumonia; however, many predictors remain unidentified (Ailawadi et al., 2017). Our literature search found no comprehensive review of post-CABG pneumonia and its influencing factors. Therefore, it is crucial to identify the factors impacting postoperative pneumonia (POP) and the primary microorganisms causing pneumonia in patients after CABG surgery through a thorough literature review. This information will help medical staff anticipate the possibility of POP and allocate postoperative medical resources effectively following CABG surgery.

METHOD

1. Research design

This review follows a scoping review design, which is a flexible method for identifying and exploring modern, fast-changing topics (Peterson et al., 2017). Scoping reviews use a broader framework to explain relevant research findings. The framework includes stages such as defining research questions, finding suitable research, selecting studies, organizing data, summarizing, and reporting (Arksey & O'Malley, 2005).

This review is based on a scoping review design, which utilizes a flexible methodological approach to identify and explore current, rapidly evolving subjects (Peterson et al., 2017). Scoping reviews provide a more extensive conceptual framework for explaining relevant research findings. The scoping review framework comprises several stages, including formulating research questions, identifying pertinent research, selecting studies, charting data, compiling literature search results, summarizing, and reporting findings (Arksey & O'Malley, 2005). This research protocol has not been published or registered.

2. Eligibility criteria

The reviewers selected articles for this review based on the PRISMA-ScR framework, as shown in Figure 1 (Page et al., 2021). This article's research questions and eligibility criteria followed the PCC (Population, Concept, and Context) approach (Peters et al., 2020). The research questions addressed in this review are: What are the main factors linked to postoperative pneumonia in patients following CABG surgery? What microorganisms are responsible for causing pneumonia in patients after CABG surgery?

P (Population): Adults and patients post Coronary Artery Bypass Graft surgery.
C (Concept): Pneumonia, Healthcare-Associated Pneumonia.
C (Context): Factors, Risk Factors, Predictors.

The review's selection criteria consisted of full-text articles in English, published between 2014 and 2024, involving case-control, cross-sectional, longitudinal, and cohort study designs that addressed factors linked to postoperative pneumonia in patients following CABG surgery. In this review, non-English language research, qualitative research, full-text publications that were not accessible, and secondary research were all excluded.

3. Search strategy

The literature search was systematically conducted across five databases (PubMed, Scopus, Science Direct, Oxford, and EBSCO) and two search engines (Sage and Google Scholar) on July 1, 2024. Results: We further expanded the literature search using a snowball technique focusing on relevant topics. The keywords used were "Coronary Artery Bypass Graft OR Coronary Artery Bypass Surgery AND Pneumonia OR Healthcare-Associated Pneumonia AND Factors OR Risk Factor OR Predictor".

4. Study selection and quality appraisal

The eligibility criteria were independently applied by three authors who selected relevant studies. The authors utilized Mendeley's Reference Manager to identify any duplicates during the initial article selection process. Subsequently, the authors reviewed the titles and abstracts and thoroughly read each paper in accordance with the relevance of the selected research topic and the specified inclusion and exclusion criteria. In the final stage of study selection, the authors utilized the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Cross-Sectional and Cohort Studies (Joanna Briggs Institute (JBI), 2022) to assess each paper that met the inclusion criteria.

Ratings consist of "Yes," "No," "Unclear," and "Not Applicable." Each "Yes" response is valued at 1, and the other responses are valued at 0. The total of these ratings determines if the item is suitable for inclusion in this review. It allows researchers to assess the dependability and relevance of their findings for potential inclusion in further discussion. We excluded all studies with a JBI score lower than 70 following the JBI assessment. The ultimate decision was ensured to reflect a unanimous consensus on the appropriateness of the studies to be thoroughly analyzed in this scoping review by the final approval of the first, second, and third authors.

5. Data extraction and analysis

At the stage of extracting and analyzing the data, this review utilized extraction tables to outline all research findings associated with the research subject. The extraction table included information about the characteristics of the studies, such as the author, study design, country, type of surgery, sample size (including the number of patients with postoperative pneumonia and the mean age), study findings (factors contributing to postoperative pneumonia), and final JBI results. All the research reviewed consisted of original studies utilizing cross-sectional and cohort designs. Thematically and qualitatively, the data was analyzed using an exploratory, descriptive method. The data analysis began with identifying and presenting the information obtained in tabular form based on the articles reviewed. Following the acquisition of the data, the researchers examined and deliberated on the findings of each study, focusing on the factors that influence postoperative pneumonia after CABG surgery. The author classified these factors into three categories according to the research findings: low, moderate, and high.

RESULTS AND DISCUSSION

1. Study selection

The initial phase of the review involved selecting articles, leading to a total of 165,726 articles. After eliminating 144,314 duplicate articles, the authors chose articles based on title, abstract, and predetermined inclusion criteria. Subsequently, they conducted a detailed analysis of 12 studies through full-text article review. Among these, two studies were excluded because they focused on the general topic of postoperative pulmonary complications (PPC) in cardiac surgery patients, and two others did not specifically focus on pneumonia. After this process, eight studies were evaluated using the JBI tool, all of which were eligible and included in the final analysis. The study selection process, resulting in eight studies, is depicted in Figure 1. These studies were scrutinized in this scoping review using the PRISMA flowchart.

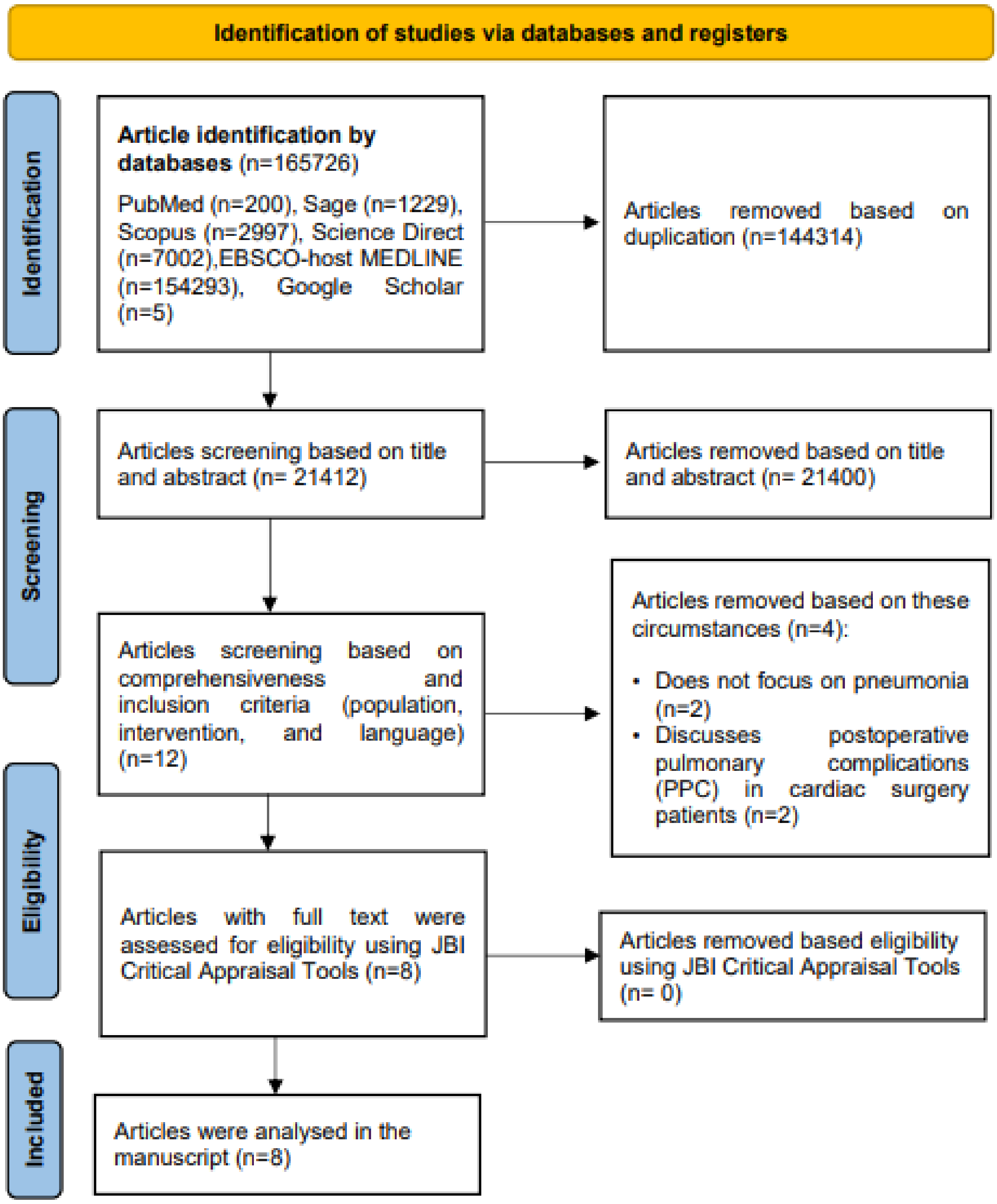

Figure 1. PRISMA Flow Diagram

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

2. Study characteristics

A total of eight articles were reviewed, which comprised three cross-sectional studies and five retrospective cohort studies. Four studies were carried out in developed nations (refer to Table 1). The cumulative participant count was 35235. Within this group, 1689 individuals (4.79%)

experienced Postoperative Pneumonia (POP). The prevalence of POP ranges from 2.4% to 18% (Ailawadi et al., 2017; Zhang et al., 2023). Most studies conducted multivariate analysis, whereas the rest performed only univariate analysis (refer to Table 1). The outcomes of the JBI analysis indicate that most cross-sectional studies analyzed were of high quality (>87%). Most of the studies needed to improve in addressing confounding factors and follow-up time and implementing strategies to address incomplete follow-up.

Table 1
Characteristics of Study

Study, Country	Design	Type of Surgery	Sample			Findings	CA
			Size	Number POP Patients (%)	Mean Age (SD)	Factors of POP	
(Kilic et al., 2016) USA	Retrospective cohort study	CABG, Valve, CABG + valve, Other	6222	282 (4,53)	61.2 ± 14.9	Age ≥65 y (OR: 1.40, 95% CI: 1.01-1.94, *p*=0.04)**, Chronic lung disease: Mild (OR: 1.97, 95% CI: 1.22-3.16, *p=0.005*)**, Moderate (OR: 3.07, 95% CI: 1.80-5.23, *p<0.001*)**, Severe (OR: 3.31, 95% CI: 1.56-7.03, *p*=0.*002*)**, *Peripheral vascular disease* (OR: 1.69, 95% CI: 1.11-2.56, *p*=0.01)**, Cardiopulmonary bypass time>100 min (OR: 1.71, 95% CI: 1.13-2.61, *p*=0.01)**, Intraoperative red blood cell transfusion (OR: 1.08, 95% CI: 1.03-1.13, *p*=0.002)**, Pre- or intraoperative intra-aortic balloon pump implantation (OR: 2.01, 95% CI: 1.30-3.11, *p*=0.002)**,	8/11 72,73 %
(K. Wang et al., 2024) China	Retrospective cohort study	CABG, AVR or MVR, CABG + Valve, AVR + MVR, Thoracic aortic surgery, Others	1188	105 (8,84)	Median (IQR) 63 (56 -71)	Age (>55 years) (OR: 1.83, 95% CI: 1.30-3.11) (P=0.0225)**, preoperative malnu- trition (OR: 3.71, 95% CI: 2.10-6.43) (P<0.0001)**, diabetes mellitus (OR: 2.33, 95% CI: 1.30-4.08) (P=0.0036) **, CPB time (Cardiopulmonary Bypass Time) > 135 min (OR: 2.80, 95% CI: 1.71-4.68) (P<0.0001)**, moderate to severe ARDS (Acute Respiratory Distress Syndrome)(OR: 1.79, 95% CI: 1.12-2.85) (P=0.0148)**, use of ECMO or IABP or CRRT (ECMO: Extra Corporeal Membrane Oxygenation; IABP: Intra-Aortic Balloon Pump; CRRT: Continuous Renal Replacement Therapy) (OR: 2.60, 95% CI: 1.31-5.10) (P=0.0057)** and	9/11 81,82 %

						MV (Mechanical Ventilation) > 20 hours (OR: 3.11, 95% CI: 1.88-5.12) (P<0.0001)**	
(Strobel et al., 2016) USA	Prospective observational study	CABG	16084	531 (3.3)	66.35 ± 10.9	Age: (β: -0.0813, p=0.01)** Nonwhite race (OR: 1.66, β: 0.5046, p<0.001)** Laboratory values: Hematocrit (OR: 0.98, β: -0.0208, p=0.01)** White blood cell count (OR: 1.03, β: 0.0271, p<0.001)** Comorbid disease: Dyslipidemia (OR: 0.73, β: -0.3174, p=0.03)** Peripheral vascular disease (OR: 1.48, β: 0.3903, p<0.001)** Cerebrovascular disease (OR: 1.44, β: 0.3668, p<0.001)** Diabetes mellitus (OR: 1.26, β: 0.2269, p=0.02)** Liver disease (OR: 1.82, β: 0.5983, p=0.004)** Pulmonary function: • Home oxygen therapy (OR: 1.74, β: 0.5520, p=0.02)** • History of pneumonia (OR: 1.55, β: 0.4355, p=0.001)** Current cigarette smoking (OR: 2.06, β: 0.7204, p<0.001)** Chronic lung disease: • Mild (OR: 1.27, β: 0.2364, p=0.04)** • Moderate/severe (OR: 1.91, β: 0.6459, p<0.001)** Cardiac function Preoperative intra-aortic balloon pump (OR: 1.59, β: 0.4614, p=0.002)** History of arrhythmia: • Recent (OR: 1.48, β: 0.3948, p=0.002)** Ejection fraction (OR: 0.99, β: -0.0111, p=0.002)** Operative status Emergent (OR: 2.19, β: 0.7836, p<0.001)**	7/8 87.5%
(Zhang et al., 2023) China	Retrospective cohort study	CABG	500	90 (18)	58.12 ± 7.45	Endotracheal intubation time (OR: 2.391, β: 0.864, 95% CI: 1.062-5.128, p=0.032)**, operation time, (OR: 3.361, β: 1.302, 95% CI: 1.251-8.692, p=0.002)**,smoking history (OR: 11.271, β: 2.401, 95% CI: 1.256-56.251, p=0.039)**,	8/11 72,73 %
(Ailawadi et al., 2017) USA	Prospective observational study	CABG, Valve, CABG + valve, LVAD/Tx,	5158	123 (2,4)	64.4 ± 13.2	Management practices associated with pneumonia: Second-generation CEPH (HR: 0.66, 95% CI: 0.45-0.97, p=0.04)*** Ventilation:	8/8 100%

		Thoracic aortic, Other				24-48 hour (HR: 2.83, 95% CI: 1.72-4.66, p<0.001)*** >48 hour (HR: 4.67, 95% CI: 2.70-8.08, p<0.001)*** NG tube (HR: 1.80, 95% CI: 1.10-2.94, p=0.02)*** PRBC (HR: 1.16, 95% CI: 1.08-1.26, p<0.001)*** Platelet (HR: 0.49, 95% CI: 0.30-0.79, p=0.004)*** Patient and procedure characteristics associated with pneumonia: Age (HR: 1.02, 95% CI: 1.00-1.03, p=0.05)*** COPD (HR: 2.17, 95% CI: 1.47-3.21, p<0.001)*** Corticosteroids (HR: 1.91, 95% CI: 1.01-3.59, p=0.05)*** Hemoglobin (HR: 0.88, 95% CI: 0.79-0.97, p=0.01)*** LVAD/Tx (HR: 2.79, 95% CI: 1.50-5.17, p=0.001)*** Duration of surgery (HR: 1.38, 95% CI: 1.25-1.53, p<0.001)***	
(Alsulami et al., 2020) SAU	Retrospective cohort study	Cardiac surgery	255	5 (2.5)	47 ± 18	Smokers (4/5)*, hypertensive (3/5)*, ASA 4 (4/5)*, Elective operation (3/5)*	8/11 72,73 %
(D. Wang et al., 2021) China	Retrospective cohort study	CABG, Valve, CABG+Valve, Aortic, Others	5323	530 (9,96)	51,18 ± 12,92	Age >60 years (OR: 1.984, β: 0.685, 95% CI: 1.617–2.435, p<0.001)** Hypertension (OR: 1.787, β: 0.581, 95% CI: 1.447–2.208, p<0.001)** Diabetes mellitus (OR: 1.378, β: 0.321, 95% CI: 1.015–1.871, p=0.040)** Smoking history (OR: 1.689, β: 0.524, 95% CI: 1.380–2.068, p<0.001)** COPD (OR: 1.422, β: 0.352, 95% CI: 1.070–1.889, p=0.015)** BMI ≥24 kg/m2 (OR: 1.274, β: 0.242, 95% CI: 1.039–1.562, p=0.020)** Renal insufficiency (OR: 2.670, β: 0.982, 95% CI: 2.095–3.402, p<0.001)** Heart surgery history (OR: 2.544, β: 0.934, 95% CI: 1.872–3.456, p<0.001)** NYHA class III-IV (OR: 1.447, β: 0.369, 95% CI: 1.146–1.826, p=0.002)** Preoperative anemia (OR: 1.617, β: 0.481, 95% CI: 1.186–2.205, p=0.002)** Hypoalbuminemia (OR: 1.347, β: 0.298, 95% CI: 1.003–1.809, p=0.047)**	9/11 81,82 %

						CPB time >120 minutes (OR: 2.622, β: 0.964, 95% CI: 2.133–3.223, p<0.001)** Blood transfusion (OR: 3.531, β: 1.262, 95% CI: 2.212–5.636, p=0.001)**	
(Duchnowski & Śmigielski, 2023) Poland	Prospective observational study	CABG, Valve, Double Valve	505	23 (4,55)	63 ± 12	Hemoglobin, g/dL (OR: 0.711, 95% CI: 0.551–0.919, p=0.009)* Hs-TnT, ng/L (OR: 2.086, 95% CI: 1.211–3.593, p=0.008)** NT-proBNP, pg/mL (OR: 1.475, 95% CI: 1.067–2.041, p=0.01)* RVSP, mm Hg (OR: 1.303, 95% CI: 1.007–1.061, p=0.01)**	8/8 100%

Notes: *Proportion, **Multiple Logistic Regression, ***Cox proportional hazards,

Abbreviations:

ARDS, Acute Respiratory Distress Syndrome; B, Beta; BMI, Body Mass Index; CA, Critical Appraisal; CI, Confidence Interval; COPD, Chronic Obstructive Pulmonary Disease; CPB, Cardio-Pulmonary Bypass; CRRT, Continuous Renal Replacement Therapy; ECMO, Extra Corporeal Membrane Oxygenation; HR, Hazard ratio; Hs-TnT = high sensitivity troponin t; IABP: Intra-Aortic Balloon Pump; LVAD/Tx: LVAD/Tx, left ventricular assist device or heart transplant surgery; MV, Mechanical Ventilation; NG, NasoGastric Tube; N/I, Not Information; NT-proBNP, n-terminal of the prohormone brain natriuretic peptide; NYHA, New York Heart Association; OR, Odd Ratio; POP, PostOperative Pneumonia; PRBC, packed red blood cells; RVSP, Right Ventricular Systolic Pressure.

3. Factors related to postoperative pneumonia

This review identified factors significantly associated with postoperative pneumonia in CABG patients. The analysis results showed that the factors associated with postoperative pneumonia had heterogeneous results. Based on the analysis, demographic characteristics, laboratory values, comorbidities, pulmonary function, cardiac function, history, operative/surgical findings, and use of devices had a significant association with postoperative pneumonia in CABG patients. Researchers categorized these factors into three categories for convenience: low, moderate, and high (see Table 2).

Table 2
Factors Associated with Postoperative Pneumonia after CABG Surgery

Categories	Highest Ratio OR or HR (95% CI)	Lowest Ratio OR or HR (95% CI)	B Coefficient	Categories	References
Demographic characteristics					
Age > 55	1.984 (1.617–2.435)	HR: 1.02 (1.00-1.03)	0.685	Moderate	(Ailawadi et al., 2017; Kilic et al., 2016; Strobel et al., 2016; D. Wang et al., 2021; K. Wang et al., 2024)
BMI ≥24 kg/m2	1.274 (1.039–1.562)	1.274 (1.039–1.562)	0.242	Low	(D. Wang et al., 2021)
Nonwhite race	1.66	1.66	0.5046	Moderate	(Strobel et al., 2016)
Laboratory values					
Hemoglobin	1.617 (1.186–2.205)	0.711 (0.551–0.919)	0.481	Moderate	(Ailawadi et al., 2017), (D. Wang et al., 2021), (Duchnowski & Śmigielski, 2023)
Hematocrit	0.98	0.98	-0.0208	Low	(Strobel et al., 2016)
Leukocytes	1.03	1.03	0.0271	Low	(Strobel et al., 2016)
Albumin	1.347 (1.003–1.809)	1.347 (1.003–1.809)	0.298	Low	(D. Wang et al., 2021)

Hs-TnT	2.086 (1.211–3.593)	2.086 (1.211–3.593)	N/I	Moderate	(Duchnowski & Śmigielski, 2023)
NT-proBNP	1.475 (1.067–2.041)	1.475 (1.067–2.041)	N/I	Moderate	(Duchnowski & Śmigielski, 2023)
Comorbidities					
Dyslipidemia	0.73	0.73	-0.3174	Low	(Strobel et al., 2016)
Diabetes mellitus	2.33 (1.30-4.08)	1.26	0.2269	Moderate	(Strobel et al., 2016; D. Wang et al., 2021; K. Wang et al., 2024)
Liver disease	1.82	1.82	0.5983	Moderate	(Strobel et al., 2016)
Renal insufficiency	2.670 (2.095–3.402)	2.670 (2.095–3.402)	0.982	Moderate	(D. Wang et al., 2021)
Hypertension	1.787 (1.447–2.208)	1.787 (1.447–2.208)	0.581	Moderate	(Alsulami et al., 2020; D. Wang et al., 2021)
Peripheral vascular disease	1.69 (1.11-2.56)	1.48	0.3903	Moderate	(Kilic et al., 2016; Strobel et al., 2016)
Cerebrovascular disease	1.44	1.44	0.3668	Low	(Strobel et al., 2016)
Preoperative malnutrition	3.71 (2.10-6.43)	3.71 (2.10-6.43)	N/I	High	(K. Wang et al., 2024)
Pulmonary function					
Chronic lung disease:	HR: 2.17 (1.47-3.21)	1.422 (1.070–1.889)	0.352	Moderate	(Ailawadi et al., 2017)
• Mild	1.97 (1.22-3.16)	1.27	0.2364	Moderate	(Kilic et al., 2016; Strobel et al., 2016)
• Moderate	3.07 (1.80-5.23)	1.91	0.6459	High	(Kilic et al., 2016; Strobel et al., 2016)
• Severe	3.31 (1.56-7.03)	3.31 (1.56-7.03)	N/I	High	(Kilic et al., 2016)
Moderate to severe ARDS	1.79 (1.12-2.85)	1.79 (1.12-2.85)	N/I	Moderate	(K. Wang et al., 2024)
Home oxygen therapy	1.74	1.74	0.5520	Moderate	(Strobel et al., 2016)
Cardiac function					
Use of ECMO or IABP or CRRT	2.60 (1.31-5.10)	1.59	0.4614	Moderate	(Kilic et al., 2016; Strobel et al., 2016; K. Wang et al., 2024)
Ejection fraction	0.99	0.99	-0.0111	Low	(Strobel et al., 2016)
NYHA class III-IV	1.447 (1.146–1.826)	1.447 (1.146–1.826)	0.369	Low	(D. Wang et al., 2021)
LVAD/Tx	HR: 2.79 (1.50-5.17)	HR: 2.79 (1.50-5.17)	N/I	High	(Ailawadi et al., 2017)
RVSP	1.303 (1.007–1.061)	1.303 (1.007–1.061)	N/I	Low	(Duchnowski & Śmigielski, 2023)
History of					
Pneumonia	1.55	1.55	0.4355	Moderate	(Strobel et al., 2016)
Recent arrhythmia	1.48	1.48	0.3948	Moderate	(Strobel et al., 2016)
Smoking	11.271 (1.256-56.251)	1.689 (1.380–2.068)	0.524 - 2.401	High	(Alsulami et al., 2020; Strobel et al., 2016; D. Wang et al., 2021; Zhang et al., 2023)
Heart surgery	2.544 (1.872–3.456)	2.544 (1.872–3.456)	0.934	Moderate	(D. Wang et al., 2021)
Operative/Surgical Findings					
Emergent Operative	2.19	2.19	0.7836	Moderate	(Strobel et al., 2016)

Duration of surgery	3.361 (1.251-8.692)	HR: 1.38 (1.25-1.53)	1.302	High	(Ailawadi et al., 2017; Zhang et al., 2023)
CPB time	2.80 (1.71-4.68)	1.71 (1.13-2.61)	N/I	High	(Kilic et al., 2016; D. Wang et al., 2021; K. Wang et al., 2024)
Blood transfusion (PRBC)	3.531 (2.212–5.636)	1.08 (1.03-1.13)	1.262	High	(Ailawadi et al., 2017; Kilic et al., 2016; D. Wang et al., 2021)
Use of:					
Mechanical Ventilation	HR: 4.67 (2.70-8.08)	2.391 (1.062-5.128)	0.864	High	(Ailawadi et al., 2017; K. Wang et al., 2024; Zhang et al., 2023)
NG tube	HR: 1.80 (1.10-2.94)	HR: 1.80 (1.10-2.94)	N/I	Moderate	(Ailawadi et al., 2017)
Corticosteroids	HR: 1.91 (1.01-3.59)	HR: 1.91 (1.01-3.59)	N/I	Moderate	(Ailawadi et al., 2017)

Abbreviations:

ARDS, Acute Respiratory Distress Syndrome; B, Beta; BMI, Body Mass Index; CA, Critical Appraisal; CI, Confidence Interval; CPB, Cardio-Pulmonary Bypass; CRRT, Continuous Renal Replacement Therapy; ECMO, Extra Corporeal Membrane Oxygenation; HR, Hazard ratio; Hs-TnT = high sensitivity troponin t; IABP: Intra-Aortic Balloon Pump; LVAD/Tx: LVAD/Tx, left ventricular assist device or heart transplant surgery; MV, Mechanical Ventilation; NG, NasoGastric Tube; N/I, Not Information; NT-proBNP, n-terminal of the prohormone brain natriuretic peptide; NYHA, New York Heart Association; OR, Odd Ratio; POP, PostOperative Pneumonia; PRBC, packed red blood cells; RVSP, Right Ventricular Systolic Pressure.

In this review, factors related to POP included in the preoperative factors category were demographic characteristics (age, BMI, race), laboratory values (hemoglobin, hematocrit, leukocytes, albumin, Hs-TnT, NT-proBNP), comorbidities (dyslipidemia, diabetes mellitus, liver disease, renal insufficiency, hypertension, peripheral vascular disease, cerebrovascular disease, preoperative malnutrition), pulmonary function (chronic lung disease, ARDS, home oxygen therapy), cardiac function (use of ECMO or IABP or CRRT, ejection fraction, NYHA class III-IV, LVAD/Tx, RVSP), history of (pneumonia, recent arrhythmia, smoking, heart surgery), operative/ surgical findings (emergent operative, duration of surgery, CPB time, blood transfusion), and use of (mechanical ventilation, NG tube, corticosteroids).

Based on the results of the study, most studies reported age (Ailawadi et al., 2017; Kilic et al., 2016; Strobel et al., 2016; K. Wang et al., 2024), and history of smoking (Alsulami et al., 2020; Strobel et al., 2016; Zhang et al., 2023), as factors that influence the occurrence of POP. Meanwhile, the most influential factors for POP in CABG based on OR or HR values (95% CI) are preoperative malnutrition 3.71 (2.10-6.43), chronic lung disease: Moderate 3.07 (1.80-5.23) and severe 3.31 (1.56-7.03), LVAD/Tx 2.79 (1.50-5.17), history of smoking 11.271 (1.256-56.251), Duration of surgery 3.361 (1.251-8.692), CPB time 2.80 (1.71-4.68), Blood transfusion 3.531 (2.212–5.636), and Mechanical Ventilation 4.67 (2.70-8.08).

4. Pathogenic microorganisms discovered from patients with postoperative pneumonia

Four research papers examined pathogenic microorganisms discovered in patients who developed postoperative pneumonia after undergoing CABG surgery (refer to Table 3). Most of the microorganisms causing pneumonia were gram-negative bacteria (57.22%), such as acinetobacter baumannii (26.18%), klebsiella pneumoniae (17.67%), pseudomonas aeruginosa (9.55%).

Table 3
Pathogenic microorganisms isolated from patients with postoperative pneumonia (n=1211)

No.	Microorganisms	Frequencies	(%)
	Gram-Negative Bacteria:	693	57.22
1	Acinetobacter baumannii	317	26.18
2	Klebsiella pneumoniae	214	17.67

3	Pseudomonas aeruginosa	115	9.50
4	Enterobacter cloacae	11	0.91
5	Escherichia coli	11	0.91
6	Burkholderia cepacia	16	1.32
7	Haemophilus influenzae	9	0.74
	Gram-Positive Bacteria:	148	12.22
8	Staphylococcus aureus	148	12.22
9	Polymicrobial	184	15.19
10	Other bacteria	172	14.2
	Yeast (Yeast Cells):	11	0.91
11	Candida albicans	11	0.91
12	Normal Upper Respiratory Tract Flora	3	0.25

Source: (Ailawadi et al., 2017; Alsulami et al., 2020; Wang et al., 2021; Zhang et al., 2023)

DISCUSSION

This scoping review identifies the factors that could impact POP and microorganisms leading to pneumonia following CABG surgery. Overall, the findings of this review indicated that most of the analyzed research studies indicated that the occurrence of POP in CABG patients ranged from 2.4% to 18% (Ailawadi et al., 2017; Zhang et al., 2023). Eight domains may influence the occurrence of POP, including demographic characteristics, laboratory values, comorbidities, pulmonary function, cardiac function, history of disease, operative/ surgical findings, and use of devices. We further categorized these factors into low, moderate, and high.

A history of the disease was the factor that had the strongest influence on POP in this review. Smoking history was the factor that most influenced POP, with the highest OR value in this review (OR: 11.271, 95% CI: 1.256-56.251) (Zhang et al., 2023). After smoking, the lungs produce tar and nicotine, which damages the lungs and leads to pulmonary fibrosis. Patients with a history of smoking who have had CABG surgery are more likely to get lung infections. Longer surgeries increase the risk of bacterial lung infections after surgery (Ono et al., 2021; Zhang et al., 2023). The history of other diseases that affect POP is a history of pneumonia that increased 1.55 times, a history of Recent arrhythmia that increased 1.48 times, and a history of previous heart surgery 2.54 times for the occurrence of POP after CABG surgery (Strobel et al., 2016; D. Wang et al., 2021). Patients with a history of pneumonia are more susceptible to post-cardiac surgery pneumonia. Similarly, individuals with a history of arrhythmia may have compromised pulmonary reserve and poor cardiac function, making them more prone to postoperative pneumonia (Strobel et al., 2016). Moreover, previous heart surgery can result in reduced pulmonary function and altered immune responses, further increasing the risk of pneumonia (D. Wang et al., 2021).

The next most influential factor for POP was using medical devices and medications. The use of mechanical ventilation was the second factor with the highest OR after smoking history. A study conducted by Ailawadi et al. (2017) reported that patients who were intubated between 24 and 48 hours or >48 hours had a 2.83 and 4.67-fold increased risk of pneumonia (Ailawadi et al., 2017). Extended mechanical ventilation may impair mucociliary clearance, diminish the cough reflex, and elevate the risk of aspiration pneumonia (Gerodias et al., 2021). Using nasogastric tubes can impact the proper function of the gastroesophageal sphincter, potentially leading to bacterial migration and colonization in the oropharynx, thereby increasing vulnerability to pneumonia (Paleczny et al., 2022). Moreover, the use of corticosteroid medications has been linked to a heightened risk of pneumonia due to their immunosuppressive effects (Long et al., 2013).

Another factor that influences POP after CABG surgery is comorbidity. Preoperative malnutrition is the most highly influential comorbidity, increasing the risk of POP 3.71-fold (K. Wang et al., 2024).

Kuo Wang et al. (2024) study reported that patients with malnutrition had a significantly higher incidence of pneumonia compared to those without malnutrition. Other comorbidities that moderately affect POP are diabetes mellitus, liver disease, renal insufficiency, hypertension, and peripheral vascular disease. These factors can all impact the body's ability to combat infections and may elevate the risk of various complications (Kilic et al., 2016; Strobel et al., 2016; D. Wang et al., 2021). In comparison, comorbidities that have a low influence are dyslipidemia and cerebrovascular disease. Dyslipidemia and cerebrovascular disease can increase the risk of postoperative infections, including pneumonia, by creating a pro-inflammatory state in the body and impairing the immune response. These conditions are also associated with cardiovascular risk factors, which further exacerbate susceptibility to infections. Additionally, they may impact respiratory function and contribute to vascular damage, increasing the risk of complications post-surgery (Abukhodair et al., 2023; Kilic et al., 2016).

Findings during surgery were the next factor affecting POP after CABG surgery. Transfusion administration was the factor that most influenced POP and had the highest beta coefficient value in this study (β=1.262) (D. Wang et al., 2021). It is essential to consider the potential impact of transfusion-related immunomodulation, which occurs when allogeneic blood products affect the recipient's immune response. Blood transfusion can lead to increased inflammation, potentially affecting the body's ability to combat infections, including pneumonia. Furthermore, there is evidence linking blood transfusions to a higher risk of postoperative infections, and a clear relationship has been observed between the amount of red blood cell transfusion and the likelihood of developing pneumonia (Al-Harbi et al., 2019; Kilic et al., 2016; D. Wang et al., 2021).

Demographic characteristics are the next factor affecting POP in this review. Age is the most widely reported demographic characteristic affecting POP after CABG surgery (Ailawadi et al., 2017; Kilic et al., 2016; Strobel et al., 2016; D. Wang et al., 2021; K. Wang et al., 2024). Research by Kuo Wang et al. (2024) reported that age > 55 increased the risk of POP by 1.83 times (K. Wang et al., 2024). They used a quadratic function to model patient age due to its nonlinear impact on the likelihood of postoperative pneumonia. As a result, there is a greater and nonlinear projected risk of pneumonia as age increases (K. Wang et al., 2024). Other factors were BMI > 24 kg/m2 and nonwhite race (Strobel et al., 2016; D. Wang et al., 2021).

Several laboratory values have also been reported as factors affecting POP, including hemoglobin, hematocrit, leukocytes, albumin, Hs-TnT, and NT-proBNP. Research by Strobel et al. (2016) identified hematocrit (OR: 0.98, β: -0.0208, p=0.01) and leukocytes (OR: 1.03, β: 0.0271, p<0.001) as risk factors for POP in CABG patients (Strobel et al., 2016). While research by Dashuai Wang et al. (2021) reported anemia (OR: 1.617, β: 0.481, 95% CI: 1.186-2.205, p=0.002) and hypoalbuminemia (OR: 1.347, β: 0.298, 95% CI: 1.003-1.809, p=0.047) as risk factors for POP after cardiac surgery (D. Wang et al., 2021). High-sensitivity troponin T (Hs-TnT) and N-terminal pro-brain natriuretic peptide (NT-proBNP) are biomarkers that reflect cardiac stress and injury, which can lead to problems with the heart's function and blood circulation (Shen et al., 2024). This biomarkers can result in poor blood flow to the lungs and fluid buildup, creating a good environment for respiratory infections to develop (Duchnowski & Śmigielski, 2023; Lee et al., 2011). Monitoring these laboratory values and biomarkers after surgery and addressing any heart issues may help reduce the risk of pneumonia and improve patient outcomes.

Pulmonary and cardiac function are also factors that affect POP. Pulmonary function, such as having chronic lung disease, ARDS, and using oxygen at home, are factors that influence POP. With the most influencing factor being moderate to severe chronic lung disease. Patients with chronic lung disease, such as chronic obstructive pulmonary disease (COPD), often have pre-existing structural lung abnormalities, impaired mucociliary clearance, and increased airway inflammation, which can predispose them to postoperative pulmonary complications, including pneumonia (Fujii et al., 2020).

Meanwhile, mild chronic lung disease increases the risk of POP by 1.97 times (Kilic et al., 2016). ARDS can develop due to various factors, such as a systemic inflammatory response triggered by surgery, cardiopulmonary bypass, and mechanical ventilation (Rong et al., 2016). The use of oxygen at home shows a decrease in gas exchange function so that atmospheric oxygen can no longer meet the patient's oxygen needs.

Cardiac functions such as the use of extracorporeal devices (ECMO, IABP, CRRT), ejection fraction, NYHA Class, LVAD/Tx, and RVSP affect the occurrence of POP after CABG surgery. LVAD increases the risk of POP 2.8-fold (Ailawadi et al., 2017). LVADs alter the heart's hemodynamics, affecting cardiac output and systemic circulation. The continuous flow can disrupt normal blood flow, impacting the right ventricle and blood clearance from the lungs, which may lead to pulmonary issues and increased pneumonia risk post-surgery (Ailawadi et al., 2017; Zalawadiya et al., 2015). The use of extracorporeal devices increases the risk of POP due to the risk of infection from blood exchange outside the body. Patients who require IABP, ECMO, or CRRT typically experience decreased cardiac output necessitating these support devices and resulting in detrimental effects on the immune system, such as the occurrence of respiratory infections or pneumonia (K. Wang et al., 2024).

Patients needing IABP, ECMO, or CRRT typically experience decreased cardiac output necessitating these support devices and resulting in detrimental effects on the immune system, such as an increased risk of respiratory infections or pneumonia (K. Wang et al., 2024). Patients with low ejection fraction tend to have significant left ventricular dysfunction, which can lead to fluid accumulation in the lungs (pulmonary congestion) and increase the risk of postoperative pneumonia (Ailawadi et al., 2017). Patients with high NYHA class usually experience more severe symptoms of heart failure, such as dyspnea at rest or mild exertion. This indicates significant impairment of heart function and may contribute to an increased risk of postoperative complications, including pneumonia (D. Wang et al., 2021). RVSP increases the risk of postoperative pneumonia in post-heart surgery patients involves a combination of factors, including pulmonary hypertension, right ventricular dysfunction, pulmonary congestion, impaired gas exchange, increased cardiac workload, and the risk of fluid overload (Duchnowski & Śmigielski, 2023).

The most common microorganisms causing Postoperative Pneumonia (POP) in cardiac surgery patients are often associated with specific pathogens that are prevalent in healthcare settings and can lead to respiratory infections. Studies have shown that Acinetobacter baumannii, a Gram-negative bacillus, is a predominant pathogen in patients with postoperative pneumonia. This multidrug-resistant microorganism is linked to adult patients with kidney disease and prolonged extracorporeal circulation time during surgery, as well as the use of postoperative nasogastric tubes (D. Wang et al., 2021). Another common pathogenic bacterium responsible for postoperative pneumonia is Pseudomonas aeruginosa. This Gram-negative bacterium has been identified as the most frequent pathogen causing postoperative pneumonia after cardiac surgery (Ailawadi et al., 2017). Postoperative pneumonia is frequently caused by Gram-negative pathogens, with multidrug-resistant bacteria accounting for a significant proportion of cases. These pathogens can include various Gram-negative bacteria commonly found in healthcare settings (Zhang et al., 2023).

Other gram-negative bacteria that cause pop from our review are klebsiella pneumoniae (17.67%), enterobacter cloacae (0.91%), klebsiella oxytoca (0.66%), stenotrophomonas spp. (0.58%), serratia marcescens (0.5%), escherichia coli (0.91%), proteus mirabilis (0.25%), achromobacter spp. (0.17%), citrobacter koseri (0.71%), citrobacter freundii (0.08%), dan enterobacter aerogenes (0.08%). The most common microorganisms causing postoperative pneumonia in cardiac surgery patients include multidrug-resistant bacteria such as acinetobacter baumannii, pseudomonas aeruginosa, and various gram-negative pathogens. The most common gram-positive bacteria found to cause pop is staphylococcus aureus (11.89%), with 4 of these developing into methicillin-resistant staphylococcus aureus (mrsa) (0.33%), staphylococcus epidermidis (0.08%), and streptococcus spp. (0.25%). Patients can also get infections involving more than one type of microorganism (polymicrobial), other bacteria such as diphtheroid species, fungi, as well as normal upper respiratory tract flora, such as streptococcus viridans. These microorganisms are often associated with healthcare settings and can lead to respiratory infections in surgical patients, highlighting the importance of infection control measures and targeted antimicrobial therapy in preventing and managing postoperative pneumonia in this patient population.

LIMITATION OF THE STUDY

The limitation of this scoping review is that the authors required assistance in classifying the factors that impact postoperative pneumonia. The results of studies related to postoperative pneumonia that were analyzed were quite heterogeneous, so it took much work to classify them. To overcome this limitation, the authors decided to categorize the studies into three categories based on OR values to determine which factors had the highest influence. Then, in determining these categories, the authors conducted an in-depth analysis of the meaning of each factor so that any factors with the same meaning could be combined. In this review, only two studies focused on patients undergoing CABG. Therefore, future research should prioritize additional studies on postoperative pneumonia in CABG patients to ensure more accurate research findings.

Despite some limitations, this is the initial examination of factors linked to postoperative pneumonia in CABG patients. Furthermore, the studies assessed in this review are high quality and have been critically evaluated using the JBI tool. This review may enhance comprehension of the factors influencing postoperative pneumonia in CABG patients. As such, it may assist healthcare professionals in understanding postoperative pneumonia and allocating postoperative medical resources appropriately immediately after CABG surgery.

CONCLUSIONS AND SUGGESTIONS

This review categorized the findings into low, moderate, and high. The dominant factors affecting postoperative pneumonia include duration of surgery, CPB time, blood transfusion, mechanical ventilation, LVAD/Tx, smoking history, chronic lung disease, and preoperative malnutrition. Meanwhile, the main microorganisms causing postoperative pneumonia, based on the study results of this article, are gram-positive and negative bacteria, fungi, and other bacteria. The identification of high-risk populations and personalized risk assessment for postoperative pneumonia can assist nurses in enhancing their clinical decision-making and aid patients in making well-informed choices. Different researchers have found different risk factors for POP after CABG surgery. Many factors influence the occurrence of POP, including demographic characteristics, laboratory values, comorbidities, pulmonary function, cardiac function, history of disease, operative/ surgical findings, and use of devices, which collectively affect POP after CABG surgery. Understanding and addressing these factors is critical in daily clinical practice to optimize patient outcomes, reduce complications, and improve the efficiency of postoperative care. Early and rapid identification of patients with the highest risk allows them to be directed to the most appropriate structures to avoid risks.

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