Total intravenous versus desflurane-based anesthesia for shunt procedure in pediatric congenital cyanotic heart disease

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Background Congenital cyanotic heart disease (CCHD), inclusive of all types of cyanotic heart disease with resulting hypoxemia and hypoxia, has diverse multisystem effects, including erythrocytosis, hyperviscosity, cholelithiasis, cerebral abscess, vascular dysfunction, and hemoptysis. Most, but not all, patients with CCHD, undergo surgical repair in childhood, resulting in either an elimination or reduction in the degree of hypoxemia and its complications. Systemic-to-pulmonary artery shunt is a necessity as a life-saving procedure that is carried out through placement of extracardiac systemic-to-pulmonary artery shunts, using many procedures such as Blalock–Taussig shunt procedure or its modification [modified Blalock–Taussig shunt (MBTS)], which is commonly used nowadays, modified Blalock–Thomas–Taussig shunt (commonly called the MBTS) is a surgical procedure used to increase pulmonary blood flow for palliation in duct-dependent cyanotic heart defects such as pulmonary atresia, which are common causes of blue baby syndrome. In this procedure, there is temporarily direction of the blood flow to the lungs and relieve cyanosis. Traditionally, these surgical procedures are accomplished by either a total intravenous anesthesia (TIVA) or inhalational-based anesthesia. The TIVA technique achieves hemodynamic stability but has many disadvantages such as increases in the period of mechanical ventilation and its associated complications, and increase in ICU stay. Although inhalational anesthetic-based technique may be associated with myocardial depression and dysarrythmias (up to ventricular arrhythmia), but, due to lower blood solubility, facilitates early awakening and endotracheal extubation; this technique decreases the duration of mechanical ventilation, ICU stay, and, therefore, total hospital stay.

Patients and methods Forty ASA classes III and IV patients between 18 months and 6 years, scheduled for MBTS procedure for repairing CCHD, were to undergo systemic to pulmonary shunt using cardiopulmonary bypass (CPB) after median sternotomy. They were divided into two groups: patients in the TIVA group (n=20) were administered a combination of midazolam–fentanyl–propofol along with neuromuscular blockade, whereas the desflurane group (n=20) was administered desflurane with 0.6–1 MAC in 100% oxygen with a combination of fentanyl with neuromuscular blockade. Hemodynamic parameters [heart rate (HR), mean blood pressure], duration of elective ventilation, incidence of supraventricular tachycardia and ventricular tachycardia/ventricular fibrillation, and level of myocardial injury were detected by cardiac troponin I as a cardiac biomarker for myocardial injury recorded as primary outcome, whereas duration of inotrope use, ICU and hospital stay, and serum creatinine levels were recorded preoperatively, thereafter, at 24 h postoperatively, they were recorded as secondary outcome. Any serious adverse events, such as acute renal injury, or any other major cardiovascular/neurologic events were recorded.

Results Repeated measure analysis was carried out to see the trend in HR from HR1 (at baseline) in both groups, HRs HR2 (just prior to CPB), HR3 (weaning from CPB), and HR4 (arrival at ICU) were significantly higher than HR1 ($P<0.001$). The mean arterial pressures recorded at time intervals where T2 (just prior to CPB) and T4 (arrival at ICU) were found to be significantly lower in patients included in the TIVA than in the desflurane group (P=0.003 and 0.002, respectively), but mean arterial pressure values at T1 (at baseline) and T3 (weaning from CPB) were insignificant in both the groups ($P>0.05$). Duration of mechanical ventilation, ICU stay and hospital stay were lower in the desflurane group compared with the TIVA group ($P<0.005$). While patients in the TIVA group recorded significantly lower inotrope use than those in the desflurane group ($P<0.001$). Likewise, the creatinine values measured at baseline and 24 h postoperatively were compared in both groups and also, inbetween group itself, were only significantly increased in the TIVA group (P=0.018). For cardiac troponin I levels, at T2 there were significantly higher than those at T1 in the TIVA group (P=0.001) when compared to the desflurane group (P=0.836).

Conclusion TIVA has the advantage of hemodynamic stability, but it prolongs the duration of controlled ventilation and length of hospital stay. The current study demonstrated that a desflurane-based anesthetic provides comparable stability, early recovery of myocardial contractility, decreased duration of controlled ventilation, duration of ICU admissions, and total hospital stay.

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Introduction

Congenital cyanotic heart disease (CCHD) was defined as the presence of cyanotic heart disease (CHD) with a history of at least 1 year of chronic

hypoxemia (arterial saturation ≤92%). In many cases, they would be born with this disease because of a genetic factor. An infant is more at risk when there is a family history of congenital heart diseases. Certain genetic syndromes can be accompanied by defects that cause CCHD, and this includes Down syndrome, Tumer syndrome, Marfan syndrome, and Noonan syndrome. In some instances, outside factors, such as exposure of pregnant women to toxic chemicals, can lead to heart defects in their infant; infections during pregnancy are also a factor, and poorly controlled gestational diabetes is also a factor; all of these factors can cause CCHD [1]. Symptoms occur in infancy as a result of high pulmonary blood flow associated with pulmonary hypertension. Failure to thrive, as well as congestive heart failure and frequent pulmonary infections, are invariably seen [2]. If a significant regurgitation of the common atrioventricular valve is present, a systolic cardiac murmur and gallop rhythm are frequently heard. Over time, irreversible pulmonary hypertension develops, improving the signs of congestive heart failure but worsening tolerance to effort. When pulmonary artery resistances become higher than systemic artery resistances, cyanosis develops, further decreasing the exercise capacity [3]. Over time, pulmonary hypertension becomes irreversible, thus precluding the surgical therapy [4]. Medical treatment (digitalis, diuretics, and vasodilators) plays a role only as a bridge toward surgery; medication is usually started between the third and sixth month of life until the time of surgery. Genetic antenatal counseling after the fetal echocardiographic diagnosis of CCHD is mandatory [4].

Aim

The current study aimed to compare the utility of desflurane to total intravenous anesthesia (TIVA) in modified Blalock–Taussig shunt (MBTS) procedure in congenital cyanotic cardiac surgery repair; hemodynamic stability, duration of elective ventilation, incidence of arrhythmias, duration of inotrope used, ICU and hospital stay, and myocardial protective effect were detected by cardiac troponin I (CTnI) as a cardiac biomarker for myocardial injury, and adverse effects as renal affection.

Patients and methods

This prospective, randomized, and double-blind study was conducted at the Cadiothoracic Surgery Department, El-Helmia Military Hospital, Cairo, Egypt. This study was approved by the clinical research Ethics Committee of Anesthesia and Intensive Care Department, Faculty of Medicine, Al-Azhar University, Egypt, and it was also approved by the clinical research Ethics Committee of the Anesthesia Department in El-Helmia Military Hospital, Cairo, Egypt. Enrollment study started in April 2013 and ended in May 2015. Forty ASA classes III and IV patients between 18 months and 6 years, scheduled for MBTS procedure for CCHD, were studied after receiving approval written informed parental consent. Patients requiring support before surgery, or medications that interact with inhalational anesthetics (such as beta-blockers, angiotensin- converting enzyme inhibitors, angiotensin II antagonists, and diuretics), were excluded. Patients were randomly divided by computer-generated and sealed opaque envelopes into two groups: the desflurane group (n=20) and the TIVA group (n=20). Before induction noninvasive blood pressure, oxygen saturation by pulse oximeter and ECG were monitored. All patients undergoing MBTS procedure were to undergo cardiopulmonary bypass (CPB) following median sternotomy. In the TIVA group, patients were administered a combination of midazolam–fentanyl–propofol along with neuromuscular blockade; induction of anesthesia was achieved with100% oxygen, fentanyl 1 μg/kg and propofol 2 mg/kg intravenously, followed by 0.15–0.2 mg/kg cisatracurium besylate to facilitate endotracheal intubation (at the same time induction infusion of propofol was started in another peripheral canulla). However, in desflurane group, induction of anesthesia was achieved with the use of 4–6% sevoflurane in 100% oxygen, 1 μg/kg fentanyl, 0.05 mg/kg midazolam and 0.15–0.2 mg/kg cisatracurium besylate. After induction and endotracheal intubation, femoral arterial canullation and central venous catheters were placed; the technique for maintenance of anesthesia was dictated by sealed envelope randomization into two groups. In the TIVA group, anesthesia was maintained using incremental doses of midazolam–fentanyl administered as needed to control hemodynamic responses for surgical stimulation; midazolam (0.05 mg/kg/h) and fentanyl (2–3 μg/kg/h) were administered intravenously and also added to the venous reservoir of the CPB pump on an hourly basis; intravenous infusion of propofol was administered in a dose range of 50–70 μg/kg/min for all patients in the TIVA group and titrated to maintain mean arterial pressure (MAP). In the desflurane group, anesthesia was maintained with desflurane at 0.6–1 MAC in 100% oxygen, 0.05 mg/kg midazolam, and 1–2 μg/kg fentanyl, and neuromuscular blockade was maintained using timed boluses of cisatracurium 0.03 mg/kg. In both

groups and following intubation, pressure control ventilation was commenced targeted to an end-tidal carbon dioxide level of 30–35 mmHg. Hydration was accomplished with lactated Ringer's infusion, and blood loss was replaced, keeping hematocrit above 35% in all patients. Hemodynamic parameters were maintained within 20% of baseline values. Before initiation of CPB, heparin was administered into a central vein in a dosage of 400 U/kg, to maintain the kaolin-activated clotting time (ACT) above 400 s. The ACT was measured every 30 min during CPB, and, after a reversal of heparin with protamine, magnesium sulfate in the dose of 20–40 mg/kg was administered on CPB at aortic cross-clamp removal. After separation from CPB, protamine sulfate was infused in a dose of 1.3 mg/kg of heparin to antagonize the effects of heparin. An additional dose of protamine 0.2 mg/kg was added in cases wherein the ACT was more than 130 s. At the conclusion of the procedure, both groups were transported to the ICU electively ventilated. On arrival in the ICU, hemodynamic parameters were recorded. Patients in both groups received midazolam intravenously for sedation and paracetamol 15 mg/kg intravenously for analgesia. Sedation was stopped once the patients were hemodynamically stable, and the patients were taken off mechanical ventilation using standard weaning protocols. The starting point to note the duration of elective mechanical ventilation, inotrope use, and ICU and hospital stay commenced from the time the patient arrived in the ICU. Baseline heart rate and MAP (HR1 and MAP1) were recorded before the induction of anesthesia in all patients included in this study. Thereafter, HRs and MAPs were then serially recorded just before institution of CPB (HR2, MAP2), on weaning off CPB (HR3, MAP3), and on arrival in the ICU (HR4, MAP4). Hours of inotrope usage while under anesthesia and postoperatively for 24 h in the ICU was tabulated. Blood samples were drawn from the central venous catheter for measuring CTnI at baseline after induction (T1) and at 12 h (T2) postoperatively. Serum creatinine value was measured at baseline before the induction of anesthesia (T1) and at 24 h (T2) postoperatively. Any serious adverse events, such as stroke, acute renal injury, arrhythmia, or any other major cardiovascular/neurologic events were recorded.

Statistics

Continuous variables were summarized using range and mean±SD. Categorical variables were summarized using frequencies (number of cases) and relative frequencies (percentages). Continuous data were compared using the Wilcoxon signed-rank test. All statistical calculations were carried out using statistical package for the social science (SPSS Inc., Chicago, Illinois, USA), version 18 for Microsoft Windows. Data were compared using the Student *t* test to compare the two groups. If data points were not normally distributed Mann–Whitney, *U* tests were used. Categorical variables between the two groups were tested with χ^2 test or Fisher's exact test was used. Whenever appropriate, for comparison between groups as regards categorical variables, analyses using a one way analysis of variance followed by Tukey's (post-hoc) test for intergroup comparisons, a difference with *P* value less than or equal to 0.05 was considered statistically significant, a difference with *P* value less than or equal to 0.01 was considered moderately significant, and a difference with *P* value less than or equal to 0.001 was considered highly significant; otherwise, it was insignificant.

Results

There were no significant differences between the two groups as regards demographic data, hematocrit value (%), and oxygen saturation ($P>0.05$) (Table 1). The mean duration of postoperative mechanical ventilation was observed to be significantly lower among patients in the desflurane group than among patients included in the TIVA group (25.04±2.33 and 36.07±3.46 h, respectively) ($P<0.001$). Patients in the TIVA group recorded a significantly lower duration of inotrope use (19.51±2.37 h) than those in the desflurane group (27.28±4.09 h) ($P<0.001$). The incidence of arrhythmias such as supraventricular tachycardia and ventricular tachycardia/ventricular fibrillation (VT/VF) were found to be insignificant differences between two groups ($P=0.734\%$ and 0.956%, respectively). Patients in the desflurane group were determined to have significantly lower ICU stay as

Table 1 Comparison between demographic data, hematocrit, and oxygen saturation in two groups

Parameters	Desflurane group (*n*=20)		TIVA group (*n*=20)		*P* value
	Mean	SD	Mean	SD	
Age (month)	60.26	12.18	57.62	16.34	0.081
Weight (kg)	14.79	2.03	16.74	3.97	0.629
Height (cm)	59.62	4.01	53.49	5.01	0.880
Hematocrit %	49.71	9.03	47.92	7.95	0.847
SpO_2 %	92.06	3.01	91.31	3.29	0.792

SpO_2, oxygen saturation; TIVA, total intravenous anesthesia. *P*, Student's independent sample. *t* test values for comparison between the two groups; insignificant at *P* value greater than 0.05, significant at *P* value less than or equal to 0.05, highly significant at *P* less than or equal to 0.001.

Table 2 Comparison of outcome measures in two groups

Parameters	Desflurane group (*n*=20)		TIVA group (*n*=20)		*P* value
	Mean	SD	Mean	SD	
Duration of mechanical ventilation (h)	25.04	2.33	36.07	3.46	0.001
Duration of inotrope use (h)	27.28	4.09	19.51	2.37	0.001
Incidence of SVT (%)	19.01	1.41	17.92	0.87	0.734
Incidence of VT/VF (%)	16.3	0.26	15.1	0.79	0.956
ICU stay (days)	4.71	3.42	5.96	2.16	0.001
Hospital stay (days)	6.30	0.26	8.73	1.05	0.003

SVT, supraventricular tachycardia; TIVA, total intravenous anesthesia; VT/VF, ventricular tachycardia/ventricular fibrillation. *P*, Student's independent sample. *t* test values for comparison between the two groups. Insignificant at *P* value more than 0.05, significant at *P* value less than or equal to 0.05, and highly significant at *P* value less than or equal to 0.001.

Table 3 A comparison of heart rates recorded serially at different time intervals in two groups

Parameters	Desflurane group (*n*=20)		TIVA group (*n*=20)		*P* value
	Mean	SD	Mean	SD	
HR1 (beat/min)	123.61	9.427	127.05	12.083	0.669
HR2	108.14	7.393	105.90	9.157	0.546
HR3	103.44	9.036	107.22	8.312	0.752
HR4	112.43	6.204	110.80	7.604	0.552

HR, heart rate; HR1, HR2, HR3, and HR4, heart rates recorded at baseline, just prior to cardiopulmonary bypass, on weaning off cardiopulmonary bypass, and on arrival at ICU; TIVA, total intravenous anesthesia. *P*, Student's independent sample. *t* test values for comparison between the two groups. Insignificant at *P* value more than 0.05, significant at *P* value less than or equal to 0.05, and highly significant at *P* value less than or equal to 0.001 (SD).

Table 4 A comparison of mean arterial pressure recorded serially at different time intervals in two groups

Parameters	Desflurane group (*n*=20)		TIVA group (*n*=20)		*P* value
	Mean	SD	Mean	SD	
MAP T1 (mmHg)	88.12	7.452	89.15	8.341	0.539
MAP T2	94.75	6.727	80.50	5.292	0.003
MAP T3	91.22	7.020	83.47	4.319	0.002
MAP T4	95.34	8.031	87.23	5.341	0.741

MAP T1, MAP T2, MAP T3, and MAP T4, mean arterial pressure recorded at baseline, just prior to cardiopulmonary bypass, on weaning off cardiopulmonary bypass, and on arrival at ICU; MAP, mean arterial pressure; TIVA, total intravenous anesthesia. *P*, Student's independent sample. *t* test values for comparison between the two groups. Insignificant at *P* value more than 0.05, significant at *P* value less than or equal to 0.05, and highly significant at *P* value less than or equal to 0.001 (SD).

compared with those in the TIVA group (4.71±3.42 and 5.96±2.16 days, respectively) ($P<0.001$). The mean hospital stay was also found to be significantly lower in patients in the desflurane group (6.30±0.26 days) in comparison with the TIVA group (8.73±1.05 days) ($P=0.003$) (Table 2). The mean HRs recorded at time intervals were found to be comparable between both groups. Table 3 lists the mean HRs HR1, HR2, HR3, and HR4 of patients in the desflurane and TIVA groups; in both groups, HRs HR2, HR3, and HR4 were significantly higher than at baseline HR1 ($P<0.001$). However, no difference was elicited when the respective HRs were compared between the two groups ($P>0.05$). The MAPs recorded at time intervals T2 and T3 were found to be significantly higher in patients included in the desflurane group (94.75±6.727 and 91.22±7.020 mmHg, respectively) than in the TIVA group (80.50±5.292 and 83.47±4.319 mmHg, respectively) ($P=0.003$ and 0.002, respectively), whereas the MAP values at T1 and T4 were similar in both the groups ($P>0.05$) (Table 4). There were lower CTnI levels in the desflurane group than in the TIVA group but without significant difference obtained at T1 and T2 ($P=0.318$ and 0.701, respectively), while levels of CTnI obtained at T2 were significantly higher than those at T1 only in the TIVA group ($P=0.001$) but was insignificant in the desflurane group ($P=0.836$) (Table 5). The creatinine values measured at baseline before the induction of anesthesia (T1) and at 24 h (T2) postoperatively were insignificant when comparing the desflurane group (0.415±0.014 and 0.513±0.020 mg/dl) ($P=0.749$) with the TIVA group (0.470±0.026 and 0.621±0.030) ($P=0.318$); for intergroup study, it was insignificant in the desflurane group ($P=0.507$), while it was significantly higher in the TIVA group ($P=0.018$) (Table 6).

Discussion

CCHD is an important group of cardiovascular disorders affecting pediatric patients worldwide [5]. Despite the global tendency toward early diagnosis and treatment of anomalies such as atrial septal defect, aortic coarctation, Epstein's anomaly of the tricuspid valve, and congenitally corrected transposition of the great arteries, these conditions are still frequently diagnosed in adulthood [6]. CCHD refers to a subset of CHD diagnoses that often present soon

Table 5 A comparison of troponin I levels between the two groups

Troponin I (μ/dl)	Desflurane group (*n*=20)		TIVA group (*n*=20)		*P* value
	Mean	SD	Mean	SD	
Troponin I (T1) (μ/dl)	2.0104	0.0259	2.9421	0.0462	0.318
Troponin I (T2)	2.6136	0.0539	3.8301	1.0038	0.701
P value	0.836			0.001	

T1 and T2, cardiac troponin I values recorded at baseline before the induction of anesthesia and at 12 h postoperatively; TIVA, total intravenous anesthesia. *P*, Student's independent sample. *t* test values for comparison between the two groups. Post-hoc test for intergroup comparisons. Insignificant at *P* value more than 0.05, significant at *P* value less than or equal to 0.05, and highly significant at *P* value less than or equal to 0.001.

Table 6 Baseline and 24 h creatinine levels in both groups

Creatinine values (mg/dl)	Desflurane group (*n*=20)		TIVA group (*n*=20)		*P* value
	Mean	SD	Mean	SD	
Preoperative (K1)	0.415	0.014	0.479	0.026	0.701
24 h postoperative (K2)	0.513	0.020	0.621	0.030	0.318
P value	0.507			0.018	

K1 and K2, serum creatinine value recorded at baseline before the induction of anesthesia, and at 24 h postoperatively; TIVA, total intravenous anesthesia. *P*, Student's independent sample. *t* test values for comparison between the two groups. Post-hoc test for intergroup comparisons between T1 and T2. Insignificant at *P* value more than 0.05, significant at *P* value less than or equal to 0.05, highly significant at *P* value less than or equal to 0.001.

after birth with systemic hypoxemia and hypoxia related to impaired pulmonary flow and mixing of pulmonary and systemic venous blood. CCHD comprises ~10% of all CHD cases, or about 0.1% of all live births [7]. A subset of patients with cyanotic defects later develops cyanosis, most commonly due to progressive pulmonary vascular disease and Eisenmenger syndrome [1]. A shunt must be placed between the systemic and pulmonary artery where blood flows to the lungs and thus facilitates oxygenation of the body's tissues. This shunt was first performed by Blalock and Taussig who first described it in 1945 (BT shunt), wherein the shunt is from a systemic artery (e.g. the subclavian or the aorta) to the pulmonary artery (main, right, or left). It was performed in an infant aged 2–3 months [8]. Nowadays, in many studies, it is recommended to delay the procedure until 18 months of age or more [9]. The MBTS involves interposing a Gore-Tex graft between the subclavian or innominate artery and the ipsilateral PA. This shunt is performed with CPB via median sternotomy [10]. Inhalational induction with desflurane is better than intravenous induction, as this technique allows a decrease in pulmonary vascular resistance and systemic vascular resistance [11]. Maintenance of anesthesia with high-dose fentanyl, a muscle relaxant, and a benzodiazepine is most commonly used because of the hemodynamic stability achieved [2]. Opioids provide profound analgesia, attenuation of unwanted visceral responses to surgery, and, in high doses, ablation of stress responses [12]. The opioid technique, however, has disadvantages such as bradycardia, over sedation, and delay in weaning from postoperative mechanical ventilation, which not only predisposes the patient to complications of prolonged mechanical ventilation and ICU stay, but also, due to positive pressure ventilation, causes lower pulmonary blood flow to the surgically created shunts, thereby compromising shunt function [13]. The use of volatile anesthetic agents may be beneficial in terms of shortened duration of mechanical ventilation and ICU stay; moreover, both sevoflurane and desflurane have been found to have cardioprotective effects, which are attributed to 'anesthetic preconditioning,' which protects the heart from ischemic insult frequently encountered during cardiac surgery [14]. Desflurane is an acceptable volatile agent in children undergoing cardiac and noncardiac surgery. Administration up to 1 MAC does not adversely affect hemodynamic parameters, hepatic or renal function in children [15]. Desflurane has the advantage of having lower blood gas and tissue solubility than other volatile agents, allowing for rapid decrease of alveolar concentrations during elimination, thereby facilitating early awakening and extubation and therefore reduced duration of positive pressure ventilation, which is why desflurane is preferred over sevoflurane when early recovery from anesthesia is warranted [16,17]. In this study, it was found that, as regards hemodynamic stability (HR and mean blood pressure), for HR, there were insignificant differences between two groups all over the study, but, for mean blood pressure, it was significantly higher in the

desflurane group at the time just before CBP, and on weaning off CPB compared with the TIVA group, which might have been due to the enhancement effect of opioids with propofol and or higher opioid dose given during some time of the study, achieving more hemodynamic stability in the TIVA group. This study came in disagreement with that carried out by Duncan and colleagues compared different doses of fentanyl (range 2–150 μg/kg) as narcotic-based compared with desflurane-based anesthesia in young children undergoing cardiac surgery, they found that narcotic-based anesthesia provided highly effective greater cardiovascular stability than desflurane based, but it might due to fentanyl, used in dose 25 and 50 μg/kg while in this study dose used was only 1–2 μg/kg.

As regards the duration of inotrope use, it was found to significantly prolong the time in the desflurane group on comparing with the TIVA group – although there is a cardioprotective effect after cardiac preconditioning with desflurane – as inhalational anesthetics (including desflurane) are known to exert negative inotropic effects on the myocardium. In this study, there were no significant differences for the incidence of supraventricular tachycardia and ventricular tachycardia/ventricular fibrillation in both groups, whereas as regards the duration of elective mechanical ventilation, ICU and hospital stay, there was a highly significant shorter time in the desflurane group compared with the TIVA group. That is, it implies that desflurane-based anesthesia allows for early recovery, ex-ventilation, ambulation, avoidance of the hazards of prolonged mechanical ventilation, and hazards of ICU and hospital stay when compared with opioid-based anesthesia. This study came in agreement with study carried out by Delsile *et al.*, who compared TIVA with inhalational-based anesthesia in cyanotic children with atrioventricular septal repair; concern that desflurane caused sympathetically mediated tachycardia was allayed by the absence of such effects in a dose range of 0.5–1.00 MAC, and, also, it was found that there was a significant difference in the duration of inotrope use, which was prolonged in the desflurane group; moreover, there were no differences found in urine output, incidence of arrhythmias, and need for cardioversion between both groups. As regards CTnI values, which were used as a cardiac biomarker indicator for myocardial protective effect, they were measured at the beginning of the study after induction compared with the values obtained 12 h postoperatively. It was elevated significantly in the TIVA group only, which might be due to the more myocardial protective effect of inhalational anesthetic desflurane, as it has been found to have a cardioprotective effect, which is attributed to 'anesthetic preconditioning,' which protects the heart from ischemic insult frequently encountered during cardiac surgery. This study came in agreement with that carried out by Guarracino *et al.* [18] – in spite of different methodology – who evaluated the effects of desflurane-based anesthesia versus TIVA on CTnI release in off-pump coronary artery bypass grafting patients, and they found that myocardial damage could be reduced by desflurane inhalational anesthetics during off-pump coronary artery bypass grafting. However, this study came in disagreement with the study carried out by Kanko *et al.* [19], who studied the cardiac protective effect when comparing narcotic-based versus inhalational-based anesthesia. They used ischemic modified albumin as a cardiac biomarker indicator in coronary bypass surgery and found that there were no differences between both groups, which might be due to the different methodology as, in this study, CTnI was used as a cardiac biomarker indicator, and, also, in this study, the focus was on the CCHD repairer.

In this study, creatinine values were used as an indicator for renal affection, were measured preoperatively compared with that obtained 24 h postoperatively; there was less renal affection with the desflurane group when compared with the TIVA group. There were no statistically significant differences in the desflurane group, either in the intergroup studied or when compared with the TIVA group, whereas in the TIVA group, there were significantly higher creatinine values in the intergroup study, which might be due to the inhalational anesthetic desflurane having very minimal toxic metabolites such as fluorides or compounds that cause renal damage. Also, it was considered that higher mean arterial blood pressure maintaining renal perfusion pressure, and lower opioid need to be excreted. This study came in agreement with that carried out by Karine *et al.* [16] – in spite of the different methodology – who proved preconditioning by desflurane as an inhalational anesthetic rather than opioid-based anesthesia and found decreased renal dysfunction incidence in complete atrioventricular septal defect repair with the desflurane group.

This study came in agreement with the study carried out by Gold and colleagues, comparing inhalational anesthetics and TIVA on 112 children with patent duct arterioles for surgical procedure closure; they found significantly lower ICU and hospital stays, and duration of postoperative mechanical ventilation, as compared with those in the TIVA group. Moreover, the result of this study came in agreement with the study carried out by Landoni and colleagues, wherein desflurane-based anesthesia and TIVA were compared

in 75 patients undergoing CABG surgery. Similar results were found, Turani *et al*. [4] there were significant decrease in the duration of mechanical ventilation, ICU stay, and the total duration of stay in the hospital in the desflurane group.

Although, this study is in agreement with the study published by Malhotra *et al*. [20], the effects of desflurane (0.15–0.5 MAC) versus opioid anesthesia for cardiac shunt procedures in infants with cyanotic congenital heart disease were compared. Inhalational anesthesia with desflurane was proven to reduce the duration of elective ventilation and decrease ICU and hospital stay, but it was in disagreement with evidence that no difference was found between both groups in terms of duration of inotrope use; this may be because, in this study, desflurane was used in higher MAC (0.5–1 MAC).

Conclusion

Desflurane-based anesthesia is considered a better alternative anesthetic regimen in cases of TIVA, although TIVA provides more hemodynamic stability just before CPB and on arrival to ICU; however, desflurane-based anesthesia decreases duration of elective mechanical ventilation, duration of ICU admission, and total hospital stay and caused less myocardial cell injury when compared with intravenous anesthesia regimen.

Limitation of the study

To assess the effect of desflurane-based anesthesia versus TIVA on kidney function, more studies are needed using different new renal biomarkers.

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Conflicts of interest

There are no conflicts of interest.

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