

Article

Predictors of Physical Restraint After Cardiac Surgery: A Retrospective Cohort Study

Lingyao Li^{1,†}, Shurong Li^{1,†}, Chenzhen Xu², Chuanjie Yue², Junwei Gao¹, Song Wang², Siqi Zhai¹, Hao Cui^{2,*}, Jun Ma^{1,*}

¹Center for Anesthesiology, Beijing Anzhen Hospital, Capital Medical University, 100029 Beijing, China

²Department of Cardiovascular Surgery Center, Beijing Anzhen Hospital, Capital Medical University, Beijing Institute of Heart, Lung and Blood Vascular Diseases, 100029 Beijing, China

*Correspondence: tsuihao@hotmail.com (Hao Cui); majuntongxun@sohu.com (Jun Ma)

†These authors contributed equally.

Academic Editor: Giuseppe Santarpino

Submitted: 3 April 2026 Revised: 11 June 2026 Accepted: 1 July 2026 Published: 18 September 2026

Abstract

Background: This retrospective cohort study aimed to estimate the incidence of physical restraint (PR) among patients undergoing elective cardiac surgery, characterize the associated clinical features, and identify independent predictors of PR after transfer to the general ward. **Methods:** We analyzed data from 3941 adult patients at Beijing Anzhen (2018–2025). PR cases were identified through electronic medical records. Univariate and multivariable logistic regression analyses were performed to identify independent risk factors among perioperative variables. Model performance was evaluated using the C-statistic and the Hosmer–Lemeshow test, and internal stability was assessed via bootstrap resampling. **Results:** The overall incidence of PR was 5.2% (206/3941). Multivariable logistic regression identified four independent predictors: advanced age (adjusted odds ratio [aOR]: 1.04; 95% confidence interval [CI]: 1.02–1.05; $p < 0.001$), use of deep hypothermic circulatory arrest (DHCA) (aOR: 3.52; 95% CI: 1.90–6.51; $p < 0.001$), remimazolam for maintenance of anesthesia compared with propofol (aOR: 2.19; 95% CI: 1.15–4.18; $p = 0.017$), and prolonged length of stay in the intensive care unit (ICU) (aOR: 1.01; 95% CI: 1.01–1.01; $p < 0.001$). In an exploratory analysis restricted to patients aged ≥ 65 years, remimazolam maintenance was associated with higher odds of PR than propofol in a parsimonious Firth-penalized logistic regression model (adjusted OR, 5.29; 95% CI: 2.07–13.49; $p < 0.001$). **Conclusions:** Advanced age, DHCA procedures, remimazolam-based anesthesia, and extended ICU stays independently predict the use of PR in patients undergoing cardiac surgery. These findings may facilitate risk stratification and underscore the need for targeted perioperative interventions and careful anesthetic selection to minimize unnecessary restraint.

Keywords: physical restraint; cardiac surgery; cardiopulmonary bypass; risk factors

1. Introduction

Physical restraint (PR) involves attaching devices or instruments to a critically ill patient's body or nearby, making them difficult to remove and restricting the patient's movement. This practice is common among patients with cranial diseases, those in intensive care units (ICU), and individuals with mental illnesses, who often exhibit restlessness, non-cooperation, tube removal, and violent behavior, such as in psychiatry, neurology, and neurosurgery [1,2,3]. However, PR can worsen anxiety, depression, and psychological trauma, and lead to complications such as skin damage, muscle atrophy, and reduced mobility [4,5,6,7,8]. Recently, with the emphasis on enhanced recovery after surgery and increased patient safety awareness, minimizing unnecessary PR has become a clinical priority. The decision to apply PR is typically made by nursing staff at the bedside and is influenced by numerous factors across the preoperative, intraoperative, and postoperative phases. Practices vary significantly among hospitals and medical teams, indicating a lack of a unified, scientific decision-

making basis. In cardiac surgery, patients undergoing elective procedures face a unique risk profile due to complex pathophysiology, extensive surgical trauma, and potent pharmacological management. Unlike most other surgical patients, cardiac surgery patients are usually older, have a high burden of cardiovascular and cerebrovascular complications, undergo cardiopulmonary bypass (CPB), deep hypothermic circulatory arrest (DHCA), significant fluid shifts, transfusions, postoperative pain, sleep disturbance, and intensive care treatment. These factors are closely related to postoperative delirium, agitation and device safety concerns, which often prompt the use of restraints [9]. PR has been studied in general ICU populations, but evidence is limited in cardiac surgery patients after ward transfer. This study aims to estimate the incidence of ward-stage PR, explore its clinical characteristics and predictors.



2. Materials and Methods

2.1 Setting and Study Design

We conducted this retrospective cohort study at Beijing Anzhen Hospital over a 7-year period, from January 1, 2018, to February 28, 2025. Data were extracted from the electronic database and our hospital's health information system. Cases of PR were identified through the physician's order sheet in the database and electronic screening of all discharge summaries. In instances of discrepancies or missing data, we retrieved case record files from the hospital's medical registration department to review daily progress notes and nursing charts. The study protocol, approved by the Institutional Review Board of Beijing Anzhen Hospital (2025296x), included a waiver of participant consent.

2.2 Study Population

The inclusion criteria were: (1) patients aged ≥ 18 years, (2) undergoing elective cardiac surgery. Patients were excluded if one of the following conditions was met: (1) patients aged < 18 years, (2) emergency surgery, (3) unique intraoperative scenarios (such as delayed chest closure, intra-aortic balloon pump, or extracorporeal membrane oxygenation insertion) during the perioperative phase, (4) incomplete perioperative medical documentation. The exclusion criteria were defined in order to improve clinical homogeneity and minimize outcome misclassification. Emergency surgery was not considered because acute instability, shock, altered consciousness, and incomplete optimizations might independently affect delirium, sedation, and restraint use. Delayed chest closure was not considered because it usually results in severe postoperative instability and prolonged ventilation and deep sedation. Patients who needed Intra-Aortic Balloon Pump (IABP) or Extracorporeal Membrane Oxygenation (ECMO) were not considered because device-related immobilization, cannulation safety and dislodgement prevention make restraint indications different from routine postoperative care.

2.3 Definition

PR was defined as any manual method, physical or mechanical device, material, or equipment attached or adjacent to the patient's body that the patient could not easily remove and that restricted freedom of movement or normal access to the body [1]. In this study, PR referred to mechanical physical restraint documented after patients returned from the ICU to the general ward, such as soft limb restraints or equivalent restraint devices used to restrict limb movement for patient safety or prevention of unplanned device removal. PR status was assessed through the physician's order sheet in the database and electronic screening of all discharge summaries. Patients with documented eligible restraint episodes after ward transfer were classified as PR; all others were classified as non-PR. When avail-

able, the timing and duration of PR were extracted from the nursing records.

New-onset atrial fibrillation was defined as newly documented postoperative atrial fibrillation or atrial flutter in patients without preoperative atrial fibrillation, identified by monitoring, telemetry, 12-lead electrocardiography, or clinical documentation requiring treatment [10]. Pleural effusion was defined as postoperative accumulation of pleural fluid documented by chest radiography, ultrasonography, or computed tomography, with or without therapeutic drainage according to clinical indication [11]. Chronic renal dysfunction was defined as a documented preoperative diagnosis of chronic kidney disease or chronic renal insufficiency in the medical record before surgery [12]. Acute kidney injury was defined according to Kidney Disease: Improving Global Outcomes (KDIGO) as an absolute increase in serum creatinine of > 0.3 mg/dL within 48 hours after surgery, a relative increase of $> 50\%$ from baseline, or the need for postoperative dialysis [13].

Propofol, ciprofol, and remimazolam were administered intravenously for anesthesia maintenance and selected by the attending anesthesiologist according to institutional cardiac anesthesia protocols. The usual maintenance infusion ranges were 4–12 mg/kg/h for propofol, 0.4–2.4 mg/kg/h for ciprofol, and 1–3 mg/kg/h for remimazolam.

2.4 Data Collection

Preoperative data encompassed gender, age, weight, height, body mass index (BMI), left ventricular end-diastolic dimension (LVEDD), ejection fraction (EF), American Society of Anesthesiologists (ASA) physical status, and medical conditions such as hypertension, diabetes, hyperlipemia, atrial fibrillation, cerebrovascular disease, and chronic renal dysfunction. It also included the use of morphine prior to surgery. Intraoperative variables covered the use of benzodiazepines, dosage of sufentanil, anesthesia maintenance, type of surgery, involvement of CPB and DHCA, operative time, and the volume of red blood cell and plasma transfusions. Postoperative variables included ICU stay length, duration of PR, new atrial fibrillation onset, pulmonary complications like atelectasis, pleural effusion, and infection, as well as septicemia, acute kidney injury (defined as an absolute increase of more than 0.3 mg/dL or a relative increase of over 50% in serum creatinine within 48 hours post-surgery, or requiring dialysis), stroke (new permanent neurological event), hospital mortality, and total hospital stay duration.

2.5 Statistical Analysis

The analysis included measures such as mean (standard deviation) for normally distributed variables and median (interquartile range, IQR) for non-normally distributed variables for continuous variables, and frequencies and percentages for categorical variables. Group comparisons for continuous variables with a normal distribution were per-

formed using a *t*-test or analysis of variance (ANOVA), and non-normally distributed variables were compared using the Wilcoxon rank-sum test or Kruskal-Wallis test. For comparison between groups of categorical data, we used the Fisher exact test for expected frequencies <5; otherwise, we used the Chi-squared test. A *p*-value of less than 0.05 was deemed statistically significant. Baseline differences between the PR and non-PR groups were quantified using standardized mean differences (SMDs). An absolute SMD >0.10 was considered indicative of meaningful between-group imbalance. Univariate logistic regression analysis assessed the association between individual variables and PR. Candidate predictors for multiple logistic regression were selected based on both statistical and clinical criteria. Variables with a *p*-value of less than 0.10 in univariate analyses were deemed potential predictors. Sex, ejection fraction, and ASA physical status were included a priori due to their established clinical significance as markers of perioperative risk, physiological capacity, and postoperative susceptibility in cardiac surgery patients. To mitigate confounding, we opted for univariate screening. Results are presented as adjusted odds ratio (aOR) with 95% confidence interval (CI). The Hosmer and Lemeshow Test evaluated the regression model's goodness-of-fit, while model discrimination was assessed using the *C*-statistic. Internal validation employed the bootstrap method (1000 repetitions) to estimate the optimism-corrected *C*-statistic and assess model stability. Among patients aged ≥65 years, the association between maintenance anesthetic regimen and PR was examined in an exploratory, parsimonious Firth-penalized logistic regression model because of the limited number of PR events and sparse data in several covariate categories. Covariates were selected a priori based on clinical relevance and included age, sex, atrial fibrillation, preoperative morphine use, maintenance anesthetic regimen, CPB, and DHCA. Type of operation was not entered because it was highly correlated with CPB. Among patients who experienced PR, factors associated with PR duration were assessed using multivariable linear regression with the natural logarithm of PR duration in hours as the outcome. This analysis was restricted to patients with PR because PR duration is defined only among patients who experienced the event. Covariates were selected a priori, and HC3 robust standard errors were used. Exponentiated regression coefficients are reported as ratios of geometric mean PR duration with 95% confidence intervals. All statistical analyses were conducted using R software (version 4.2.2, R Foundation for Statistical Computing, Vienna, Austria) and MSTAT software (<https://www.mstata.com>).

3. Results

Fig. 1 illustrates the flow diagram of patient enrollment and exclusion in this retrospective cohort study. Between January 2018 and February 2025, 3941 adult patients undergoing cardiac surgery were retrospectively analyzed,

with 206 (5.2%) receiving PR. Table 1 details the baseline characteristics of these patients, categorized by PR status (No: *n* = 3735; Yes: *n* = 206). The PR group was notably older (61 [IQR: 55–68] yrs vs. 59 [IQR: 52–66] yrs, *p* < 0.001, SMD = −0.248), and had a higher prevalence of atrial fibrillation (21.4% vs. 11.4%, *p* < 0.001, SMD = 0.272), while sex distribution, BMI, and most comorbidities showed no significant differences. Aortic surgery and valve-involving surgery were more likely to be associated with PR (*p* < 0.001, SMD = 0.478). Significant perioperative differences included higher median sufentanil doses (1000 vs. 1000 µg, *p* < 0.001, SMD = −0.415), as well as higher rates of CPB use (78.6% vs. 61.4%, *p* < 0.001, SMD = 0.384) and DHCA (11.2% vs. 2.4%, *p* < 0.001, SMD = 0.352) in the PR group. Preoperative morphine use was less frequent in the PR group (15.0% vs. 21.3%, *p* = 0.031, SMD = 0.164), and anesthesia maintenance varied significantly (*p* = 0.006, SMD = 0.205), with higher usage of ciprofol and remimazolam in the PR group.

Table 2 highlights the differences in postoperative complications between the two groups. The PR group had significantly longer ICU stays (41 [IQR: 19–93] hours vs. 21 [IQR: 16–32] hours, *p* < 0.001) and hospital stays (15 [IQR: 11–21] days vs. 13 [IQR: 10–17] days, *p* < 0.001), along with a higher incidence of pleural effusion (5.3% vs. 2.9%, *p* = 0.049). Among patients receiving PR, the median cumulative PR duration was 59 hours (IQR, 24–124). However, no significant differences were observed in the rates of new-onset atrial fibrillation, pulmonary atelectasis, pulmonary infection, septicemia, acute kidney injury, stroke, or hospital mortality.

The univariate analysis results indicate that several factors are relative risk factors for PR after returning to the ward following cardiac surgery. These factors include older age, a preoperative history of atrial fibrillation, preoperative use of morphine, the dosage of sufentanil administered during the operation, the type of anesthetic maintenance drugs used, the type of operation, CPB, DHCA, and the length of ICU stay. In addition to variables with *p* < 0.1 from the univariate analysis, we incorporated sex, ejection fraction, ASA classification, cerebrovascular disease, benzodiazepine use during surgery, and operative time into the multiple logistic regression model, drawing on the researchers' clinical expertise. The multiple logistic regression analysis revealed several factors associated with PR use, as detailed in Table 3, **Supplementary Table 1**, and Fig. 2. Each additional year of age was significantly linked to higher odds of PR (aOR, 1.04; 95% CI, 1.02–1.05; *p* < 0.001). Patients undergoing surgery with DHCA had notably higher odds of PR compared to those without DHCA (aOR, 3.52; 95% CI, 1.90–6.51; *p* < 0.001). Using Remimazolam for anesthetic maintenance was significantly associated with increased odds of PR compared to propofol (aOR, 2.19; 95% CI, 1.15–4.18; *p* = 0.017). Furthermore, a longer ICU stay was significantly linked to increased odds of PR

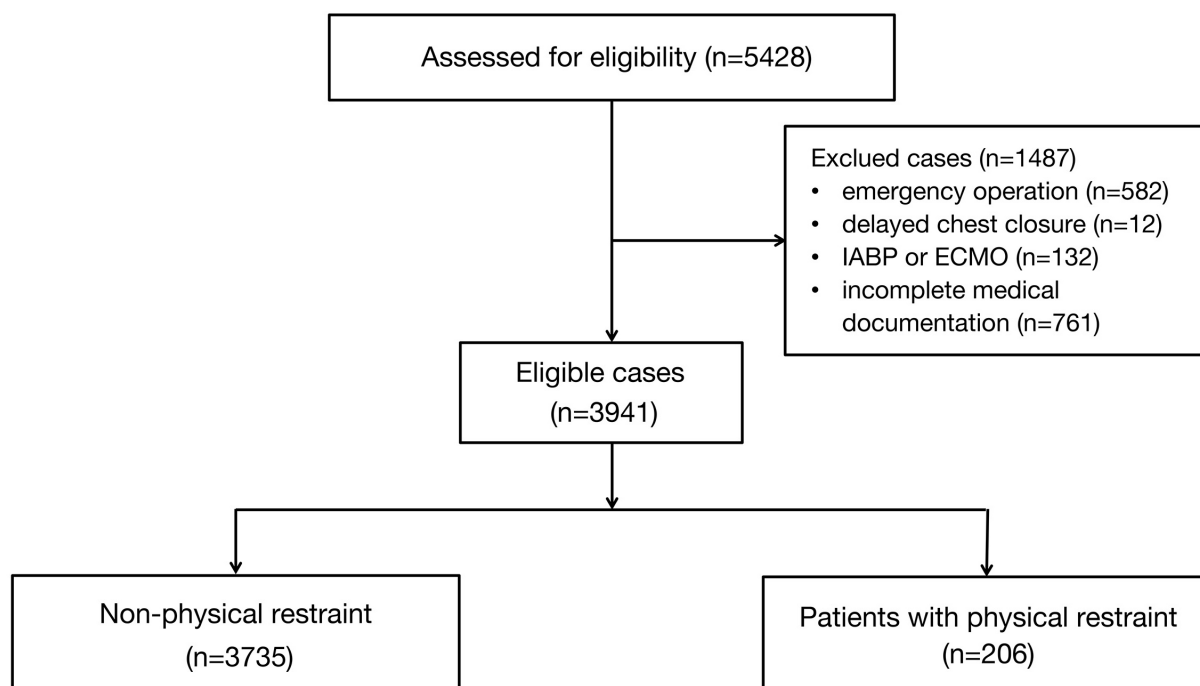


Fig. 1. Flow Diagram of Patient Selection. IABP, Intra-Aortic Balloon Pump; ECMO, Extracorporeal Membrane Oxygenation.

(aOR, 1.01; 95% CI, 1.01–1.01; $p < 0.001$). The regression model demonstrated good fit (Hosmer and Lemeshow Test χ^2 : 5.5453, $p = 0.698$) and robust discriminatory ability, with a C -statistic of 0.755 (95% CI: 0.719–0.79) and an optimism-corrected C -statistic of 0.765, indicating minimal overfitting and strong generalizability. Among the 206 patients who experienced PR, the log-duration analysis showed that ciprofol maintenance, compared with propofol, was associated with a shorter geometric mean PR duration (ratio, 0.66; 95% CI, 0.50–0.88; $p = 0.004$). Each additional 24 hours of ICU stay was associated with a longer geometric mean PR duration (ratio, 1.14; 95% CI: 1.07–1.20; $p < 0.001$). Other covariates were not significantly associated with PR duration. Detailed results are shown in **Supplementary Table 2**.

Table 4 illustrates that in the overall cohort analysis, PR use was significantly higher in the ≥ 65 age group (6.5%) compared to the < 65 age group (4.6%), with an OR of 1.43 (95% CI: 1.07–1.91; $p = 0.014$). Associations in selected clinical subgroups are presented as exploratory analyses. No statistically significant interaction effects were detected. In the supplementary analysis restricted to patients aged ≥ 65 years, remimazolam maintenance was associated with higher odds of PR than propofol after adjustment in the parsimonious Firth-penalized logistic regression model (aOR, 5.29; 95% CI: 2.07–13.49; $p < 0.001$). Detailed results are shown in **Supplementary Table 3**.

4. Discussion

PR is commonly employed in ICUs, with critical care nurses serving as the primary decision-makers and practitioners. While the intent behind the use of restraints is to ensure patient safety, they can inadvertently cause physical or psychological harm. There is currently limited qualitative evidence regarding nurses' experiences with PR. In clinical practice, we observed a relatively high incidence of PR remains relatively high among cardiac surgery patients after their transfer from the ICU to general wards, adversely affecting their physical and mental recovery. Most previous studies have investigated PR in ICUs and in psychiatric hospitals, with few addressing the incidence and duration of PR in general wards, particularly in relation to cardiac surgery contexts. This retrospective cohort study identified several independent predictors for PR use in cardiac surgery patients after returning to the general wards. These included advanced age, undergoing a DHCA procedure, maintenance with remimazolam-based anesthesia rather than propofol, and extended ICU stays. Longer ICU stay and DHCA may also contribute to prolonged PR duration. The overall rate of PR was significantly higher in patients aged ≥ 65 years (6.5%) compared to younger patients (4.6%), with an OR of 1.43. In an exploratory analysis restricted to older patients, remimazolam maintenance was associated with higher odds of PR than propofol; this association should not be interpreted as evidence of causality.

Previous studies have demonstrated that prolonged cerebral ischemia linked to DHCA, along with reperfusion

Table 1. Patient demographics and baseline characteristics.

Characteristic	Physical restraint		<i>p</i> -value	SMD
	No n = 3735	Yes n = 206		
Sex, n (%)			0.280	0.077
Female	1224 (32.8)	75 (36.4)		
Age (yrs), median (IQR)	59 (52, 66)	61 (55, 68)	<0.001	−0.248
Weight (kg), median (IQR)	72 (65, 79)	72 (65, 80)	0.973	0.020
Height (cm), median (IQR)	168 (162, 172)	167 (160, 171)	0.166	0.103
BMI (kg/m ²), median (IQR)	25.6 (23.7, 27.7)	25.7 (24.2, 28.0)	0.283	−0.058
LVEDD (mm), median (IQR)	47.0 (44.0, 50.0)	47.0 (44.0, 50.0)	0.859	0.004
EF (%), median (IQR)	60 (57, 65)	61 (57, 65)	0.609	−0.024
ASA, n (%)			0.873	0.037
II	65 (1.7)	4 (1.9)		
III	3460 (92.6)	192 (93.2)		
IV	210 (5.6)	10 (4.9)		
Hypertension, n (%)	2120 (56.8)	121 (58.7)	0.577	0.040
Diabetes, n (%)	1301 (34.8)	62 (30.1)	0.164	0.101
Hyperlipemia, n (%)	1628 (43.6)	90 (43.7)	0.977	0.002
Atrial fibrillation, n (%)	425 (11.4)	44 (21.4)	<0.001	0.272
Cerebrovascular disease, n (%)	327 (8.8)	18 (8.7)	0.993	0.001
Chronic renal dysfunction, n (%)	12 (0.3)	2 (1.0)	0.164	0.081
Use of morphine, n (%)	797 (21.3)	31 (15.0)	0.031	0.164
Use of benzodiazepines, n (%)	3123 (83.6)	179 (86.9)	0.214	0.093
Dosage of sufentanil (μg), median (IQR)	1000 (750, 1000)	1000 (1000, 1000)	<0.001	−0.415
Maintenance of anesthesia, n (%)			0.006	0.205
Propofol	2151 (57.6)	102 (49.5)		
Ciprofol	1473 (39.4)	91 (44.2)		
Remimazolam	111 (3.0)	13 (6.3)		
Type of operation, n (%)			<0.001	0.478
Off-pump CABG	1421 (38.0)	42 (20.4)		
On-pump CABG	206 (5.5)	6 (2.9)		
Valve surgery	1108 (29.7)	73 (35.4)		
Valve surgery+CABG	177 (4.7)	18 (8.7)		
Aortic surgery	691 (18.5)	62 (30.1)		
Others	132 (3.5)	5 (2.4)		
CPB, n (%)	2292 (61.4)	162 (78.6)	<0.001	0.384
DHCA, n (%)	91 (2.4)	23 (11.2)	<0.001	0.352
Operative time (hours), median (IQR)	3.78 (3.33, 4.32)	3.67 (3.20, 4.25)	0.084	0.007
RBC (U), median (IQR)	0.0000 (0.0000, 0.0000)	0.0000 (0.0000, 0.0000)	0.956	−0.008
FFP (mL), n (%)			0.944	0.014
0	3625 (97.1)	200 (97.1)		
200	39 (1.0)	2 (1.0)		
400	71 (1.9)	4 (1.9)		
Infusion (mL), median (IQR)	2500 (2000, 3000)	2500 (2000, 2950)	0.444	0.074

IQR, interquartile range; SMD, standardized mean differences; BMI, body mass index; LVEDD, left ventricular end-diastolic dimension; EF, ejection fraction; ASA, American Society of Anesthesiologists; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; DHCA, deep hypothermic circulatory arrest; RBC, red blood cell; FFP, fresh frozen plasma.

injury during rewarming, is closely associated with various adverse postoperative outcomes. These include renal dysfunction, coagulation disorders, and especially neurological complications [14,15]. This phenomenon can

be attributed to several physiological pathways, including systemic inflammation, neuroinflammation, ischemia–reperfusion injury, blood–brain barrier disruption, and temperature-related changes in cerebral metabolism. The

Table 2. Postoperative adverse events.

Adverse events	Physical restraint		<i>p</i> -value
	No	Yes	
	n = 3735	n = 206	
Length of ICU stay (hours), median (IQR)	21 (16, 32)	41 (19, 93)	<0.001
Physical restraint time (hours), median (IQR)	0 (0, 0)	59 (24, 124)	<0.001
New onset of atrial fibrillation, n (%)	67 (1.8)	5 (2.4)	0.425
Pulmonary atelectasis, n (%)	22 (0.6)	3 (1.5)	0.139
Pleural effusion, n (%)	109 (2.9)	11 (5.3)	0.049
Pulmonary infection, n (%)	23 (0.6)	1 (0.5)	>0.999
Septicemia, n (%)	2 (0.1)	0 (0.0)	>0.999
Acute kidney injury, n (%)	53 (1.4)	1 (0.5)	0.529
Stroke, n (%)	82 (2.2)	6 (2.9)	0.464
Hospital mortality, n (%)	10 (0.3)	2 (1.0)	0.127
Length of hospital stay (day), median (IQR)	13 (10, 17)	15 (11, 21)	<0.001

ICU, intensive care unit.

Table 3. Key predictors in the final multiple logistic regression model.

Predictor	Adjusted OR	95% CI	<i>p</i> -value
Age	1.04	1.02–1.05	<0.001
DHCA	3.52	1.90–6.51	<0.001
Remimazolam vs Propofol	2.19	1.15–4.18	0.017
ICU length of stay	1.01	1.01–1.01	<0.001

OR, odds ratio; CI, confidence interval.

strong correlation between DHCA procedures and use of PR (aOR = 3.52) highlights the specific challenges posed by complex surgical techniques involving major physiological changes [16]. These procedures are generally longer and more intricate, which can result in extended recovery times, and heightened agitation during emergence from anesthesia, thus increasing the perceived need for PR.

Complex procedures such as aortic or valve surgery require longer operative times, impose greater physiological stress, demand more invasive monitoring, and necessitate extended postoperative ICU care. Pain, sedation, mechanical ventilation, and indwelling tubes or drains increase the perceived need for PR to prevent device removal or self-harm. Thus, the association between surgical type and PR may reflect both patients' neurological vulnerability and the complexity of their postoperative care.

The novel insights into anesthetics warrant special attention. While propofol is commonly used for anesthesia maintenance in cardiac surgery, the emerging use of ciprofol and remimazolam introduces new considerations for postoperative management. The effects of ciprofol are comparable to those of Propofol. However, when used for anesthesia maintenance, remimazolam, independently predicts PR following cardiac surgery. The exploratory analysis among older patients suggested that remimazolam remained associated with higher odds of PR than propofol. Remimazolam is a new, ultra-short-acting benzodiazepine

that offers advantages such as rapid onset, stable hemodynamics, a short half-life, and quick recovery, leading to its increasing and widespread clinical use in recent years [17]. Traditionally, benzodiazepines have been associated with a higher incidence of neurological complications, including postoperative delirium. Luk et al. [18] confirmed that conventional benzodiazepines are significant predictors of PR in the ICU. However, recent studies suggest that remimazolam may not increase the risk of postoperative delirium [19]. A study by Aoki et al. [20] on elderly cardiovascular surgery patients also found no correlation between the use of remimazolam and postoperative delirium. The latest Chinese guidelines [21] on new intravenous anesthetics state that the risk of delirium from remimazolam in elderly patients remains unclear. However, because the number of older patients receiving remimazolam was small, this exploratory association requires confirmation in larger prospective studies and does not establish a causal medication effect. Thus, the specific impact of remimazolam on PR after cardiac surgery observed in the present study requires further investigation and confirmation.

Prolonged ICU stay was identified here as a significant predictor of PR, in line with earlier research, showing that extended stays in critical care are linked to various complications, potentially leading to increased PR [22]. The combined impact of sleep deprivation, environmental stressors, and ongoing medical interventions in the ICU likely contributes to delirium and agitation, thereby increasing the need for restraints. Furthermore, the study by Mitchell et al. [23] reported that potential adverse events, such as self-extubation, resulting from the absence of PR could cause treatment delays and extend hospital stays. Nurses are often compelled to use restraints as a defensive measure to ensure the continuity of long-term treatment. This finding underscores the importance of implementing protocols to prevent delirium and of strategies designed to shorten ICU stays, thereby reducing the need for PR.

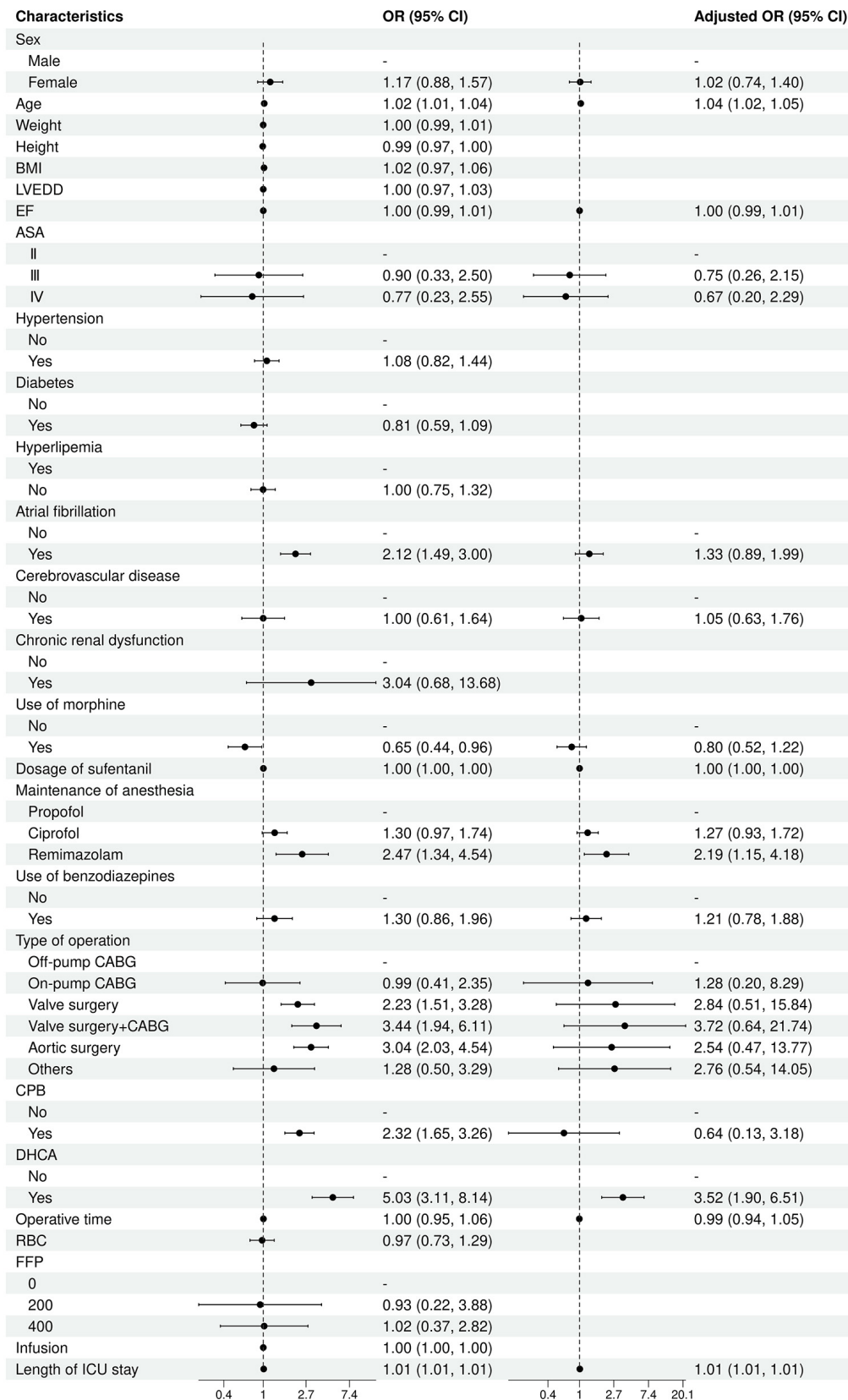


Fig. 2. Univariate and multivariate analysis.

Table 4. Subgroup analysis.

Subgroup	<65 years	≥65 years	Crude OR (95% CI)	<i>p</i> value	<i>p</i> for interaction
Overall	124/2679 (4.6)	82/1262 (6.5)	1.43 (1.07–1.91)	0.014	
Sex, n (%)					0.679
Male	83/1843 (4.5)	48/799 (6.0)	1.36 (0.94–1.95)	0.103	
Female	41/836 (4.9)	34/463 (7.3)	1.54 (0.96–2.46)	0.073	
ASA, n (%)					0.176
II	4/54 (7.4)	0/15 (0.0)	0.00 (0.00–Inf)	0.995	
III	113/2479 (4.6)	79/1173 (6.7)	1.51 (1.12–2.03)	0.006	
IV	7/146 (4.8)	3/74 (4.1)	0.84 (0.21–3.34)	0.803	
Use of morphine, n (%)					0.150
No	104/2167 (4.8)	71/946 (7.5)	1.61 (1.18–2.20)	0.003	
Yes	20/512 (3.9)	11/316 (3.5)	0.89 (0.42–1.88)	0.754	
Use of benzodiazepines, n (%)					0.988
No	15/408 (3.7)	12/231 (5.2)	1.44 (0.66–3.12)	0.362	
Yes	109/2271 (4.8)	70/1031 (6.8)	1.44 (1.06–1.97)	0.020	
Maintenance of anesthesia, n (%)					0.094
Propofol	62/1553 (4.0)	40/700 (5.7)	1.46 (0.97–2.19)	0.070	
Ciprofol	56/1030 (5.4)	35/534 (6.6)	1.22 (0.79–1.89)	0.371	
Remimazolam	6/96 (6.2)	7/28 (25.0)	5.00 (1.52–16.43)	0.008	
Type of operation, n (%)					0.084
Off-pump CABG	16/814 (2.0)	26/649 (4.0)	2.08 (1.11–3.91)	0.023	
On-pump CABG	3/123 (2.4)	3/89 (3.4)	1.40 (0.28–7.08)	0.688	
Valve surgery	39/888 (4.4)	34/293 (11.6)	2.86 (1.77–4.62)	<0.001	
Valve surgery+CABG	13/120 (10.8)	5/75 (6.7)	0.59 (0.20–1.72)	0.333	
Aortic surgery	49/622 (7.9)	13/131 (9.9)	1.29 (0.68–2.45)	0.440	
Others	4/112 (3.6)	1/25 (4.0)	1.12 (0.12–10.52)	0.918	
CPB, n (%)					0.739
No	18/833 (2.2)	26/654 (4.0)	1.87 (1.02–3.45)	0.043	
Yes	106/1846 (5.7)	56/608 (9.2)	1.67 (1.19–2.33)	0.003	
DHCA, n (%)					0.969
No	104/2576 (4.0)	79/1251 (6.3)	1.60 (1.19–2.16)	0.002	
Yes	20/103 (19.4)	3/11 (27.3)	1.56 (0.38–6.40)	0.540	

Inf, Infinite.

Exploratory subgroup analyses suggested that PR was more frequent among patients aged ≥ 65 years in several clinical strata. However, formal interaction tests did not identify statistically significant effect modification; therefore, these subgroup findings should not be interpreted as evidence that the association between age and PR is independent of surgical technique, medication exposure, or physiological support. Advanced age may contribute to vulnerability to PR through reduced physiological reserve and increased susceptibility to delirium [24]. Consistent with this interpretation, Gu et al.'s research [25] highlighted that in the Chinese ICU, age and delirium are independent predictors of PR. The physiological changes that accompany aging, such as diminished functional reserve and heightened susceptibility to delirium, likely contribute to this increased risk.

In exploratory subgroup analyses, the elevated PR risk in older patients undergoing valve surgery (OR = 2.86) could be attributed to factors such as frailty and the burden of the procedure. Conditions like chronic valvular disease, atrial enlargement, pulmonary hypertension, reduced cardiac reserve, and atrial fibrillation may contribute to this increased risk. Additionally, factors such as greater trauma during surgery, extended bypass or cross-clamp times, pain, hemodynamic instability, and the use of surgical devices can lead to hypoperfusion, inflammation, sleep disruption, delirium, and agitation. Similarly, the elevated risk in off-pump CABG patients challenges the assumption that avoiding CPB reduces complications requiring restraint. This suggests that factors beyond bypass-related inflammation contribute to the need for restraint.

Interestingly, the lack of morphine administration prior to surgery was linked to a higher risk of restraint in older patients. Although opioids can lead to delirium [26], they also confer analgesia that may alleviate pain-related agitation. This paradoxical observation suggests that inadequate pain management, rather than opioid exposure itself, may be responsible for the emergence of behaviors necessitating PR.

Our findings have significant clinical implications. By identifying specific risk factors, targeted interventions can be implemented to decrease the use of PR. For elderly patients, especially those undergoing complex procedures or receiving certain anesthetic regimens, enhanced monitoring and preventive measures could reduce the need for PR. Protocolized sedation and analgesia approaches, such as those guided by the eCASH (early Comfort using Analgesia, minimal Sedatives, and maximal Human care) framework, have proven effective in reducing PR without compromising safety [27]. Our research suggests that careful selection of anesthetic agents, particularly remimazolam, might lower the risk of restraint in elderly patients. Furthermore, developing age-specific perioperative management protocols that address the unique vulnerabilities of older surgical patients could potentially reduce complications leading to restraint use.

Limitations

This study has several limitations that should be considered when interpreting the results. The retrospective design introduces potential unmeasured confounding, even with multivariate adjustment in the multiple logistic regression model. Being a single-center study may limit generalizability, as restraint practices vary significantly across institutions due to local protocols and cultural approaches to patient management. Additionally, the absence of detailed data on delirium incidence and severity is a limitation, given that delirium is a primary indication for PR in post-operative patients [24,28,29]. The small number of ASA II patients limited the power and precision of ASA-stratified analyses. However, this distribution reflects the clinical profile of cardiac surgical patients, who are commonly classified as ASA III or above due to substantial cardiovascular disease. Therefore, ASA-based subgroup results should be interpreted cautiously. The observational nature of our data also prevents definitive conclusions about causality regarding the identified associations. In the older-patient subgroup, only 82 PR events were observed. Although a parsimonious Firth-penalized logistic regression model was used to address sparse data and separation, the subgroup findings remain exploratory and require external confirmation.

Future research should prospectively validate these risk factors in multicenter studies to improve generalizability. Investigating the mechanisms behind the differential effects of anesthetic agents, especially the significant impact of remimazolam on elderly patients, would enhance

our pharmacological understanding and inform clinical decisions. Intervention studies focusing on modifiable risk factors, like protocolized anesthesia and analgesia regimens tailored for elderly patients, could assess whether reducing restraints is possible without compromising patient safety. Moreover, research examining the relationship between PR and specific patient-centered outcomes, such as psychological effects and long-term functional recovery, would strengthen the evidence base guiding restraint practices.

5. Conclusions

In conclusion, this study identifies advanced age, DHCA procedures, remimazolam anesthesia, and prolonged ICU stays as independent predictors of PR in cardiac surgery patients. The exploratory association between remimazolam and PR among older patients requires validation in larger prospective cohorts before it can inform clinical practice.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding authors on reasonable request.

Author Contributions

LL and SL contributed to conception and were responsible for the whole work. LL and CX completed the writing and figure making of this work. CY, JG, SW, SZ, HC and JM contributed to the study conception and design, and interpretation of the results. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was carried out in accordance with the guidelines of the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of Beijing Anzhen Hospital (2025296x). This study was a retrospective analysis of existing clinical data. All patient identifiers were removed prior to analysis, and the research posed no more than minimal risk to participants. Therefore, the Institutional Review Board approved the waiver of informed consent.

Acknowledgment

Not applicable.

Funding

The study was funded by the National Natural Science Foundation of China (No.82372191); Beijing Natural Science Foundation (L251020); the Excellent Youth Fund of the National Natural Science Foundation of China

and the Excellent Youth Fund of Capital Medical University (KCA-2305); Beijing Municipal Health Commission (11000026T000003710131). The funding sources had no involvement in the study design, data collection, analysis, interpretation, or the decision to submit the article for publication.

Conflicts of Interest

The authors declare no conflicts of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at <https://doi.org/10.31083/HSF52581>.

References

- [1] Chong Y, Wang C, Min H, Zhang L, Zhi T, Wu X, et al. Physical Restraint Experience of Patients with Mental Disorders in Mainland China: A Qualitative Study. *Journal of Multidisciplinary Healthcare*. 2024; 17: 431–444. <https://doi.org/10.2147/JMDH.S438269>
- [2] Ji Y, Yang X, Wang J, Cai W, Gao F, Wang H. Factors Influencing the Physical Restraint of Patients in the Neurosurgical Intensive Care Unit. *Clinical Nursing Research*. 2022; 31: 46–54. <https://doi.org/10.1177/10547738211016874>
- [3] Kawai Y, Hamamoto M, Miura A, Yamaguchi M, Masuda Y, Iwata M, et al. Prevalence of and factors associated with physical restraint use in the intensive care unit: a multicenter prospective observational study in Japan. *Internal and Emergency Medicine*. 2022; 17: 37–42. <https://doi.org/10.1007/s11739-021-02737-5>
- [4] Salehi Z, Najafi Ghezeli T, Hajibabae F, Joolae S. Factors behind ethical dilemmas regarding physical restraint for critical care nurses. *Nursing Ethics*. 2020; 27: 598–608. <https://doi.org/10.1177/0969733019858711>
- [5] Benbenishty J, Adam S, Endacott R. Physical restraint use in intensive care units across Europe: the PRICE study. *Intensive & Critical Care Nursing*. 2010; 26: 241–245. <https://doi.org/10.1016/j.iccn.2010.08.003>
- [6] Hammervold UE, Norvoll R, Aas RW, Sagvaag H. Post-incident review after restraint in mental health care – a potential for knowledge development, recovery promotion and restraint prevention. A scoping review. *BMC Health Services Research*. 2019; 19: 235. <https://doi.org/10.1186/s12913-019-4060-y>
- [7] Chong Y, Wang C, Zhi T, Fang S, Min H, Zhang L, et al. Psychiatric Nurses' Knowledge, Attitudes, and Practice Regarding Physical Restraint in China: A Multicentre Cross-Sectional Study. *Journal of Multidisciplinary Healthcare*. 2023; 16: 1475–1489. <https://doi.org/10.2147/JMDH.S412485>
- [8] Yıldız İ, Özkaraman A. Vascular complications in extremities of physically restrained intensive care unit patients: A prospective, observational study. *Nursing in Critical Care*. 2024; 29: 931–942. <https://doi.org/10.1111/nicc.13107>
- [9] Kotfis K, Marra A, Ely EW. ICU delirium - a diagnostic and therapeutic challenge in the intensive care unit. *Anesthesiology Intensive Therapy*. 2018; 50: 160–167. <https://doi.org/10.5603/AIT.a2018.0011>
- [10] Joglar JA, Chung MK, Armbruster AL, Benjamin EJ, Chyou JY, Cronin EM, et al. 2023 ACC/AHA/ACCP/HRS Guideline for the Diagnosis and Management of Atrial Fibrillation: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*. 2024; 149: e1–e156. <https://doi.org/10.1161/CIR.0000000000001193>
- [11] Schiefenhövel F, Poncette AS, Boyle EM, von Heymann C, Menk M, Vorderwülbecke G, et al. Pleural effusions are associated with adverse outcomes after cardiac surgery: a propensity-matched analysis. *Journal of Cardiothoracic Surgery*. 2022; 17: 298. <https://doi.org/10.1186/s13019-022-02050-y>
- [12] Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2024 Clinical Practice Guideline for the Evaluation and Management of Chronic Kidney Disease. *Kidney International*. 2024; 105: S117–S314. <https://doi.org/10.1016/j.kint.2023.10.018>
- [13] Brown JK, Shaw AD, Mythen MG, Guzzi L, Reddy VS, Crisafi C, et al. Adult Cardiac Surgery-Associated Acute Kidney Injury: Joint Consensus Report. *Journal of Cardiothoracic and Vascular Anesthesia*. 2023; 37: 1579–1590. <https://doi.org/10.1053/j.jvca.2023.05.032>
- [14] Chen L, Cheng Y, Bu X, Zhang C, Sun J, Liu X, et al. Intraoperative hemodynamics in prediction of postoperative kidney injury after type a aortic dissection surgery: a retrospective cohort study. *Annals of Medicine*. 2025; 57: 2474859. <https://doi.org/10.1080/07853890.2025.2474859>
- [15] Biancari F, Mäkilä T, Rosato S, Juvonen T, Mariscalco G, El-Dean Z, et al. Carotid artery dissection and neurological complications after surgery for type 1 aortic dissection. *Open Heart*. 2025; 12: e002882. <https://doi.org/10.1136/openhrt-2024-002882>
- [16] Lou X, Chen EP. Optimal Cerebral Protection Strategies in Aortic Surgery. *Seminars in Thoracic and Cardiovascular Surgery*. 2019; 31: 146–152. <https://doi.org/10.1053/j.semthvs.2019.01.001>
- [17] Zhang H, Li H, Zhao S, Bao F. Remimazolam in General Anesthesia: A Comprehensive Review of Its Applications and Clinical Efficacy. *Drug Design, Development and Therapy*. 2024; 18: 3487–3498. <https://doi.org/10.2147/DDDT.S474854>
- [18] Luk E, Sneyers B, Rose L, Perreault MM, Williamson DR, Mehta S, et al. Predictors of physical restraint use in Canadian intensive care units. *Critical Care (London, England)*. 2014; 18: R46. <https://doi.org/10.1186/cc13789>
- [19] Yang JJ, Lei L, Qiu D, Chen S, Xing LK, Zhao JW, et al. Effect of Remimazolam on Postoperative Delirium in Older Adult Patients Undergoing Orthopedic Surgery: A Prospective Randomized Controlled Clinical Trial. *Drug Design, Development and Therapy*. 2023; 17: 143–153. <https://doi.org/10.2147/DDDT.S392569>
- [20] Aoki Y, Kurita T, Nakajima M, Imai R, Suzuki Y, Makino H, et al. Association between remimazolam and postoperative delirium in older adults undergoing elective cardiovascular surgery: a prospective cohort study. *Journal of Anesthesia*. 2023; 37: 13–22. <https://doi.org/10.1007/s00540-022-03119-7>
- [21] Feng Y, Xu J, Ma H, Wang E, Bian J, Fang X, et al. Chinese clinical practice guidelines for total intravenous anaesthesia: a systematic review and expert consensus-based recommendations*. *British Journal of Anaesthesia*. 2026; 136: 876–896. <https://doi.org/10.1016/j.bja.2025.09.038>
- [22] McPherson JA, Wagner CE, Boehm LM, Hall JD, Johnson DC, Miller LR, et al. Delirium in the cardiovascular ICU: exploring modifiable risk factors. *Critical Care Medicine*. 2013; 41: 405–413. <https://doi.org/10.1097/CCM.0b013e31826ab49b>
- [23] Mitchell DA, Panchisin T, Seckel MA. Reducing Use of Restraints in Intensive Care Units: A Quality Improvement Project. *Critical Care Nurse*. 2018; 38: e8–e16. <https://doi.org/10.4037/ccn2018211>
- [24] Sanson G, Khlopenyuk Y, Milocco S, Sartori M, Dreas L, Fabiani A. Delirium after cardiac surgery. Incidence, phenotypes, predisposing and precipitating risk factors, and effects. *Heart & Lung: the Journal of Critical Care*. 2018; 47: 408–417. <https://doi.org/10.1016/j.hrtlng.2018.04.005>

- [25] Gu T, Wang X, Deng N, Weng W. Investigating influencing factors of physical restraint use in China intensive care units: A prospective, cross-sectional, observational study. *Australian Critical Care: Official Journal of the Confederation of Australian Critical Care Nurses*. 2019; 32: 193–198. <https://doi.org/10.1016/j.aucc.2018.05.002>
- [26] Duprey MS, Dijkstra-Kersten SMA, Zaal IJ, Briesacher BA, Saczynski JS, Griffith JL, et al. Opioid Use Increases the Risk of Delirium in Critically Ill Adults Independently of Pain. *American Journal of Respiratory and Critical Care Medicine*. 2021; 204: 566–572. <https://doi.org/10.1164/rccm.202010-3794OC>
- [27] Vincent JL, Shehabi Y, Walsh TS, Pandharipande PP, Ball JA, Spronk P, et al. Comfort and patient-centred care without excessive sedation: the eCASH concept. *Intensive Care Medicine*. 2016; 42: 962–971. <https://doi.org/10.1007/s00134-016-4297-4>
- [28] Li X, Cheng W, Zhang J, Li D, Wang F, Cui N. Early alteration of peripheral blood lymphocyte subsets as a risk factor for delirium in critically ill patients after cardiac surgery: A prospective observational study. *Frontiers in Aging Neuroscience*. 2022; 14: 950188. <https://doi.org/10.3389/fnagi.2022.950188>
- [29] Pan Y, Jiang Z, Yuan C, Wang L, Zhang J, Zhou J, et al. Influence of physical restraint on delirium of adult patients in ICU: A nested case-control study. *Journal of Clinical Nursing*. 2018; 27: 1950–1957. <https://doi.org/10.1111/jocn.14334>