International Journal of Case Studies in Clinical Research

Review Article ISSN 2572-102X

Analysis of pulmonary function after ultra-fast track (UFT) cardiac surgery

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Abstract

Objective

To investigate the effect of cardiac surgery under ultra-fast-track anesthesia on postoperative pulmonary function in children with congenital heart disease and its clinical analysis. Methods: From March 2015 to June 2016, 318 patients with congenital heart disease underwent cardiac surgeries by cardiopulmonary bypass(CPB) under ultra-fast-track anesthesia in our hospital were selected as the experimental group. Meanwhile, patients in the control group were 321 cases from January 2013 to February 2015. Patients in both groups were assessed for post-anesthesia score with Steward recovery score after operation. Simultaneously, carbon dioxide partial pressure($PaCO_2$), oxygen partial pressure(PaO_2) and arterial oxygen saturation(SaO_2) were monitored and oxygenation index(OI) was calculated in patients returned to ICU after operation, within 5min, 2h, 6h and 12h postoperatively.

Results

The $PaCO_2$ and OI of the experimental group were higher than the control group in patients returned to ICU within 5min after operation ($P<0.05$). There was no significant difference in PaO_2 and SaO_2 ($P>0.05$). Furthermore, no statistical difference was found in $PaCO_2$ between the two groups 2h and 6h postoperatively ($P>0.05$), however, the OI of the experimental group was still higher than the control group ($P<0.05$). In addition, there was no difference in $PaCO_2$, PaO_2, SaO_2 and OI between the two groups 12h after operation. Using Steward recovery score, the $PaCO_2$ in children with Steward recovery score < 4 points within 5min after operation in the experimental group was higher than that in other patients in the same group, suggesting that the high $PaCO_2$ after surgery under ultra-fast-track anesthesia may be attributed to the incomplete recovery of anesthesia.

Conclusion

cardiac surgery under ultra-fast-track anesthesia can achieve recovery of anesthesia 2h after operation and good pulmonary function. Besides, it has absolute advantages in reducing ventilator-associated pneumonia and shortening length of stay in ICU and hospital, which is worth for application in clinical experience.

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Citation: Li Xiuhong 2019. Analysis of pulmonary function after ultra-fast track (UFT) cardiac surgery. Int J clinical & case. 3-1, 08-12

Received: December 18,2018

Accepted: December 28,2018

Published: February 07, 2019

Note: Sanming Project of Medicine in ShenZhen (SZSM201612003)

The cardiac surgery under ultra-fast-track anesthesia is such an operation applying analgesics, inhalation of anesthetic gases, α2 adrenergic receptor agonists and postoperative analgesia were used in cardiac surgery for congenital heart disease in children. The procedure is designed to achieve extubation in the operating room with ultra-fast-track anesthesia, and reduce postoperative respirator support[1]. Since March 2015, our hospital began to carry out congenital heart disease surgery under ultra-fast-track anesthesia, with no serious complications, accompanied by decreased incidence of ventilator-associated pneumonia, shortened the length of stay(LOS) in intensive care unit (ICU), reduced hospitalization costs, and achieving good results eventually. At present, there are few studies on cardiac surgery under ultra-fast-track anesthesia in China. Our staff found that children with cardiac surgery under ultra-fast-track anesthesia were more prone to CO_2 retention. Therefore, via a retrospective case-control study of pulmonary function before and after cardiac surgery under ultra-fast-track anesthesia in our hospital, the present study is carried out to explore the effect of cardiac surgery under ultra-fast-track anesthesia on pulmonary function of children, so as to provide evidence-based basis for pulmonary function of the above surgical procedure.

This study retrospectively analyzed 318 cases with CPB under ultra-fast-track anesthesia for congenital heart disease from March 2015 to June 2016. And 321 cases of patients underwent traditional anesthesia from January 2013 to February 2015. The data of $PaCO_2$, PO_2 and SaO_2 in arterial blood gas were analyzed within 5min, 2h, 6h and 12h after operation, and the OI (PO_2/FiO_2 of arterial blood) was calculated for control study to evaluate the effect of cardiac surgery under ultra-fast-track anesthesia on pulmonary function in children. The report is as follows:

Materials and Methods

Clinical data and grouping

The objects of study were 641 children underwent surgery of congenital heart disease in our hospital from January 2013 to June 2016. Inclusion criteria: ① patients with the age of 0~10 years old, preoperative diagnosis of congenital heart disease, and undergoing cardiac surgery with CPB; ② patients with no airway stenosis or pulmonary infection before operation[2], no history of ventilator therapy, no exudation and pleural effusion in the lungs; ③ patients with radical resection as the operative outcome; ④ patients with extubate after operation without reintubation. From March 2015 to June 2016, 318 patients with congenital heart disease underwent cardiac surgery under ultra-fast-track anesthesia in our hospital were selected as the experimental group. All children were extubated in the operating room and returned to ICU with nasal oxygen (1~2L/min). Meanwhile, patients in the control group were 321 cases of congenital heart disease underwent traditional anesthesia from January 2013 to February 2015. The children in the control group were intubation and underwent ventilator-assisted breathing, with the initial FiO_2 of 100%, followed by adjustment according to the results of blood gas analysis. Children in this group were extubated within 12hours after operation and nasal oxygen (1~2L/min)was given. In this study, in view of the 320 children of the experimental group, two of them were excluded due to the performance of noninvasive positive pressure ventilation (CPAP) owing to that $PaCO_2$ were higher than 85mmHg within 5min after operation. Finally, 318 cases in the experimental group were included in the statistical analysis.

Basic information and diagnosis information of the two groups: there were 318 patients in the experimental group (170 males and 148 females), with the age of 16h~3y (mean age of 1.3y), including 5 newborns, average age in days of 15.6 (16h~25)d; 164 children <1 year old, average age in months of 7.1 (1~12)M; 149 children >1 years old, average age of 2.7 (1~3) years old; median body weight of 8.9kg; CPB time of (62.8±16.6)min; and aortic cross-clamping time of (33.7±13.6) min. In the control group, there were 321 cases (171 males and 150 females), with the age of 25D-3y (mean age of 1.6y), including 5 newborns, average age in days of 27 (25~28)d; 175 children <1 year old, average age in months of 7.3 (1~12)M; 143 children >1 years old, average age of 2.5 (1~3) years old; median body weight of 9.2kg; CPB time of (66.7±14.4)min; and aortic cross-clamping time of (35.5±15.3) min. As shown in **Table 1**, there was no significant statistical difference in postoperative diagnosis and clinical data between the two groups.

Diagnosis	Control group (n=321)	Experimental group (n=318)
ASD	53	52
VSD	214	211
PS	7	5
AVSD	8	9
TOF	18	16
COA	5	6
DORV	5	7
TGA/VSD	1	2
Others	3	4

Table 1: The distribution of postoperative diagnostic results in two groups of children

Note: ASD: atrial septal defect, VSD: ventricular septal defect, PS: pulmonary stenosis, AVSD: atrioventricular septal defect, TAPVC+PAPVC: anomalous pulmonary venous connection, TOF: Tetralogy of Fallot, COA: coarctation of the aorta, DORV: double outlet of right ventricle, TGA/VSD: transposition of great arteries in ventricular septal defect.

Research method

Cardiac surgery with CPB were conducted in two groups of children by the same group of physician under anesthesia by the same group of anesthesiologist, and patients were delivered to the ICU after operation. Sedation and analgesia were carried out by dexmedetomidine and midazolam, besides, dopamine, milrinone and epinephrine were provided via central venous catheter in a continuous micropump infusion. Patients in both groups were assessed for post-anesthesia with Steward recovery score by the designated nurse after operation[3]. The score was from three dimensions: wakefulness, airway patency and limb mobility. The score of each dimension was 0-2 points, and it indicated that the children were well awake when the score ≥4.

Research tool

(1) Clinical data collection Excel table was drawn to collect clinical data children in the two groups, including sex, age, weight, preoperative diagnosis, surgical methods, CPB time, aortic cross-clamping time, $PaCO_2$, PaO_2, SaO_2 and OI (PaO_2/FiO_2) in arterial blood gas analysis [oxygen concentration (FiO_2) in the experimental group calculated as 0.21+0.04*L][4], the FiO_2 during mechanical ventilation, LOS in ICU (h), LOS in hospital (d), complications of atelectasis, and pneumothorax.

(2) Selection of experimental instruments Using the existing blood gas analyzer (model: GM3000) in the department, the arterial blood of the two groups was collected within 5min, 2h, 6h and 12h after operation, and the bedside blood gas analysis was performed at the same time.

Effect assessment

Primary outcome

PaCO2, PaO2, SaO2 and OI were recorded in arterial blood gas analysis within 5min, 2h, 6h and 12h after operation.

Secondary outcome

Postoperative atelectasis, pneumothorax incidence, LOS in ICU and LOS in hospital were recorded and analyzed in two groups.

Statistical methods

The data were analyzed and processed by SPSS 18 statistical software. Measurement data were expressed as (x±S) and compared with t test. Categorical data were expressed in cases and percentages, and were compared with x2. $P<0.05$ meant that the difference was statistically significant.

Results

Comparison of arterial blood gas analysis between groups

The results of arterial blood gas analysis within 5min after operation were compared between the two groups. During pulmonary ventilation in arterial blood gas analysis, PaCO2 and OI was higher in the experimental group than in the control group, with statistical difference ($P<0.05$), while there was no statistical difference in the comparison of PaO2 and SaO2 ($P>0.05$). Furthermore, no significant difference in PaCO2, PaO2 and SaO2 was found between the two groups at 2h and 6h after operation, but the OI was higher than the control group, showing statistical difference ($P<0.05$). In addition, 12h after operation, there was no obvious difference in the comparison of PaCO2, PaO2, SaO2, and OI between the two groups ($P>0.05$). **(Table 2)**

Indexes	Groups	Postoperative 5min	Postoperative 2h	Postoperative 6h	Postoperative 12h
PaCO2	Experimental group	53.43±9.61	42.32±3.92	40.46±4.81	40.39±3.81
	Control group	38.52±5.26	40.11±5.36	39.68±6.08	40.65±5.03
	P value	0.002	0.003	0.073	0.462
PaO2	Experimental group	116.2±29.8	119.63±34.7	100.3±34.7	111.5±31.16
	Control group	111.3±33.4	120.26±32.78	110.6±30.38	109.7±22.97
	P value	0.451	0.814	0.531	0.406
SaO2	Experimental group	98.5±2.5	97.8±3.7	96.3±3.7	97.2±2.8
	Control group	96.8±3.2	96.1±3.9	97.1±2.9	96.5±4.5
	P value	0.064	0.277	0.242	0.119
FiO2	Experimental group	0.29±0.04	0.29±0.04	0.29±0.04	0.29±0.04
	Control group	0.6±1.0	0.6±0.1	0.5±0.1	0.29±0.04
	P value	0.013	0.026	0.031	1
OI	Experimental group	386.67±50.4	396.67±48.3	361.24±43.9	337.33±39.9
	Control group	112.36±42.3	163.77±38.1	220±40.2	331.67±41.2
	P value	<0.001	0.017	0.025	0.078

Table 2: Comparison of arterial blood gas analysis in two groups of children at different time points X±S)

There were significant difference between the two groups in the LOS in ICU and hospital, indicating statistical significance ($P<0.05$)

The basic data of the two groups were comparable in this study. The PaCO2 in the experimental group was higher than the control group within 5min after operation, with statistical difference ($P<0.05$). Of the 318 cases in the experimental group, 142 cases PaCO2>44mmHg, but all less than 55 mmHg. About half of the children had the level of PaCO2 above normal value of (33~44mmHg)[5]. These children were then evaluated by Steward recovery score were <4 points, which showed that high PaCO2 was related to the lack of consciousness after anesthesia. There was statistical difference that the OI was higher in the experimental group than the control group within 5min after operation ($P<0.05$). PaO2 and SaO2 equaled basically that of the control group, without statistical difference. Furthermore, there was no statistical difference in PaCO2, PaO2 and SaO2 between the two groups 2h and 6h after operation ($P>0.05$), besides, statistical difference was also observed in OI when compared with the control group ($P<0.05$). Next, 12h after operation, ventilator was removed in the control group and changed to oxygen inhalation through nasal catheter (1~2L/min). After the withdrawal, reexamination based on blood gas analysis showed that there was no difference in PaCO2, PaO2, SaO2 and OI compared to those in the control group ($P>0.05$).

In this study, the incidence of atelectasis was 0.63% and 1.56% in the experimental group and the control group, and the incidence of pneumothorax was 0.94% and 2.18%, respectively. No significant difference was detected in the incidence of atelectasis and pneumothorax between the operation under ultra-fast-track anesthesia group and the traditional operation group ($P>0.05$). However, the number of cases was still superior to that of traditional operation group, which may be related to less sample size (Table 3).

The duration of stay in the ICU and days of hospitalization in the operation under ultra-fast-track anesthesia group were remarkably shorter than those in the traditional operation group, and the difference was statistically significant ($P<0.05$ or $P<0.01$) **(Table 4)**.

Groups	Cases	Atelectasis (case/ proportion%)	Pneumothorax (case/ proportion%)
Experimental group	318	2/0.63	3/0.94
Control group	321	5/1.56	7/2.18
P value		0.451	0.340

Table 3: Comparison of atelectasis and pneumothorax in two groups of children
There were no differences in atelectasis and pneumothorax between this two groups ($P<0.05$)

LOS in ICU (h)	33.5±10.87	64.7±28.34	18.3410	0.033
LOS in hospital (d)	8.3±1.56	12.6±1.97	30.5700	0.028

Table 4: Comparison of LOS in ICU and hospital
There were significant difference between the two groups in the LOS in ICU and hospital, indicating statistical significance ($P<0.05$)

Discussion

The ultra-fast-track anesthesia refers to that the spontaneous ventilation of the patient was resumed in a short time after operation and extubated in the operating room. Ultra-fast-track anesthesia was one of the important steps of fast-track rehabilitation surgery, which can reduce the incidence of postoperative complications and improve the utilization rate of medical resources[6]. Cardiac surgery under ultra-fast-track anesthesia plays an active role in improving pulmonary function. Early recovery of spontaneous breathing after operation in this procedure can effectively reduce complications such as atelectasis, pneumothorax and pulmonary infection, and then improve intrapulmonary blood shunt in children, which is conducive to early recovery of children, which is especially critical for children with imperfect physical development[7].

The purpose of this study was to evaluate the difference between the pulmonary function related indicators of children after cardiac surgery under ultra-fast-track anesthesia and traditional cardiac surgery, so as to further optimize the monitoring program after cardiac surgery under ultra-fast-track anesthesia.

It is worth noting that according to the Steward recovery score, the $PaCO_2$ in children with scores <4 points within 5min after operation in the experimental group was higher than that of other children in the same group, suggesting that the cause of high partial pressure of carbon dioxide in children underwent cardiac surgery under ultra-fast-track anesthesia may be associated with incomplete anaesthesia and resuscitation. In this study, as for two children excluded in the experimental group within their first month of cardiac surgery under ultra-fast-track anesthesia in our hospital, the level of $PaCO_2$ via blood gas analysis was higher than 85 mmHg within 5min after operation, and the two cases were provided with noninvasive positive pressure ventilation. Two hours after noninvasive positive pressure ventilation, the two patients were scored to have the Steward recovery score ≥4 points, followed by successful removal of noninvasive positive pressure ventilation and replacement of oxygen inhalation through nasal catheter (1~2L/min). The two patients were monitored to have no other complications and discharged from the hospital after rehabilitation. With the improvement of ultra-fast-track anesthesia and post-operative resuscitation techniques, such incidents did not occur again, but the $PaCO_2$ in children with ultra-fast-track anesthesia after operation was still slightly higher than that in normal population. Therefore, it was necessary to monitor blood gas analysis of children in the early stage after operation closely, correctly evaluate the recovery of children, check the status of CO_2 retention, provide good preparing for active rescue, prepare first aid items and medicines such as ventilator, naloxone, so as to ensure the safety of children after operation. The two groups of children who participated in this study were all recovered and discharged from hospital. After discharging, the effect of operation was followed up to be satisfied without the occurrence of complications. However, the two groups of comparative data selected in this study were in two different time periods, there may be some limitations in this study owing to the improvement of surgical methods, the maturity of anesthesia technology and post-operative monitoring methods over time.

In accordance with the analysis on hospitalization data of children with congenital ventricular septal defect in different areas by Jiang Ying et al. [8], it was concluded that the condition of children with congenital ventricular septal defect in urban areas is relatively critical in recent decades and should be paid attention to in clinical practice. Children in rural areas have benefited from the policy of serious illness medical insurance, and there is an increased trend in the number of active diagnosis and treatment year by year[8] The number of visits for various congenital heart diseases is increasing year by year accordingly. With the improvement of anesthesia technique, surgical procedures and post-operative monitoring techniques, the safety and effectiveness of cardiac surgery under ultra-fast-track anesthesia are effectively guaranteed[7]. Cardiac surgery under ultra-fast-track anesthesia has significant economic benefits in shortening length of stay in hospital and reducing hospitalization costs[9]. Cardiac surgery under ultra-fast-track anesthesia has been carried out in our hospital since 2015. The cardiopulmonary function of children after operation is better than that of the traditional operation, which was worth infaction widely in clinic in order to benefit more children and families.

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