

Original Article



Association between Cardiac Output and Anesthesia Emergence Time in Elderly Patients with Coronary Heart Disease: A Secondary Analysis Based on DRYAD Databases

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Abstract:

Background: General anesthesia is widely regarded as a safe and effective procedure; however, in elderly patients, it is associated with an increased risk of both intraoperative and postoperative complications, as well as higher mortality rates, primarily due to age-related physiological changes. During general anesthesia for noncardiac surgery, knowledge gaps remain regarding the effect of cardiac output (CO) on patient-centered anesthesia wake. Therefore, this study aims to evaluate whether CO is associated with anesthesia emergence time among elderly patients with coronary heart disease (CHD).

Methods: Data for this study were sourced from the Dryad Digital Repository and included 121 elderly patients aged 65 to 80 years who underwent laparoscopic surgery with an estimated surgical time of ≥ 4 hours. Patients were divided into two groups based on the median preoperative CO. The relationship between preoperative CO and anesthesia emergence time was analyzed using linear regression models, adjusting for various confounding factors.

Results: Univariate linear regression analysis showed a significant association between preoperative CO and anesthesia emergence time ($P < 0.05$). Multivariate stepwise regression analysis confirmed this association, even after adjusting for age, BMI, anesthetic type, blood loss, and other factors ($P < 0.05$).

Conclusions: Preoperative CO adjustment is significantly associated with anesthesia emergence time in elderly patients with CHD. It is essential to optimize CO before surgery to enhance postoperative recovery and minimize complications.

Keywords: Anesthesia emergence time, Cardiac output, Coronary heart disease, Elderly patients, Preoperative optimization.

Introduction

Elderly patients constitute an increasingly large proportion of the high-risk surgical group. The rising proportion of elderly people has made coronary heart disease (CHD) a major health problem among this demographic. Patients with prior cardiovascular diseases are at high risk for cardiovascular disease events (Kerr et al., 2009). In patients with CHD, fatal and non-fatal rates of recurrent cardiovascular disease events are high (De Bacquer et al., 2022). Systematic reviews have generally found that Goal-directed therapy (GDT) (Conti et al., 2020) reduces hospital length of stay and overall postoperative complication rate

(Jessen et al., 2022).

Blood pressure management in elderly patients undergoing prolonged surgery can significantly enhance the quality of postoperative anesthesia recovery and facilitate the patients' postoperative rehabilitation (Lan et al., 2023). Cardiac output (CO), expressed in liters per minute, is the amount of blood the heart pumps in one minute. CO measurement is crucial in cardiac function monitoring and can provide parameters for GDT perioperatively.

While general anesthesia is generally considered safe, elderly patients are at a higher risk of intra-

and postoperative complications and mortality (Ilala et al., 2023). During general anesthesia for noncardiac surgery, knowledge gaps remain regarding the effect of cardiac output on patient-centered anesthesia wake. Therefore, this study aims to evaluate whether CO is associated with anesthesia emergence time among elderly patients with CHD.

Methods

Data Source and Study Population

Data for this study were collected from the Dryad Digital Repository (<https://datadryad.org/>), which

houses numerous datasets from previously published papers (fig 1) (Zhang et al., 2017). The original study was conducted by the Institutional Research Ethics Committee of Zhejiang Provincial People's Hospital to compare the cardioprotective effects of sevoflurane versus propofol-remifentanyl in elderly patients with CHD. A total of 121 patients undergoing laparoscopic surgery were enrolled from June 2014 to June 2016 in Zhejiang Provincial People's Hospital and the First Affiliated Hospital of Wenzhou Medical University.

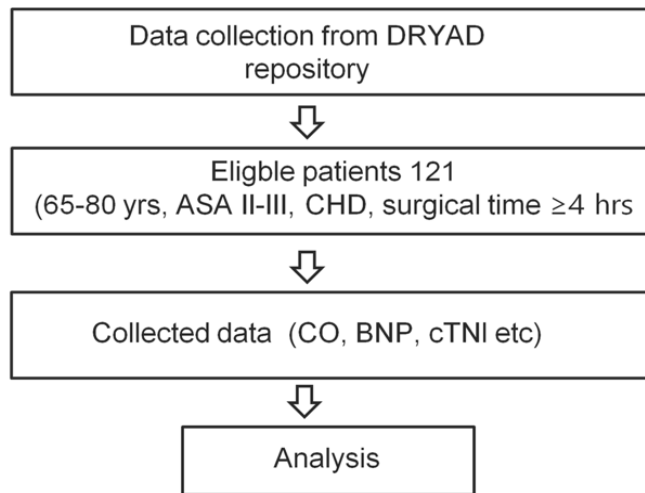


Figure 1. Flow diagram of the study protocol

This study included elderly patients aged 65 to 80 years with ASA grades II-III, scheduled for laparoscopic pancreaticoduodenectomy and radical cystectomy, with an estimated surgical time of ≥ 4 hours. Patients diagnosed with CHD through cardiac catheterization, who had undergone stent implantation and had serum cardiac troponin I (cTnI) and brain natriuretic peptide (BNP) levels within normal ranges, and were classified as NYHA I-II, were eligible. Patients with surgical times less than 4 hours or intraoperative blood loss exceeding 1000 ml were excluded. Additional exclusion criteria included postoperative admission to the intensive care unit, myocardial infarction in the past six months, hepatic or renal dysfunction, history of stroke, mental disorders, or preoperative use of steroids.

Data collection

Two anesthesia methods were used: one group received sevoflurane anesthesia, while the other received propofol combined with remifentanyl

anesthesia. Intraoperatively, dynamic monitoring was conducted for changes in cardiac output (CO), stroke volume variation (SVV), and ST-T segment, as well as for surgical and anesthesia durations, use of vasoactive drugs, and blood loss. We collected CO values at five time points in the Dryad Digital Repository, specifically before induction, and at 1 hour (CO 1 hour), 2 hours (CO 2 hour), 3 hours (CO 3 hour), and 4 hours (CO 4 hour) after induction, as well as after the completion of the surgery (CO after op). Cardiac output (CO) was recorded using the FloTrac/Vigileo system (Edwards Lifesciences LLC). Measurements of cTnI and BNP were taken preoperatively (cTnI T0h, BNPT1), at 8 hours postoperatively (cTnI T8h), and at 24 hours postoperatively (cTnI T24h, BNP T2).

Statistical Analyses

Data from all participants were analyzed descriptively. Mean and standard deviation (SD) or median were used for continuous data, while proportions (%) represented categorical variables.

An analysis of the relationship between CO and anesthesia emergence time was conducted using linear regression models. The statistical software packages R (<http://www.R-project.org>, The R Foundation) and Free Statistics software version 1.8 were used for all analyses. Statistical significance was determined by comparing OR (Odds Ratio) with 1.0 and describing 95% confidence intervals (95% CIs). A two-tailed test was conducted and $P < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

A total of 121 patients were included in the analysis. Patients were divided into two groups based on the median preoperative cardiac output

(CO): CO1 and CO2. The CO1 group included patients with CO less than the median preoperative CO, while the CO2 group included those with CO greater than the median preoperative CO. There were no significant differences in patient characteristics or surgery-related factors between the two groups, except for CO, the mean CO, and the duration of anesthesia (Table 1). There was no significant difference in anesthesia emergence times between the high CO and low CO groups (as shown in Table 1), but there was a difference in anesthesia duration and surgical time. We acknowledge the question of why anesthesia duration would differ when surgical times were the same. To further investigate this, we analyzed the factors that might influence anesthesia emergence time.

Table 1. Data characteristics of the participants

Variables	Total (n = 121)	CO1 (n = 55)	CO2 (n = 66)	p-value
Age, Years, Mean + SD	70.8 + 3.9	70.7 + 4.1	70.8 + 3.9	0.88
BMI, kg/m ² , Mean + SD	23.1 + 1.1	23.0 + 0.9	23.2 + 1.3	0.21
duration of surgery, min, Mean + SD	301.7 + 34.7	295.5 + 34.7	307.0 + 34.0	0.069
duration of anesthesia, min, Mean + SD	335.1 + 35.5	327.6 + 36.8	341.4 + 33.5	0.034*
Anesthetic, n (%)				0.528
Sevo	60 (49.6)	29 (52.7)	31 (47)	
Propo	61 (50.4)	26 (47.3)	35 (53)	
emergence time, min, Mean + SD	13.5 + 2.8	13.9 + 2.9	13.2 + 2.8	0.199
blood amount, mL, Mean + SD	493.6 + 106.6	492.2 + 114.8	494.8 + 100.1	0.892
trasfusion amount, n (%)				0.573
0 mL	100 (82.6)	48 (87.3)	52 (78.8)	
100 mL	2 (1.7)	0 (0)	2 (3)	
200 mL	15 (12.4)	6 (10.9)	9 (13.6)	
300 mL	2 (1.7)	1 (1.8)	1 (1.5)	
400 mL	2 (1.7)	0 (0)	2 (3)	
vasodilator, Mean + SD	25.3 + 19.9	26.4 + 20.3	24.4 + 19.7	0.591
vasoconstrictor, Mean + SD	460.3 + 218.5	461.8 + 198.6	459.1 + 235.3	0.946
cTnl T0h, 10 ⁻² µg/mL, Mean + SD	0.40 + 0.17	0.39 + 0.18	0.40 + 0.15	0.692
cTnl T8h, 10 ⁻² µg/mL, Mean + SD	0.97 + 0.33	0.93 + 0.32	1.00 + 0.33	0.224
cTnl T24h, 10 ⁻² µg/mL, Mean + SD	3.77 + 1.04	3.70 + 1.00	3.83 + 1.11	0.47
BNP T1, Pg/mL, Mean + SD	53.4 + 10.3	51.7 + 10.1	54.8 + 10.3	0.093
BNP T2, Pg/mL, Mean + SD	71.3 + 15.8	68.3 + 14.4	73.9 + 16.5	0.051
CO mean, L/min, Mean + SD	4.1 + 0.1	4.1 + 0.1	4.2 + 0.1	< 0.001***
CO before induction, L/min, Mean + SD	4.5 + 0.3	4.2 + 0.1	4.8 + 0.2	< 0.001***
CO 1hour, L/min, Mean + SD	3.9 + 0.3	3.8 + 0.3	3.9 + 0.3	0.756
CO 2hour, L/min, Mean + SD	3.8 + 0.2	3.8 + 0.2	3.9 + 0.2	0.587
CO 3hour, L/min, Mean + SD	4.0 + 0.2	4.0 + 0.2	3.9 + 0.2	0.115
CO 4hour, L/min, Mean + SD	4.4 + 0.2	4.3 + 0.2	4.4 + 0.3	0.468
CO after op, L/min, Mean + SD	4.3 + 0.3	4.3 + 0.3	4.3 + 0.2	0.851

BMI : Body mass index; Sevo: received sevoflurane anesthesia; Propo: received propofol combined with remifentanil anesthesia; cTnI T0h: cTnI preoperatively; cTnI T8h: cTnI at 8 hours postoperatively; cTnI T24h: cTnI at 24 hours postoperatively; BNP T1: BNP preoperatively; BNP T2: BNP at 24 hours postoperatively; CO: cardiac output; CO mean: mean of CO before induction, CO 1hour, CO 2hour, CO 3hour, CO 4hour and CO after op; CO before induction: before anesthesia induction CO CO 1hour: CO one hour after anesthesia induction; CO 2hour: CO two hours after anesthesia induction; CO

3hour: CO three hours after anesthesia induction; CO 4hour: CO four hours after anesthesia induction; CO after op: CO after surgery. Values were expressed as number (percentage), mean \pm SD or median [interquartile ranges]. ***P < 0.001.

Association Between Preoperative CO and Anesthesia Emergence Time

Based on univariate linear regression analysis, blood loss amount and CO before induction were significantly related to anesthesia emergence time (all P < 0.05) (Table 2).

Table 2 Univariate regression analysis

Variable	Coefficient (95%CI)	P-value
Age (cont. var.)	-0.039 (-0.169,0.091)	0.5499
BMI (cont. var.)	-0.026 (-0.475,0.422)	0.9079
duration of surgery (cont. var.)	-0.008 (-0.023,0.007)	0.2802
duration of anesthesia (cont. var.)	-0.007 (-0.022,0.007)	0.3045
Anesthetic: Propo vs Sevo	-0.835 (-1.84,0.17)	0.1026
blood amount (cont. var.)	0.005 (0.001,0.01)	0.0262*
trasfusion amount: ref.=0		
100 mℓ	2.48 (-1.472,6.432)	0.2164
200 mℓ	0.28 (-1.252,1.812)	0.718
300 mℓ	-3.52 (-7.472,0.432)	0.0803
400 mℓ	-1.52 (-5.472,2.432)	0.4477
vasodilator (cont. var.)	-0.011 (-0.037,0.014)	0.3877
vasoconstrictor (cont. var.)	-0.002 (-0.004,0.001)	0.1901
cTnI T0h (cont. var.)	-160.6 (-465.5,144.4)	0.2992
cTnI T8h (cont. var.)	-162.8 (-316.2,-9.4)	0.0377*
cTnI T24h (cont. var.)	-5.927 (-54.8,42.9)	0.8105
BNP T1 (cont. var.)	-0.012 (-0.062,0.038)	0.633
BNP T2 (cont. var.)	-0.013 (-0.045,0.019)	0.4246
CO mean (cont. var.)	-1.386 (-5.9,3.128)	0.5442
CO before induction (cont. var.)	-1.569 (-3,-0.138)	0.0319*
CO 1hour (cont. var.)	0.096 (-1.716,1.908)	0.9166
CO 2hour (cont. var.)	1.347 (-1.351,4.046)	0.3247
CO 3hour (cont. var.)	0.725 (-1.758,3.208)	0.5644
CO 4hour (cont. var.)	0.147 (-1.805,2.099)	0.8819
CO after op (cont. var.)	-0.154 (-2.163,1.856)	0.8798

BMI Body mass index; CO: cardiac output; Sevo: received sevoflurane anesthesia; Propo: received propofol combined with remifentanyl anesthesia; cTnI T0h: cTnI preoperatively; cTnI T8h: cTnI at 8 hours postoperatively; cTnI T24h: cTnI at 24 hours postoperatively; BNP T1: BNP preoperatively; BNP T2: BNP at 24 hours postoperatively; CO mean: mean of CO before induction, CO 1hour, CO 2hour, CO 3hour, CO 4hour and CO after op; CO before induction: before anesthesia induction CO; CO 1hour: CO one hour after anesthesia induction; CO 2hour: CO two hours after anesthesia induction; CO 3hour: CO three hours after anesthesia induction; CO 4hour: CO four hours after anesthesia induction; CO after op: CO after surgery. Values were expressed as number (percentage), mean \pm SD or median [interquartile ranges]. * $P < 0.05$

In Table 3, the results of the multivariate stepwise regression analysis for the association between CO of before induction and anesthesia emergence

time are presented. The unadjusted model (Model I) showed an increased risk of prolonged anesthesia emergence time related to CO of before induction (OR: -1.6, 95% CI: -3.02 to -0.17, $P < 0.05$). After controlling for age, BMI, type of anesthetic used, blood loss amount, vasodilator use, vasoconstrictor use, and transfusion amount (Model II), CO of before induction and anesthesia emergence time were still significantly associated (OR: -1.60, 95% CI: -3.02 to -0.17, $P < 0.05$). After further adjustment for age, BMI, and duration of surgery (Model III), the association between CO of before induction and anesthesia emergence time remained significant (OR: 1.57, 95% CI: -2.99 to -0.06, $P < 0.05$). Even after further adjustment for all relevant factors, including age, BMI, type of anesthetic, TnIT0h, and BNPT1 (Model IV), the significant association between CO before induction remained (OR: 1.47, 95% CI: -2.93 to -0.02, $P < 0.05$).

Table 3. Multivariate regression analysis of the association between CO of before induction and anesthesia emergence time.

Variable	Coefficient(95%CI)	P-value
Model I ^a	-1.6 (-3.02~-0.17)	0.030
Model II ^b	-1.6 (-3.02~-0.17)	0.030
Model III ^c	-1.52 (-2.99~-0.06)	0.044
Model IV ^d	-1.47 (-2.93~-0.02)	0.049

Model I^a: no adjusted.

Model II^b: adjusted for age + BMI + type of used anesthetic + blood loss amount + vasodilator use + vasoconstrictor use + transfusion amount.

Model III^c: adjusted for age + BMI + duration of surgery times

Model IV^d: adjusted for age + BMI + type of used anesthetic+ TnIT0h+ BNPT1

A subgroup analysis of the data is presented in Fig. 2. In subgroup analyses by age, type of anesthetic, and amount of blood loss, no statistically significant interaction was noted (all $P > 0.05$). Although no significant differences were observed, a more pronounced negative correlation

was noted between anesthesia emergence time and the following subgroups: age greater than 70 years (OR = 0.92; 95% CI, -2.32 to 0.49), comparison of propofol to sevoflurane (OR = -1.37; 95% CI, -2.8 to -0.05), and blood loss exceeding 500 ml (OR = -1.01; 95% CI, -2.5 to 0.48).

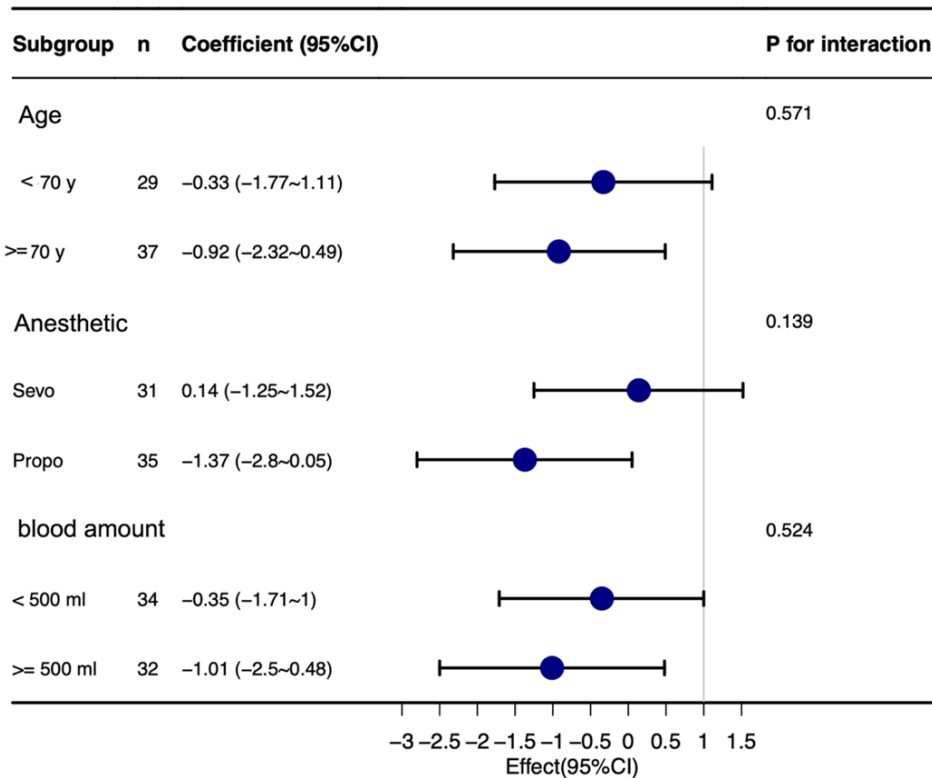


Figure 2. Association between CO of before induction and anesthesia emergence time

Sevo: received sevoflurane anesthesia; Propo: received propofol combined with remifentanil anesthesia.

Discussion

This regression study involving 121 patients undergoing laparoscopic surgery found that preoperative cardiac output (CO) was inversely associated with anesthesia emergence time, particularly in elderly patients with coronary heart disease (CHD). In contrast, intraoperative CO showed no significant correlation with emergence time, highlighting the potential importance of preoperative CO as a factor influencing recovery times.

Anesthesia emergence time is a crucial indicator in the perioperative period and is influenced by various factors, including the patient's health status, the drugs used in anesthesia, the complexity of the surgery, and intraoperative management (Wang *et al.*, 2019). In elderly patients, declines in cardiovascular function and other organ systems often lead to prolonged emergence from anesthesia. Additionally, patients with CHD may experience more complex recovery due to underlying cardiovascular conditions, fluid management, and preoperative medications (Molliex *et al.*, 2019; Sun *et al.*, 2023). Our study focused on preoperative CO as a potential influencing factor and found that

preoperative CO was significantly associated with anesthesia recovery time, especially in elderly patients with CHD. These findings underscore the potential importance of considering preoperative CO as a factor in anesthesia management for high-risk patients.

Cardiac output plays a key role in maintaining organ perfusion and oxygen delivery. A decrease in CO, particularly in patients with compromised cardiovascular function, can limit oxygen supply to critical organs such as the brain and heart, thereby prolonging the metabolism of anesthetics and delaying recovery (Molliex *et al.*, 2019). In patients with CHD, pathophysiological mechanisms contributing to reduced CO include myocardial ischemia and impaired contractility due to atherosclerosis, increased peripheral vascular resistance from arterial stiffness, and elevated cardiac workload resulting from hypertension (Pinsky & Payen, 2005). These changes likely contribute to delayed emergence and postoperative complications in this patient population.

Our findings are consistent with existing literature that supports the role of preoperative CO optimization in improving perioperative outcomes. For example, Kobe *et al.* (Kobe *et al.*,

2019) demonstrated that goal-directed CO monitoring significantly improved recovery outcomes in high-risk patients. Similarly, Luo et al. (Liu et al., 2020; Luo et al., 2021) found that preoperative cardiovascular optimization reduced the incidence of perioperative myocardial injury and other cardiovascular complications. However, our study specifically emphasizes the role of preoperative CO in anesthesia emergence times. The lack of a significant correlation between intraoperative CO and emergence time further highlights the potential impact of preoperative CO, suggesting that earlier optimization could be key.

This study provides new insights into the role of preoperative CO in managing anesthesia emergence time, particularly in elderly patients with CHD. We found that preoperative CO significantly affects anesthesia emergence time, while intraoperative CO showed no such correlation. This highlights the importance of considering preoperative cardiovascular status when managing anesthesia emergence and may suggest that targeted interventions to optimize CO could improve recovery times in high-risk patients.

Clinicians, particularly anesthesiologists, can apply these findings by prioritizing preoperative cardiovascular assessments in elderly patients with CHD undergoing non-cardiac surgery. Practical strategies may include dynamic CO monitoring, goal-directed therapies, and individualized interventions aimed at improving preoperative CO. Although these interventions may show promise, it is important to approach preoperative CO optimization cautiously, particularly in light of the potential risks and lack of clear evidence regarding the benefits of such interventions. Further research is needed to identify the most effective and safe strategies for optimizing CO and to explore the long-term clinical impact of such approaches.

Limitations

While this study offers valuable insights, it has several important limitations. First, as a secondary analysis of previously collected data, we did not have access to all potential confounding factors, such as preoperative medications, other comorbidities, or specific anesthesia protocols, which may have influenced emergence times.

Second, our sample consisted only of elderly patients with CHD undergoing laparoscopic surgery, which limits the generalizability of these findings to other patient populations or types of surgery. The absence of long-term follow-up data also prevents us from assessing the impact of preoperative CO optimization on postoperative recovery and outcomes over time. Future studies should consider expanding the sample size, including a more diverse patient population, and collecting data on additional confounders to better understand the broader applicability of these findings. Moreover, examining the long-term outcomes of preoperative CO optimization, including its effects on postoperative complications and quality of life, would be beneficial.

Conclusion

In conclusion, this study highlights the significant association between preoperative cardiac output (CO) and anesthesia emergence time in elderly patients with coronary heart disease. While optimizing preoperative CO may have the potential to reduce emergence times and improve postoperative recovery, the study's findings should be interpreted with caution due to its limitations. The role of preoperative CO optimization in clinical practice requires further investigation, particularly in diverse patient populations and across various surgical contexts. Future research should examine the long-term outcomes of preoperative CO optimization and explore the potential risks and benefits of targeted interventions in this high-risk group.

Conflict of Interest Statement:

The authors declare no conflict of interest.

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