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Original Contribution

Impact of intraoperative anesthesia handover on major adverse cardiovascular events after thoracic surgery: A propensity-score matched retrospective cohort study

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HIGHLIGHTS

- Patients undergoing intrathoracic surgery are at increased risk of major cardiovascular complications.
- We tested if intraoperative handover of anesthesia care might increase the risk of major cardiovascular complications.
- We found that anesthesia handover was associated with increased major adverse cardiovascular events after surgery.

ARTICLE INFO

Keywords:
Adult patients
Elective thoracic surgery
Handover of anesthesia care
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ABSTRACT

Study objective: Handover of anesthesia care is often required in busy clinical settings. Herein, we investigated whether intraoperative anesthesia handover was associated with an increased risk of major adverse cardiovascular events (MACEs) after thoracic surgery.
Design: A retrospective cohort study.
Setting: A tertiary hospital.
Patients: Adult patients who underwent elective thoracic surgery.
Exposures: A complete handover of intraoperative anesthesia care was defined when the outgoing anesthesiologist transferred patient care to the incoming anesthesiologist and no longer returned.
Measurements: Our primary endpoint was a composite of MACEs, including acute myocardial infarction, new-onset congestive heart failure, non-fatal cardiac arrest, and cardiac death, that occurred within 7 days after surgery. The impact of complete anesthesia handover on postoperative MACEs was analyzed using propensity score matching.
Main results: Of 6962 patients (mean age 59.7 years; 57.4 % female) included in the analysis, 2319 (33.3 %) surgeries were conducted with anesthesia handover whereas 4643 (66.7 %) were conducted without. After propensity score matching, 2165 (50.0 %) surgeries were conducted with anesthesia handover whereas the other half were conducted without. Patients with anesthesia handover developed more MACEs when compared with those without (10.4 % [225/2165] vs. 8.4 % [181/2165]; relative risk 1.24, 95 % CI 1.03 to 1.50, $P = 0.022$). Specifically, myocardial infarction was more common in patients with anesthesia handover than in those without (9.2 % [199/2165] vs. 7.4 % [160/2165]; relative risk 1.24, 95 % CI 1.02 to 1.52, $P = 0.032$).
Conclusions: For adult patients undergoing thoracic surgery, a complete handover of intraoperative anesthesia care was associated with an increased risk of MACEs after surgery.

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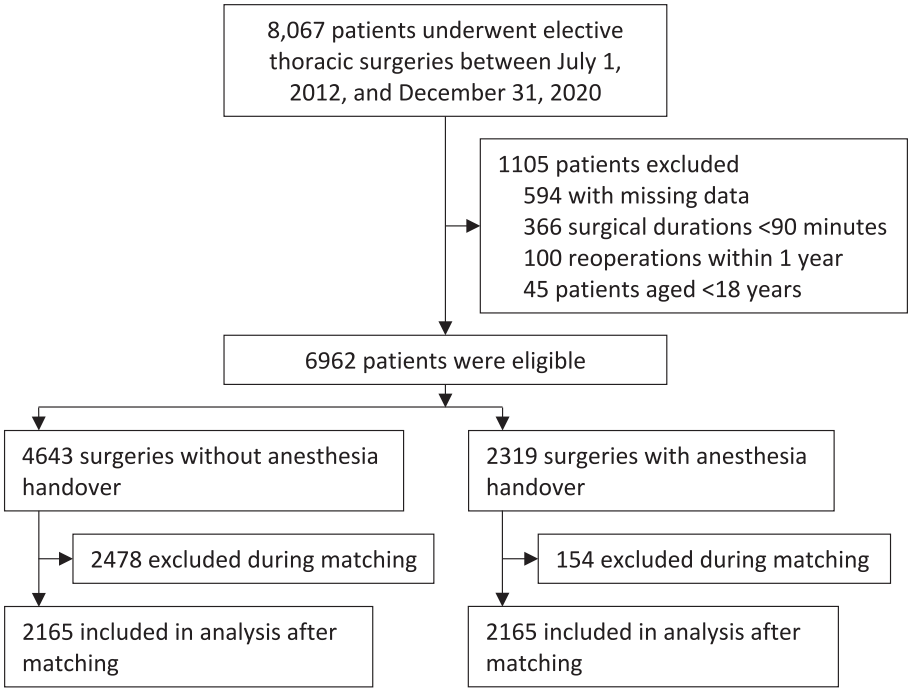

Fig. 1. Flowchart of the study.

1. Introduction

Major cardiovascular complications, including arrhythmia requiring intervention, myocardial infarction, congestive heart failure (pulmonary oedema), and cardiac death, occur in 2 % to 11 % of patients undergoing major lung resection [1–3] and in up to 18 % of high-risk patients (such as those with a thoracic revised cardiac risk index of class D) [4]. Intrathoracic surgeries are classified as intermediate-risk or high-risk procedures for cardiac death and nonfatal myocardial infarction [5,6]. The situation tends to be worse with the aging population [1,7]. Occurrence of cardiovascular complications after thoracic surgery is associated with increased morbidity and mortality and prolonged hospital stay [8]. How to reduce cardiovascular complications by improving perioperative management in thoracic patients is a widespread concern [9].

Perioperative patient safety requires effective teamwork among healthcare providers [10,11]. In the past three decades, anesthesia-related mortality has greatly decreased, but anesthesia-related morbidity remains high [12–14]. It was estimated that more than 10 % of patients experience an intraoperative incident, mainly due to human error and inadequate teamwork. In a recent cross-sectional study, 71 % of anesthetic deaths were considered preventable [7]. Along with the growing number of surgeries [15,16], the proportion of patients who experienced intraoperative handover of anesthesia care is also increasing [17]. According to available data, an estimated 9 million patients underwent surgery with a complete anesthesia handover each year worldwide [15,17]. Anesthesia handover helps reduce job stress and burnout of anesthesiologists [18–20], but increases the risk of incomplete data transfer which may harm patients' safety [21,22]. Indeed, some studies reported that handover of anesthesia care was associated with adverse postoperative outcomes [17,23,24]. However, neutral results also exist and conclusions cannot be reached in this aspect [25,26].

In our center, anesthesia handover was introduced in July 2012 to limit working hours of anesthesiologists. The objective of this retrospective cohort study was to test our hypothesis that intraoperative handover of anesthesia care was associated with an increased risk of major adverse cardiovascular events (MACEs) after elective thoracic surgery.

2. Methods

2.1. Study design and setting

This single-center retrospective cohort study was conducted in an 1800-bed tertiary general hospital in Beijing, China. The study protocol was approved by the local Biomedical Research Ethics Committees before data acquisition and analysis (2022–487). Since all data were collected from the inpatient medical record system and the anesthesia information system and no patient follow-up was performed, the Ethics Committee agreed to waive written informed consents from participants. However, all personal data was kept strictly confidential.

2.2. Patients

We screened patients who underwent thoracic surgery between July 1, 2012, and December 31, 2020. For this study, we included patients who underwent elective thoracic surgeries; we excluded those who were aged <18 years, received surgery under local anesthesia, had surgical durations <90 min, or underwent second surgery within one year.

2.3. Anesthesia and perioperative care

During the study period, there were a 40-bed thoracic surgery ward with 8 to 10 senior thoracic surgeons, a 10-bed surgical intensive care unit with 8 senior intensivists, and a 17-room operating center with 20 to 35 senior anesthesiologists who were qualified for thoracic anesthesia in our hospital. Elective thoracic surgeries were usually performed in two to three operating rooms during working days. For each patient, a senior (attending) anesthesiologist and an assistant (usually a resident or a fellow) were designated to implement anesthesia and intraoperative care; a senior surgeon and one or two assistants (usually junior surgeons or surgery residents) were designated to conduct surgical operation. A senior anesthesiologist usually took care of one or more operating rooms concurrently, depending on the condition of patients and scheduled surgeries.

Table 1
Baseline and intraoperative variables included for propensity score matching.

Variables	All patients (n = 6962)	Full cohort			After matching		
		No handover (n = 4643)	Handover (n = 2319)	ASD[a]	No handover (n = 2165)	Handover (n = 2165)	ASD[b]
Baseline data							
Demographics							
Age, year	59.7 ± 12.4	59.2 ± 12.9	60.6 ± 11.4	**0.126**	60.4 ± 12.2	60.5 ± 11.5	0.003
Female sex	3999 (57.4 %)	2550 (54.9 %)	1449 (62.5 %)	**0.156**	1262 (58.3 %)	1310 (60.5 %)	0.046
Body mass index, kg/m^2	24.0 ± 3.0	24.0 ± 3.0	24.0 ± 3.0	0.008	24.0 ± 3.0	24.0 ± 2.9	<0.001
Smoking	1949 (28.0 %)	1247 (26.9 %)	702 (30.3 %)	**0.074**	598 (27.6 %)	630 (29.1 %)	0.032
Alcohol use	1958 (28.1 %)	1232 (26.5 %)	726 (31.3 %)	**0.103**	621 (28.7 %)	643 (29.7 %)	0.022
Comorbidity							
Hypertension	2368 (34.0 %)	1568 (33.8 %)	800 (34.5 %)	0.015	765 (35.3 %)	757 (35.0 %)	0.008
Ischemic heart disease	1070 (15.4 %)	742 (16.0 %)	328 (14.1 %)	**0.053**	303 (14.0 %)	313 (14.5 %)	0.013
History of heart failure	92 (1.3 %)	65 (1.4 %)	27 (1.2 %)	0.022	25 (1.2 %)	25 (1.2 %)	<0.001
Atrial fibrillation	145 (2.1 %)	97 (2.1 %)	48 (2.1 %)	0.001	47 (2.2 %)	45 (2.1 %)	0.006
Stroke	657 (9.4 %)	440 (9.5 %)	217 (9.4 %)	0.004	209 (9.7 %)	202 (9.3 %)	0.011
Diabetes mellitus	1222 (17.6 %)	815 (17.6 %)	407 (17.6 %)	0.001	374 (17.3 %)	389 (18.0 %)	0.018
Renal dysfunction[c]	211 (3.0 %)	142 (3.1 %)	69 (3.0 %)	0.005	67 (3.1 %)	63 (2.9 %)	0.011
COPD	306 (4.4 %)	216 (4.7 %)	90 (3.9 %)	0.040	101 (4.7 %)	88 (4.1 %)	0.031
Pre-existing anemia[d]	148 (2.1 %)	98 (2.1 %)	50 (2.2 %)	0.003	49 (2.3 %)	45 (2.1 %)	0.013
Medication							
Antihypertensives	1794 (25.8 %)	1179 (25.4 %)	615 (26.5 %)	0.026	584 (27.0 %)	583 (26.9 %)	0.001
Insulin	256 (3.7 %)	156 (3.4 %)	100 (4.3 %)	0.047	80 (3.7 %)	93 (4.3 %)	0.030
Oral hypoglycemic drugs	377 (5.4 %)	241 (5.2 %)	136 (5.9 %)	0.029	124 (5.7 %)	130 (6.0 %)	0.012
General status							
ASA physical status, class				**0.152**			<0.001
1	674 (9.7 %)	508 (10.9 %)	166 (7.2 %)		163 (7.5 %)	160 (7.4 %)	
2	5449 (79.0 %)	3642 (78.4 %)	1857 (80.1 %)		1721 (79.5 %)	1729 (79.9 %)	
3	769 (11.0 %)	483 (10.4 %)	286 (12.3 %)		272 (12.6 %)	269 (12.4 %)	
4	20 (0.3 %)	10 (0.2 %)	10 (0.4 %)		9 (0.4 %)	7 (0.3 %)	
Revised Cardiac Risk Index, point				**0.130**			0.001
0	342 (4.9 %)	262 (5.6 %)	80 (3.4 %)		84 (3.9 %)	79 (3.6 %)	
1	4376 (62.9 %)	2882 (62.1 %)	1494 (64.4 %)		1388 (64.1 %)	1383 (63.9 %)	
2	1477 (21.2 %)	967 (20.8 %)	510 (22.0 %)		478 (22.1 %)	481 (22.2 %)	
3	767 (11.0 %)	532 (11.5 %)	235 (10.1 %)		215 (9.9 %)	222 (10.3 %)	
Intraoperative data							
Surgery-related							
Site of surgery				**0.278**			<0.001
Chest wall/biopsy	478 (6.9 %)	341 (7.3 %)	137 (5.9 %)		127 (5.9 %)	132 (6.1 %)	
Esophagus	801 (11.5 %)	381 (8.2 %)	420 (18.1 %)		266 (12.3 %)	304 (14.0 %)	
Mediastinum	508 (7.3 %)	388 (8.4 %)	120 (5.2 %)		117 (5.4 %)	116 (5.4 %)	
Lung	5175 (74.3 %)	3533 (76.1 %)	1642 (70.8 %)		1655 (76.4 %)	1613 (74.5 %)	
Type of surgery				0.026			0.008
Video-assisted	5862 (84.2 %)	3895 (83.9 %)	1967 (84.8 %)		1833 (84.7 %)	1827 (84.4 %)	
Open	1110 (17.3 %)	778 (16.1 %)	352 (15.2 %)		332 (15.3 %)	338 (15.6 %)	
Duration of surgery, h	4.6 (3.2, 6.1)	4.4 (3.1, 5.8)	4.9 (3.5, 6.7)	**0.268**	4.7 (3.2, 6.2)	4.8 (3.5, 6.3)	0.046
Cancer surgery	5769 (82.9 %)	3757 (80.9 %)	2012 (86.8 %)	**0.172**	1849 (85.4 %)	1862 (86.0 %)	0.018
Anesthesia-related							
Duration of OLV, min	157 (78, 231)	149 (73, 220)	173 (89, 251)	**0.178**	162 (91, 243)	169 (84, 244)	0.037
Fluid infusion rate, ml/kg/h	5.7 (4.3, 7.5)	5.6 (4.2, 7.4)	5.9 (4.6, 7.7)	**0.130**	5.8 (4.3, 7.7)	5.8 (4.5, 7.6)	0.030
Blood transfusion	247 (3.5 %)	119 (2.6 %)	128 (5.5 %)	**0.129**	82 (3.8 %)	90 (4.2 %)	0.016
Intraoperative hypotension [e]	662 (9.5 %)	429 (9.2 %)	233 (10.0 %)	0.027	201 (9.3 %)	210 (9.7 %)	0.014
Use of vasopressors [f]	1950 (28.0 %)	1184 (25.5 %)	766 (33.0 %)	**0.160**	644 (29.7 %)	666 (30.8 %)	0.022
Concurrent care, n[g]				**0.135**			<0.001
1	2647 (38.0 %)	1859 (40.0 %)	788 (34.0 %)		780 (36.0 %)	750 (34.6 %)	
2	2849 (40.9 %)	1867 (40.2 %)	982 (42.3 %)		869 (40.1 %)	904 (41.8 %)	
3	1466 (21.1 %)	917 (19.8 %)	649 (23.7 %)		516 (23.8 %)	511 (23.6 %)	
Clinical experience, year[h]	19.2 ± 7.6	17.4 ± 7.7	22.7 ± 6.1	**0.879**	22.1 ± 6.3	22.5 ± 6.1	0.052
Patient-controlled analgesia				**0.238**			<0.001
Intravenous	4729 (67.9 %)	3076 (66.3 %)	1653 (71.3 %)		1520 (70.2 %)	1530 (70.7 %)	
Epidural	1151 (16.5 %)	871 (18.8 %)	280 (12.1 %)		270 (12.5 %)	268 (12.4 %)	
Intravenous + PNB	998 (13.5 %)	626 (13.5 %)	372 (16.0 %)		363 (16.8 %)	353 (16.3 %)	
None	84 (1.2 %)	70 (1.5 %)	14 (0.6 %)		12 (0.6 %)	12 (0.6 %)	

Data are presented as median (IQR), mean ± SD, or n (%). ASD, absolute standardized difference. COPD, Chronic obstructive pulmonary disease; ASA, American Society of Anesthesiologists; VATS, Video-assisted thoracic surgery; OLV, One lung ventilation; PNB, peripheric nerve block.

[a] An ASD in bold indicates ≥0.050 and is considered imbalanced between the two groups.

[b] An ASD in bold indicates ≥0.060 and is considered imbalanced between the two groups.

[c] Serum creatinine >177 μmol/L.
[d] Hemoglobin <120 g/L in men, or < 110 g/L in non-pregnant women.
[e] Systolic blood pressure < 90 mmHg or mean blood pressure < 65 mmHg for ≥5 min. Extracted and calculated from database.
[f] Continuous infusion of noradrenaline, epinephrine, dopamine, metaraminol, and/or phenylephrine for >15 min.
[g] Number of operating rooms that were taken care of by the (outgoing) senior anesthesiologists.
[h] Mean clinical experience in years of the (outgoing and incoming) senior anesthesiologists for patients with intraoperative anesthesia handover.

Table 2
Outcomes in patients before and after propensity score matching.

	Full cohort				After matching			
	No handover (n = 4643)	Handover (n = 2319)	RR or HR (95 % CI)	*P* value	No handover (*n* = 2165)	Handover (n = 2165)	RR or HR (95 % CI)	P value
Primary endpoint								
MACEs within 7 days	337 (7.3 %)	244 (10.5 %)	1.45 (1.24, 1.70)	**<0.001**	181 (8.4 %)	225 (10.4 %)	1.24 (1.03, 1.50)	**0.022**
Secondary endpoints								
Individual component of MACEs								
Acute myocardial infarction	291 (6.3 %)	218 (9.4 %)	1.50 (1.27, 1.78)	**<0.001**	160 (7.4 %)	199 (9.2 %)	1.24 (1.02, 1.52)	**0.032**
Congestive heart failure	80 (1.7 %)	45 (1.9 %)	1.13 (0.78, 1.62)	0.520	46 (2.1 %)	40 (1.8 %)	0.87 (0.57, 1.32)	0.513
Cardiac death	2 (0.04 %)	2 (0.1 %)	2.00 (0.28, 14.2)	0.479	2 (0.1 %)	2 (0.1 %)	1.00 (0.14, 7.09)	>0.999
ICU admission after surgery	251 (5.4 %)	208 (9.0 %)	1.66 (1.39, 1.98)	**<0.001**	141 (6.5 %)	179 (8.3 %)	1.27 (1.03, 1.57)	**0.027**
Hospital stay after surgery, day	5 (4, 7)	6 (4, 9)	0.79 (0.75, 0.83)	**<0.001**	5 (4, 8)	6 (4, 9)	0.96 (0.90, 1.02)	0.122
Exploratory endpoint								
Pulmonary complications	175 (3.8 %)	102 (4.4 %)	1.17 (0.92, 1.48)	0.205	89 (4.1 %)	89 (4.1 %)	1.00 (0.75, 1.33)	>0.999

Data are presented as n (%) or median (IQR). *P* values in bold indicate <0.05. MACEs, major adverse cardiovascular events; ICU, intensive care unit; RR, relative risk; HR, hazard ratio.

Intraoperative monitoring during thoracic surgery usually included electrocardiogram, pulse oxygen saturation, non-invasive and invasive blood pressure, concentrations of inhaled anesthetics and expired carbon dioxide, bispectral index (BIS), nasopharyngeal temperature, and urine output. As a routine practice, general anesthesia was performed with a double-lumen endotracheal intubation. One-lung ventilation was performed during open thoracotomy or video-assisted thoracic surgery. Both intravenous and inhalational anesthetics were used. Regional (epidural or peripheral nerve) block was conducted when possible. Anesthesia depth was guided with BIS to a target between 40 and 60. Fluid therapy was provided according to clinical routine and was generally constrictive. Vasopressors were administered when considered necessary.

During the daily working hours, short breaks were mandatory for junior anesthesiologists at lunch (12 am) or dinner (6 pm) time. Each break lasted 20 to 30 min. Handover of anesthesia care was mainly indicated for patients whose surgery was expected to last beyond 6 pm. As a routine practice, handovers were limited to senior anesthesiologists and conducted between 4 and 5 pm each working day; surgical handover was not allowed. A complete handover was defined when the outgoing anesthesiologist transferred patient care to the incoming anesthesiologist and no longer returned. According to local regulations, handover of patient care required face-to-face communication between senior anesthesiologists in the operating room. No checklist was used during the study period. In our hospital, intraoperative handover was marked by the incoming anesthesiologists in the electronic anesthesia information system. This handover mark was expected to be accurate because it was used to separate the performance of anesthesiologists.

After surgery, patients were generally extubated in the operating room, observed in the post-anesthesia care unit by the on-duty anesthesiologists and nurses for at least 30 min, and transferred back to the general wards when they had a modified Aldrete score (total scores range from 0 to 10, with higher score indicating better recovery) ≥9 [27]. Patients whose surgeries ended after 8 pm were continuously observed in the operating room by the responsible anesthesiologists until the above criteria was met. Those with unstable conditions were admitted to the intensive care unit for continued monitoring and therapy.

In the ward, patients were monitored with electrocardiogram, pulse oxygen saturation, and non-invasive blood pressure which were recorded hourly by nurses until the first postoperative morning, and then with non-invasive blood pressure which was recorded once or twice daily until hospital discharge. Blood routine and biochemical examinations were generally performed on the first postoperative day and included cardiac troponin I and N-terminal pro-B-type natriuretic peptide (NT-proBNP) or B-type natriuretic peptide (BNP); the measurements were repeated when considered necessary. Patients with suspected adverse cardiovascular or other events were consulted by physicians of related subspecialities and managed accordingly. Other perioperative managements were provided per clinical routine.

2.4. Data collection and outcome assessments

The same electronic healthcare system was used in our hospital during the study period, i.e., from 2012 to 2020. Potential participants who underwent thoracic surgeries were screened using the International Classification of Diseases and Procedures-Ninth Revision volume 3 (ICD-9-v3) codes. Eligible patients were verified by an experienced investigator (YZ, senior anesthesiologist).

Baseline data included demographic characteristics, comorbidities and medications, history of smoking and alcohol use, and American Society of Anesthesiologists (ASA) classification. Risk for cardiac

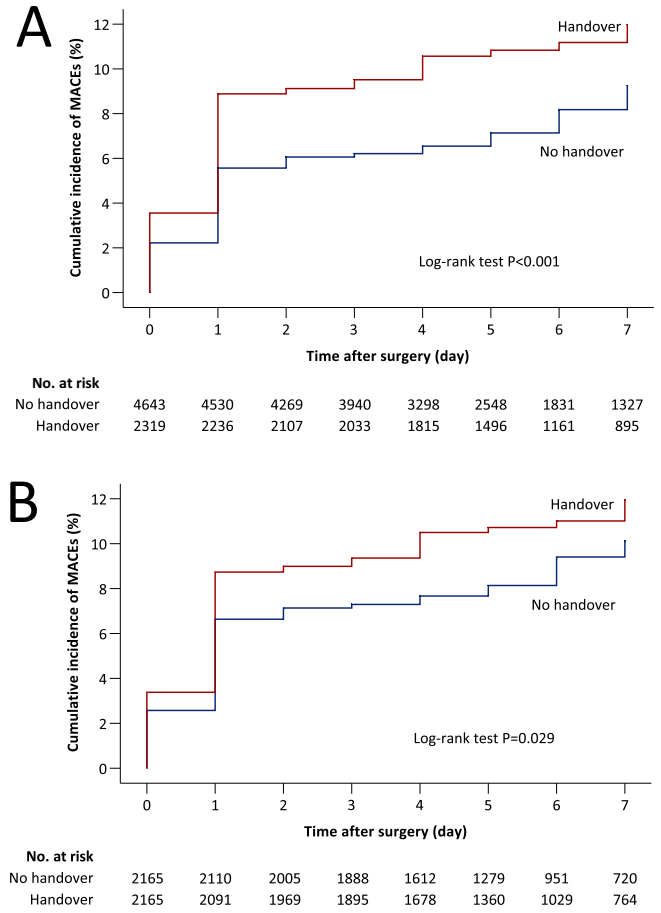

Fig. 2. The Kaplan-Meier curves for cumulative incidence of MACEs in the full cohort (A) and in the cohort after matching (B).

complications was evaluated with the revised Cardiac Risk Index [28]. Intraoperative data included site, type, and duration of surgery, surgery for cancer, type of anesthesia, duration of one-lung ventilation, fluid infusion rate, blood transfusion, occurrence of hypotension, and use of vasopressors. Data of blood pressure was collected from the anesthesia information management system, which captured invasive blood pressure every 10 s and non-invasive blood pressure at each measurement. Intraoperative hypotension was defined as systolic blood pressure < 90 mmHg or mean blood pressure < 65 mmHg for ≥ 5 min. Anesthesiologist-related data included the number of operating rooms that were concurrently supervised by the (outgoing) anesthesiologists and the working years of the (outgoing and incoming) anesthesiologists. We also collected types of patient-controlled analgesia provided at the end of surgery.

After surgery, we collected data of examinations and managements. Postoperative MACEs were defined as acute myocardial infarction (ST-segment elevation myocardial infarction and non-ST-segment elevation myocardial infarction), new-onset heart failure, non-fatal cardiac arrest, or/and cardiac death that occurred within 7 days after surgery during hospital stay. For patients who developed multiple events, the first event was marked as the onset time of MACEs and included in the analysis. We developed an algorithm to identify MACEs according to the ICD-9 and ICD-10 [5,29–34]. The algorithm has been validated in our previous studies [35,36]. Specifically, we searched ICD codes I21 and I22 for suspected acute myocardial infarction, ICD codes I50, I97.104, T81.810, I11.001, I13.201, I97.106, N18.820, O29.102, O74.202, O75.402, O89.102, O99.408, and O99.423 for suspected as heart failure, and ICD code I46 for suspected non-fatal cardiac arrest. We also reviewed records of patients who required cardiopulmonary resuscitation or died during hospital stay [35]. For suspected patients, we analyzed laboratory test results (cardiac troponin I, NT-proBNP or BNP, etc.), initial medications, interdepartmental consultations, and modified medical therapies recorded in the electronic information system and identified potential MACEs. Potential events were manually reviewed by two investigators (XLZ and YZ, senior anesthesiologists). The final diagnoses of MACEs were confirmed by a senior cardiologist (LL).

Our primary endpoint was the occurrence of MACEs during the first 7 days after surgery. Secondary endpoints included admission to intensive care unit (ICU), individual component of MACEs within 7 days, and length of hospital stay after surgery. As an exploratory endpoint, the occurrence of pulmonary complications was also evaluated within 7 days after surgery [37]. Diagnoses of pulmonary complications required therapeutic intervention, i.e., grade II or higher on the Clavien-Dindo classification [38]. Suspected pulmonary complications were screened by two investigators (XLZ and YZ, senior anesthesiologists). Final diagnoses were confirmed by a senior pulmonologist (XW).

2.5. Statistical analysis

2.5.1. Sample size estimation

According to previous studies, major cardiovascular complications occurred in 2 % to 18 % of patients after thoracic surgery [3,4]. We assumed that the incidence of postoperative MACEs would be 9 % in patients without anesthesia handover, and the incidence would be 30 % higher in patients with complete anesthesia handover. The calculated sample size that provided 80 % power to detect this difference at one-sided significance level of 0.025 was 2418 patients in each group. Considering a dropout rate of about 40 % during propensity-score matching, we needed to enroll 6770 patients in this study. Sample size estimation was performed with the PASS 15.0 software (NCSS Statistical Software, Utah, USA).

2.5.2. Data analysis

The included patients were divided into two groups according to whether there was a complete handover of anesthesia care during surgery. Propensity score matching was performed to balance the influence of potential confounding factors. Patients with missing data were excluded.

Factors used for propensity score matching were selected according to clinical importance and literature. Specifically, general characteristics included age, sex, body mass index, and history of smoking and alcohol use; preoperative comorbidities included hypertension, ischemic heart disease, history of heart failure, atrial fibrillation, previous stroke, diabetes mellitus, renal dysfunction, chronic obstructive pulmonary disease (COPD), and pre-existing anemia; preoperative medications included antihypertensives, insulin, and oral hypoglycemic agents; general status included American Society of Anesthesiologist (ASA) physical status and revised cardiac risk index; surgery-related data included site, type, and duration of surgery, surgery for cancer; anesthesia-related data included duration of one-lung ventilation, fluid infusion rate, blood transfusion, occurrence of intraoperative hypotension, use of vasopressors, number of concurrent anesthesia care, working experience of senior anesthesiologists, and type of patient-controlled analgesia [39,40]. A logistic regression model was used to calculate propensity scores. We used a 1:1 nearest-neighbor matching algorithm with a caliper width of 0.2 to match samples from the handover and non-handover groups.

The balance of baseline and intraoperative variables between the two groups both before and after propensity score matching were analyzed using the absolute standardized differences (ASDs), defined as absolute differences in means, mean ranks, or proportions divided by the pooled standard deviation. An ASD $>1.96 \times \sqrt{(n1+n2)/(n1 \times n2)}$ was considered imbalanced between the two groups [41].

For primary endpoint, the incidence of MACEs within 7 days was

	OR (95% CI)	P value	Favors handover	Favors no handover
Handover of anesthesia	1.24 (1.03, 1.50)	0.023		
Age, year	1.03 (1.02, 1.04)	<0.001		
Female sex	1.46 (1.20, 1.78)	<0.001		
Atrial fibrillation	1.77 (1.12, 2.80)	0.015		
COPD	1.45 (1.02, 2.06)	0.040		
Revised CRI, point				
I	Reference			
II	1.29 (1.04, 1.60)	0.019		
III	1.64 (1.27, 2.12)	<0.001		
Site of surgery				
Chest wall/ biospsy	Reference			
Esophagus	0.48 (0.28, 0.81)	0.007		
Mediastinum	2.22 (1.27, 3.87)	0.005		
Lung	2.10 (1.35, 3.26)	0.001		
Open vs. video-assisted	1.86 (1.48, 2.34)	<0.001		
Cancer surgery	1.37 (1.00, 1.88)	0.047		
Duration of surgery, h	1.21 (1.15, 1.27)	<0.001		
Fluid infusion rate, ml/kg/h	1.03 (1.02, 1.05)	<0.001		
Blood transfusion	2.18 (1.50, 3.16)	<0.001		
Vasopressor use	1.86 (1.55, 2.55)	<0.001		
Patient-controlled analgesia				
Epidural	Reference			
Intravenous + PNB	1.81 (1.29, 2.53	0.001		
Intravenous/none	1.37 (1.06, 1.78)	0.018		

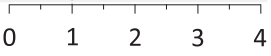

Fig. 3. Forest plot of variables in association with MACEs in the full cohort. Independent variables were screened by backward stepwise logistic regression analysis. Also see Additional Tables.

compared with a chi-square test, with difference between groups expressed as relative risk (RR) and 95 % CI. For secondary and other endpoints, categorical data (ICU admission after surgery, individual component of MACEs, and pulmonary complications within 7 days) were analyzed with chi-square, continuity-corrected chi-square, or Fisher exact tests; differences were expressed as RRs and 95 % CIs. Time-to-event results (time to onset of MACEs and length of hospital stay after surgery) were analyzed with Kaplan-Meier survival analyses and log-rank tests; Cox proportional hazards models were used to calculate hazard ratios (HRs) and 95 % CIs.

As sensitivity analyses, we also used logistic regression models to evaluate the association between handover of anesthesia care and occurrence of MACEs within 7 days among patients in the full cohort. Univariable analyses were firstly performed for baseline and intra-operative factors. Factors with univariable *P* values <0.20 or were considered clinical important were included in a multivariate logistic regression model. Backward stepwise regression analyses were used to identify independent factors. Results were displayed in forest plots.

A two-sided P value of <0.05 was considered statistically significant. Statistical analysis and data management were performed using the SPSS 25 software (IBM SPSS Inc., Chicago, IL, USA) and the free software package "R" version 2.15.3 including the "Matchit" and the "ROC" plugin.

3. Results

3.1. Patients

From July 1, 2012, to December 31, 2020, a total of 8067 patients underwent elective thoracic surgeries. Of these, 45 patients were excluded due to aged <18 years, 366 patients were excluded due to duration of surgery <90 min, 100 patients were excluded due to reoperation within 1 year, and 594 patients were excluded due to missing data. At last, 6962 patients were included in the analyses. Among the

eligible patients, 2319 (33.3 %) surgeries were performed with anesthesia handover whereas 4643 (67.7 %) were performed without. After propensity score matching, 4330 patients remained in the analysis; of these, 2165 (50.0 %) surgeries were performed with anesthesia handover whereas the other half were performed without (Fig. 1). All baseline and intraoperative variables were well balanced between the two groups in the cohort after matching (Table 1).

3.2. Postoperative outcomes

In the matched cohort, patients with anesthesia handover developed more MACEs within 7 days when compared with those without (10.4 % [225/2165] with anesthesia handover vs. 8.4 % [181/2165] without: RR 1.24, 95 % CI 1.03 to 1.50, $P = 0.022$). Among individual components of MACEs, patients with anesthesia handover developed more acute myocardial infarction within 7 days (RR 1.24, 95 % CI 1.02 to 1.52, $P = 0.032$). Patients with anesthesia handover also required more ICU admission (RR 1.27, 95 % CI 1.03 to 1.57, $P = 0.027$). Results in the matched cohort were like those in the full cohort (Table 2; Fig. 2A and B).

3.3. Sensitivity analysis

Sensitivity analyses in the full cohort gave similar results, anesthesia handover remained as an independent factor that was significantly associated with an increased risk of MACEs after adjusting confounders (OR 1.24, 95 % CI 1.03 to 1.50, $P = 0.023$). Among other factors, older age, female sex, preoperative atrial fibrillation, preoperative COPD, higher revised cardiac risk index, lung and mediastinal surgery, open surgery, long duration surgery, cancer surgery, high fluid infusion rate, requirement of blood transfusion, use of vasopressors during anesthesia, and non-epidural analgesia were also associated with an increased risk of MACEs after surgery (Fig. 3; Additional Tables A1 and A2).

4. Discussion

Our results showed that patients who experienced complete handovers of anesthesia care during elective thoracic surgeries developed more MACEs within the first 7 postoperative days. Specifically, these patients developed more acute myocardial infarction during the early postoperative period. The association between handover of anesthesia care and increased risk of MACEs persisted after adjusting confounders with propensity score matching and multiple logistic regression analysis. Patients with anesthesia handover also required more ICU admission after surgery.

The potential mechanisms underlying our findings are not totally clear but might be related to incomplete data transfer which frequently occurred during handover of anesthesia care [21,22]. Indeed, many studies reported that poor-quality handover of intraoperative anesthesia care is associated with adverse events. Among these, minor adverse events included increased documentation errors for controlled drugs [42] and delayed extubation at the end of surgery [43]; major adverse events included increased delirium [23], increased major complications and early mortality [17,24,44–46], prolonged hospital stay, [23,24] and even elevated 1-year mortality [24]. There are also studies that reported neutral results [25,26]. In a recent multicenter trial, 1817 patients undergoing major surgery were randomized to receive either complete handover or no handover of anesthesia care. The composite primary endpoint consisting all-cause death, hospital readmission, and major complications within 30 postoperative days did not differ between the two groups (odds ratio 0.89, 95 % CI 0.72 to 1.10, $P = 0.27$) [26]. Nevertheless, as admitted by the authors, anesthesia personnel who were involved in handover could not be masked during the trial and might have produced bias [26]. Our results derived from real-world data support the hypothesis that anesthesia handover was associated with increased MACEs. Considering the growing number of surgeries [15,16], measures to improve quality of intraoperative anesthesia handover are urgently needed.

Patients undergoing noncardiac thoracic surgery are at a higher risk of postoperative MACEs [1–3,5,6]. Reasons leading to this phenomenon are multiple and may include the following. Intrathoracic surgical procedures are performed close to the heart and thus are more likely to cause hypotension. In an observational study, intraoperative hypotension (defined as systolic blood pressure $<$ 100 mmHg for $\geq$5 min) occurred in 54.2 % of patients undergoing lung cancer surgery [47]. This may reduce myocardial oxygen supply and increase the likelihood of myocardial ischemia/infarction [48]. Procedures close to the heart also increase the risk of new-onset perioperative atrial fibrillation [49]. Furthermore, fluid infusion during thoracic surgery requires careful monitoring; too much fluid may induce congestive heart failure after lung resection [50]. In the present study, 73.2 % of our patients underwent lung resection; MACEs occurred in 7.7 % of them during the first 7 days after surgery. The incidence of MACEs in our patients was within the range of previously reported results [1–4].

During data analysis, we included baseline and intraoperative variables that might be associated with the development of MACEs for propensity-score matching. After matching, the two groups were well balanced in the above variables. We found that patients with intraoperative anesthesia handover developed more MACEs in the cohort both before and after matching. Sensitivity analyses with logistic regression models also confirmed the independent associations between handover of anesthesia care and development of MACEs. In accordance with this, patients with anesthesia handovers required more ICU admission after surgery. Our results are generally consistent with many previous works which showed that anesthesia handover was associated with more major complications [17,24,44–46]. We also identified other risk factors of MACEs using multivariable regression analyses, including older age, female sex, preoperative atrial fibrillation and COPD, high revised cardiac risk index, lung and mediastinal surgery, open, long duration, and cancer surgery, rapid fluid infusion, blood transfusion, use of vasopressors during anesthesia, and non-epidural analgesia after surgery. Similar risk factors were reported by others [51–56].

There are some limitations. First, considering the observational nature of the study, we cannot establish a causal relationship between intraoperative handover of anesthesia care and the occurrence of MACEs after surgery. Second, we excluded 100 patients who underwent a second surgery within one year. This was a predefined exclusion criteria but might influence the rate of detected MACEs. Third, as a retrospective study, data of electrocardiographic monitoring (such as ST-segment changes and arrhythmia) was largely unavailable, and blood pressure was measured sparsely during the postoperative period. MACEs were diagnosed according to laboratory test results and clinical signs and symptoms recorded in the medical record system. The detected rate might have been underestimated. Fourth, we could not get data regarding clinical experience of junior anesthesiologists, which might also have impacts on the occurrence of MACEs. Fifth, although we performed propensity-score matching for all baseline and intraoperative variables listed in Table 1, there might still be unknown factors that may influence outcomes. Sixth, as a single-center study of retrospectively collected data from 2012 to 2020, the generalizability of our results is limited. Prospective studies, especially well-designed interventional studies, are needed to verify if handover checklist could improve outcomes.

5. Conclusions

For adult patients undergoing elective thoracic surgeries, a complete handover of intraoperative anesthesia care was associated with an increased risk of MACEs, especially acute myocardial infarction, within 7 days after surgery. The association persisted after correction for confounding factors with propensity score matching and multiple logistic regression analysis. Further studies are required to verify if

improvement in intraoperative anesthesia handover can reduce MACEs following thoracic surgery.

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Data sharing

Anonymized individual patient data collected for this study can be made available upon publication to researchers who provide a sound proposal and ethics approval, considering possible legal restrictions of China. Proposals should be submitted to the corresponding author (wangdongxin@hotmail.com or dxwang65@bjmu.edu.cn).

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CRediT authorship contribution statement

Xiao-Ling Zhang: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Yan Zhou:** Writing – original draft, Validation, Investigation, Data curation. **Mo Li:** Validation, Investigation. **Jia-Hui Ma:** Validation, Investigation. **Lin Liu:** Validation, Investigation, Data curation. **Dong-Xin Wang:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

None of the authors has a personal financial interest related to this research.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclinane.2025.111778.

References

[1] Kozower BD, Sheng S, O'Brien SM, et al. STS database risk models: predictors of mortality and major morbidity for lung cancer resection. Ann. Thorac. Surg. 2010;90:875–81. discussion 81-3.
[2] Ferguson MK, Saha-Chaudhuri P, Mitchell JD, Varela G, Brunelli A. Prediction of major cardiovascular events after lung resection using a modified scoring system. Ann. Thorac. Surg. 2014;97:1135–40.
[3] Thomas DC, Blasberg JD, Arnold BN, et al. Validating the thoracic revised cardiac risk index following lung resection. Ann. Thorac. Surg. 2017;104:389–94.
[4] Brunelli A, Cassivi SD, Fibla J, et al. External validation of the recalibrated thoracic revised cardiac risk index for predicting the risk of major cardiac complications after lung resection. Ann. Thorac. Surg. 2011;92:445–8.
[5] Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: a report of the American College of Cardiology/American Heart Association task force on practice guidelines. J. Am. Coll. Cardiol. 2014;64:e77–137.
[6] Chinese Society of Cardiology CMA, Cardiology EBoCJo. Chinese expert consensus on perioperative cardiovascular assessment and management of patients undergoing non-cardiac surgery. Zhonghua Xin Xue Guan Bing Za Zhi 2023;51:1043–55.
[7] Wang Y, Wang J, Ye X, et al. Anaesthesia-related mortality within 24 h following 9,391,669 anaesthetics in 10 cities in Hubei Province, China: a serial cross-sectional study. Lancet Reg. Health Western Pacific 2023;37:100787.
[8] Keshava HB, Boffa DJ. Cardiovascular complications following thoracic surgery. Thorac. Surg. Clin. 2015;25:371–92.
[9] Koike T, Tsuchida M. Perioperative Management for Prevention of Cardiac Complications in General Thoracic Surgery. Kyobu geka. Japan. J. Thoracic Surg. 2017;70:639–42.
[10] Manser T. Teamwork and patient safety in dynamic domains of healthcare: a review of the literature. Acta Anaesthesiol. Scand. 2009;53:143–51.
[11] Wahr JA, Prager RL, Abernathy JH, et al. Patient safety in the cardiac operating room: human factors and teamwork: a scientific statement from the American Heart Association. Circulation 2013;128:1139–69.
[12] Li Q, Zhang X, Xu M, Wu J. A retrospective analysis of 62,571 cases of perioperative adverse events in thoracic surgery at a tertiary care teaching hospital in a developing country. J. Cardiothorac. Surg. 2019;14:98.
[13] Nizeyimana F, Skelton T, Bould MD, Beach M, Twagirumugabe T. Perioperative anesthesia-related complications and risk factors in children: a cross-sectional observation study in Rwanda. Anesth. Analg. 2024;138:1063–9.
[14] Guo K, Xu F, Li Y, Ma M, Li J, Wang L. Mortality and cardiac arrest rates of emergency surgery in developed and developing countries: a systematic review and meta-analysis. BMC Anesthesiol. 2024;24:178.
[15] Weiser TG, Haynes AB, Molina G, et al. Estimate of the global volume of surgery in 2012: an assessment supporting improved health outcomes. Lancet (London, England) 2015;385(Suppl. 2):S11.
[16] Meara JG, Leather AJM, Hagander L, et al. Global surgery 2030: evidence and solutions for achieving health, welfare, and economic development. Lancet (London, England) 2015;386:569–624.
[17] Jones PM, Cherry RA, Allen BN, et al. Association between handover of anesthesia care and adverse postoperative outcomes among patients undergoing major surgery. JAMA 2018;319:143–53.
[18] Sanfilippo F, Noto A, Palumbo GJ, et al. Burnout in cardiac anesthesiologists: results from a National Survey in Italy. J. Cardiothorac. Vasc. Anesth. 2018;32:2459–66.
[19] Khan FA, Shamim MH, Ali L, Taqi A. Evaluation of job stress and burnout among anesthesiologists working in academic institutions in 2 major cities in Pakistan. Anesth. Analg. 2019;128:789–95.
[20] Yang G, Pan L-Y, Fu X-L, Qing Z, Dong B-H, Ye J-M. Burnout and job stress of anesthesiologists in the tertiary class a hospitals in Northwest China: a cross-sectional design. Front. Med. 2023;10:1140552.
[21] Choromanski D, Frederick J, McKelvey GM, Wang H. Intraoperative patient information handover between anesthesia providers. J. Biomed. Res. 2014;28:383–7.
[22] Lane S, Gross M, Arzola C, et al. What are we missing? The quality of intraoperative handover before and after introduction of a checklist. *Canadian journal of anaesthesia* =. Journal canadien d'anesthesie 2022;69:832–40.
[23] Liu G-Y, Su X, Meng Z-T, et al. Handover of anesthesia care is associated with an increased risk of delirium in elderly after major noncardiac surgery: results of a secondary analysis. J. Anesth. 2019;33:295–303.
[24] Sun LY, Jones PM, Wijeysundera DN, Mamas MA, Eddeen AB, O'Connor J. Association between handover of anesthesiology care and 1-year mortality among adults undergoing cardiac surgery. JAMA Netw. Open 2022;5:e2148161.
[25] Terekhov MA, Ehrenfeld JM, Dutton RP, Guillamondegui OD, Martin BJ, Wanderer JP. Intraoperative care transitions are not associated with postoperative adverse outcomes. Anesthesiology 2016;125:690–9.
[26] Meersch M, Weiss R, Küllmar M, et al. Effect of intraoperative handovers of anesthesia care on mortality, readmission, or postoperative complications among adults: the HandiCAP randomized clinical trial. JAMA 2022;327:2403–12.
[27] Deshmukh PP, Chakole V. Post-anesthesia recovery: a comprehensive review of Sampe, modified Aldrete, and white scoring systems. Cureus 2024;16:e70935.
[28] Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999;100:1043–9.

[29] Andersson C, Mérie C, Jørgensen M, et al. Association of β-blocker therapy with risks of adverse cardiovascular events and deaths in patients with ischemic heart disease undergoing noncardiac surgery: a Danish nationwide cohort study. JAMA Intern. Med. 2014;174:336–44.
[30] Andersson C. Incorrect ICD-10 code and MACE endpoint. JAMA Intern. Med. 2015; 175:E1.
[31] Amsterdam EA, Wenger NK, Brindis RG, et al. 2014 AHA/ACC guideline for the management of patients with non-ST-elevation acute coronary syndromes: a report of the American College of Cardiology/American Heart Association task force on practice guidelines. Circulation 2014;130:e344–426.
[32] Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/ AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and Management of High Blood Pressure in adults: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines. J. Am. Coll. Cardiol. 2018;71:e127–248.
[33] Shima D, Ii Y, Higa S, et al. Validation of novel identification algorithms for major adverse cardiovascular events in a Japanese claims database. J Clin Hypertens (Greenwich) 2021;23:646–55.
[34] Ruigómez A, Plana E, Gilsenan A, et al. Identification and validation of major cardiovascular events in the United Kingdom data sources included in a multi-database post-authorization safety study of Prucalopride. Drug Saf. 2021;44: 541–51.
[35] Zhou Y, Liu L, Fan F, Hong-Yun Y. Relation between elevated first SBP from baseline (delta SBP) and postoperative outcome. J. Hypertens. 2021;39:1982–90.
[36] Zhou Y, Liu L, Cheng T, et al. Grade 3 echocardiographic diastolic dysfunction is associated with increased risk of major adverse cardiovascular events after surgery: a retrospective cohort study. Anesth. Analg. 2019;129:651–8.
[37] Abbott TEF, Fowler AJ, Pelosi P, et al. A systematic review and consensus definitions for standardised end-points in perioperative medicine: pulmonary complications. Br. J. Anaesth. 2018;120:1066–79.
[38] Katayama H, Kurokawa Y, Nakamura K, et al. Extended Clavien-Dindo classification of surgical complications: Japan clinical oncology group postoperative complications criteria. Surg. Today 2016;46:668–85.
[39] Donati A, Ruzzi M, Adrario E, et al. A new and feasible model for predicting operative risk. Br. J. Anaesth. 2004;93:393–9.
[40] Schwarze ML, Barnato AE, Rathouz PJ, et al. Development of a list of high-risk operations for patients 65 years and older. JAMA Surg 2015;150:325–31.
[41] Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. Stat. Med. 2009;28:3083–107.
[42] Epstein RH, Dexter F, Gratch DM, Lubarsky DA. Intraoperative handoffs among anesthesia providers increase the incidence of documentation errors for controlled drugs. Jt Comm J Qual Patient Saf 2017;43:396–402.
[43] Anastasian ZH, Kim M, Heyer EJ, Wang S, Berman MF. Attending handoff is correlated with the decision to delay Extubation after surgery. Anesth. Analg. 2016;122:758–64.
[44] Saha AK, Segal S. A quality improvement initiative to reduce adverse effects of transitions of anesthesia care on postoperative outcomes: a retrospective cohort study. Anesthesiology 2024;140(3):387–98.
[45] Hudson CCC, McDonald B, Hudson JKC, Tran D, Boodhwani M. Impact of anesthetic handover on mortality and morbidity in cardiac surgery: a cohort study. J. Cardiothorac. Vasc. Anesth. 2015;29:11–6.
[46] Hyder JA, Bohman JK, Kor DJ, et al. Anesthesia care transitions and risk of postoperative complications. Anesth. Analg. 2016;122:134–44.
[47] Huang W-W, Zhu W-Z, Mu D-L, et al. Intraoperative hypotension is associated with shortened overall survival after lung cancer surgery. BMC Anesthesiol. 2020;20: 160.
[48] Harris DE. Perioperative acute myocardial infarction and ischemia after noncardiac surgery: pathophysiology, prevention, and nursing implications. AORN J. 2022; 116:517–31.
[49] Liu J, Huang Y, Ma W, Liu H, Cao Y, Wu C. Prediction, prevention and management of new onset perioperative atrial fibrillation and flutter in patients undergoing non-cardiac thoracic surgery. Minerva Anestesiol. 2022;88:490–8.
[50] Batchelor TJP. Modern fluid management in thoracic surgery. Curr. Opin. Anaesthesiol. 2024;37:69–74.
[51] Xu L, Yu C, Jiang J, et al. Major adverse cardiac events in elderly patients with coronary artery disease undergoing noncardiac surgery: a multicenter prospective study in China. Arch. Gerontol. Geriatr. 2015;61:503–9.
[52] Vrsalović M, Presečki AV. Atrial fibrillation and risk of cardiovascular events and mortality in patients with symptomatic peripheral artery disease: a meta-analysis of prospective studies. Clin. Cardiol. 2017;40:1231–5.
[53] Matthay ZA, Smith EJ, Flanagan CP, et al. Association of Intraoperative and Perioperative Transfusions with postoperative cardiovascular events and mortality after Infrainguinal revascularization. Ann. Vasc. Surg. 2023;88:70–8.
[54] Liu Z, Xu G, Xu L, Zhang Y, Huang Y. Perioperative cardiac complications in patients over 80 years of age with coronary artery disease undergoing noncardiac surgery: the incidence and risk factors. Clin. Interv. Aging 2020;15:1181–91.
[55] Shin CH, Long DR, McLean D, et al. Effects of intraoperative fluid management on postoperative outcomes: a hospital registry study. Ann. Surg. 2018;267:1084–92.
[56] Bennett KM, Hoch JR, Scarborough JE. Predictors of 30-day postoperative major adverse clinical events after carotid artery stenting: an analysis of the procedure-targeted American College of Surgeons National Surgical Quality Improvement Program. J. Vasc. Surg. 2017;66:1093–9.