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CLINICAL TRIAL REPORT

The Effects of Different Ciprofol Doses on Hemodynamics During Anesthesia Induction in Patients Undergoing Cardiac Surgery: A Randomized, Double-Blind, Controlled Study

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Objective: To evaluate the effects of different ciprofol doses on hemodynamics in patients undergoing cardiac surgery.

Methods: 209 patients were randomly divided into four groups: 0.2 mg/kg etomidate group (group E, n = 50), 0.2 mg/kg, 0.3mg/kg, 0.4mg/kg ciprofol group (group A, n = 53, group B, n = 51, group C, n = 54). Mean arterial pressure (MAP), heart rate (HR), cardiac output (CO), stroke volume (SV), systemic vascular resistance (SVR), and bispectral index were recorded at the following time points: 5 minutes after entering the operating room (T_0); before anesthesia induction (T_1); immediately after induction (T_2); 1 minute and 2 minutes after induction (T_3~T_4); at intubation (T_5); 1 minute, 3 minutes, 5 minutes and 10 minutes after intubation (T_6~T_9); at skin incision (T_{10}). The incidence of hypotension and bradycardia and the doses of vasoactive drugs were recorded.

Results: Compared with T_0, HR, MAP, SV, CO all decreased to varying degrees after administration, and the decrease time in Group B and Group C were earlier than that in other two groups ($P < 0.05$). SVR increased slowly after T_4 in all groups, but there was no significant differences ($P > 0.05$). Compared with group E, the norepinephrine dose was significantly lower in groups A and B (both $P < 0.05$). Group C showed a greater decline in CO and SV than the other three groups from T_7 to T_{10} ($P < 0.05$), while there was no significant difference between groups A and E in CO and groups A, B, and E in SV ($P > 0.05$). No significant differences were observed in MAP, SVR, and the incidences of hypotension and bradycardia among the four groups ($P > 0.05$).

Conclusion: 0.2 mg/kg ciprofol has the least impact on hemodynamics in patients undergoing cardiac surgery, and reduced norepinephrine use.

Keywords: ciprofol, hemodynamics, cardiac surgery

Introduction

The ideal intravenous anesthetic[1] should exhibit a rapid onset, short duration of action, rapid recovery after drug withdrawal, minimal effect on various organ functions, and low incidence of adverse reactions, such as respiratory depression.[2,3] The quest to identify anesthetic drugs with optimal characteristics has been an ongoing endeavor for researchers. In recent years, a new intravenous anesthetic has been developed, ciprofol,[4–8] which has a chemical structure similar to that of propofol. However, ciprofol have been added to the 2,6 side chains of propofol, enhancing its binding ability to gamma-aminobutyric acid (GABA)-A receptors. The mechanism of action of ciprofol involves the enhancement of GABA-A receptor-mediated ion channel activity, allowing chloride influx and causing hyperpolarization of the neural cell membrane, thereby achieving central nervous system depression.[4]

Ciprofol has been approved for sedation during various endoscopic procedures, general anesthesia for surgery, and sedation in the intensive care unit. Wang et al[9] compared the effects of 0.4 mg/kg ciprofol with the effects of 2 mg/kg

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propofol on the induction of general anesthesia in patients undergoing elective surgery. The authors showed that ciprofol provided superior sedation with less blood pressure and heart rate fluctuations than propofol. Moreover, a study conducted on older patients undergoing major non-cardiac surgery showed that 0.2–0.4 mg/kg ciprofol was safe and effective for the induction of anesthesia without serious adverse events.[10] Duan et al investigated the hemodynamic and bispectral index (BIS) changes associated with different doses of ciprofol in older patients under general anesthesia. They discovered that a ciprofol dose of 0.3 mg/kg had the lowest incidence of adverse reactions and minimal hemodynamic changes while effectively inhibiting the tracheal intubation stress response.[11] However, most studies on its clinical application have focused on patients undergoing non-cardiac surgery. Safe management of the induction of anesthesia for patients undergoing heart surgery is essential, etomidate is one of the most commonly used intravenous anesthetic for induction in these patients due to the less effect on the circulation and less vasopressin use, and did not affect the mortality of patients undergoing cardiac surgery,[12,13] However, etomidate still has some limitations,[14,15] such as the increased risk of myofibrillation and adrenocortical inhibition. Whether ciprofol or etomidate has more advantages on hemodynamics during the induction of anesthesia in patients undergoing cardiac surgery warrant investigation. As such, we conducted this study to compare different doses of ciprofol with etomidate for the induction of anesthesia in patients undergoing cardiac surgery.

Patients and Methods

Ethical Approval

This study was a prospective, double-blind, randomized controlled clinical trial, and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. The First Affiliated Hospital of USTC Ethics Committee approved the study protocol (Date: March 19, 2023; Registration number: 2023-KY-043). Prior to patient enrollment, the trial was registered in the Chinese Clinical Trial Registry (Registration number: ChiCTR2300074434; Principal investigator: YanHu Xie; Date of registration: August 7, 2023). The investigators obtained written informed consent from the participants after providing a thorough explanation of the study.

Sample Size Calculation

Since few literatures have reported the incidence of hypotension between ciprofol and etomidate during anesthesia induction in cardiac surgery, we determined the required sample size based on the incidence of hypotension in each group in our preliminary study. With an assumed alpha level of 0.05 and a power of 0.90, the sample size ratio of the four groups was 1:1:1:1, β=0.1, we needed 172patients (43/group), using PASS, version 11. Considering a dropout rate of 20%, a total of 216 patients are proposed to be enrolled in this study, with 54 cases in each group.

Design and Patients

Overall, 216 patients from August 2023 to July 2024 undergoing cardiac surgery were recruited, with the following inclusion criteria: 1) aged 18–75 years; 2) body mass index 18–30 kg/m^2; 3) American Society of Anesthesiologists' status of III–IV; 4) New York Heart Association functional classification of II–III; and 5) scheduled coronary artery bypass grafting or heart valve replacement. The exclusion criteria were 1) a history of psychiatric and neurological disorders (such as cerebrovascular disease, epilepsy, Alzheimer's disease, schizophrenia, depression); 2) acute heart failure or angina attacks before anesthesia induction; 3) severe lung, liver, or kidney dysfunction; 4) anesthesia with ciprofol or etomidate within the preceding 3 months; 5) allergy to ciprofol/etomidate; 6) alcohol and drug abuse; and 7) a Q-T interval ≥450 ms. Based on these criteria, 209 patients were selected and randomly divided into the etomidate group (group E, n = 50), ciprofol 0.2 mg/kg group (group A, n = 53), ciprofol 0.3 mg/kg group (group B, n = 51), and ciprofol 0.4 mg/kg group (group C, n = 54).

Interventions

Heart rate (HR), electrocardiogram, non-invasive blood pressure, peripheral oxygen saturation, and BIS were monitored after patients entered the operating room. A nasal catheter was used for oxygen inhalation at 2 L/min. Radial artery catheterization under local anesthesia was performed, and the LiDCO Rapid was connected. HR, mean arterial pressure

(MAP), cardiac output (CO), stroke volume (SV), and systemic vascular resistance (SVR) were monitored in real-time by LiDCO Rapid[16] (Masimo Corporation, US). Ultrasound-guided internal jugular venipuncture was performed, and a three-cavity 7-F catheter was inserted to provide intraoperative fluid replacement, monitor central venous pressure (CVP), and administer vasoactive drugs. The induction of anesthesia was performed after the puncture was completed.

Patients in group E were anesthetized with etomidate (TYT24B14) at a dose of 0.2 mg/kg. Group A, group B, and group C were anesthetized with ciprofol (33231181) at doses of 0.2, 0.3, and 0.4 mg/kg, respectively, with an administration time of 30 seconds. All groups received an intravenous injection of sufentanil at a dose of 1 μg/kg and rocuronium at a dose of 1 mg/kg. Endotracheal intubation was performed 3 minutes after administration, and a ventilator was connected with the following parameters: tidal volume 8 mL/kg, frequency 12 times/min. The period from intubation to incision was maintained by total inhalation anesthesia (1% sevoflurane), which was supplemented with 2 mg midazolam when the BIS was >60. When MAP exceeded 20% of the baseline value for more than 2 minutes, hypotension were concluded and norepinephrine was administered 4ug/ dose until the MAP rose to 80% of the baseline value. Bradycardia is defined when the HR drops below 50 beats and atropine is given as a single injection of 0.5mg. The experiment was terminated after skin incision. Sedation and analgesics were administered, and anesthesia was maintained by intravenous and inhalational anesthetics throughout the operation.

Outcome Measures

MAP, HR, CO, SV, SVR, and BIS were recorded at the following time points: 5 minutes after patients entered the operating room (T_0), before the induction of anesthesia (T_1), immediately after induction (T_2), 1 minute after induction (T_3), 2 minutes after induction (T_4), at intubation (T_5), 1 minute after intubation (T_6), 3 minutes after intubation (T_7), 5 minutes after intubation (T_8), 10 minutes after intubation (T_9), and at skin incision (T_{10}). The incidence of hypotension and bradycardia during the induction period and the dose of vasoactive drugs administered during the induction period were recorded.

Statistical Analysis

SPSS 25.0 software (IBM Corp., Armonk, NY, US) was used for the statistical analyses. The Kolmogorov–Smirnov test was performed for check the normality of continuous data. Normally distributed measurement data are presented as the mean ± standard deviation. One-way analysis of variance (ANOVA) was used for inter-group comparisons, the Bonferroni test was used for pairwise comparison among multiple groups. Repeated-measures ANOVA was used for intra-group comparisons. Non-normally distributed measurement data are presented as the median (interquartile range), and the rank-sum test was used for inter-group comparisons. Count data are expressed as frequency (%), and comparisons between the groups were performed using the chi-square test or Fisher's exact probability method. $P < 0.05$ was considered statistically significant.

Results

Overall, 216 patients were screened, 16 patients did not meet the inclusion criteria, one patient refused to be included for other reasons, and a total of 209 patients were included in the statistics and were randomly divided into four groups (Figure 1). Table 1 shows that there were no statistically significant differences in the baseline characteristics and preoperative echocardiographic assessment results in the four groups ($P > 0.05$). The drug doses used for the induction of anesthesia, and fluid volume administered among the four groups shows no statistical difference either ($P > 0.05$).

Table 2 shows the changes of hemodynamic indexes in the four groups at different time points. Compared with T_0: HR was significantly decreased at T_7–T_{10} in group E and group A, while decreased at T_5–T_{10} in group B and group C ($P < 0.05$); Map was significantly decreased at T_3–T_{10} in group E, group A and group B, while decreased at T_2–T_{10} in group C ($P < 0.05$); CO was decreased at T_4–T_{10} in four groups ($P < 0.05$); SV was decreased at T_3–T_{10} in four groups ($P < 0.05$); there was no significant differences in SVR at any timepoint in four groups ($P > 0.05$). Compared with Group E, HR was significantly lower at T_2–T_{10} in groups B and C; no significant differences in MAP were observed between the four groups ($P > 0.05$). Given that the baseline CO and SV differed significantly among the four groups, the change in CO (ΔCO) and SV (ΔSV) in the four groups (the

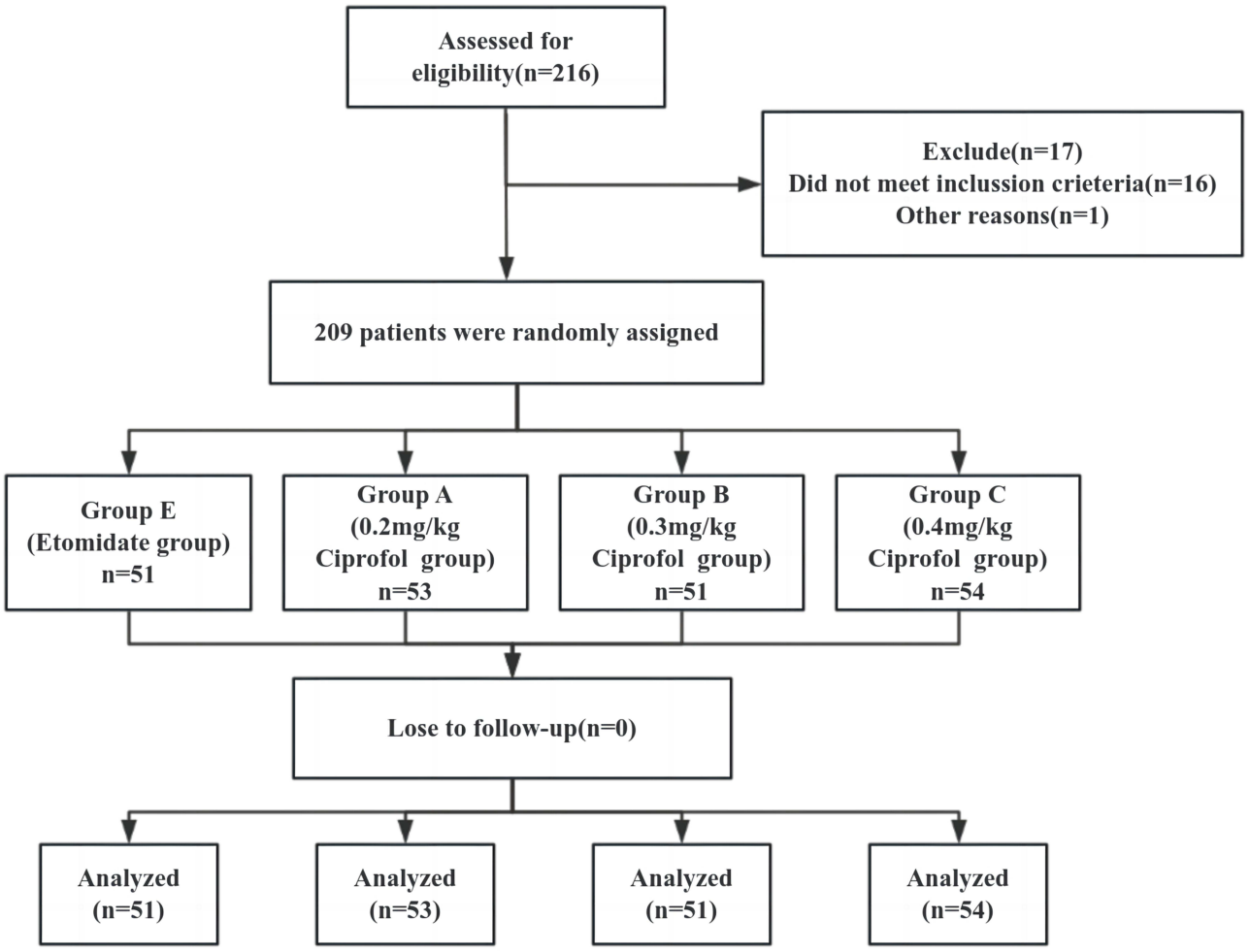

Figure 1 Flow diagram of patient enrollment. Flow diagram of patient enrollment.A total of 209 eligible patients were included in the study, with 51 patients in group E (0.2mg/kg etomidate group), 53 patients in group A (0.2mg/kg ciprofol group), 51 patients in group B (0.3mg/kg ciprofol group), and 54 patients in group C (0.4mg/kg ciprofol group).

difference between CO at T_0 and CO at T_1–T_{10}; difference between SV at T_0 and SV at T_1–T_{10}) ware analyzed (Figure 2). A greater decline in CO from T_4 to T_{10} was observed in group B and group C than in group E and group A ($P < 0.05$). Furthermore, group C demonstrated a greater decline in CO from T_7 to T_{10} than the other three groups ($P < 0.05$). There was no significant difference between group A and group E ($P > 0.05$). There was

Table 1 Comparison of the Baseline Characteristics Among the Four Groups

Parameters	Group E	Group A	Group B	Group C	*P*
Sex(Male/Female)	(24/27)	(31/22)	(33/18)	(29/25)	0.374
Age(years)	59.9±9.6	57.3±10.0	59.6±10.2	59.8±8.7	0.434
Body weight(kg)	62.6±11.7	65.5±10.4	65.7±10.0	63.0±11.4	0.326
Height(cm)	161.7±9.7	164.5±9.4	165.3±9.0	163.4±9.4	0.244
BMI(kg/m^2)	23.8±3.1	24.0±2.7	23.9±2.9	23.6±3.0	0.904
ASA PS(III/IV)	(1/50)	(2/50)	(3/48)	(6/48)	0.238
NYHA PS(II/III/IV)	(2/45/4)	(6/45/1)	(10/37/4)	(10/41/3)	0.214
Surgical type (CABG / Heart valve surgery)	(15/36)	(15/38)	(14/37)	(19/35)	0.819

(*Continued*)

Table 1 (Continued).

Parameters	Group E	Group A	Group B	Group C	*P*
Preoperative complications					
Atrial fibrillation(n,%)	11(21.6)	14(26.9)	4(9.8)	7(13.0)	0.054
Hypertension(n,%)	21(41.2)	28(52.8)	24(47.2)	23(42.6)	0.626
Diabetes(n,%)	7(13.7)	11(20.8)	7(13.7)	6(11.1)	0.539
Cerebrovascular disease(n,%)	9(17.6)	9(17.0)	9(17.6)	9(16.4)	0.998
Preoperative echocardiographic assessment					
LVEF(%)	64[55~70]	66[58~72]	63[56~69]	64.5[59~70]	0.201
SV(mL)	91±35	93±28	101±34	97±34	0.377
CO(L/min)	7.1±3.5	6.9±2.8	6.9±2.4	7.0±2.8	0.978
RWMA(n,%)	9(17.6)	7(12.7)	8(15.7)	6(11.1)	0.775
Induction of anesthesia					
Sufentanil dosage(μg)	50(50~50)	50(50~55)	50(50~50)	50(50~50)	0.778
Rocuronium bromide dosage (mg)	70(60~100)	70(60~100)	70(70~75)	70(60~75)	0.394
Total liquid input (mL)	200(150~300)	200(200~300)	200(200~300)	250(200~300)	0.074

Notes: The data are presented as the mean ± standard deviation, numbers with percentages or median (interquartile range). Group E, 0.2mg/kg etomidate group. Group A, 0.2mg/kg ciprofol group. Group B, 0.3mg/kg ciprofol group. Group C, 0.4mg/kg ciprofol group.
Abbreviations: BMI, body mass index. ASA, American Society of Anesthesiologists. NYHA, New York Heart Association. LVEF, Left Ventricular Ejection Fraction. SV, Stroke Volume; CO, Cardiac Output; RWMA, Regional wall motion abnormalities.

a greater decline in SV in group C than in the other three groups at T_4–T_{10} ($P < 0.05$). There was no significant difference between group A, group B, and group E ($P > 0.05$).

The dose of norepinephrine was significantly lower in group A and group B than in group E ($P < 0.05$; Table 3). There were no significant differences in the incidences of hypotension and bradycardia among the four groups ($P > 0.05$).

Discussion

Patients undergoing cardiac surgery have a high risk of hypotension during the induction of anesthesia due to their fragile cardiac function. In patients with cardiovascular disease, even minor hemodynamic changes can disrupt the balance between myocardial oxygen supply and demand, potentially increasing the risk of postoperative complications.[17,18] Etomidate is currently widely used for the induction of anesthesia in patients undergoing cardiac surgery due to its low risk of hypotension.[19–21] Ciprofol is a new drug for intravenous anesthesia and sedation and has less effect on blood pressure[22] Whether ciprofol has an advantage in stable hemodynamics compared with etomidate remains unknown.

In the present study, varying doses of ciprofol (0.2–0.4 mg/kg) were administered to induce anesthesia in patients undergoing cardiac surgery. The results shows that MAP was decreased at 1 minute after induction in etomidate group and 0.2, 0.3mg/kg ciprofol group, but decreased immediately after induction in 0.4mg/kg ciprofol group, this indicates that a dose of 0.4mg/kg ciprofol has a faster effect on MAP. However, no significant differences in MAP and the incidences of hypotension during the induction period were observed between the four groups. The norepinephrine dose in the 0.2 mg/kg and 0.3 mg/kg ciprofol groups was lower than that in the etomidate group. Norepinephrine[23,24] activates α-adrenergic receptors, causing vasoconstriction, increasing blood pressure, and enhancing coronary blood flow. This indicates that a low dose of norepinephrine is necessary to maintain normal MAP in 0.2–0.3 mg/kg ciprofol group, in another sense, 0.2–0.3 mg/kg ciprofol provides a more stable blood pressure than etomidate.

0.3–0.4 mg/kg ciprofol experienced an earlier and lower HR after induction than etomidate group and 0.2mg/kg ciprofol group. However, there were no adverse HR events in the four groups, and there was no difference in the incidence of bradycardia. 0.3 mg/kg and 0.4 mg/kg ciprofol inhibit the increase in HR caused by tracheal intubation.

CO is calculated as the product of SV and HR; however, CO is affected by a combination of factors,[25,26] including HR, myocardial contractility, preload, and afterload. In the present study, SV decreased in all patients after

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Table 2 HR, MAP, CO, SV and SVR at Different Times in Patients Among the Four Groups ($\overline{X} \pm S$)

Index	Group	Time Point										
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
HR (bpm)	E	81.9±19.4	81.1±15.2	82.7±16.9	80.4±23.6	76.8±18.4	78.6±19.4	75.6±15.9	73.5±15.8$^{\#}$	73.0±20.7$^{\#}$	67.9±15.0$^{\#}$	67.4±17.5$^{\#}$
	A	76.9±12.7	77.5±13.8	77.6±12.2	76.3±15.0	72.9±13.8	73.7±15.8	74.8±18.0	70.5±16.0$^{\#}$	67.5±13.1$^{\#}$	66.3±12.9$^{\#}$	65.6±12.9$^{\#}$
	B	74.0±14.1	76.3±16.0	76.6±16.2 *	73.0±17.3 *	70.2±15.7 *	67.2±15.1$^{\#}$*	67.6±13.8$^{\#}$*	66.2±15.0$^{\#}$*	65.1±14.2$^{\#}$*	64.1±12.7$^{\#}$*	63.3±12.6$^{\#}$*
	C	76.7±13.6	76.9±14.2	75.8±14.4 *	76.0±18.3 *	72.4±17.0 *	69.7±15.2$^{\#}$*	70.4±15.0$^{\#}$*	67.7±14.6$^{\#}$*	65.3±13.7$^{\#}$*	64.8±13.4$^{\#}$*	64.7±12.6$^{\#}$*
MAP (mmHg)	E	94.2±13.5	92.8±14.8	92.5±14.7	85.6±15.7$^{\#}$	82.5±15.7$^{\#}$	81.6±12.2$^{\#}$	82.3±13.5$^{\#}$	79.4±11.4$^{\#}$	78.7±12.6$^{\#}$	79.2±13.5$^{\#}$	77.7±11.9$^{\#}$
	A	96.8±16.8	95.7±16.0	93.2±16.5	84.5±15.4$^{\#}$	83.0±15.2$^{\#}$	84.6±17.8$^{\#}$	82.9±15.3$^{\#}$	78.8±14.7$^{\#}$	80.8±14.9$^{\#}$	79.8±13.5$^{\#}$	79.6±13.8$^{\#}$
	B	91.0±11.6	91.0±13.7	89.4±14.7	78.5±15.4$^{\#}$	75.2±14.4$^{\#}$	77.3±13.1$^{\#}$	76.5±12.0$^{\#}$	77.4±12.8$^{\#}$	75.7±11.5$^{\#}$	78.3±11.2$^{\#}$	78.8±10.5$^{\#}$
	C	94.4±13.3	94.3±12.4	88.7±14.8$^{\#}$	80.4±13.8$^{\#}$	78.4±14.7$^{\#}$	79.4±15.8$^{\#}$	76.8±15.4$^{\#}$	75.0±13.5$^{\#}$	75.0±12.9$^{\#}$	76.5±11.5$^{\#}$	76.1±12.6$^{\#}$
CO (L/min)	E	5.7±1.9	5.8±1.9	5.9±2.1	5.2±1.8	4.8±1.9$^{\#}$	4.7±1.7$^{\#}$	4.8±1.7$^{\#}$	4.6±1.7$^{\#}$	4.3±1.4$^{\#}$	4.1±1.4$^{\#}$	3.9±1.2$^{\#}$
	A	5.8±1.8	5.9±1.9	5.8±2.0	5.3±2.0	4.9±1.9$^{\#}$	5.1±2.1$^{\#}$	4.8±2.2$^{\#}$	4.6±2.2$^{\#}$	4.4±2.0$^{\#}$	4.3±1.7$^{\#}$	4.2±1.7$^{\#}$
	B	6.2±2.5	6.4±2.6	6.4±2.8	5.3±2.3	4.9±2.1$^{\#}$	4.8±2.1$^{\#}$	4.8±2.2$^{\#}$	4.6±2.1$^{\#}$	4.5±2.1$^{\#}$	4.5±2.1$^{\#}$	4.4±2.0$^{\#}$
	C	6.5±2.5	6.6±2.6	6.3±2.7	6.2±3.5	5.3±2.5$^{\#}$	5.2±2.5$^{\#}$	5.0±2.1$^{\#}$	4.7±1.8$^{\#}$	4.5±1.7$^{\#}$	4.5±1.7$^{\#}$	4.6±2.0$^{\#}$
SV (mL)	E	73.4±25.1	74.6±24.8	73.5±25.2	67.7±24.1$^{\#}$	65.4±23.1$^{\#}$	65.5±22.6$^{\#}$	66.5±22.2$^{\#}$	64.5±22.5$^{\#}$	63.0±21.2$^{\#}$	62.8±21.9$^{\#}$	62.6±20.3$^{\#}$
	A	76.2±21.2	76.9±21.2	76.4±23.0	69.8±21.4$^{\#}$	67.6±21.4$^{\#}$	67.7±22.7$^{\#}$	65.7±22.6$^{\#}$	64.7±21.6$^{\#}$	65.5±20.4$^{\#}$	65.2±18.7$^{\#}$	64.8±18.8$^{\#}$
	B	83.8±31.1	84.5±30.6	84.7±32.2	73.2±28.9$^{\#}$	72.5±29.6$^{\#}$	73.3±30.8$^{\#}$	73.2±29.7$^{\#}$	71.0±26.7$^{\#}$	69.6±26.6$^{\#}$	70.0±28.1$^{\#}$	70.9±27.6$^{\#}$
	C	86.2±31.0	86.5±30.3	83.1±31.7	76.5±27.8$^{\#}$	73.0±26.5$^{\#}$	73.1±27.4$^{\#}$	71.3±29.0$^{\#}$	71.0±26.8$^{\#}$	69.6±25.1$^{\#}$	69.9±26.1$^{\#}$	70.9±26.3$^{\#}$
SVR (dyn·s·cm^{-5})	E	1331.7±427.6	1334.8±433.0	1322.6±505.6	1308.7±489.8	1412.0±588.3	1439.3±615.5	1476.6±602.9	1449.0±550.5	1525.5±541.5	1552.8±592.4	1601.0±516.6
	A	1371.4±509.0	1346.1±488.6	1350.6±559.6	1335.0±523.9	1421.8±573.8	1447.2±618.1	1453.6±569.6	1461.7±627.6	1533.2±607.0	1556.0±653.4	1590.3±741.2
	B	1236.5±433.6	1222.9±432.6	1221.8±435.2	1256.3±497.0	1290.1±500.9	1376.2±546.3	1355.7±633.6	1419.5±523.6	1391.2±482.7	1468.7±529.2	1537.7±557.4
	C	1197.2±529.1	1217.5±483.1	1216.8±522.3	1180.0±453.3	1270.5±522.1	1320.5±555.3	1284.4±530.0	1341.6±623.3	1367.7±587.4	1412.5±53.4	1386.5±569.9

Notes: Compared to T_0, $^{\#}P < 0.05$; Compared to the group E, $^{*}P < 0.05$. The data are presented as the mean ± standard deviation. Group E, 0.2mg/kg etomidate group. Group A, 0.2mg/kg ciprofol group. Group B, 0.3mg/kg ciprofol group. Group C, 0.4mg/kg ciprofol group.

Abbreviations: HR, Heart Rate; MAP, Mean Arterial Pressure; SV, Stroke Volume; CO, Cardiac Output; SVR, systemic vascular resistance.

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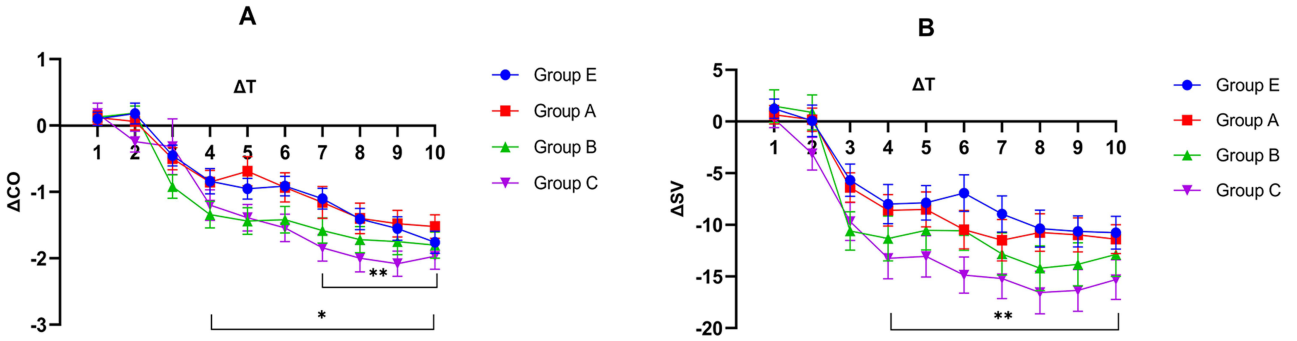

Figure 2 ΔCO and ΔSV among the four groups.
Notes: *Groups B and C declined more than Group E and Group A ($P < 0.05$). **Group C declined more than other three groups ($P < 0.05$). The change in CO (ΔCO) and SV (ΔSV) in the four groups (the difference between CO at T_0 and CO at T_1–T_{10}; difference between SV at T_0 and SV at T_1–T_{10}). A greater decline in CO from T_4 to T_{10} was observed in group B and group C than in group E and group A ($P < 0.05$). Furthermore, group C demonstrated a greater decline in CO from T_7 to T_{10} than the other three groups ($P < 0.05$). There was also a greater decline in SV in group C than in the other three groups at T_4–T_{10} ($P < 0.05$).

administration, with the 0.4 mg/kg ciprofol group exhibiting a more significant decrease in SV than the other three groups. CO declined to a greater extent in the 0.3 mg/kg and 0.4 mg/kg ciprofol groups than in the etomidate and 0.2 mg/kg ciprofol groups. This finding is consistent with the results of previous studies on propofol, indicating that higher induction doses lead to a stronger inhibitory effect on hemodynamics.[27] However, the decrease in blood pressure induced by propofol can mainly be attributed to peripheral blood vessel dilation,[28–30] while hypotension observed in the present study more likely occurred due to a decrease in myocardial contractility, which may be related to the fact that the participants included in this study were undergoing cardiac surgery. The specific mechanism of blood pressure reduction in patients with heart disease after ciprofol anesthesia requires further investigation.

Limitations

This study has several limitations that should be considered when interpreting the results. First, the types of cardiac surgery were not differentiated. Moreover, pathophysiological differences exist between valve disease and coronary artery disease, so it may be relevant to evaluate the effects of propofol in different types of cardiac surgery. Although the types of surgery did not differ significantly between the groups, the inclusion of patients undergoing different types of cardiac surgery may have influenced the results. Second, patients with atrial fibrillation were not excluded. The instantaneous changes in HR and blood pressure among patients with atrial fibrillation may have affected the precision of the results. Finally, all patients included in this study underwent preoperative pharmacological treatment of cardiac dysfunction, particularly targeting ejection fraction. Patients with lower ejection fraction and without pharmacological intervention may have exhibited different clinical outcomes, warranting further investigation in the future.

Table 3 Comparison of the Doses of Norepinephrine and the Incidences of Hypotension and Bradycardia Among the Four Groups

	Group E	Group A	Group B	Group C	*P*
Hypotension(n,%)	17(33.3)	12(22.6)	16(31.4)	21(38.9)	0.338
Bradycardia(n,%)	9(17.6)	7(13.2)	10(19.6)	6(11.1)	0.603
The dosages of Norepinephrine(μg)	34[5~80]	16[8~40]*	20[8~60]*	40[19~80]	0.037

Notes: *$P < 0.05$ vs group E. The data are presented as the median (interquartile range) for norepinephrine dose, and as n (%) for the incidences of hypotension and bradycardia. Group E, 0.2mg/kg etomidate group. Group A, 0.2mg/kg ciprofol group. Group B, 0.3mg/kg ciprofol group. Group C, 0.4mg/kg ciprofol group.

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Conclusion

Ciprofol can be safely administered for the induction of anesthesia in patients undergoing cardiac surgery. Induction with 0.2 mg/kg ciprofol has the least impact on hemodynamic parameters, resulting in a lower incidence of hypotension and a reduced requirement for norepinephrine to maintain blood pressure.

Data Sharing Statement

The basic data, research plan, and statistical analysis of this study will be will be made available upon reasonable request. Data are available beginning 3 months after online publication and for up to 24 months thereafter. To request data, please contact the corresponding author (Dr. YanHu Xie). Requests must include a methodologically sound proposal, and approval will be at the discretion of the study investigators.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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