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REVIEW

A Scoping Review of Factors Associated with Delayed Extubation in Post Cardiac Surgery Patients

Regina Indah Kumalasari[1], Cecep Eli Kosasih[2], Ayu Prawesti Priambodo[2]

[1]Master Study Program, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, Indonesia; [2]Department of Critical Care and Emergency Nursing, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, Indonesia

Correspondence: Cecep Eli Kosasih, Faculty of Nursing, Universitas Padjadjaran, Jl. Raya Ir, Soekarno KM. 21, Hegarmanah, Jatinangor, Sumedang, West Java, 45363, Indonesia, Tel +6281320941727, Fax +6202287793411, Email cecep.e.kosasih@unpad.ac.id

Background: Delayed extubation (DE) after cardiac surgery is associated with high morbidity, mortality, increased length of stay in the intensive care unit, and hospital costs. Various studies have identified factors that influence the occurrence of DE in patients after cardiac surgery, but no review has systematically synthesized the results.

Purpose: This review aimed to identify the influencing factors and the leading causes of DE in patients after cardiac surgery.

Methods: This scoping review uses the framework developed by Arksey and O'Malley (2005). Literature was searched through four databases: PubMed, Scopus, Science Direct, and CINAHL, and two search engines, Sage and Google Scholar, accessed on October 20, 2024. The articles analyzed met the inclusion criteria, such as full-text articles in English, published from 2014–2024, with case-control, cross-sectional, longitudinal, and cohort study designs and had good quality as assessed using the Joanna Briggs Institute critical appraisal checklist. Data was synthesized using thematic analysis.

Results: Eight articles with a total of 13801 participants were included in this review. The prevalence of DE after cardiac surgery ranged from 13.6% to 91.9%. The factors affecting DE were categorized into preoperative, intraoperative and postoperative. The factors most commonly reported to influence ED include preoperative factors (age $\geq$ 60 and EF < 50%), intraoperative factors (duration of surgery $\geq$7 hours, use of IABP and sedatives), and postoperative factors (BNP$\geq$806 pg/mL). The leading causes of DE after cardiac surgery are hemodynamic instability requiring increased inotropes (33.51%), reduced level of consciousness or drowsiness (31.91%), and postoperative bleeding (20.74%).

Conclusion: The process of extubation is a crucial phase in postoperative care. By comprehending the elements that impact DE, healthcare providers can effectively allocate medical resources to enhance the success of weaning, extubation, and recovery following cardiac surgery. Consequently, further research focusing on DE is essential, particularly in patients who have undergone cardiac surgery.

Keywords: cardiac surgery, delayed extubation, mechanical ventilation

Introduction

Mechanical ventilation is essential for adequate oxygenation and ventilation during cardiac surgery and post-anesthesia recovery.[1,2] When patients are admitted to the ICU, mechanical ventilation remains in use throughout the recovery period until the patient is ready for weaning.[3] However, there are some conditions where patients, after CABG surgery or cardiac surgery, experience pulmonary problems and complications that cause respiratory distress.[4]

Respiratory distress after cardiac surgery can be caused by a combination of factors, including pre-existing lung disease, the surgical procedure itself, and the inflammatory response triggered by surgery.[5,6] Conditions such as chronic obstructive pulmonary disease and pulmonary dysfunction due to heart disease such as congestive heart failure may lead to postoperative respiratory problems.[6] In addition, the use of cardiopulmonary bypass during surgery and general anaesthesia can impact lung mechanics and gas exchange, potentially causing lung injury by triggering the production of

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proinflammatory mediators.[5] Delaying extubation (DE) is also often done due to fear of myocardial ischemia and the use of high doses of sedation or narcotics during anaesthesia.[7] Previous study stated that the prevalence of respiratory distress after cardiac surgery varied from 0.4% to 8.1%.[8] Respiratory distress can result in increased respiratory support and DE postoperatively.[4,9]

The Enhanced Recovery After Surgery (ERAS) Cardiac Society recommends early extubation to overcome the negative impact of delayed extubation.[10,11] Per the 2019 cardiac surgery ERAS guidelines, extubation within six hours after surgery was defined as early extubation, and extubation after surgery was defined as late extubation in the present study.[10,12] The time limit for late extubation varies between studies, but the majority of researchers state late extubation as extubation time more than six hours after ICU admission.[13–16]

The trend of early extubation is gaining importance nowadays as it can reduce healthcare costs and length of stay in the ICU.[14,16] In addition, it allows patients to communicate verbally, reduces their anxiety, and reduces the use of sedatives.[15,17,18] In contrast, delayed extubation after cardiac surgery is associated with high morbidity and mortality, increased length of stay in the intensive care unit, and healthcare costs.[4,19,20] DE also increases the risk of postoperative complications, including acute kidney injury and delirium.[21,22] Despite many efforts to implement early extubation after cardiac surgery, delayed extubation is unavoidable due to several risk factors.[14] Therefore, it is essential to identify patients at risk of delayed extubation.[20]

The incidence of DE in patients who have undergone cardiac surgery is undoubtedly affected by various factors. While several studies have explored this issue, none have systematically reviewed the factors influencing DE across the preoperative, intraoperative, and postoperative stages. Our literature search also confirmed no systematic reviews exist on DE and its influencing factors across these stages. Therefore, it is essential to identify the factors and primary causes contributing to DE in postoperative cardiac surgery patients through a comprehensive literature review. The findings of this study can assist medical professionals in anticipating the risk of delayed extubation and in effectively allocating postoperative resources immediately following cardiac surgery.[20]

Materials and Methods

Design

This review used a scoping review design, which features a flexible methodological approach to identifying and investigating modern, rapidly evolving topics.[23] This review uses the framework developed by Arksey and O'Malley (2005). Scoping reviews have a more comprehensive conceptual framework to explain relevant research findings. This framework consists of several stages, including articulating research questions, identifying relevant research, selecting studies, mapping data, compiling literature search results, summarizing, and reporting.[24] This research protocol was not published or registered.

Eligibility Criteria

Articles in this review were selected by three reviewers based on the PRISMA Extension for Scoping Reviews (PRISMA-ScR) (see Figure 1).[25] This research questions and eligibility criteria used the PCC (Population, Concept, and Context) approach.[26] The research questions in this review are: What are the significant factors associated with DE in patients after cardiac surgery? What are the leading causes of DE in patients after cardiac surgery?

P (Population): Adults and patients post cardiac surgery.

C (Concept): Delayed Extubation, Extubation Time.

C (Context): Factors, Risk Factors, Predictors.

The inclusion criteria for this review were full-text articles in English, published from 2014–2024, with case-control, cross-sectional, longitudinal, and cohort study designs that discussed factors associated with delayed extubation in patients after cardiac surgery. Furthermore, this review excluded non-English language studies, qualitative studies, inaccessible full-text publications, and secondary studies.

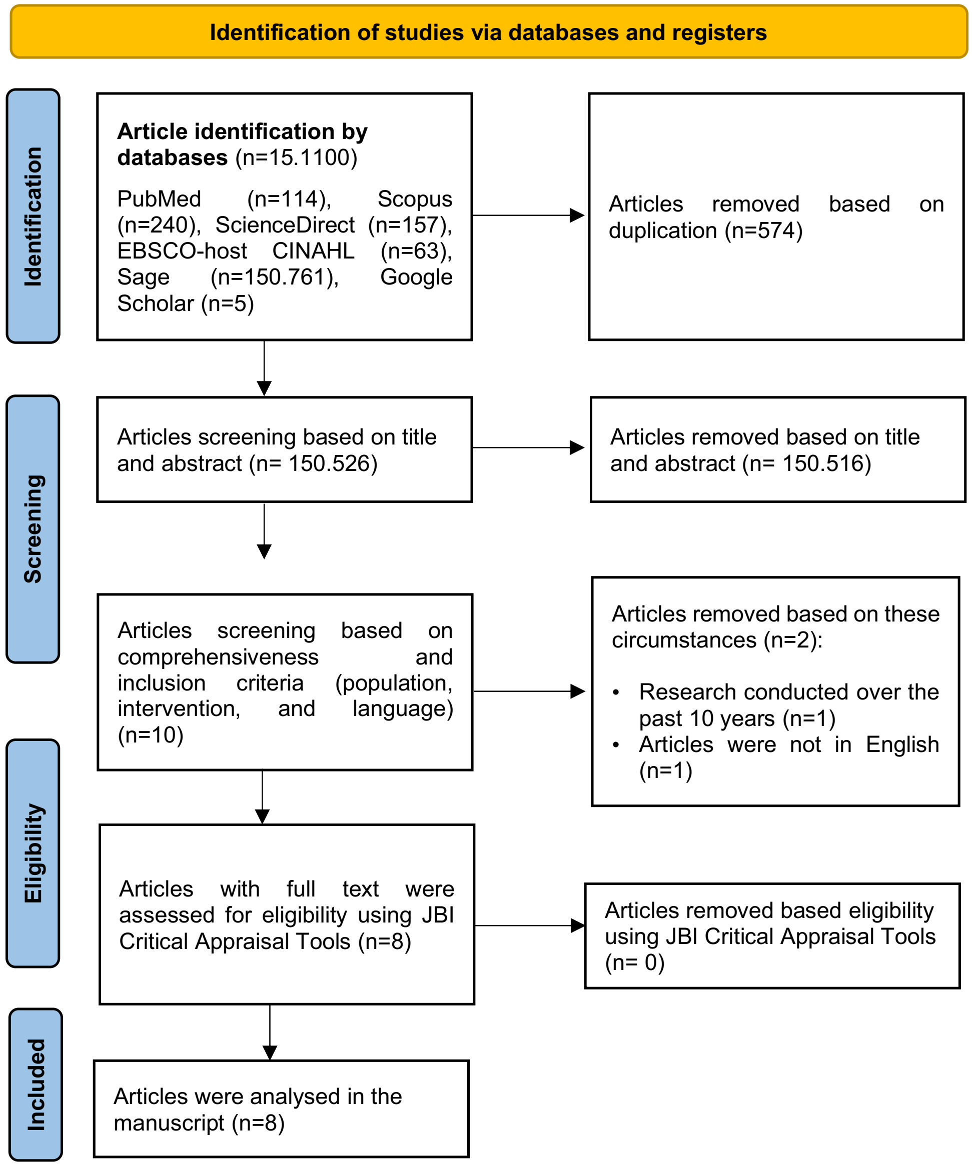

Figure 1 PRISMA Flow Diagram adapted from Page MJ, McKenzie JE, Bossuyt PM et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. Creative Commons.[25]

Data Collection and Analysis

Search Strategy

The literature search was conducted systematically using four databases (PubMed, Scopus, Science Direct, and CINAHL) and two search engines (Sage and Google Scholar) accessed on October 20, 2024. We expanded the literature search using a snowball technique based on relevant topics. The keywords used were "Cardiac Surgery OR Coronary Artery Bypass Graft OR Coronary Artery Bypass Surgery AND Delayed Extubation OR Extubation Time AND Factors OR Risk Factor OR Predictor".

Study Selection and Quality Appraisal

Three authors independently selected relevant studies that met the eligibility criteria. The authors used Mendeley's Reference Manager to check for duplicates during the initial article selection process. The authors then checked the titles and abstracts and read the entire paper according to the relevance of the selected research topic and based on the inclusion and exclusion criteria set by the authors. In the final stage of study selection, the authors evaluated each paper that met the inclusion criteria using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Cross-Sectional and Cohort Studies.[27]

Ratings consist of "Yes", "No", "Unclear", and "Not Applicable", with each "Yes" answer worth 1 and the other answers worth 0. The sum of these ratings determines how suitable the item is for inclusion in your review. This allows researchers to determine the reliability and relevance of their findings for inclusion in further discussion. After the JBI assessment, we excluded all studies with a JBI score below 70, with the final approval of the first, second, and third authors, so that the final decision resulted in a unanimous opinion on the appropriateness of the studies that will be analyzed in depth in this scoping review.

Data Extraction and Analysis

At the data extraction and analysis stage, this review used extraction tables to describe all research findings related to the research topic. The extraction table contains information related to study characteristics, including author, study design, country, type of surgery, DE, sample (sample size, number of DE patients, and mean age), study findings (causes of DE and factors of DE), and final JBI results. All studies analyzed were primary studies with cross-sectional and cohort designs. Data analysis was conducted thematically and qualitatively with an exploratory, descriptive approach. The data analysis process began with identifying and presenting the data obtained in tabular form based on the articles reviewed. After the data was obtained, the authors analyzed and discussed the results of each study with a focus on factors affecting patient DE after cardiac surgery. The author categorized these factors into three categories based on the research findings: preoperative, intraoperative, and postoperative factors.

Results

Study Selection

The study selection results at this review's initial stage yielded 151.100 articles. 574 duplicate articles were excluded from the study. The authors then selected articles based on the title, abstract, and predetermined inclusion criteria, leaving ten studies further analyzed based on a full-text article analysis. Two studies were excluded because they were not in English, and the study was more than 10 years. As a result, eight studies were evaluated using the JBI tool, all eligible and included in the final analysis. Figure 1 shows the study selection process resulting in 8 studies. These studies were analyzed in this scoping review using the PRISMA flowchart.

Study Characteristics

Eight articles were analyzed in this review, including cross-sectional studies (n=5) and three retrospective cohort studies. Most studies (n=7) were conducted in developing countries (see Table 1). The total number of participants was 13.801. The total number of participants who experienced DE was 6.980 (50.57%). The prevalence of DE ranges from 13.6% to 91.9%.[15,20] Three studies performed multivariate analysis,[15,20,28] while the remaining five studies only performed bivariate analysis (see Table 1).[11–14,29] The results of the JBI analysis show that most studies analyzed using the cross-sectional method are of good quality (>70%). Most of the studies studied had weaknesses in not including strategies to overcome confounding factors and follow-up time and not including strategies to overcome incomplete follow-up.

Factors Related to Delayed Extubation

The analysis results showed that the factors associated with DE had heterogeneous results. Based on the analysis, demographic characteristics, clinical findings, comorbidities, surgical findings, surgical procedures, use of intra-operative devices, and postoperative events, they had a significant association with DE in cardiac surgery patients. For convenience, researchers categorized these factors into three categories: preoperative, intraoperative and postoperative factors (see Table 2). One study categorized the study variables into two categories: preoperative and intraoperative,[20] and Xie et al presented and validated data based on preoperative, intraoperative, and postoperative data in cardiac surgery patients.[28] While other studies did not group variables into categories.[11–15,29]

Table 1 Characteristics of Study

Study	Design	Country	Type of Operation	DE (hour)	Sample			Findings		
					Size	Number DE Patients (%)	Mean Age	Causes of DE (n, %)	Factors of DE	Critical Appraisal
[14]	Cross-Sectional Study	Pakistan	CABG, valve, congenital	> 6	81	26 (32.09)	42.76 ±15.52	Cardiovascular Instability (n=9, 34.6%) Reduced Level of Consciousness (n=9, 34.6%) Post-op Bleeding (n=6, 23.07%) Hypoxemia (n=1, 3.85%) Increased Respiratory Rate (n=1, 3.85%)	Diabetes (n=11) (*p*=0.003)*	6/8 75%
[15]	Cross-Sectional Study	Iran	CABG, valve	> 6	210	193 (91.9)	55 (63–46)	N/I	Age (OR: 0.045, 95% CI: 1.008–1.084) (*p*=0.017)**** Duration of Pulmonary circulation (OR: 1.015, 95% CI: 0.999–1.031) (*p*=0.068)**** Lung liquid secretion (OR: 1.003, 95% CI: 0.999–1.006) (*p*=0.117) **** Sedatives (Propofol) (OR: 3.601, 95% CI: 1.184–10.952) (*p*=0.024)****	7/8 87.5%

(*Continued*)

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Table 1 (Continued).

Study	Design	Country	Type of Operation	DE (hour)	Sample			Findings		
					Size	Number DE Patients (%)	Mean Age	Causes of DE (n, %)	Factors of DE	Critical Appraisal
[29]	Cross-Sectional Study	Pakistan	CABG, valve CABG+valve, aortic root replacements	> 6	270	130 (48.15)	56.3 ±10.5	Hemodynamic instability (n=48, 36.9%), Drowsy, poor cough/gag reflexes (n=51, 39.2%), Significant bleeding (n=28, 21.5%), Rapid shallow breathing index > 80–100 (n=8, 6.2%), Respiratory insufficiency (n=6, 4.6%), Hypothermia (n=5, 3.8%), Metabolic acidosis (n=3, 2.3%)	Preoperative renal dysfunction (p=0.003)*, Postoperative renal dysfunction (p=0.001)*, Bypass time (p=0.009)**,	7/8 87.5%
[11]	Cross-Sectional Study	Pakistan	CABG, valve, non-complex adult congenital cardiac surgical procedures	> 4	86	16 (18.6)	N/I	High Doses Inotropes (n=6, 37.5%), Increase Drain Output (n=5, 31.2%) Respiratory Insufficiency (n=2, 12.5%)	Baseline variables: NYHA (p=0.002)**, Clinical parameters: Ventilation Time (Hours) (p=0.001)**, Inotropic Support (p=0.047)**, Drain in 4 hours (mL) (p=0.039)**, Drain at time of removal (mL) (p=0.002)**,	8/8 100%
[13]	Cross-Sectional Study	Iran	CABG	> 6	93	53 (56.98)	61.75 ±10.07	N/I	Age (years) (p=0.01)***,	7/8 87.5%

[20]	Retrospective cohort study	China	CABG, valve, aortic, CABG +valve, CABG+Aortic, Valve +Aortic	> 48	3919	533 (13.6)	N/I	N/I	Age (years): • 50–60 (OR: 1.75, 95% CI: 1.09–2.89) (p=0.03)**** • 60–70 (OR: 2.90, 95% CI: 1.80–4.82) (p<0.001)**** • ≥70 (OR: 4.69, 95% CI: 2.49–8.89) (p<0.001)**** BMI ≥ 28 kg/m2 (OR: 2.50, 95% CI: 1.72–3.58) (p<0.001)**** EF < 50% (OR: 3.04, 95% CI: 2.09–4.36) (p<0.001)**** History of cardiac surgery (OR: 2.41, 95% CI: 1.40–4.05) (p<0.001)**** Type of operation: • Aortic only (OR: 1.89, 95% CI: 1.04–3.38) (p=0.03)**** • CABG + valve (OR: 1.79, 95% CI: 1.15–2.80) (p=0.01)**** • CABG + aortic (OR: 2.52, 95% CI: 0.92–6.88) (p=0.07)**** Emergency surgery (OR: 2.38, 95% CI: 1.03–5.46) (p=0.04)**** CPB ≥ 120 min (OR: 2.26, 95% CI: 1.67–3.08) (p<0.001)**** Duration of surgery: ≥7 h (OR: 3.80, 95% CI: 1.71–8.83) (p<0.001)**** Use of IABP (before extubation) (OR: 9.37, 95% CI: 5.43–16,54) (p<0.001)**** Preoperative eGFR < 60 mL/min/1.73m2 (OR: 1.94, 95% CI: 1.30–2.88) (p<0.001)****	9/11 81.81%

(*Continued*)

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Table 1 (Continued).

Study	Design	Country	Type of Operation	DE (hour)	Sample			Findings		
					Size	Number DE Patients (%)	Mean Age	Causes of DE (n, %)	Factors of DE	Critical Appraisal
[12]	Retrospective cohort study	Canada	CABG, valve, adult congenital surgeries	> 6	8.872	5.922 (66.75)	65 (56–73)	N/I	Age (y) (p<0.001)** Surgical procedures CABG and valve (p<0.001)* Aortic surgery (p<0.001)* VAD/ECMO (p<0.001)* Heart transplantation (p<0.001)* Lung transplantation (p<0.001)*, Difficult intubation (p=0.043)*, Postoperative events: Requiring mechanical circulatory support (p<0.001)* Comorbidities: Stroke/TIA (p=0.001)* Cardiac tamponade (p<0.001)* Endocarditis (p=0.008)* COPD (p<0.001)* Pneumonia (p<0.001)* Chronic kidney disease (p<0.001)*	8/11 72.72%
[28]	Retrospective cohort study	China	CABG, valve, aortic, combined procedures	> 24	270	107 (39.63)	60.3 ± 11.9	N/I	Male (OR: 2.811, 95% CI: 1.141–6.926) (p=0.025)**** EuroSCOREII (OR: 1.485, 95% CI: 1.211–1.821) (p<0.001)**** Pump time≥135min (OR: 4.029, 95% CI: 1.684–9.643) (p=0.002)**** Bleeding≥650 mL (OR: 2.822, 95% CI: 1.028–7.748) (p=0.044)**** Post-operative BNP≥806 pg/mL (OR: 5.198, 95% CI: 2.066–13.079) (p<0.001)****	10/11 90.91%

Notes: *Chi-squared or Fisher's exact test, ***t*-test or Mann–Whitney U, ***Anova, ****Multiple Logistic Regression.

Abbreviations: BMI, Body Mass Index; BNP, B-type natriuretic peptide; CABG, Coronary Artery Bypass Graft; COPD, Chronic Obstructive Pulmonary Disease; CPB, Cardio-Pulmonary Bypass; CI, Confidence Interval; ECMO, Extra-Corporeal Membrane Oxygenation; eGFR, estimated glomerular filtration rate; EF, Ejection Fraction; EuroSCORE, European System for Cardiac Operative Risk Evaluation; IABP, Intra-Aortic Balloon Pump; NYHA, New York Heart Association; OR, Odd Ratio; TIA, transient ischemic attack; VAD, ventricular assist device.

Table 2 Factors Associated with Delayed Extubation After Cardiac Surgery

Categories	Subcategories	Highest Ratio OR (95% CI)	Lowest Ratio OR (95% CI)	*p*-value	Ref
Preoperative	**Demographic Characteristics**				
	Age (years):			$p<0.001$	[12,13,15,20]
	• 50–60	1.75 (1.09–2.89)	1.75 (1.09–2.89)		[20]
	• 60–70	2.90 (1.80–4.82)	2.90 (1.80–4.82)		[20]
	• ≥70	4.69 (2.49–8.89)	4.69 (2.49–8.89)		[20]
	Gender (Male)	2.81 (1.14–6.92)	2.81 (1.14–6.92)		[28]
	BMI ≥ 28 kg/m2	2.50 (1.72–3.58)	2.50 (1.72–3.58)		[20]
	Clinical findings				
	EuroSCOREII	1.48 (1.21–1.82)	1.48 (1.21–1.82)		[28]
	EF < 50%	3.04 (2.09–4.36)	3.04 (2.09–4.36)		[20]
	NYHA	N/I	N/I	$p=0.002$	[11]
	Emergency surgery	2.38 (1.03–5.46)	2.38 (1.03–5.46)		[20]
	History of cardiac surgery	2.41 (1.40–4.05)	2.41 (1.40–4.05)		[20]
	Comorbidities				
	Diabetes	N/I	N/I	$p=0.003$	[14]
	Stroke/TIA	N/I	N/I	$p=0.001$	[12]
	Chronic kidney disease	1.94 (1.30–2.88)	1.94 (1.30–2.88)		[12,20,29]
	Cardiac tamponade	N/I	N/I	$p<0.001$	[12]
	Endocarditis	N/I	N/I	$p=0.008$	[12]
	COPD	N/I	N/I	$p<0.001$	[12]
	Pneumonia	N/I	N/I	$p<0.001$	[12]
Intraoperative	**Surgical Findings**				
	Duration of cardiopulmonary bypass (min)	2.26 (1.67–3.08)	1.015 (0.999–1.031)	$p<0.001$	[15,20,29]
	Duration of surgery ≥7 hours	3.80 (1.71–8.83)	3.80 (1.71–8.83)		[20]
	Difficult intubation	N/I	N/I	$p=0.043$	[12]
	Sedatives (Propofol)	3.60 (1.18–10.9)	3.60 (1.18–10.9)		[15]
	Bleeding≥650 mL	2.82 (1.02–7.74)	2.82 (1.02–7.74)		[28]
	Surgical Procedures				
	CABG + valve	1.79 (1.15–2.80)	1.79 (1.15–2.80)		[12,20]
	CABG + aortic	2.52 (0.92–6.88)	2.52 (0.92–6.88)		[20]
	Use of intra-operative devices				
	VAD/ECMO	N/I	N/I	$p<0.001$	[12]
	Use of IABP	9.37 (5.43–16,54)	9.37 (5.43–16,54)		[20]

(*Continued*)

Table 2 (Continued).

Categories	Subcategories	Highest Ratio OR (95% CI)	Lowest Ratio OR (95% CI)	*p*-value	Ref
Postoperative	**Postoperative Events**				
	Renal dysfunction	N/I	N/I	p=0.001	[29]
	BNP ≥806 pg/mL	5.19 (2.06–13.07)	5.19 (2.06–13.07)		[28]
	Inotropic Support	N/I	N/I	p=0.047	[11]
	Lung liquid secretion	1.00 (0.99–1.00)	1.00 (0.99–1.00)		[15]
	Drain in 4 hours (mL)	N/I	N/I	p=0.039	[11]
	Drain at time of removal (mL)	N/I	N/I	p=0.002	[11]

Abbreviations: BMI, Body Mass Index; BNP, B-type Natriuretic Peptide; CABG, Coronary Artery Bypass Graft; COPD, Chronic Obstructive Pulmonary Disease; CPB, Cardio-Pulmonary Bypass; CI, Confidence Interval; ECMO, ExtracorporealExtracorporeal Membrane Oxygenation; eGFR, estimated Glomerular Filtration Rate; EF, Ejection Fraction; EuroSCORE, European System for Cardiac Operative Risk Evaluation; IABP, Intra-Aortic Balloon Pump; NYHA, New York Heart Association; N/I, Not Information; OR, Odd Ratio; TIA, Transient Ischemic Attack; VAD, Ventricular Assist Device.

In this review, factors related to DE included in the preoperative factors category were demographic characteristics (age, gender, BMI), clinical findings (EuroSCOREII, EF <50%, NYHA, emergency surgery, history of cardiac surgery), comorbidities (diabetes, stroke/TIA, chronic kidney disease, cardiac tamponade, endocarditis, COPD, pneumonia). In addition, intraoperative factors include surgical findings (duration of cardiopulmonary bypass, duration of surgery ≥7 hours, difficult intubation, sedation, bleeding ≥650 mL), surgical procedures (CABG+valve, CABG+aortic), and use of intraoperative assistive devices (ventricular assist devices, extracorporeal membrane oxygenation, intra-aortic balloon pump). Postoperative factors significantly affected DE were postoperative events, including renal dysfunction, BNP ≥806 pg/mL, inotropic support, lung liquid secretion, drainage within 4 hours, and drainage at the time of removal.

Based on the results of the study, most studies reported age,[12,13,15,20] preoperative renal dysfunction and duration of cardiopulmonary bypass,[15,20,29] and surgical procedures (CABG + valve),[12,20] as factors that influence the occurrence of DE. Meanwhile, the most influential factors for DE in CABG postoperative patients based on OR values (95% CI) are use of IABP 9.37 (5.43–16.54), BNP≥806 pg/mL 5.198 (2.066–13.079), age ≥70 4.69 (2.49–8.89), duration of surgery ≥7 hours 3.80 (1.71–8.83), sedatives 3.601 (1.184–10.952), and EF < 50% 3.04 (2.09–4.36).

The Major Causes of Delayed Extubation

In this review, three studies discussed the significant causes of DE following cardiac surgery (see Table 3), where the three studies agreed that the leading causes of DE were haemodynamic instability requiring increased inotropic (33.51%), post-op bleeding or significant mediastinal bleeding (20.74%), and respiratory insufficiency (4.79%).[11,14,29] Other causes are reduced level of consciousness or drowsiness (31.91%),[14,29] rapid shallow breathing index >80-100 (4.25%), hypothermia (2.66%), metabolic acidosis (1.59%),[29] and increased respiratory rate (0.53%).[14]

Discussion

This scoping review identifies the factors that may influence and the leading causes of DE in patients after cardiac surgery. This review showed that most of the analyzed studies reported that the incidence of DE in cardiac surgery patients varied from 13.6% to 91.9%.[15,20] Seven domains may influence the occurrence of DE, including demographic characteristics, clinical findings, comorbidities, surgical findings, surgical procedures, use of intra-operative devices, and postoperative events. This review categorized these factors into preoperative, intraoperative, and postoperative.

The findings of this review found that patients with DE were mainly caused by haemodynamic instability requiring increased inotropic (33.51%), reduced level of consciousness or drowsiness (31.91%), and post-op bleeding or significant mediastinal bleeding (20.74%).[11,14,29] Previous studies reported that hemodynamic instability is mostly caused by

Table 3 The Major Causes of Delayed Extubation After Cardiac Surgery (n=188)

No.	Causes of Delayed Extubation	N (%)	References
1	Haemodynamic instability requiring increased inotropic	63 (33.51)	[11,14,29]
2	Reduced Level of Consciousness/ drowsiness (difficulty to arouse)	60 (31.91)	[14,29]
3	Post-op Bleeding/ significant mediastinal bleeding	39 (20.74)	[11,14,29]
4	Respiratory Insufficiency/hypoxemia or hypercapnia	9 (4.79)	[11,14,29]
5	Rapid shallow breathing index > 80–100	8 (4.25)	[29]
6	Hypothermia	5 (2.66)	[29]
7	Metabolic acidosis	3 (1.59)	[29]
8	Increased Respiratory Rate	1 (0.53)	[14]

hypotension due to low cardiac output or vasodilation, which causes an increase in inotropes or vasopressors, thus delaying extubation for more than 6 hours. Drowsiness is seen more in elderly patients, especially those over 65. A previous study reported that significant mediastinal bleeding was the most critical postoperative factor delaying extubation.[11]

Another contributing cause to delayed extubation is respiratory insufficiency (4.79%), such as hypoxemia or hypercapnia after cardiac surgery.[11,14,29] In addition, rapid shallow breathing index > 80–100 (4.25%), hypothermia (2.66%), metabolic acidosis (1.59%),[29] and increased respiratory rate (0.53%) also affect DE.[14] The imbalance of the body's acid-base status due to metabolic acidosis affects breathing and muscle function, where the body makes respiration compensation to normalize PH by doing rapid shallow breathing, increased respiratory rate, and changes in tidal volume, all of which can be reflected in parameters such as rapid shallow breathing index (RSBI).[30,31] RSBI values above 80–100 indicate increased work of breathing and respiratory muscle fatigue, which can lead to delayed extubation after cardiac surgery.[30] Metabolic acidosis can affect the cardiovascular system, causing hemodynamic instability, a common reason for delaying extubation after cardiac surgery.[14] Hypothermia is part of CPB procedures to protect vital organs and reduce metabolic demands.[32]

The most reported preoperative factors affecting DE in this review are comorbid diseases. CKD is one of the most commonly reported comorbidities causing DE.[12,20,29] Previous study reported that patients with renal impairment had doubled the risk of delayed extubation compared to patients with normal renal function.[20] In addition, cardiovascular diseases such as stroke, cardiac tamponade, and endocarditis are also risk factors for DE. Cardiac tamponade increases the pressure around the heart, causing impaired cardiac filling and hemodynamic abnormalities.[33] Stroke can affect a patient's ability to breathe effectively,[34] while endocarditis can cause systemic inflammation, sepsis and myocardial dysfunction.[35] These may affect hemodynamics and respiratory function after cardiac surgery, increasing the risk of delayed extubation and requiring extended ventilatory support.[19] Pulmonary diseases such as COPD and pneumonia also affect DE due to impaired gas exchange, so patients require prolonged ventilation support.[9] This is because patients with COPD significantly decrease vital capacity, total lung capacity and functional residual capacity,[36] while pneumonia patients have inflammation of the lung parenchyma.[37] Diabetes is also an independent risk factor for delayed extubation following cardiac surgery.[14]

Age is the other most widely reported preoperative factor affecting DE.[12,13,15,20] The results showed that the risk of DE after cardiac surgery increased significantly with age, especially after sixty years.[20] This increased risk is primarily due to decreased lung compliance and functional residual capacity, which substantially decrease lung function and thus affect the recovery process and weaning from mechanical ventilation.[28] Decreased lung compliance and functional residual capacity are the leading causes of impaired lung function in obese patients with BMI ≥ 28 kg/m2, which are exacerbated by general anaesthesia and mechanical ventilation.[20,38] In addition, gender is an often-debated risk factor for

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DE. Some studies report a higher prevalence of DE in women,[14,16] while another study showed men are a risk factor for DE, which may be related to the higher incidence in men.[28]

Patients with higher NYHA class often demonstrate more severe cardiac impairment, including decreased left ventricular ejection fraction and impaired myocardial contractility. This cardiac dysfunction can lead to inadequate tissue perfusion and oxygen delivery, causing patients to experience postoperative respiratory distress and a prolonged need for mechanical ventilation.[39,40] Critically ill patients, such as those with high EuroSCORE, may find it difficult to wean from the ventilator.[28] History of cardiac surgery and emergency surgery are independently associated with DE after cardiac surgery.[20] Patients undergoing emergency cardiac surgery are often in an unstable and sometimes life-threatening condition. Incomplete preoperative assessment and preparation expose patients to unknown risks, and extubation decisions must be carefully considered.[20]

The most reported intraoperative factor associated with DE is the duration of cardiopulmonary bypass.[15,20,29] Activation of systemic inflammatory mediators caused by CPB increases susceptibility to lung injury.[41] A previous study reported that the risk of postoperative extubation delay increased up to two times when the duration of CPB exceeded 120 minutes.[20] In addition, another finding from a previous study showed there was a significant difference in the duration of surgery and duration of cardiopulmonary bypass ($p>0.05$) between patients who were extubated for less and more than six hours.[15]

Other surgical findings that affect DE are difficult intubation, sedation, and bleeding. Decreased cardiac output and blood pressure due to bleeding during surgery can cause impaired pulmonary perfusion and ventilation rate, resulting in postoperative respiratory distress.[42] Approximately 36.7% of cases of early extubation failure are caused by bleeding.[43,44] Patients with intubation difficulties also show a low probability of being extubated early.[12] The influence of the type and dose of sedation during surgery affects the success of postoperative extubation. Intravenous propofol combined with Nonsteroidal Anti-Inflammatory Drugs (NSAIDs) provides the best improvement in patients undergoing cardiac surgery.[45] However, a systematic review and meta-analysis stated that dexmedetomidine shortens extubation time compared to Propofol. Therefore, sedative protocols still need to be developed.[15,46]

Type of surgery was the most reported intraoperative factor affecting DE. The risk of DE in patients undergoing combined cardiac surgery is doubled compared to isolated CABG.[12,20] Patients undergoing more than two surgical cardiac procedures during the operation tend to require a longer duration of surgery and CPB time and may be more unstable and at greater risk during surgery. In addition to more extended mechanical ventilation, a higher incidence of cardiac or cerebrovascular adverse events is observed in patients undergoing combined cardiac surgery.[47,48] Then, initiating intraoperative device use was the most influential factor.[12,20] The use of IABP increases the risk of DE up to nine times. The use of IABP intra- or postoperatively means poorer cardiac function. Therefore, the need for longer ventilation time is usually due to cardiopulmonary dysfunction or slower recovery after cardiac surgery.[20] In addition, the use of ventricular assist devices or implantable extracorporeal membrane oxygenation was performed more frequently in the late-extubated group.[12]

The most influential postoperative factor for DE is the Brain Natriuretic Peptide (BNP) level. Increased postoperative BNP levels are considered a biomarker of ventricular dysfunction, and early decompensated heart failure can be identified after cardiac surgery.[49] Thus, increased BNP levels are an independent risk factor for difficult weaning after cardiac surgery.[28] Moreover, preoperative and postoperative renal dysfunction were significant comorbidities contributing to Fast Track Extubation (FTE) failure.[29] Inotropic support, volume drainage at 4 hours, and drain at the time of removal were significantly lower in the FTE compared to the DE group.[11] Meanwhile, the volume of tubular secretions from the chest affects the duration of mechanical ventilation in cardiac surgery patients.[28] The condition of pleural effusion after cardiac surgery can affect pleural fluid extraction and the pulmonary function of patients requiring mechanical ventilation.[50]

Delayed extubation in post-cardiac surgery patients can impact recovery and increase the risk of complications. Thus, a multidiscipline approach is needed to prevent it. The development of predictive models based on perioperative risk factors can help identify patients at high risk for delayed extubation, allowing for targeted preventive measures.[20] In addition, comprehensive preoperative assessment to optimize comorbidities, especially in patients with COPD or obesity, is essential as these conditions can affect postoperative respiratory function.[51] Intraoperatively, maintaining hemodynamic stability and reducing the duration of cardiopulmonary bypass can help reduce the inflammatory response and prevent delayed extubation.[51] Postoperatively, an extubation protocol that includes early mobilization, optimal pain management, and close monitoring of extubation readiness can accelerate the recovery of respiratory function.[52,53] This comprehensive approach can improve the chances of timely extubation and overall patient recovery outcomes after cardiac surgery.

Strengths and Limitations

The main limitation of this scoping review is related to the variability in the reported rates of delayed extubation across the included studies, which may affect the generalizability of our findings. In addition, the methodologies used in these studies varied significantly, particularly in the use of multivariate analysis, which was only used in three studies, making it difficult for the authors to classify these factors based on OR values to determine which factors had the highest influence. In addition, the authors need help to classify the factors that influence DE. The results of the studies related to DE analysis were quite heterogeneous, and much work was required to classify them. 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.

Although this study has several limitations, this is the first review of factors associated with DE in cardiac surgery patients. In addition, the studies analyzed in this review were of good quality and had undergone critical appraisal using the JBI tool. Thus, this review can help healthcare professionals understand DE and allocate postoperative medical resources appropriately immediately after cardiac surgery.

Conclusion

Three categories of factors affect DE in patients after cardiac surgery, including preoperative, intraoperative, and postoperative factors. The most commonly reported factors affecting DE include age, EF, duration of surgery, use of IABP, sedation, and BNP levels. In addition, hemodynamic instability, decreased consciousness, and bleeding are the leading causes of delayed extubation reported by many studies. The duration of mechanical ventilation after cardiac surgery can be an important endpoint in clinical trials. In addition, successful ventilator weaning and extubation in the intensive care unit can accelerate postoperative recovery for all cardiac surgery patients. Understanding and managing these factors are essential in daily clinical practice to optimize patient outcomes, reduce complications, and improve the efficiency of postoperative care. Early and rapid identification of patients at the highest risk allows them to be directed to the most appropriate structure to avoid risk.

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Disclosure

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