Section: CTVS

Original Research Article

COMPARISON OF OUTCOMES OF EARLY VERSUS LATE EXTUBATION IN PATIENTS FOLLOWING CORONARY ARTERY BYPASS GRAFTING: A PROSPECTIVE OBSERVATIONAL COHORT STUDY

Arvind Pandey[1], Narendra Nath Das[1]

[1]*Associate Professor, Department of CTVS, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India*

Received : 10/05/2024
Received in revised form : 20/06/2024
Accepted : 07/07/2024

Corresponding Author:
Dr. Arvind Pandey,
Associate Professor, Department of CTVS, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India
Email: apandey@bhu.ac.in

DOI: 10.70034/ijmedph.2024.3.213

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2024; 14 (3); 1201-1206

ABSTRACT

Background: Early extubation has become a central element of fast-track recovery after coronary artery bypass grafting (CABG), yet uncertainty persists regarding which patients can be safely extubated early and how delayed extubation affects postoperative recovery, particularly in routine practice. We compared clinical outcomes of early (<6 h) versus late (>6 h) extubation and identified independent predictors of delayed extubation.

Materials and Methods: This prospective observational cohort study enrolled 90 adults (aged 18–80 years) undergoing elective isolated on-pump CABG, classified by time to extubation into an early group (<6 h, n=45) and a late group (>6 h, n=45). Baseline, intraoperative, and postoperative variables were compared, and multivariable logistic regression identified predictors of delayed extubation.

Results: Patients extubated late were older (63.5 ± 7.7 vs 56.7 ± 8.8 years, p<0.001), had lower ejection fraction (45.5 ± 8.1% vs 53.1 ± 7.5%, p<0.001) and higher EuroSCORE II (3.4 ± 1.2 vs 1.8 ± 1.0, p<0.001). Compared with the early group, the late group had longer ICU stay (3.9 ± 1.9 vs 2.0 ± 0.7 days, p<0.001), longer hospital stay (10.2 ± 3.5 vs 7.1 ± 1.7 days, p<0.001), and a higher composite morbidity rate (84.4% vs 31.1%, p<0.001), including more pneumonia (26.7% vs 0%), acute kidney injury (42.2% vs 6.7%) and surgical-site infection (15.6% vs 0%). In-hospital mortality was 6.7% versus 0% (p=0.24). Age, cardiopulmonary bypass time and EuroSCORE II were independent predictors of delayed extubation.

Conclusion: Early extubation after elective CABG was associated with faster recovery and fewer complications, while delayed extubation marked a higher-risk population with worse outcomes. Preoperative risk stratification and optimized perioperative care may expand the proportion of patients eligible for safe early extubation.

Keywords: Coronary artery bypass grafting; early extubation; fast-track cardiac surgery; mechanical ventilation; intensive care unit; postoperative outcomes.

INTRODUCTION

Coronary artery disease remains a leading cause of morbidity and mortality worldwide, and coronary artery bypass grafting (CABG) continues to be the standard of care for patients with complex multivessel disease and impaired ventricular function. Historically, patients undergoing cardiac surgery were sedated and mechanically ventilated overnight, on the assumption that prolonged ventilation protected against the haemodynamic and respiratory stresses of the early postoperative period. The introduction of fast-track cardiac anaesthesia, using short-acting hypnotics and opioids that permit rapid emergence, challenged this paradigm and demonstrated that selected patients could be extubated within a few hours of surgery without an increase in adverse events.[1,2]

Early extubation is now recognized as a cornerstone of enhanced recovery after cardiac surgery. Shorter durations of mechanical ventilation reduce exposure to positive-pressure ventilation and sedation, lower the risk of ventilator-associated pneumonia, facilitate earlier mobilization, and shorten intensive care unit (ICU) and hospital stay, with consequent reductions in cost and resource utilization.[1,3,4]

Extubation within six hours of cardiac surgery has accordingly been adopted as a quality benchmark, and operating-room or ultra-early extubation has been shown to be feasible and safe in appropriately selected patients managed by experienced teams.[5-9]

The economic dimension of this question is considerable. The early postoperative period in a cardiac ICU is among the most resource-intensive phases of surgical care, and even modest reductions in ventilation time and ICU occupancy translate into meaningful cost savings and improved bed availability. In health systems where demand for cardiac surgery outstrips ICU capacity, the ability to safely accelerate recovery has direct implications for throughput and waiting times. At the same time, the heterogeneity of cardiac surgical populations means that protocols validated in one setting may not transfer directly to another, underscoring the need for locally relevant data.

Nevertheless, practice remains variable. Definitions of "early" extubation have ranged from immediate extubation in the operating room to extubation within six, eight, or twelve hours, and the proportion of patients extubated early differs widely between institutions. This variability reflects genuine differences in case mix, anaesthetic practice, and ICU organization, and it complicates direct comparison between studies. Robust, context-specific data that pair outcome comparisons with an analysis of the determinants of delayed extubation therefore remain valuable.

Despite these benefits, early extubation is not universally appropriate. Older patients and those with poor ventricular function, significant comorbidity, prolonged cardiopulmonary bypass, perioperative bleeding, or haemodynamic instability frequently require prolonged ventilation, and premature extubation in such patients carries a risk of reintubation, which is itself associated with worse outcomes.[3,4,6]

Identifying the patients who can safely be extubated early—and recognizing those in whom delayed extubation reflects a higher-risk physiological state—is therefore central to optimizing recovery pathways, particularly in resource-limited settings where ICU capacity is constrained. The present study was undertaken to compare the clinical outcomes of early (<6 h) versus late (>6 h) extubation in patients undergoing elective CABG, to evaluate the associated postoperative complications, and to identify independent predictors of delayed extubation.[7,8,10]

MATERIAL AND METHODS

Study design and population: This prospective observational cohort study compared the clinical outcomes of early (<6 h, n=45) versus late (>6 h, n=45) extubation in adult patients undergoing elective CABG. After obtaining institutional ethics committee approval and written informed consent from all participants, patients aged 18 to 80 years scheduled for isolated CABG with cardiopulmonary bypass (CPB) were enrolled consecutively. Exclusion criteria included emergency procedures, combined cardiac surgery, severe pulmonary disease, ongoing sepsis, significant neurological deficits, chronic dialysis dependence, and any anticipated perioperative complication precluding early extubation.

Preoperative assessment: Each patient underwent detailed clinical evaluation, routine laboratory investigations, transthoracic echocardiography to assess left ventricular function, and pulmonary function testing where indicated. Operative risk was quantified using the EuroSCORE II. Demographic data and comorbidities (diabetes mellitus, hypertension, chronic obstructive pulmonary disease, chronic kidney disease, and smoking status) were systematically recorded.

Anaesthetic and surgical management: Standardized anaesthesia protocols emphasizing fast-track principles were employed, using short-acting agents such as propofol, fentanyl, sevoflurane, and remifentanil to facilitate rapid postoperative recovery. Surgery was performed via midline sternotomy by experienced cardiac surgeons using conventional CABG techniques, with CPB conducted under systemic heparinization and reversed with protamine. Measures to minimize intraoperative blood loss and allogeneic transfusion were implemented routinely.

Extubation criteria and grouping: Extubation timing was determined by predefined clinical criteria: haemodynamic stability; adequate oxygenation ($PaO2 > 70$ mmHg on $FiO2 < 0.4$); satisfactory spontaneous ventilation (tidal volume > 5 mL/kg, respiratory rate < 25 breaths/min, $PaCO2 < 50$ mmHg); normothermia; adequate neurological status; and minimal chest-tube drainage (< 100 mL/h). Patients meeting all criteria within six hours of surgery were classified into the early extubation group, whereas those requiring mechanical ventilation beyond six hours formed the late extubation group. Weaning and extubation were conducted according to a standardized ICU protocol by an experienced critical care team.

Outcomes and data collection: Patients were monitored for haemodynamic parameters, respiratory function, neurological status, and the development of complications including pneumonia, arrhythmia, renal dysfunction, and infection. Recorded outcomes comprised duration of mechanical ventilation, ICU and total hospital stay, postoperative complications, in-hospital mortality, transfusion requirements, need for reoperation, and time to mobilization and oral intake. Baseline demographics, intraoperative variables (CPB and aortic cross-clamp times, number of grafts), and estimated blood loss were also documented.

Statistical analysis: Analyses were performed using SPSS. Continuous variables are reported as mean ± standard deviation and were compared using the independent-samples t-test; skewed variables (ventilation duration, ICU and hospital stay, blood loss, transfusion, EuroSCORE II, and recovery times) were compared using the Mann–Whitney U test. Categorical variables are expressed as frequencies and percentages and were analyzed using the chi-square or Fisher exact test as appropriate. Multivariable logistic regression was used to identify independent predictors of delayed extubation, adjusting for age, ventricular function, operative risk, and surgical parameters. A two-tailed p-value < 0.05 was considered statistically significant.

Sample and analysis set: The study sample comprised 90 patients, 45 in each extubation group, providing a balanced cohort for the comparison of recovery outcomes and complications. All enrolled patients who completed surgery were included in the analysis, and no patient was lost to in-hospital follow-up.

RESULTS

Baseline characteristics: Ninety patients were analyzed, 45 in each group. As shown in [Table 1], the late extubation group was significantly older (63.5 ± 7.7 vs 56.7 ± 8.8 years, p<0.001) and had a higher body mass index (26.5 ± 3.4 vs 25.0 ± 3.7 kg/m², p=0.046). Left ventricular ejection fraction was lower in the late group (45.5 ± 8.1% vs 53.1 ± 7.5%, p<0.001), and a greater proportion presented in NYHA functional class III–IV (62.2% vs 28.9%, p=0.002). Operative risk, expressed as EuroSCORE II, was almost twice as high in the late group (3.4 ± 1.2 vs 1.8 ± 1.0, p<0.001). Chronic obstructive pulmonary disease was more frequent in the late group (20.0% vs 4.4%, p=0.050), while the difference in chronic kidney disease (26.7% vs 11.1%, p=0.059) and hypertension (66.7% vs 46.7%, p=0.056) approached significance. The distribution of sex, smoking, and diabetes did not differ significantly between groups.

Intraoperative variables: Intraoperative data are presented in [Table 2]. The late group had substantially longer CPB times (106.6 ± 17.9 vs 77.4 ± 15.0 min, p<0.001) and aortic cross-clamp times (67.6 ± 13.5 vs 50.3 ± 10.9 min, p<0.001), together with greater estimated intraoperative blood loss (587.4 ± 126.7 vs 398.9 ± 143.6 mL, p<0.001). The mean number of grafts was marginally higher in the late group (3.2 ± 0.7 vs 2.9 ± 0.7, p=0.065).

Postoperative recovery: By definition, ventilation duration differed markedly between groups (12.4 ± 5.0 vs 4.2 ± 0.9 h, p<0.001) [Table 3]. This translated into clinically meaningful differences in recovery. The late group required a longer ICU stay (3.9 ± 1.9 vs 2.0 ± 0.7 days, p<0.001) and total hospital stay (10.2 ± 3.5 vs 7.1 ± 1.7 days, p<0.001). Recovery milestones were delayed: time to mobilization (39.1 ± 13.2 vs 20.2 ± 6.5 h, p<0.001) and time to resumption of oral intake (17.7 ± 6.1 vs 9.5 ± 2.2 h, p<0.001) were roughly double in the late group, which also received more red-cell transfusions (2.7 ± 1.6 vs 0.8 ± 0.8 units, p<0.001).

Complications and mortality: Postoperative complications were consistently more frequent in the late extubation group [Table 4]. Pneumonia occurred in 26.7% of late patients versus none in the early group (p<0.001), acute kidney injury in 42.2% versus 6.7% (p<0.001), and surgical-site infection in 15.6% versus none (p=0.012). Re-exploration for bleeding (17.8% vs 2.2%, p=0.030) and new-onset atrial fibrillation (42.2% vs 24.4%, p=0.074) were also more common, and reintubation occurred in 13.3% of late patients versus 2.2% of early patients (p=0.110). A composite morbidity endpoint (any of reintubation, pneumonia, atrial fibrillation, acute kidney injury, surgical-site infection, or reoperation) occurred in 84.4% of the late group compared with 31.1% of the early group (p<0.001). Three in-hospital deaths (6.7%) occurred, all in the late group; no deaths occurred after early extubation, although this difference did not reach statistical significance (p=0.24).

Predictors of delayed extubation: On multivariable logistic regression, increasing age (odds ratio [OR] 1.18 per year, 95% CI 1.01–1.37, p=0.037), longer CPB time (OR 1.12 per minute, 95% CI 1.05–1.18, p<0.001), and higher EuroSCORE II (OR 4.78 per point, 95% CI 1.73–13.22, p=0.003) were identified as independent predictors of delayed extubation. Lower ejection fraction showed a strong trend (OR 0.90 per 1% increase, 95% CI 0.80–1.01, p=0.070), whereas diabetes and COPD were not independently predictive after adjustment.

Table 1: Baseline demographic and clinical characteristics.

Variable	Early (<6 h) (n=45)	Late (>6 h) (n=45)	p-value
Age, years	56.7 ± 8.8	63.5 ± 7.7	<0.001
Female sex, n (%)	14 (31.1)	12 (26.7)	0.642
Body mass index, kg/m²	25.0 ± 3.7	26.5 ± 3.4	0.046
Smoker, n (%)	11 (24.4)	15 (33.3)	0.352
Diabetes mellitus, n (%)	17 (37.8)	22 (48.9)	0.288
Hypertension, n (%)	21 (46.7)	30 (66.7)	0.056
COPD, n (%)	2 (4.4)	9 (20.0)	0.050
Chronic kidney disease, n (%)	5 (11.1)	12 (26.7)	0.059

LVEF, %	53.1 ± 7.5	45.5 ± 8.1	<0.001
NYHA class III–IV, n (%)	13 (28.9)	28 (62.2)	0.002
EuroSCORE II	1.8 ± 1.0	3.4 ± 1.2	<0.001

Values are mean ± SD unless otherwise stated. COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association.

Table 2: Intraoperative variables

Variable	Early (<6 h) (n=45)	Late (>6 h) (n=45)	p-value
Number of grafts	2.9 ± 0.7	3.2 ± 0.7	0.065
Cardiopulmonary bypass time, min	77.4 ± 15.0	106.6 ± 17.9	<0.001
Aortic cross-clamp time, min	50.3 ± 10.9	67.6 ± 13.5	<0.001
Intraoperative blood loss, mL	398.9 ± 143.6	587.4 ± 126.7	<0.001

Values are mean ± SD. Blood loss and bypass times compared using the Mann–Whitney U test.

Table 3: Postoperative recovery outcomes

Outcome	Early (<6 h) (n=45)	Late (>6 h) (n=45)	p-value
Mechanical ventilation, h	4.2 ± 0.9	12.4 ± 5.0	<0.001
ICU stay, days	2.0 ± 0.7	3.9 ± 1.9	<0.001
Hospital stay, days	7.1 ± 1.7	10.2 ± 3.5	<0.001
Red-cell transfusion, units	0.8 ± 0.8	2.7 ± 1.6	<0.001
Time to mobilization, h	20.2 ± 6.5	39.1 ± 13.2	<0.001
Time to oral intake, h	9.5 ± 2.2	17.7 ± 6.1	<0.001

Values are mean ± SD. ICU, intensive care unit. Skewed variables compared using the Mann–Whitney U test.

Table 4: Postoperative complications and in-hospital mortality

Complication, n (%)	Early (<6 h) (n=45)	Late (>6 h) (n=45)	p-value
Reintubation	1 (2.2)	6 (13.3)	0.110
Pneumonia	0 (0.0)	12 (26.7)	<0.001
Atrial fibrillation	11 (24.4)	19 (42.2)	0.074
Acute kidney injury	3 (6.7)	19 (42.2)	<0.001
Surgical-site infection	0 (0.0)	7 (15.6)	0.012
Reoperation for bleeding	1 (2.2)	8 (17.8)	0.030
Composite morbidity	14 (31.1)	38 (84.4)	<0.001
In-hospital mortality	0 (0.0)	3 (6.7)	0.242

Composite morbidity = any of reintubation, pneumonia, atrial fibrillation, acute kidney injury, surgical-site infection, or reoperation. Categorical variables compared using chi-square or Fisher exact test.

DISCUSSION

In this prospective cohort of elective CABG patients, early extubation within six hours was associated with a markedly smoother postoperative course—shorter ICU and hospital stay, faster mobilization and resumption of oral intake, fewer transfusions, and a substantially lower burden of complications—than late extubation. These findings are consistent with the original randomized trials of fast-track cardiac anaesthesia, in which early extubation reduced ICU and hospital length of stay and lowered cost without increasing perioperative morbidity or mortality.[1,2]

It is important to interpret these associations in the context of an observational design. Extubation timing was determined by predefined clinical readiness criteria rather than randomization, so the late group was not simply ventilated longer by protocol but represented a sicker population: older, with lower ejection fraction, higher operative risk, longer bypass and cross-clamp times, and greater blood loss. The worse outcomes observed after late extubation therefore reflect, in part, the underlying severity of illness that delayed extubation in the first place, rather than harm caused by ventilation per se. This interpretation aligns with prior work showing that delayed extubation is a marker of higher-risk physiology and is itself associated with prolonged ICU stay, increased morbidity, and higher mortality.4,10,11

The independent predictors of delayed extubation in our analysis—advancing age, prolonged cardiopulmonary bypass time, and higher EuroSCORE II—are concordant with the established literature. Wong and colleagues derived a cardiac risk score in which advanced age, female sex, and markers of haemodynamic compromise predicted delayed extubation, prolonged ICU stay, and mortality after fast-track CABG, and subsequent studies confirmed the predictive value of CPB and cross-clamp times, intra-aortic balloon support, and operative complexity.[3,4]

A systematic review of the determinants of prolonged mechanical ventilation after CABG similarly identified age, impaired ventricular function, renal dysfunction, and prolonged bypass as the most consistent risk factors, reinforcing the value of preoperative risk stratification in planning the recovery pathway.[11]

The mechanisms linking prolonged ventilation to adverse outcomes are multifactorial. Extended mechanical ventilation prolongs sedation and immobility, predisposing to atelectasis, ventilator-associated pneumonia, deconditioning, and delirium, while delaying enteral nutrition and physiotherapy. Earlier extubation, by contrast, restores spontaneous ventilation and physiological negative-pressure breathing, supports earlier mobilization, and shortens ICU dependency.[1,3]

Randomized data indicate that the pulmonary function of CABG patients is not adversely affected by early extubation provided standard readiness criteria are met, supporting the safety of the approach in appropriately selected patients.[6]

Our complication data—higher rates of pneumonia, acute kidney injury, surgical-site infection, and atrial fibrillation in the late group—mirror the morbidity gradient reported across the fast-track literature and the Cochrane review of fast-track cardiac care, which concluded that early extubation strategies reduce ventilation time and ICU stay without increasing the risk of death or major complications.[8]

More recent large-database and institutional analyses have extended the concept to ultra-early and operating-room extubation, again demonstrating safety and reduced resource use when undertaken with rigorous patient selection and protocolized multidisciplinary care.[7,9,12]

These observations carry practical implications, particularly for centres with limited ICU capacity. Because delayed extubation clusters in identifiable high-risk patients, preoperative optimization—of anaemia, renal function, glycaemic control, and pulmonary status—together with strategies to shorten bypass time and minimize bleeding may increase the proportion of patients eligible for safe early extubation. A standardized, criteria-driven weaning protocol applied by an experienced team allows early extubation to be pursued aggressively in low-risk patients while avoiding premature extubation, and consequent reintubation, in those who are physiologically unready.[5,10]

The magnitude of the differences observed is clinically meaningful. A reduction of roughly two days in ICU stay and three days in total hospital stay, together with a halving of the time to mobilization and to resumption of oral intake, represents a substantial acceleration of recovery for the individual patient and a meaningful release of capacity for the institution. Earlier mobilization is itself protective, reducing the risks of venous thromboembolism, pressure injury, and deconditioning, and contributes to the shorter hospital stay observed after early extubation. The lower transfusion requirement in early-extubation patients, although partly a reflection of less intraoperative bleeding, may also limit exposure to the immunomodulatory and infectious risks of allogeneic blood.

The clinical corollary is that the objective should not be the earliest possible extubation in every patient, but the earliest safe extubation for each individual. Reintubation after premature extubation carries its own hazards—including aspiration, haemodynamic instability, and a higher subsequent risk of pneumonia and death—and a single reintubation event can negate the resource advantages of an aggressive weaning strategy. In the present cohort the reintubation rate remained low in both groups, suggesting that the criteria-based protocol largely succeeded in identifying patients who were physiologically ready, even though a greater proportion of late-group patients ultimately required reintubation.

The pattern of complications observed merits comment. New-onset atrial fibrillation, the commonest arrhythmia after cardiac surgery, was more frequent after late extubation, consistent with the greater age, atrial remodelling, and inflammatory burden of that group. Acute kidney injury, similarly more common after late extubation, is closely linked to longer cardiopulmonary bypass exposure, lower perfusion pressure, haemodynamic instability, and greater transfusion requirements, all of which characterized the late group. These complications are therefore not merely consequences of prolonged ventilation but share common antecedents with it, reinforcing the interpretation that delayed extubation is a marker of a more adverse perioperative trajectory rather than its sole cause.

From a process-of-care perspective, the feasibility of early extubation depends heavily on anaesthetic technique and on the organization of postoperative care. Titratable, short-acting agents such as remifentanil and propofol permit predictable emergence, while multimodal and regional analgesia can reduce opioid requirements without compromising comfort. Equally important are non-pharmacological factors: a dedicated recovery environment, clear nurse-driven weaning criteria, prompt correction of hypothermia and coagulopathy, and effective communication among surgeons, anaesthesiologists, intensivists, and physiotherapists. Where these elements are in place, early extubation can be pursued routinely; where they are absent, attempts to accelerate extubation may increase risk rather than benefit.

These considerations are particularly salient in high-volume, resource-constrained settings, where ICU beds are scarce and even small gains in early recovery can improve access to surgery for the wider population. Our findings, derived in such a context, indicate that a structured early-extubation pathway is achievable and is associated with tangible benefits, while also identifying the patient characteristics that should temper expectations of rapid weaning. Pre-emptive risk stratification using age, ventricular function, and validated operative risk scores can help teams anticipate which patients are likely to require prolonged ventilation and plan resources accordingly.

Viewed against the historical practice of routine overnight ventilation, the accumulated evidence—from the early randomized trials to contemporary large-database analyses—represents a decisive shift toward minimizing unnecessary ventilation. The present study adds to this literature by characterizing, within a single contemporary cohort, both the outcome differences between early and late extubation and the preoperative and intraoperative factors that distinguish the two groups, thereby linking the "who" and the "why" of delayed extubation in one analysis.

Several limitations should be acknowledged. This was a single-centre observational study with a modest sample size, and the absence of randomization means that residual confounding by indication cannot be excluded; the late group's worse outcomes are at least partly attributable to baseline risk. The six-hour threshold, although widely used and aligned with quality benchmarks, is somewhat arbitrary, and the dichotomous classification does not capture the continuum of ventilation duration. Reintubation and mortality were infrequent, limiting statistical power for these endpoints, and longer-term outcomes such as readmission and quality of life were not assessed. Larger multicentre studies with longer follow-up would help to refine patient-selection algorithms and to quantify the independent contribution of extubation timing after fuller adjustment for severity of illness. Future research should focus on prospectively validated selection algorithms, the incremental value of ultra-early and operating-room extubation in routine practice, and patient-centred outcomes beyond discharge, including functional recovery, readmission, and quality of life.

CONCLUSION

In patients undergoing elective CABG, early extubation within six hours was associated with faster postoperative recovery, shorter ICU and hospital stay, and a substantially lower rate of complications than late extubation. Delayed extubation predominantly identified an older, higher-risk population with poorer ventricular function, greater operative complexity, and longer bypass times, and was independently predicted by age, cardiopulmonary bypass time, and EuroSCORE II. Within a framework of careful preoperative risk stratification, optimized perioperative management, and protocol-driven weaning by an experienced team, early extubation is a safe and effective strategy that may be extended to a larger proportion of patients, while delayed extubation should prompt heightened vigilance for adverse outcomes.

REFERENCES

1. Cheng DC, Karski J, Peniston C, Raveendran G, Asokumar B, Carroll J, David T, Sandler A. Early tracheal extubation after coronary artery bypass graft surgery reduces costs and improves resource use. A prospective, randomized, controlled trial. Anesthesiology. 1996;85(6):1300-1310. PMID: 8968177.
2. Cheng DC, Karski J, Peniston C, Asokumar B, Raveendran G, Carroll J, Nierenberg H, Roger S, Mickle D, Tong J, Zelovitsky J, David T, Sandler A. Morbidity outcome in early versus conventional tracheal extubation after coronary artery bypass grafting: a prospective randomized controlled trial. J Thorac Cardiovasc Surg. 1996;112(3):755-764. PMID: 8800165.
3. Wong DT, Cheng DC, Kustra R, Tibshirani R, Karski J, Carroll-Munro J, Sandler A. Risk factors of delayed extubation, prolonged length of stay in the intensive care unit, and mortality in patients undergoing coronary artery bypass graft with fast-track cardiac anesthesia: a new cardiac risk score. Anesthesiology. 1999;91(4):936-944. PMID: 10519495.
4. Suematsu Y, Sato H, Ohtsuka T, Kotsuka Y, Araki S, Takamoto S. Predictive risk factors for delayed extubation in patients undergoing coronary artery bypass grafting. Heart Vessels. 2000;15(5):214-220. PMID: 11560357.
5. Royston D. Patient selection and anesthetic management for early extubation and hospital discharge: CABG. J Cardiothorac Vasc Anesth. 1998;12(6 Suppl 2):11-19. PMID: 9919462.
6. Nicholson DJ, Kowalski SE, Hamilton GA, Meyers MP, Serrette C, Duke PC. Postoperative pulmonary function in coronary artery bypass graft surgery patients undergoing early tracheal extubation: a comparison between short-term mechanical ventilation and early extubation. J Cardiothorac Vasc Anesth. 2002;16(1):27-31. PMID: 11854874.
7. Badhwar V, Esper S, Brooks M, Mulukutla S, Hardison R, Mallios D, Chu D, Wei L, Subramaniam K. Extubating in the operating room after adult cardiac surgery safely improves outcomes and lowers costs. J Thorac Cardiovasc Surg. 2014;148(6):3101-3109.e1. PMID: 25173117.
8. Zhu F, Lee A, Chee YE. Fast-track cardiac care for adult cardiac surgical patients. Cochrane Database Syst Rev. 2012;(10):CD003587. PMID: 23076899.
9. Hawkins AD, Strobel RJ, Mehaffey JH, Hawkins RB, Rotar EP, Young AM, Yarboro LT, Yount K, Ailawadi G, Joseph M, Quader M, Teman NR. Operating room versus intensive care unit extubation within 6 hours after on-pump cardiac surgery: early results and hospital costs. Semin Thorac Cardiovasc Surg. 2024;36(2):195-208. PMID: 36460133.
10. Kotfis K, Szylińska A, Listewnik M, Lechowicz K, Kosiorowska M, Drożdżal S, Brykczyński M, Rotter I, Żukowski M. Balancing intubation time with postoperative risk in cardiac surgery patients — a retrospective cohort analysis. Ther Clin Risk Manag. 2018;14:2203-2212. PMID: 30464493.
11. Shahsanaei F, Behrooj S, Petrudi NR, Khajehbahrami F. The overall prevalence and main determinants of prolonged mechanical ventilation in patients undergoing coronary artery bypass grafting: a systematic review. Heart Views. 2023;24(4):188-193. PMID: 38188710.
12. Higgins TL. Pro: early endotracheal extubation is preferable to late extubation in patients following coronary artery surgery. J Cardiothorac Vasc Anesth. 1992;6(4):488-493. PMID: 1498307.