The Impact of Propofol- and Inhalant-Based Anesthesia on Acute Kidney Injury After Major Abdominal Surgery: A Retrospective Observational Study

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Abstract

Background: The optimal anesthetic for preventing postoperative acute kidney injury (AKI) remains unclear, and few studies on this topic have been conducted in the context of non-cardiac surgery. The purpose of this retrospective study was to compare propofol- and inhalant-based anesthesia in terms of the risk of AKI after open major abdominal surgery (MAS).

Methods: Adult patients who underwent open MAS (gastrectomy, hepatectomy, colectomy, or pancreatectomy) at our institute from January 2016 to December 2018 were included. Using multivariable logistic regression, the risk of postoperative AKI was compared between patients who underwent propofol-based anesthesia (propofol group) and those who received inhalant-based anesthesia (inhalant group). Additional logistic regression analyses were performed after propensity score matching and inverse probability of treatment weighting (IPTW).

Results: In total, 3,616 patients were analyzed. The incidence of postoperative AKI was 5.0% (77/1546) and 7.8% (161/2070) in the propofol and inhalant groups, respectively. The risk of AKI was significantly higher in the inhalant group (adjusted odds ratio [aOR], 1.69; 95% confidence interval [CI], 1.23–2.30; P= 0.001) than the propofol group. In the propensity score-matched cohort, the inhalant group had a higher risk of AKI than the propofol group (aOR, 1.68; 95% CI, 1.21–2.34; P= 0.002), and the logistic regression with IPTW showed similar results (OR, 1.74; 95% CI 1.14–1.66; P< 0.001).

Conclusion: The risk of AKI after open MAS may differ significantly according to the anesthetic used. Patients receiving inhalant-based anesthesia may have a greater risk of postoperative AKI than those anaesthetized with propofol.

Introduction

Acute kidney injury (AKI), which is one of the most common and significant complications following abdominal surgery, can progress to chronic kidney disease and is associated with cardiovascular morbidities and mortality.(1) A variety of clinical factors, such as older age,(2) hypertension,(3) diabetes mellitus,(4) higher body mass index (BMI),(5) preexisting renal insufficiency,(3) red blood cell transfusion, (6) and the use of hydroxyethyl starch(7) have been suggested as predictors of postoperative AKI. Moreover, AKI after abdominal surgery is not uncommon, with a reported incidence of over 10%.(8) Given its clinical significance, more research on the potential risk factors for postoperative AKI is required.

Postoperative AKI is a multifactorial complication in which perioperative oxidative stress and the inflammatory response are known to play a pivotal role.(9, 10) Notably, some anesthetics have anti-oxidant and/or anti-inflammatory properties.(11–14) Propofol was shown to reduce susceptibility to oxidative stress and tissue injury in an *in vitro* animal study.(11) Another recent study reported that sevoflurane had both immunomodulatory and renoprotective effects after liver transplantation in rat models.(14) Based on these findings, several clinical studies comparing the effects of propofol and inhalants on postoperative AKI followed, but showed equivocal results.(15–17) Therefore, the best

anesthetic with respect to prevention of postoperative AKI remains to be determined, especially in patients undergoing major non-cardiac surgery.(15, 18)

In this retrospective observational study, we aimed to assess the effect of different anesthetics in terms of the risk for AKI after open major abdominal surgery (MAS). We hypothesized that the risk for postoperative AKI would differ significantly between propofol- and inhalant-based anesthesia.

Methods

Study population

The protocol of this retrospective study was approved by the Institutional Review Board of Seoul National University Hospital (H-1903-102-1018). The requirement for written informed consent was waived due to the retrospective nature of the study. All adult patients (aged ≥ 18 years) who underwent open MAS, including gastrectomy, hepatectomy, colectomy, and pancreatectomy, at our tertiary teaching hospital (Seoul National University Hospital, Seoul, Korea) from January 2016 to December 2018 were consecutively enrolled in this study. Only the data from the first MAS were analyzed in patients who had undergone multiple MAS procedures during the study period. Patients without pre- or postoperative serum creatinine (SCr) data and those with a history of end-stage renal disease, renal replacement therapy (RRT), kidney transplantation, or nephrectomy were excluded from the study.

Data collection

Demographic data, preoperative morbidities, medication history, preoperative laboratory data, operation type, and intraoperative anesthesia data were obtained from the electronic medical records (Table 1). Data were also obtained on the outcome variables of postoperative AKI, requirement for RRT, length of hospital stay, and in-hospital mortality. Postoperative AKI was determined according to the criteria provided by Kidney Disease: Improving Global Outcomes (KDIGO), i.e., an increase in SCr a) of ≥ 0.3 mg dl^{-1} within 48 hours or b) to ≥ 1.5 times the baseline level within 7 days.(19) The baseline SCr level was defined as the most recent preoperative value. Postoperative SCr measurement was not mandatory and depended on the decision of the attending physicians.

Table 1
Patients' characteristics and perioperative data

	Propofol (n = 1546)	Inhalant (n = 2070)	P
Age (year)	60.7 (13.5)	60.4 (13.8)	0.598
Male	942 (60.9%)	1237 (59.8%)	0.476
Body mass index	23.8 (3.3)	23.4 (3.4)	0.001
Smoking	329 (21.3%)	396 (19.1%)	0.110
ASA physical status classification			0.320
Class 1	374 (24.2%)	523 (25.3%)	
Class 2	992 (64.2%)	1345 (65.0%)	
Class 3	176 (11.4%)	197 (9.5%)	
Class 4	4 (0.3%)	5 (0.2%)	
Past medical history			
Hypertension	596 (38.6%)	756 (36.5%)	0.212
Diabetes mellitus	388 (25.1%)	475 (22.9%)	0.133
Chronic obstructive pulmonary disease	48 (3.1%)	68 (3.3%)	0.761
Atrial fibrillation	50 (3.2%)	43 (2.1%)	0.030
Myocardial infarction	23 (1.5%)	23 (1.1%)	0.317
Percutaneous coronary intervention	68 (4.3%)	85 (4.1%)	0.666
Congestive heart failure	7 (0.5%)	12 (0.6%)	0.601
Chronic liver disease	143 (9.2%)	174 (8.4%)	0.375
Previous abdominal surgery	279 (18.0%)	338 (18.4%)	0.174
Medication history			
Aspirin	203 (13.1%)	244 (11.8%)	0.225
ACEi/ARB	381 (24.6%)	421 (20.3%)	0.002
βblocker	91 (5.9%)	111 (5.4%)	0.497
Calcium channel blocker	307 (19.9%)	370 (17.9%)	0.130

Values are expressed as mean (standard deviation), median [interquartile range] or number (%). ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure.

	Propofol (n = 1546)	Inhalant (n = 2070)	P
Statin	64 (4.1%)	79 (3.8%)	0.622
Insulin	61 (3.9%)	75 (3.6%)	0.614
Oral hypoglycemic agent	298 (19.3%)	347 (16.8%)	0.051
Preoperative laboratory data			
Hemoglobin (g dL^{-1})	13.0 [11.6–14.1]	12.8 [11.4–14.1]	0.044
Albumin (g dL^{-1})	4.0 [3.8–4.3]	4.0 [3.7–4.3]	0.767
Uric acid (mg dL^{-1})	4.9 [4.0-5.9]	4.8 [3.9–5.8]	0.059
Serum creatinine (mg dL^{-1})	0.80 [0.67–0.94]	0.80 [0.67–0.93]	0.189
Operative profiles			
Type of surgery			< 0.001
Gastrectomy	50 (3.2%)	317 (15.3%)	
Hepatectomy	449 (29.0%)	525 (25.4%)	
Colectomy	689 (44.6%)	668 (32.3%)	
Pancreatectomy	341 (22.1%)	527 (25.5%)	
Combined	17 (1.1%)	33 (1.6%)	
Emergent surgery	28 (1.8%)	65 (3.1%)	0.013
Anesthesia duration (min)	195 [120–300]	225 [140–308]	< 0.001
Intraoperative colloid use	89 (5.8%)	288 (13.9%)	< 0.001
Intraoperative RBC transfusion	133 (8.6%)	249 (12.0%)	0.001
Intraoperative average MBP (mmHg)	83 [78–89]	83 [78–89]	0.464
Continuous infusion of phenylephrine	44 (2.8%)	141 (6.8%)	< 0.001
Continuous infusion of norepinephrine	52 (3.4%)	49 (2.4%)	0.072
Furosemide use	10 (0.6%)	28 (1.4%)	0.039

Values are expressed as mean (standard deviation), median [interquartile range] or number (%). ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure.

Statistical Analysis

Patients were assigned to the propofol group or the inhalant group according to the type of anesthesia received. The type of anesthesia used was at the discretion of the attending anesthesiologist. In the propofol group, anesthesia was induced and maintained via target-controlled infusion of propofol and remifentanil. In the inhalant group, a bolus of propofol 1.0–2.5 mg kg^{-1}, with or without fentanyl 0.5–1.5 mcg kg^{-1}, was used for anesthesia induction; a volatile anesthetic (sevoflurane or desflurane) was used for maintenance. Also, target-controlled infusion of remifentanil was used as an adjunct to the volatile anesthetic in all patients in the inhalant group.

The primary outcome was AKI after open MAS. Secondary outcomes included AKI stage, postoperative requirement for RRT, length of postoperative hospital stay, and in-hospital mortality.

Continuous variables are presented as mean (standard deviation) or median (interquartile range) and were analyzed using the *t*-test or Mann–Whitney U-test after checking the normality of the data distribution. Categorical variables are expressed as number (%) and were analyzed using the chi-squared test or Fisher's exact test, as appropriate.

Logistic regression was used to analyses the primary outcome data. Univariable logistic regression was performed to analyze the effect of type of anesthesia on the outcomes; the analysis included all of the potential confounders listed in Table 1. Before the analyses, patients were categorized according to BMI based on the World Health Organization classification, i.e., as underweight, normal, overweight, or obese. All variables included in the univariable analyses were then entered into a multivariable logistic regression. A propensity score analysis was also conducted, with the study groups matched based on all of the covariates included in the multivariable logistic regression. The nearest-neighbor matching method (1:1 ratio) was applied, with a caliper width of 0.05 for the logit-transformed propensity score. A second multivariable logistic regression was performed on the matched cohort. An absolute standardized mean difference of < 0.1 was taken to indicate balanced covariates.(20) We also performed a logistic regression with inverse probability of treatment weighting (IPTW) to adjust for the propensity score.(21–23)

All statistical analyses were carried out using R software (version 3.6.1; R Development Core Team, Vienna, Austria). The R package *MatchIt* was used for the propensity score matching, and the argument *weights* in the *glm* function was used for the IPTW. *P*-values < 0.05 were considered statistically significant.

Results

In total, 3,925 patients underwent open MAS between 2016 and 2018, of whom 138 were excluded because they had undergone multiple open MAS procedures during the study period. Additionally, 101 patients were excluded because their pre- or postoperative SCr data were missing, and 70 others were excluded due to a history of end-stage renal disease, RRT, kidney transplantation, or nephrectomy. Thus, 3,616 patients were included in the final analysis (Fig. 1). The patient characteristics and perioperative data are summarized in Table 1.

In total, 1,546 patients (42.8%) received propofol-based anesthesia, and 2,070 (57.2%) received inhalant-based anesthesia. Overall, AKI developed in 238 patients (6.6%) following open MAS. The incidence of postoperative AKI was 5.0% (77/1546) and 7.8% (161/2070) in the propofol and inhalant groups, respectively.

The results of the univariable and multivariable logistic regression analyses are presented in Table 2. Patients who underwent inhalant-based anesthesia had a significantly higher likelihood of postoperative AKI compared to those who received propofol-based anesthesia (adjusted odds ratio [aOR], 1.69; 95% confidence interval [CI], 1.23–2.30; $P = 0.001$). After the propensity score analysis, 1482 patients in each study group were matched, and no covariates remained unbalanced after the propensity score matching (Fig. 2). The multivariable logistic regression analysis of the propensity score-matched cohort showed similar results to those for the whole study population (Table 3). The inhalant group had a significantly higher likelihood of AKI following open MAS than the propofol group (aOR, 1.68; 95% CI, 1.21–2.34; $P = 0.002$). The logistic regression analysis with IPTW also showed that the likelihood of postoperative AKI was significantly higher in the inhalant group than in the propofol group (OR, 1.74; 95% CI 1.14–1.66; $P < 0.001$).

Table 2
Logistic regression for acute kidney injury after open major abdominal surgery

	Univariable Model		Multivariable Model	
	Crude OR (95% CI)	P	Adjusted OR (95% CI)	P
Anesthetics				
Propofol	1.00 (Reference)		1.00 (Reference)	
Inhalant	1.61 (1.22–2.13)	0.001	1.69 (1.23–2.23)	0.001
Age (year)	1.03 (1.02–1.04)	< 0.001	1.00 (0.99–1.02)	0.799
Male	1.82 (1.36–2.44)	< 0.001	1.16 (0.80–1.68)	0.442
Body mass index				
Normal (18.5–24.9 kg m^{-2})	1.00 (Reference)		1.00 (Reference)	
Overweight (25.0-29.9 kg m^{-2})	1.28 (0.96–1.71)	0.095	1.26 (0.91–1.74)	0.173
Obesity (≥ 30 kg m^{-2})	1.31 (0.67–2.55)	0.431	1.22 (0.59–2.53)	0.597
Underweight (< 18.5 kg m^{-2})	1.00 (0.56–1.80)	0.995	0.86 (0.44–1.68)	0.661
Smoking	1.38 (1.01–1.87)	0.045	1.23 (0.857–1.76)	0.263
ASA physical status classification				
Class 1	1.00 (Reference)		1.00 (Reference)	
Class 2	2.65 (1.73–4.07)	< 0.001	1.47 (0.91–2.38)	0.116
Class 3	4.91 (2.97–8.12)	< 0.001	1.585 (0.86–2.92)	0.140
Class 4	9.97 (1.97–50.41)	0.005	1.97 (0.30-13.07)	0.481
Past medical history				
Hypertension	2.16 (1.66–2.82)	< 0.001	1.16 (0.75–1.80)	0.510
Diabetes mellitus	1.97 (1.50–2.59)	< 0.001	1.14 (0.67–1.95)	0.633

OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure.

	Univariable Model		Multivariable Model	
	Crude OR (95% CI)	P	Adjusted OR (95% CI)	P
Chronic obstructive pulmonary disease	1.05 (0.51–2.19)	0.890	0.50 (0.23–1.12)	0.091
Atrial fibrillation	2.38 (1.31–4.35)	0.010	1.45 (0.71–2.95)	0.307
Myocardial infarction	2.16 (0.91–5.14)	0.113	1.00 (0.33–2.99)	0.995
Percutaneous coronary intervention	2.10 (1.27–3.46)	0.007	1.24 (0.65–2.35)	0.511
Congestive heart failure	5.16 (1.84–14.44)	0.007	2.51 (0.72–8.74)	0.148
Chronic liver disease	1.43 (0.94–2.15)	0.105	0.98 (0.60–1.61)	0.935
Previous abdominal surgery	1.88 (1.39–2.54)	< 0.001	1.64 (1.17–2.30)	0.004
Medication history				
Aspirin	1.38 (0.96–1.98)	0.091	0.70 (0.45–1.10)	0.123
ACEi/ARB	1.68 (1.26–2.23)	0.001	0.90 (0.60–1.34)	0.590
βblocker	1.91 (1.21–3.02)	0.009	1.03 (0.60–1.77)	0.906
Calcium channel blocker	2.17 (1.63–2.89)	< 0.001	1.71 (1.14–2.55)	0.009
Statin	2.28 (1.38–3.76)	0.003	4.66 (0.84–25.89)	0.078
Insulin	1.96 (1.14–3.36)	0.024	0.20 (0.03–1.23)	0.083
Oral hypoglycemic agents	1.86 (1.38–2.50)	< 0.001	1.12 (0.63–1.99)	0.690
Preoperative laboratory data				
Hemoglobin (g dl^{-1})	0.85 (0.79–0.91)	< 0.001	0.98 (0.89–1.07)	0.602
Albumin (g dl^{-1})	0.33 (0.26–0.43)	< 0.001	0.50 (0.28–0.57)	< 0.001
Uric acid (mg dl^{-1})	1.12 (1.03–1.22)	0.008	1.05 (0.95–1.16)	0.363
Creatinine (mg dl^{-1})	6.59 (4.17–10.41)	< 0.001	4.616 (2.55–8.35)	< 0.001

OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure.

	Univariable Model		Multivariable Model	
	Crude OR (95% CI)	P	Adjusted OR (95% CI)	P
Operative profiles				
Type of surgery				
Gastrectomy	1.00 (Reference)		1.00 (Reference)	
Hepatectomy	1.44 (0.86–2.43)	0.170	2.05 (1.12–3.75)	0.020
Colectomy	0.92 (0.55–1.56)	0.760	1.22 (0.67–2.22)	0.524
Pancreatectomy	1.73 (1.03–2.91)	0.038	1.79 (0.99–3.23)	0.054
Combined	3.49 (1.44–8.46)	0.006	2.92 (1.10–7.73)	0.031
Emergent surgery	1.74 (0.89–3.40)	0.129	1.31 (0.61–2.81)	0.487
Anesthesia duration (min)	1.003 (1.002–1.005)	< 0.001	1.001 (0.999–1.003)	0.226
Intraoperative colloid use	4.17 (3.08–5.64)	< 0.001	2.23 (1.52–3.26)	< 0.001
Intraoperative RBC transfusion	4.29 (3.18–5.80)	< 0.001	1.61 (1.07–2.40)	0.021
Intraoperative average MPB (mmHg)	0.95 (0.94–0.97)	< 0.001	0.98 (0.96–0.99)	0.023
Continuous infusion of phenylephrine	2.36 (1.52–3.68)	0.001	0.80 (0.47–1.35)	0.396
Continuous infusion of norepinephrine	3.99 (2.42–6.58)	< 0.001	1.07 (0.56–2.05)	0.831
Furosemide use	3.27 (1.43–7.51)	0.014	1.76 (0.65–4.73)	0.265

OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure.

Table 3
Logistic regression for acute kidney injury after open major abdominal surgery in the propensity score-matched cohort

	Adjusted OR (95% CI)	P
Anesthetics		
Propofol	1.00 (Reference)	
Inhalant	1.68 (1.21–2.34)	0.002
Age (year)	1.01 (0.99–1.03)	0.291
Male	1.22 (0.78–1.90)	0.379
Body mass index		
Normal (18.5–24.9 kg m^{-2})	1.00 (Reference)	
Overweight (25.0-29.9 kg m^{-2})	1.04 (0.71–1.52)	0.842
Obesity (≥ 30 kg m^{-2})	1.01 (0.42–2.43)	0.977
Underweight (< 18.5 kg m^{-2})	0.96 (0.44–2.07)	0.914
Smoking	1.40 (0.94–2.09)	0.103
ASA physical status classification		
Class 1	1.00 (Reference)	
Class 2	1.60 (0.91–2.79)	0.102
Class 3	1.55 (0.77–3.15)	0.222
Class 4	1.25 (0.11–13.70)	0.856
Past medical history		
Hypertension	1.14 (0.68–1.89)	0.622
Diabetes mellitus	1.19 (0.64–2.24)	0.584
Chronic obstructive pulmonary disease	0.35 (0.13–0.94)	0.037
Atrial fibrillation	1.27 (0.54–3.01)	0.580
Myocardial infarction	0.93 (0.26–3.38)	0.909
Percutaneous coronary intervention	1.44 (0.72–2.91)	0.306

OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure

	Adjusted OR (95% CI)	P
Congestive heart failure	4.65 (1.07–20.16)	0.040
Chronic liver disease	1.25 (0.72–2.16)	0.430
Previous abdominal surgery	1.51 (1.02–2.24)	0.038
Medication history		
Aspirin	0.68 (0.41–1.13)	0.135
ACEi/ARB	0.99 (0.63–1.55)	0.952
βblocker	0.97 (0.52–1.80)	0.925
Calcium channel blocker	1.71 (1.09–2.68)	0.019
Statin	3.47 (0.50-24.38)	0.210
Insulin	0.23 (0.03–1.79)	0.159
Oral hypoglycemic agents	1.22 (0.63–2.35)	0.562
Preoperative laboratory data		
Hemoglobin (g dl^{-1})	1.05 (0.93–1.17)	0.440
Albumin (g dl^{-1})	0.40 (0.26–0.60)	< 0.001
Uric acid (mg dl^{-1})	1.05 (0.94–1.19)	0.380
Creatinine (mg dl^{-1})	4.82 (2.34–9.95)	< 0.001
Operative profiles		
Type of surgery		
Gastrectomy	1.00 (Reference)	
Hepatectomy	1.65 (0.59–4.61)	0.337
Colectomy	1.50 (0.54–4.17)	0.435
Pancreatectomy	1.46 (0.53–4.06)	0.465
Combined	4.56 (1.20-17.32)	0.026
Emergent surgery	1.45 (0.57–3.70)	0.437
Anesthesia duration (min)	1.002 (1.000-1.004)	0.017

OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure

	Adjusted OR (95% CI)	P
Intraoperative colloid use	2.12 (1.26–3.56)	0.004
Intraoperative RBC transfusion	1.37 (0.82–2.27)	0.227
Intraoperative average MBP (mmHg)	0.98 (0.96–0.99)	0.039
Continuous infusion of phenylephrine	1.20 (0.61–2.38)	0.600
Continuous infusion of norepinephrine	1.16 (0.54–2.48)	0.702
Furosemide use	0.44 (0.05–4.32)	0.485
OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; RBC, red blood cell; MBP, mean blood pressure		

The secondary outcomes are listed in Table 4. All postoperative AKI stages were more frequent in the inhalant group ($P = 0.007$) than in the propofol group, and the length of hospital stay was slightly longer in the inhalant group ($P < 0.001$; Table 4). There was no significant difference in the incidence of newly required RRT or in-hospital death after open MAS between the groups (Table 4).

Table 4
Comparison of secondary outcomes according to the study groups

	Propofol (n = 1546)	Inhalant (n = 2070)	P
Acute kidney injury			0.007
Stage 1	60 (3.9%)	130 (6.3%)	
Stage 2	7 (0.4%)	17 (0.8%)	
Stage 3	10 (0.6%)	14 (0.7%)	
Postoperative renal replacement therapy	8 (0.5%)	9 (0.4%)	0.719
Length of hospital stay (day)	7 [5–10]	8 [6–11]	< 0.001
In-hospital mortality	6 (0.4%)	7 (0.3%)	0.804
Values are expressed as number (%) or median [interquartile range].			

Discussion

In this study, we found that, in patients who underwent open MAS, the type of anesthetic used had a significant effect on the likelihood of postoperative AKI, as defined by KDIGO criteria. The risk for postoperative AKI was 1.7-fold higher in patients who underwent inhalational anesthesia using sevoflurane or desflurane compared to those receiving propofol-based anesthesia; the score analysis and

IPTW confirmed this finding. Moreover, all stages of AKI were more frequent in inhalant-based anesthesia than in propofol-based anesthesia.

In most cases, the choice of anesthetic agent is still based largely on the preference of the attending anesthesiologist, as no agent is known to be definitively superior to the others in terms of patient outcomes, except in specific contexts such as neurosurgical anesthesia.(24) Recent research on the relationship between anesthetics and postoperative outcomes, including long-term survival, has centered on the field of 'onco-anesthesia'.(25) Numerous studies have assessed the effects of anesthetics on mortality after various types of cancer surgeries.(26–29). Although large randomized controlled trials are still required, a significant difference in the risk of mortality according to the anesthetic used in patients undergoing cancer surgery has been reported by previous studies.(26–28) Against this background, it seems clear that, to optimize outcomes, the choice of anesthetic should be based on the characteristics of the individual case rather than the anesthesiologist's discretion. However, the literature on this topic is currently insufficient.

Postoperative AKI is a frequent complication associated with increased medical expenses.(30) Thus, prevention of postoperative AKI is important, and many studies have been performed to identify potential risk factors and construct prediction models. Previous studies typically enrolled patients undergoing cardiac surgery, among whom the incidence of postoperative AKI is exceptionally high.(31–36) These studies included numerous variables in their prediction models, such as older age, higher BMI, impaired preoperative renal function, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, emergent surgery, and prolonged duration of cardiopulmonary bypass.(31–36) However, none of the models considered the type of anesthetic as a risk factor for AKI, and few studies were performed in a non-cardiac surgery setting. In the present study, we found that the type of anesthetic may significantly affect the likelihood of AKI following major non-cardiac surgery.

Propofol has attracted the attention of researchers due to its organ-protective effects (exerted via anti-inflammatory and immune-modulatory actions) and anti-oxidant properties.(37, 38) *In vivo* studies showed that propofol attenuated tissue injury by reducing susceptibility to oxidative stress and improving anti-oxidant capacity.(11, 39) Inhalational anesthetics are also known to confer organ protection by attenuating inflammation, necrosis, and apoptosis *in vivo*.(14, 40) Based on such findings, several clinical studies evaluated the renoprotective effects of anesthetics.(15, 16, 18) Yoo and colleagues showed that patients who received propofol anesthesia had a significantly lower risk of AKI following valvular heart surgery than those who received sevoflurane anesthesia.(16) They also showed that propofol suppressed the release of inflammatory cytokines such as interleukin (IL)-1, IL-6, and tumor necrosis factor-α. In terms of major non-cardiac surgery, Bang and co-workers observed a lower incidence of AKI after colorectal surgery with propofol- than with sevoflurane-based anesthesia.(15) In contrast, a recent study found no significant difference in the incidence of AKI between propofol- and sevoflurane-based anesthesia after lung resection surgery.(18) However, the results of previous studies lack generalizability and cannot be extrapolated to all types of major non-cardiac surgery. In our study, we included patients who underwent not only colorectal surgery but also gastrectomy, hepatectomy, and pancreatectomy, and found that

propofol may be more advantageous than inhalational anesthetics in terms of preventing postoperative AKI.

The present study has several limitations. First, it used a retrospective design, and although numerous potential confounders were adjusted for in the multivariable model, the results should only be considered as a source of hypotheses; the causal relationship between type of anesthetic and postoperative AKI could not be established. Second, although we performed two additional logistic regression analyses after propensity score matching and IPTW to strengthen our findings, the results may have been biased to some degree. Third, postoperative measurement of SCr was not mandatory; thus, given that patients with more comorbidities are typically tested more frequently, the incidence of postoperative AKI may have been biased. Fourth, we did not define AKI based on the urine output criteria of KDIGO, and the hourly urine output data in the electronic medical records may have been inaccurate because they were recorded manually. Thus, the incidence of AKI may have been underestimated.

In conclusion, the type of anesthetic can have an independent and significant effect on the likelihood of AKI after open MAS. Patients undergoing inhalational anesthesia using sevoflurane or desflurane may be more prone to postoperative AKI than those anaesthetized with propofol. Large, well-controlled randomized trials should be performed to further investigate this association.

Abbreviations

Acute kidney injury, AKI; body mass index, BMI; major abdominal surgery, MAS; serum creatinine, SCr; renal replacement therapy, RRT; Kidney Disease
Improving Global Outcomes, KDIGO; inverse probability of treatment weighting, IPTW; adjusted odds ratio, aOR; confidence interval, CI; interleukin, IL

Declarations

Ethics approval and consent to participate

This trial was approved by the Institutional Review Board of Seoul National University Hospital (H-1903-102-1018) and written informed consent was waived due to the retrospective nature of the study.

Consent for publication: Not applicable

Availability of data and materials

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

Competing interests: The authors declare that they have no competing interests.

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Author Contributions

All authors contributed to conception and design; B.R.K., G.Y.S. and S.L collected data; B.R.K., S.Y., J.-H.B. and K.N. analyzed the data and drafted the manuscript; S.Y., S.L., G.Y.S., J.-H.B. and K.N. revised the manuscript; all authors approved the final version of the manuscript, and all authors are accountable for all aspects of the work.

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Figures

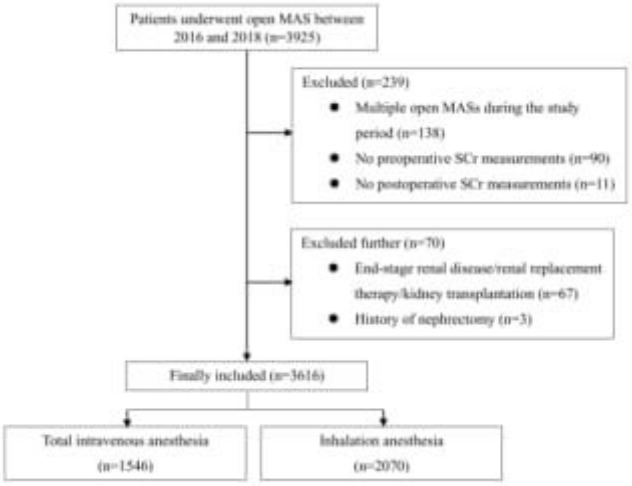

Figure 1

Flow diagram of the study. MAS, major abdominal surgery; SCr, serum creatinine.

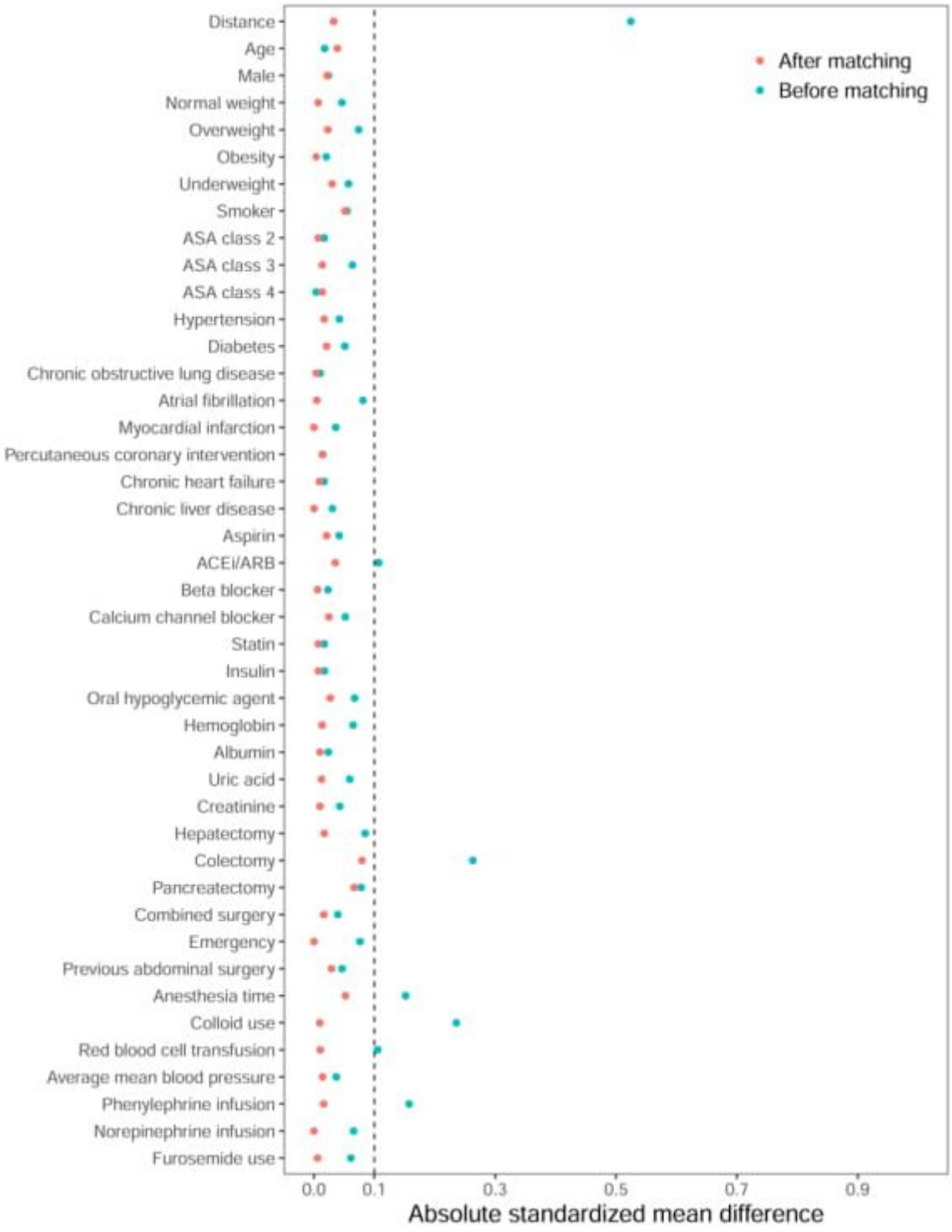

Figure 2

Absolute standardized mean differences before and after propensity score matching. ASA, American Society of Anesthesiologists; ACE, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker.