

**Original
Article**

Comparison of Fast-Track and Conventional Anesthesia for Transthoracic Closure of Ventricular Septal Defects in Pediatric Patients

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Background: To compare and analyze the safety and efficacy of fast-track and conventional anesthesia for transthoracic closure of ventricular septal defects (VSDs) in pediatric patients.

Methods: A total of 82 pediatric patients undergoing transthoracic closure of VSDs between September and December 2017 were retrospectively analyzed. The patients were divided into two groups, including 42 patients in group F (fast-track anesthesia) and 40 patients in group C (conventional anesthesia). The perioperative clinical data of both groups were collected and statistically analyzed.

Results: There were no fatal complications in both groups. No complete atrioventricular block (AVB), new aortic valve regurgitation, and device closure failure were observed. No significant difference was found in preoperative general data or intraoperative hemodynamic changes between the two groups ($P > 0.05$). However, the mechanical ventilation time, length of postoperative intensive care unit (ICU) stay, length of hospital stay, and hospitalization expenses of group F were significantly lower than those of group C ($P < 0.05$).

Conclusion: It is safe and effective to use fast-track anesthesia for transthoracic closure of VSDs in pediatric patients.

Keywords: fast-track anesthesia, CHD, septal defects, cardiac intervention

Introduction

Transthoracic device closure of ventricular septal defects (VSDs) has become a popular clinical operation

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in the recent years, especially in China.^{1–4} This procedure is associated with faster recovery, fewer complications, and a shortened hospital stay and, therefore, has greater requirements for anesthesia. Fast-track cardiac anesthesia (FTCA) involves choosing the appropriate anesthetic methods and anesthetics for immediate or early tracheal extubation (within 6 h after the operation), decreased lengths of intensive care unit (ICU) and hospital stays, and eventually less medical costs for the patients.^{5–7} Fast-track anesthesia has been shown to be feasible and safe for pediatric heart surgery in many studies. However, few reports have examined the application of fast-track anesthesia for transthoracic closure of VSDs. In this study, we retrospectively analyzed the application of fast-track anesthesia for transthoracic closure of VSDs in our hospital and compared the postoperative condition of

Table 1 Comparison of clinical data in both groups

	Group F	Group C	P value
Number of patients	42	40	
Age (years)	3.31 ± 1.52	3.12 ± 1.72	0.870
Body weight (kg)	13.53 ± 5.78	12.87 ± 5.29	0.906
VSD size (mm)	5.03 ± 0.98	5.23 ± 1.45	0.620
Occluder size (mm)	6.54 ± 1.13	6.62 ± 1.20	0.936

VSD: ventricular septal defect

patients who received fast-track anesthesia and conventional anesthesia to evaluate the safety and efficacy of fast-track anesthesia.

Data and Methods

The present study was approved by the ethics committee of our university and adhered to the Declaration of Helsinki. In addition, written informed consent was obtained from the patient's parents.

Clinical data

A total of 82 pediatric patients undergoing transthoracic closure of VSD between September and December 2017 in our hospital were retrospectively analyzed. The patients were divided into two groups according to the types of anesthesia, including 42 patients in group F (fast-track anesthesia) and 40 patients in group C (conventional anesthesia). All the patients were diagnosed as perimembranous VSD without any other cardiac deformities. No preoperative complications and anesthetic contraindications were found in routine examination. Relevant clinical preoperative data of both groups were collected in **Table 1**.

The inclusion criteria and exclusion criteria for transthoracic device closure of VSD were the same as those previous reports.¹⁻⁴⁾ The indications included transthoracic echocardiography (TTE) evidence of significant left to right shunts and isolated VSD, the size of the VSD ranged from 3 to 6 mm, and/or heart chamber enlargement, and/or mild pulmonary hypertension despite medical therapy. Exclusion criteria included misaligned and nonrestrictive VSD with high pulmonary hypertension, the size of the VSD was larger than 6 mm or smaller than 2 mm, age below 1 year, especially with large VSD, combined with other cardiac malformations. We also excluded those patients who refused to sign the informed consent form and accept such procedure.

Fast-track anesthesia group

Pediatric patients underwent routine preoperative fasting and were injected with ketamine (5 mg/kg) intramuscularly before entering the operating room for sedation. After entering the operation room, electrocardiogram (ECG) traces and peripheral oxygen saturation were monitored. A 5% glucose solution was infused intravenously, and arterial blood pressure was monitored through radial artery puncture. Anesthesia induction consisted of intravenous (IV) injection of 1.5 µg/kg remifentanyl and 0.5 mg/kg cisatracurium besylate. After muscle relaxation, lidocaine gel was applied to the front of the tracheal tube, and mechanical ventilation was started after intubation. The ventilation mode was set to the pressure control mode, and the end-tidal carbon dioxide partial pressure was monitored. The central venous pressure was monitored through subclavian vein puncture. Body temperature was monitored via the nasopharyngeal temperature and maintained at greater than 36.5 °C. Arterial blood gas was analyzed to determine the ventilation condition and the condition of the internal environment. Anesthesia was maintained by IV infusion of 0.8 µg/kg/min remifentanyl and inhalation of 2–3% sevoflurane. After closing the sternum, 0.375% ropivacaine was applied to the incision and sternal membrane for local infiltration anesthesia.

Conventional anesthesia group

Prior to anesthesia induction, patients in group C were treated in the same manner as those in group F. Anesthesia induction was performed by IV injection of 1 µg/kg sufentanil and 0.5 mg/kg cisatracurium besylate. Anesthesia was maintained by continuous IV infusion of 0.2 µg/kg/min sufentanil and inhalation of 2–3% sevoflurane. The doses of the two anesthetics were adjusted according to the depth of anesthesia.

Surgical procedure

Patients were placed in the supine position, and a transesophageal echocardiography (TEE) probe was

Table 2 Comparison of interoperative hemodynamic data in both groups during the procedure

	Group F	Group C	P value
Anesthesia induction			
CVP (mmH ₂ O)	6.21 ± 0.75	6.10 ± 1.02	0.692
MAP (mmHg)	86.66 ± 9.42	87.25 ± 8.33	0.821
HR (beats/min)	105.23 ± 12.25	98.64 ± 11.34	0.843
After intubation			
CVP (mmH ₂ O)	6.10 ± 0.86	5.98 ± 0.95	0.895
MAP (mmHg)	87.56 ± 9.65	88.89 ± 8.25	0.836
HR (beats/min)	110.43 ± 13.36	95.67 ± 12.87	0.904
Skin incision			
CVP (mmH ₂ O)	6.24 ± 1.01	6.11 ± 1.25	0.780
MAP (mmHg)	96.74 ± 10.13	98.68 ± 11.51	0.859
HR (beats/min)	121.43 ± 15.42	125.41 ± 13.44	0.856
Occluder release			
CVP (mmH ₂ O)	6.32 ± 1.08	6.23 ± 1.17	0.915
MAP (mmHg)	90.43 ± 10.23	92.15 ± 9.69	0.943
HR (beats/min)	118.56 ± 16.27	121.70 ± 14.79	0.899
After procedure			
CVP (mmH ₂ O)	6.36 ± 1.19	6.29 ± 1.07	0.888
MAP (mmHg)	91.16 ± 9.13	93.25 ± 10.61	0.843
HR (beats/min)	120.26 ± 17.81	118.86 ± 16.59	0.925

CVP: central venous pressure; MAP: mean arterial pressure; HR: heart rate

Table 3 Comparison of interoperative and postoperative clinical data in both groups

	Group F	Group C	P value
Operative time (minutes)	36.14 ± 3.35	35.33 ± 4.96	0.619
Mechanical ventilation time (h)	1.26 ± 0.39	4.55 ± 2.74	0.045
Intensive care time (h)	4.67 ± 1.42	11.18 ± 5.98	0.034
Hospital stay (days)	2.04 ± 0.75	4.68 ± 1.46	0.047
Medical cost (Ten thousand RMB)	2.59 ± 0.47	3.84 ± 1.63	0.049

RMB: renminbi (China's currency)

introduced. The chest was exposed by a 2–3 cm incision at the inferior sternum. Pericardiotomy was performed to expose the free wall of the right ventricle, and 1 mg/kg heparin was administered by IV injection. The puncture site was confirmed under TEE guidance. A purse-string suture was placed at the site, and the free wall of the right ventricle was punctured. A delivery pathway consisting of the right ventricle-VSD-left ventricle was established under TEE guidance. The occluder was delivered and placed under TEE guidance. No obvious residual shunt or aortic valve regurgitation was identified. Absence of conduction block was verified via the ECG. The delivery device was released, and the incision was closed. Patients were monitored in the ICU after the procedure.

The hemodynamic indices including heart rate, blood pressure, and central venous pressure prior to anesthesia induction, after intubation, skin incision, occluder release, and after procedure were recorded in both groups and are shown in **Table 2**. The operative

time, duration of mechanical ventilation, length of the postoperative ICU stay, length of hospital stay, and hospitalization expenses were recorded and are shown in **Table 3**.

Statistical analysis

The continuous data were all in accordance with normal distribution by normal test and were statistically analyzed by independent sample t-test. Chi-square test was used to compare the number of postoperative complications between the two groups. A P value less than 0.05 was defined as statistically significant.

Results

The procedure was successful in all patients. **Table 1** shows that the preoperative clinical data of the two groups of pediatric patients were not significantly different ($P > 0.05$). **Table 2** shows that the hemodynamic

indices of the two groups were not significantly different prior to anesthesia induction, after intubation, during the skin incision, during occluder release, and after procedure ($P > 0.05$). **Table 3** shows that the operation time of both groups was not significantly different. However, the duration of mechanical ventilation, length of the postoperative ICU stay, length of hospital stay, and hospitalization expenses were significantly reduced in group F compared to those of group C ($P < 0.05$).

There were no fatal complications in both groups. Minor complications were occurred in some patients, such as perioperative transient arrhythmias in other nine patients, for whom drug treatment was not required. No complete atrioventricular block (AVB), newly aortic or tricuspid valve regurgitation, occluder detachment, hemolysis, or thrombosis were observed in perioperative period. In addition, the incidences of postoperative pulmonary infection were significantly reduced in group F (1/42, 2%) compared to group C (6/40, 15%) ($P < 0.05$), and the incidences of postoperative bronchospasm were also significantly reduced in group F (0/42, 0%) compared to group C (4/40, 10%) ($P < 0.05$). There were no delayed complete AVB and newly aortic valve regurgitation during the 3-month follow-up period. Also there were no anesthesia-related complications.

Discussion

VSD is one of the most common congenital heart defects.^{8,9)} The traditional repair of VSDs by cardiopulmonary bypass is safe, reliable, effective, and widely applicable. However, this technique introduces substantial trauma and results in high incidences of postoperative complications and a long recovery time.^{10,11)} Although transcatheter device closure of VSD causes less trauma, is effective, and is associated with a fast recovery, the technique is difficult to perform, requires expensive equipment, and introduces X-ray exposure.^{12,13)} Recently, transthoracic device closure of VSD has been used clinically. This technique has the advantages of minimal trauma, rapid recovery, simple operation, safety, and wide indications.¹⁻⁴⁾ Due to the development of this technique, the corresponding rapid recovery after anesthesia is needed. FTCA results in stable perioperative hemodynamics in patients. Additionally, FTCA also leads to early tracheal extubation, reduced postoperative complications, decreased lengths of postoperative ICU and hospital stays, and decreased hospitalization expenses; therefore, limited medical resources are more rationally applied.^{14,15)}

Meissner et al. monitored the cardiac index, stroke volume index, systemic vascular resistance index, and extravascular lung water index during open-heart surgery for congenital heart disease under fast-track anesthesia in pediatric patients.¹⁶⁾ They concluded that fast-track anesthesia in pediatric patients with congenital heart disease promotes early, safe extubation, which shortens the mechanical ventilation time and reduces pulmonary complications. Groesdonk et al. performed follow-up evaluations of patients who underwent FTCA in their heart center and found that use of ultra-short-acting opioids did not cause intraoperative awareness, indicating that fast-track anesthesia is safe and effective.¹⁷⁾ In a study of 613 pediatric patients with congenital heart disease, they found that 89% of the patients underwent fast-track anesthesia and that early extubation could reduce postoperative complications and the lengths of the postoperative ICU and hospital stays.

Selection of appropriate fast-track anesthetics not only accomplishes the goal of the surgery and effectively prevents or alleviates adverse reactions induced by all types of stimulations but also results in early extubation. The core principle of fast-track anesthesia is to reduce the use of opioids or to use short-acting opioids combined with other short-acting sedative analgesics or anesthetic techniques for balanced anesthesia. In this study, the procedure only lasted about 30–50 minutes, making it necessary to apply FTCA for faster recovery. Cisatracurium besylate is a fast-acting muscle relaxant that does not induce secretion of histamine, resulting in a stable hemodynamic condition. Sevoflurane is colorless, transparent, and releases a non-pungent aroma. It has low blood gas solubility and can be cleared rapidly. It is easy to manipulate and induces a rapid recovery as well as a myocardial protective effect. Remifentanyl is a short-acting opioid receptor agonist. It acts rapidly, and spontaneous breathing is recovered within 3–5 min of stopping the infusion. And it has a short half-life and does not change as a result of changes in infusion time and age.^{18,19)} However, sufentanil is a highly lipophilic opioid and has a high plasma protein binding rate. It has an elimination half-life of approximately 150 min and acts rapidly with a strong analgesic effect. It has a subtle effect on the cardiovascular system and hemodynamics. In this study, the perioperative hemodynamic indices remained stable in both groups, and no significant difference was detected between these groups.

Compared to sufentanil, remifentanyl, which was used in group F, is eliminated rapidly due to a short elimination

half-life.²⁰⁾ As a result, the duration of mechanical ventilation, length of the postoperative ICU stay, length of the hospital stay, hospitalization expenses, and incidence of complications were significantly reduced in group F compared to those of group C.^{5,21)} It is worth noting that, due to the gradual elimination and reduced plasma concentration, remifentanyl was unable to effectively suppress stress responses during extubation and the postoperative period. Therefore, after closing the sternum, 0.375% ropivacaine was applied to the incision and sternal membrane for local infiltration anesthesia,²²⁾ and lidocaine gel was applied to the tracheal tube to reduce the stimulation of the airway, resulting in an efficiently reduced body stress response after surgery. Postoperative analgesia in children was not routinely used, which did not affect the patient's hemodynamics.

Pulmonary complications are common after surgery for congenital heart disease and increase the length of hospital stay, hospitalization expenses, and mortality. Previous studies have shown that pulmonary complications are closely associated with the indwelling tracheal tube time.²³⁾ In this study, the most common pulmonary complication was pulmonary infection and bronchospasm. Prolonged tracheal intubation not only leads to increased incidences of pulmonary infection but also results in discomfort to the pediatric patients, which negatively impacts the stability of the circulatory system. Therefore, early extubation is important to promote recovery of the heart and lung functions of patients. One outstanding advantage of fast-track anesthesia is that it allows early postoperative extubation; therefore, it reduces the adverse impacts of prolonged tracheal intubation, such as stimulation of the airway, tracheal mucosa damage, airway obstruction by secretions, tube displacement, and pulmonary infection. In this study, we found that the incidence of pulmonary infection in group F was significantly lower than that of group C. However, other postoperative complications including death, complete AVB, occluder detachment, aortic valve regurgitation, atrioventricular valve regurgitation, hemolysis, and thrombosis were not significantly different between the two groups, indicating that these complications are not associated with the selection of anesthetics.

Compared to conventional anesthesia, FTCA has obvious advantages for transthoracic closure of VSDs. However, it is worth noting that a comprehensive assessment of the perioperative status of pediatric patients should be performed to determine whether the use of fast-track anesthesia is appropriate. As our previous paper reported, the transthoracic method is easier to establish the delivery

track than the percutaneous method, the indications for this method are larger. There are a subset of patients who are suited to transthoracic method and not to percutaneous method but often the operative time of these part of patients will be longer. So, we chose to exclude this part of cases. Except for the surgical factors, the application of fast-track anesthesia is based on the age, weight, and health status of the patient.²⁴⁾ Fast-track anesthesia is also not suitable for patients who have other cardiac malformations requiring correction, liver and kidney dysfunction, severe pulmonary hypertension, and severe preoperative pulmonary infection.

Our study is a retrospective study and not a prospective randomized control study. The choice of cases and different anesthetic techniques is based on the decisions and experiences of the operators and anesthesiologists. Although some selective offset was found, our results largely support our conclusion. In addition, bispectralindex was not routinely used in this study, which may affect the evaluation of the depth of anesthesia. In the future, we hope to complete multicenter randomized controlled studies, as well as long-term follow-up, to determine the efficacy and safety of fast-track anesthesia using in transthoracic closure of VSDs in pediatric patients.

Conclusion

Application of remifentanyl-based fast-track anesthesia is as safe and effective as conventional anesthesia for transthoracic closure of VSDs. Fast-track anesthesia substantially reduces the extubation time, duration of mechanical ventilation, length of the postoperative ICU stay, length of the hospital stay, and hospitalization expenses and improves utilization of medical resources. Its clinical application value is high, and it is therefore worth promoting.

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Disclosure Statement

The authors declare that they have no competing interests.

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