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Research of hemodynamic change and oxygen metabolism during anesthesia of off-pump coronary artery bypass grafting (OPCABG).

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Abstract

Objectives: The purpose of this study is to evaluate the anesthesia methods by observing hemodynamic changes, oxygen supply and demand balance in order to provide the reference for the Off-Pump Coronary Artery Bypass Grafting (OPCABG) anesthesia management level during OPCABG.

Methods: Thirty patients scheduled for elective OPCABG were premedicated with intramuscular scopolamine 0.3 mg/kg and morphine 0.15 mg, 30 min before anesthesia. Artery blood pressure was monitored through radial artery catheter. Hemodynamic and oxygen metabolism index was recorded respectively at preoperative (T1), after the sternal incision (T2), LAD anastomosis (T3), CX/DIA anastomosis (T4), RCA anastomosis (T5) and the end of the operation (T6).

Results: The preload parameters change significantly at T1 and T5. Compared to T1, CVP and RVEDV decrease significantly at T4 ($P<0.05$), PCWP increase significantly at T5 ($P<0.05$). The afterload parameters change at T3 and T5. SVR and SVRI decrease significantly at T3 ($P<0.01$). SVRI decreases significantly at T5 ($P<0.05$). The cardiac systolic function was mainly influenced at T3, T4 and T5. Compared to T1, RVEF, CCO and CCI increase significantly ($P<0.05$), SV and SVI decreased significantly ($P<0.01$), RVEF increase significantly at T3 ($P<0.05$). The pressure related parameters change at T4 and T5. CVP decreases significantly at T4 ($P<0.05$), while PCWP increase significantly at T5 ($P<0.05$). Oxygen supply and demand balance parameters change at T2, T3, T4 and T5. O2ER and O2EI decrease significantly ($P<0.01$), Ca-vO_2 decrease significantly at T2 ($P<0.05$). SvO_2 increase significantly at T3 ($P<0.01$), increase relative slightly at T2 and decrease significantly compared to T1. DO_2 and DO_2I increase significantly ($P<0.05$), PvO_2 increase significantly until T5 ($P<0.01$), but the lactic acid level decrease significantly ($P<0.05$).

Conclusion: During the management of OPCABG anesthesia, maintaining the stable hemodynamic may ensure oxygen supply, demand balance and make the operation safe.

Keywords: Off-pump, Coronary artery bypass grafting (OPCABG), Hemodynamic, Oxygen metabolism.

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Introduction

With the increasing incidence of coronary heart disease, coronary heart disease has become a threat to human (especially the elderly) one of the major health diseases. Since 1964, Buffolo et al. first reported Off-Pump Coronary Artery Bypass Grafting (OPCABG), with the growing maturity of surgical techniques, anesthesia management level continues to improve, as well as surgical instruments, advanced cardiac fixation devices (such as Octopus). So that coronary artery bypass grafting (OPCABG) without Cardiopulmonary Bypass (CPB) is possible [1]. OPCABG avoid CPB to the human body's internal environment disrupt a series of complications, compared with the pump coronary artery bypass grafting (conventional CABG, CCABG), OPCABG also reduce the body's inflammatory response, and significantly reduce oxygen free radical production and myocardial injury [2-4]. It also reduces the risk of postoperative brain damage, intraoperative blood loss, renal dysfunction and postoperative cognitive dysfunction [5]. To a certain extent, it will short the patient's hospital stay and the cost of medical care [6,7].

With the development of operation technology and the improvements of the anesthetic management level, OPCABG has become one of the effective methods which are used to cure the coronary heart disease. Compared to CCABG, OPCABG has fewer effects on the internal environment of the patients and fewer complications. The heart keep beating during the operation period, the change of the heart location and the application of heart holder may influence hemodynamic and oxygen metabolism at different operation stage.

Compared with the traditional CABG, OPCABG is in the heart of the case of non-stop operation, it will cause hemodynamics to varying degrees of adverse effects, which affecting oxygen metabolism. Surgical procedures in different parts of OPCABG can lead to different hemodynamic changes. Such as anastomosis of the Left Anterior Descending artery (LAD), hemodynamic changes smaller, but anastomosis Circumflex artery (CX), posterior descending branch (Posterior Descending Artery, PDA) or right coronary artery (Right Coronary Artery, RCA). It is usually necessary to raise the apex of the heart, so that the apex of the heart is upright, and according to the location of the anastomosis also need to rotate the heart to the right or left to an angle. This change in cardiac location can lead to significant changes in hemodynamics, mainly for atrial pressure was significantly increased cardiac output (Cardiac Output, CO) and arterial pressure decreased, mixed venous oxygen saturation (mixed venous oxygen saturation, SvO_2). Heart upright position, the atrium is located in the corresponding ventricle below, and the original blood from the atrium into the ventricle, so atrial filling pressure is bound to increase, and maintained at a higher than normal levels, only more than ventricular end diastolic pressure in order to maintain ventricular filling. In this case, the atrial volume increased by approximately 50% and the pressure was increased accordingly. The use of a cardiac fixator also has an impact on hemodynamics, since the cardiac fixator limits local motion of the chamber wall and reduces ventricular volume. Cardiac fixation position and heart position changes can affect the cardiac output [8].

OPCABG surgery often need to temporarily block the coronary artery to ensure anastomosis without blood, clear vision, which will lead to a temporary ischemic myocardium, the impact of its ischemia depends on the degree of stenosis and the formation of collateral collateral circulation has been formed. Coronary stenosis>95% of those who have often formed collateral circulation, intraoperative blocking the patient is generally well tolerated. If the stenosis is <90%, hemodynamic decompensation and arrhythmia may occur during intraoperative blockage. Coronary artery stenosis<75% of the patients, stenotic distal myocardial perfusion is still mainly from the coronary artery, there is no formation of collateral circulation, in blocking the anastomosis can occur when the area of myocardial ischemia and arrhythmia, affecting hemodynamics stability.

5-lead ECG monitoring should be performed routinely with ST-segment analysis. As the operation often change the heart and body surface lead electrode position, resulting in P, QRS and T waveform and amplitude changes in the anastomosis of CX and posterior wall blood vessels is particularly evident. CO is an important indicator of cardiac pump function, it is affected by heart rate, myocardial contractility and load before and after the impact of not only a comprehensive reflection of the whole hemodynamic conditions, but also can be calculated accordingly related to the value of hemodynamic parameters to guide treatment, including the use of positive inotropic drugs, vasodilator drugs and liquid therapy. Measurement of CO commonly used methods are invasive monitoring and non-invasive monitoring of two categories, the former is through the Swan-Ganz catheter to thermal dilution continuous measurement, which is mainly through the surface impedance method, transesophageal echocardiography (Trans-Esophagealechocardiography, TEE) and Doppler method. Intracranial vein or subclavian vein puncture placed central venous catheter monitoring of central venous pressure, which can assess the preload and right ventricular function. Most studies suggest that Swan-Ganz catheter monitoring is necessary in OPCABG because myocardial ischemia during surgery can result in decreased ventricular compliance, limited diastolic function, and elevated pulmonary arterial pressure. TEE is important in assessing left ventricular function, estimating left ventricular end-diastolic pressure, finding new segmental wall motion abnormalities, and identifying the cause of persistent hypotension.

Oxygen supply and demand balance can be monitored by oxygen delivery (DO_2), oxygen consumption (VO_2), SvO_2, and blood lactate content, and SvO_2 reflects systemic oxygen metabolism. The most common monitoring method is through Swan -Ganz catheter for pulmonary arterial blood gas analysis. DO_2 represents the total amount of oxygen transported from the left ventricle to the whole body in unit time. The influencing factors are hemoglobin, CO, arterial oxygen saturation (SaO2) and arterial oxygen content (CaO_2). VO_2 is the actual amount of oxygen consumed by tissue cells per unit time, representing the total oxygen demand of the body. When the oxygen supply is significantly reduced, the body relies on anaerobic metabolism to provide energy, blood lactate content increased. Blood lactate is also used to reflect cardiac output to assess the relationship between oxygen delivery and oxygen consumption. Moreover, urine volume, electrolytes, blood glucose, Activated Clotting Time (ACT), body temperature and hemoglobin monitoring are very important indicators.

The observation of the relationship between hemodynamic changes and oxygen metabolism in OPCABG has been reported [9-11]. Our clinical observation found that, after anesthesia management and surgical operation improvement, can make OPCABG intraoperative hemodynamics and oxygen metabolism changes become less obvious. The purpose of this study is to observe the changes of hemodynamics and oxygen consumption during OPCABG anesthesia, to further evaluate the rationality of current anesthesia and operation, and to provide a reference for the improvement and improvement of anesthesia management level in the future.

Materials and Methods

Experimental design

Thirty patients with OPCABG who underwent elective coronary artery occlusion were selected from May to June

2016, including 22 males and 8 females. Age 65 ± 9 y, body weight 72.7 ± 10.7 kg, Body Surface Area (BSA) 1.83 ± 0.15 m^2, ASA II-III grades, LVEF 55 ± 11%, Hb 139.6 ± 18.2 g/L. The operation time was 2.9 ± 0.65 h and the blood loss was 274 ± 74 ml. Lactate-free liquid crystal 913 ± 276 ml, colloid 593 ± 263 ml and urine 275 ± 112 ml/h were obtained. Coronary angiography stenosis>95% were 24.8%, stenosis<75% were 33.9%.

Anesthetic management

Thirty patients scheduled for elective OPCABG were premedicated with intramuscular scopolamine 0.3 mg/kg and morphine 0.15 mg, 30 min before anesthesia. Artery blood pressure was monitored through radial artery catheter. Swan-Ganz floating catheter was placed into pulmonary artery through the right internal jugular vein and connected to Edwards Lifesciences™ Vigilance II monitor to gain hemodynamic changes and oxygen metabolism index. Anesthesia was induced with midazolam 0.05~0.1 mg/kg, sufentanil 1~2 μg/kg, etomidate 0.3 mg/kg, vecuronium 0.1~0.2 mg/kg and maintained with propofol by target control infusion. The infusion rate of propofol was 1~4 μg/(kg.min), intravenous sufentanil and atracurium was administered discontinuously. Conventional continuous intravenous nitroglycerin 3~5 μg/(kg.min) and dopamine 3~8 μg/(kg.min) were administered through infusion pump, adjusting the infusion speed according to the hemodynamic changes in order to maintain hemodynamic relatively stable.

Indicator monitoring

Hemodynamic and oxygen metabolism index was recorded respectively at preoperative (T1), after the sternal incision (T2), LAD anastomosis (T3), CX/DIA anastomosis (T4), RCA anastomosis (T5) and the end of the operation (T6). The indexes of hemodynamics including the Central Venous Pressure (CVP), Mean Arterial Pressure (MAP) and Mean Arterial Pressure (MAP) were measured before and after thoracotomy. (MAP), Mean Pulmonary Artery Pressure (MPAP), Pulmonary Capillary Wedge Pressure (PCWP), Right Ventricle Diastolic Volume (RVEDV), Systemic Vascular Resistance (SVR), Systemic Vessel Resistance Index (SVRI), Pulmonary Vessel Resistance (PVR), Pulmonary Vessel Resistance Index (PVRI), Stroke Volume, SV), Stroke Volume Index (SVI), Right Ventricle Eject Fraction (RVEF), Continuous Cardiac Output (CCO) and Continuous Cardiac Index (CCI) (LVSWI) and Right Ventricle Stroke Work Index (RVSWI), and blood gas and oxygen metabolism were monitored at the same time. The indexes including blood gas and oxygen metabolism were measured, including: heart rate, left ventricular stroke index, left ventricular stroke index, DO_2, oxygen delivery index (DO_2I), VO_2, oxygen consumption index (VO_2I), venous oxygen content (CvO_2), CaO_2, PvO_2, PaO_2, oxygen uptake rate (extraction rate of oxygen, ERO_2), arterio-venous oxygen content difference, $Ca\text{-}vO_2$, SvO_2, Lactate Arterial Concentration (LAC (A)), Lactate Venous Concentration (LAC (V)). The groups were successfully completed under the off-pump surgery.

Statistics

The data was analysed with the SPSS statistics 18.0. Non-continuous numeration data was analysed by using the Chi-square test. Measurement data was expressed as mean ± standard deviation ($\bar{x} \pm s$). Means compare with the two groups by using the independent-sample T test. One-Way ANOVA analysis was performed to assess the variables of several subgroups, and pairwise comparisons by using the Least-Significant-Difference (LSD) t-test. Significant difference between groups was assumed at the level of error<5%.

Results

The general data of patients

As shown in Table 1, there were no significant differences in the age, gender, weight, ASA grade, and operation time and blood loss of patients. The difference of the patient's age, gender ratio, height, body mass, Body Mass Index (BMI), the circumference, the systolic pressure, and diastolic pressure was not significant between the PCI group and the control group (Table 1).

Preload related parameter changes

After thoracotomy, CVP and RVEDV were slightly reduced. When compared with LAD, PCWP and RVEDV also decreased slightly, but no statistically significant. In patients with CX / DIA, CVP and RVEDV were significantly lower than those before operation ($P<0.05$), and PCWP was slightly elevated. Compared with RCA, PCWP was significantly higher than that before operation ($P<0.05$). CVP and RVEDV were slightly higher than those before operation. After surgery, these three indicators did not change compared with preoperative (Table 2).

In this study, we observed that CVP and RVEDV were significantly decreased ($P<0.05$) in the case of CX / DIA and RCA when the anesthesia and surgery were significantly changed. In the case of RCA, PCWP was significantly increased ($P<0.01$). CVP mainly reflects the balance between right heart function and venous return blood volume. In this group, CVP was significantly lower than that before operation ($P<0.05$), but the fluctuation did not exceed the normal range, which indicated that the operation and Anesthesia treatment had no significant effect on right ventricular preload. PCWP can be used to estimate the pulmonary circulation status and left ventricular function can reflect the left atrial pressure and indirectly reflect the left ventricular end diastolic pressure, used to determine the left ventricular preload. This group of patients with RCA significantly increased PCWP ($P<0.05$), indicating that anastomosis RCA, the location of the heart caused by a significant increase in the left ventricular load before, but because in the process of our changes in hemodynamics in time The use of patients with low head

(Trendelenberg position) and the application of vasodilator drugs, making PCWP basic and normal value of the difference.

Afterload related parameter change

From Table 3, we can know that after thoracotomy, SVR, SVRI and MAP decreased slightly, but no statistically significant, PVR and preoperative, PVRI slightly elevated, no statistically significant. Compared with LAD, SVR and SVRI were significantly lower than those before operation ($P<0.01$). PVR and PVRI were slightly higher than those before operation, MAP decreased slightly, but there was no statistical significance. Compared with CX/DIA, SVR, SVRI, PVR and PVRI were slightly higher than those before operation, MAP decreased slightly before operation, and no statistically significant difference. Compared with RCA, SVR, SVRI, PVR, PVRI and MAP were slightly decreased before operation, and SVRI was significantly lower than that before operation ($P<0.05$). SVR and SVRI were restored to preoperative level, while PVR, PVRI and MAP were slightly higher than those before operation, but not statistically significant.

RVEF, CCO and CCI were significantly increased ($P<0.05$). When SVA and RCA were inoculated with LAD and RCA, SVR and SVRI were significantly decreased ($P<0.01$). RVEF was significantly increased ($P<0.01$), and SV and SVI were significantly decreased ($P<0.05$), and the levels of SV and SVI were significantly decreased ($P<0.01$), LVSWI and RVSWI were significantly decreased ($P<0.05$) heart position changes and lack of preload.

Changes of cardiac systolic function

There were no significant changes in SV, SVI and LVSWI after thoracotomy, and RVEF increased slightly, but there was no statistical significance. There was no change in CCO, CCI and RVSWI. Compared with LAD, SV, SVI, LVSWI and RVSWI were slightly lower than those before operation, but there was no significant difference between the two groups ($P>0.05$). RVEF increased slightly, but not statistically significant ($P<0.01$), while CCO, CCI, LVSWI and RVSWI were slightly decreased (no statistically significant), while SV and SVI were significantly decreased ($P<0.01$). The compared with preoperative, SV, SVI and LVSWI were significantly lower than those before operation ($P<0.05$). The levels of CCO and CCI were significantly higher than those before operation, and RVSWI had no obvious change.

The levels of SV, SVI, LVSWI and RVSWI were slightly lower than those before operation. RVEF, CCO and CCI were slightly higher than those before operation, and there was no statistical significance (Table 4).

The effect of OPCABG on cardiac systolic function was mainly in RADF and CX/DIA, but only RVEF decreased ($P<0.05$). SV and SVI were significantly decreased ($P<0.01$), SV mainly reflected the cardiac ejection function, depending on the ventricular preload, myocardial contraction Force and systemic vascular resistance, is an important parameter of hemodynamics. SV and SVI were significantly decreased and LVSWI was significantly decreased ($P<0.05$), and the change of cardiac position had a significant effect on myocardial contractility.

Pressure-related parameters

There was no significant change in MAP after thoracotomy, MPAP and PCWP were slightly elevated, CVP was slightly decreased, no statistically significant. There was no significant change in MAP, PCWP decreased slightly, and CVP was mildly increased, which was not statistically significant. MAP, MPAP and CVP were significantly reduced in CX/DIA, with CVP being the most significant ($P<0.05$) and slightly increased PCWP. Compared with RCA, MAP decreased slightly, MPAP, CVP and PCWP were increased in different degrees, among which PCWP was the most obvious ($P<0.05$). MAP, MPAP and PCWP were slightly elevated and CVP decreased slightly (Table 5).

The effect of OPCABG on pressure-related parameters was significantly decreased ($P<0.05$) when compared with CX/DIA ($P<0.05$), and PCWP was significantly increased in RCA ($P<0.05$), indicating that the anesthesia management was appropriate and the effect of operation on the circulatory system is not obvious.

Oxygen supply and demand balance parameters

The levels of VO_2, VO_2I, O_2ER, O_2EI and Ca-vO_2 were significantly lower than those of the rats treated with O_2ER and O_2EI ($P<0.01$), and the levels of DO_2, DO_2I, CvO_2, PvO_2, PaO_2 and SvO_2 were higher than those before operation ($P<0.01$), followed by Ca-vO_2 ($P<0.05$). CaO_2, LAC (A) and LAC (V) did not change. VO_2, CvO_2, CaO_2, PvO_2, LAC (A) and LAC (V) were slightly increased. PaO_2, O_2ER, O_2EI, Ca-vO_2 ($P<0.01$), DO_2, DO_2I and SvO_2 were significantly increased mildly reduced. In the case of CX/DIA, DO_2I, VO_2, CaO_2, PaO_2, O_2ER, O_2EI, Ca-vO_2, SvO_2 and LAC (A) were slightly increased, PvO_2 was significantly increased ($P<0.01$), DO_2 Decreased, LAC (A) and CvO_2 basically no change. CvO_2, SvO_2, LAC (A) and LAC (V) were slightly decreased, and SvO_2 and ($P<0.01$) were significantly increased ($P<0.01$), and DO_2, DO_2I, VO_2, PaO_2, O_2ER and O_2EI were slightly increased and PvO_2 Ca-vO_2 did not change. The levels of DO_2, DO_2I, VO_2, O_2ER, O_2EI and Ca-vO_2 were significantly higher than those before operation ($P<0.01$), and the levels of CvO_2, PaO_2 and SvO_2 decreased slightly, the levels of SvO_2 and PvO_2 are basically no change (Table 6).

The expression of VO_2I was slightly higher than that of thoracic anastomosis ($P<0.01$), and Ca^{2+} was significantly decreased ($P<0.05$) and SvO_2 was significantly increased ($P<0.01$), DO_2 and DO_2I decreased ($P<0.05$), SvO_2 did not change significantly compared with that after thoracotomy, and it was considered that sedation, anesthesia and muscle relaxation caused by oxygen relaxation related. In the case of CX/DIA, PvO_2 was significantly increased ($P<0.01$). Compared with RCA, PvO_2 was significantly increased ($P<0.01$), while lactate decreased ($P<0.05$). O2ER reflects the diffusion of oxygen from the capillaries to the mitochondrial inner membrane, depending on the oxygen concentration in the capillaries and the transport distance of oxygen from the plasma to the mitochondria. When DO_2 rises or falls, the VO_2 constant is maintained by changing O_2ER.

Table 1. *The general data of patients (n=30, $\bar{x}$ ± s).*

Total no.	Gender (Male/Female)	Age	EF>40%	History of myocardial infarction	Diabetes mellitus	Hypertension	Cerebral infarction
30	22/8	65 ± 9	30	3	8	10	3

Table 2. *Changes in the relevant load parameters (n=30, $\bar{x}$ ± s).*

	Preoperative	Thoracotomy	LAD	CX/DIA	RCA	Complete surgery
CVP (mmHg)	7.5 ± 2.7	6.7 ± 3.2	8.4 ± 3.2	6.5 ± 2.9*	9.2 ± 4.1	7.3 ± 3.1
PCWP (mmHg)	9.9 ± 3.1	10.0 ± 4.2	9.1 ± 4.1	10.4 ± 4.7	12.4 ± 2.1*	10.0 ± 3.5
RVEDV (ml)	188.4 ± 31.0	185.5 ± 33.2	178.4 ± 37.8	160.5 ± 30.2*	188.5 ± 22.0	187.1 ± 30.1

Table 3. *Afterload related parameters change (n=30, $\bar{x}$ ± s).*

	Preoperative	thoracotomy	LAD	CX/DIA	RCA	Complete surgery
SVR (dn-s•cm^{-5})	1467.4 ± 486.4	1406.1 ± 365.2	1195.8 ± 510.0**	1522.9 ± 551.0	1186.1 ± 270.5	1462.3 ± 423.5
SVRI (dn-s-m^{2}•cm^{-5})	2671.2 ± 843.0	2541.8 ± 660.9	2192 ± 1016.7**	2793.7 ± 1016.7	2082.7 ± 478.7*	2643.9 ± 760.5
PVR (dn-s•cm^{-5})	110.9 ± 54.7	110.9 ± 64.1	115.1 ± 60.0	127.9 ± 88.3	105.0 ± 46.3	131.3 ± 67.9
PVRI (dn-s-m•cm^{-5})	195.0 ± 96.4	199.7 ± 115.0	217.1 ± 130.3	235.8 ± 166.2	181.7 ± 79.2	237.5 ± 125.1
MAP (mmHg)	73.6 ± 20.3	73.5 ± 10.4	72.2 ± 10.1	70.4 ± 11.9	67.5 ± 19.0	79.3 ± 10.8

Table 4. *Changes in cardiac systolic function parameters (n=30, $\bar{x}$ ± s).*

	Preoperative	Thoracotomy	LAD	CX/DIA	RCA	Complete surgery
SV (ml/beat)	63.6 ± 19.1	57.2 ± 13.6	59.0 ± 18.2	46.7 ± 13.7**	57.8 ± 17.5	55.5 ± 18.4
SVI (ml/(beat•m^{2}))	34.9 ± 10.2	31.8 ± 8.6	32.3 ± 10.0	25.5 ± 7.1**	32.7 ± 10.2	30.7 ± 10.5
RVEF (%)	26.6 ± 7.3	29.2 ± 7.8	33.0 ± 9.9*	31.0 ± 9.8	34.4 ± 13.1*	29.8 ± 10.3
CCO (L/min)	3.8 ± 1.0	3.8 ± 0.7	4.4 ± 1.3*	3.7 ± 1.0	4.2 ± 0.9	4.1 ± 1.1
CCI (L/(min•m^{2}))	2.1 ± 0.5	2.1 ± 0.4	2.5 ± 0.7*	2.0 ± 0.5	2.4 ± 0.5	2.3 ± 0.6
LVSWI (g•m/m^{2})	30.8 ± 9.9	27.7 ± 7.4	26.6 ± 7.6	20.1 ± 6.4*	26.5 ± 7.1	28.1 ± 9.5
RVSWI (g•m/m^{2})	3.8 ± 2.8	3.8 ± 1.7	3.6 ± 2.4	2.7 ± 1.4*	3.8 ± 2.3	3.6 ± 2.3

Table 5. *Pressure-related parameter changes (n=30, $\bar{x}$ ± s).*

		Preoperative	Thoracotomy	LAD	CX/DIA	RCA
MAP (mmHg)	73.6 ± 20.3	73.5 ± 10.4	72.2 ± 10.1	70.4 ± 11.9	67.5 ± 19.0	79.3 ± 10.8
MPAP (mmHg)	15.0 ± 6.6	18.3 ± 13.4	15.0 ± 6.2	13.7 ± 4.0	17.2 ± 3.8	15.4 ± 4.7
CVP (mmHg)	7.5 ± 2.7	6.7 ± 3.2	8.4 ± 3.2	6.5 ± 2.9*	9.2 ± 4.1	7.3 ± 3.1
PCWP (mmHg)	9.9 ± 3.1	10.0 ± 4.2	9.1 ± 4.1	10.4 ± 4.7	12.4 ± 2.1*	10.0 ± 3.5

Table 6. *Changes in oxygen supply and demand balance parameters (n=30, $\bar{x} \pm s$).*

		Preoperative	Thoracotomy	LAD	CX/DIA	RCA
DO_2 (ml/min)	727.9 ± 193.5	764.8 ± 165.0	863.6 ± 254.8*	706.4 ± 239.9	778.8 ± 165.6	776.4 ± 221.7
DO_2I (ml/ (min•m^2))	370.7 ± 109.6	418.6 ± 87.6	449.9 ± 165.7*	402.1 ± 112.8	442.0 ± 90.4	420.1 ± 114.6
VO2 (ml/min)	161.9 ± 45.8	142.28 ± 39.4	184.7 ± 65.4	165.8 ± 45.7	188.7 ± 36.7	200.6 ± 99.5
VO_2I (ml/ (min•m^2))	88.47 ± 24.3	76.1 ± 20.9	96.5 ± 34.0	93.7 ± 24.8	107.0 ± 21.0	111.2 ± 51.3
CvO_2 (m•dl^{-1})	14.6 ± 2.1	15.3 ± 2.3	14.8 ± 2.4	14.4 ± 2.9	13.9 ± 1.3	13.6 ± 2.8
CaO_2 (m•dl^{-1})	18.9 ± 2.0	18.9 ± 2.0	19.0 ± 2.0	19.1 ± 2.0	18.2 ± 1.3	18.6 ± 1.9
PvO_2 (mmHg)	39.4 ± 3.2	41.2 ± 4.8	41.4 ± 4.8	48.5 ± 3.5**	44.9 ± 6.3**	40.2 ± 4.4
PaO_2 (mmHg)	193.2 ± 86.6	206.5 ± 83.9	181.5 ± 58.8	201.5 ± 49.8	207.8 ± 53.6	166.2 ± 53.6
O_2ER (%)	23.1 ± 6.1	19.8 ± 5.5**	22.1 ± 7.8	24.6 ± 7.9	24.0 ± 4.0	26.7 ± 11.5
O_2EI (%)	21.2 ± 6.2	17.6 ± 5.4**	20.2 ± 7.9	22.7 ± 8.2	22.0 ± 3.9	25.2 ± 11.9
Ca-vO_2 (m/dl)	4.3 ± 1.2	3.7 ± 1.0*	4.2 ± 1.5	4.6 ± 1.2	4.3 ± 0.7	5.0 ± 2.3
SvO_2 (%)	76.9 ± 5.4	81.4 ± 4.8**	80.7 ± 7.0*	77.1 ± 10.4	75.3 ± 12.0	74.1 ± 11.9
LAC (A) (mmol/L)	1.0 ± 1.3	1.0 ± 0.3	1.1 ± 0.3	1.1 ± 0.3	0.8 ± 1.3*	1.2 ± 0.4**
LAC (V) (mmol/L)	1.0 ± 0.2	1.0 ± 0.3	1.1 ± 0.4	1.0 ± 0.4	0.9 ± 0.2	1.2 ± 0.3**

Discussion

Coronary Artery Bypass Grafting (CABG) is one of the most effective means of treating coronary heart disease in the present year. In 2001 and 2002, three groups of large sample prospective studies showed that Off-Pump Coronary Artery Bypass Grafting (OPCABG) Mortality was lower than in Cardiopulmonary Bypass Coronary Artery Bypass Grafting (CCABG) [10-12]. In the past, the literature reported that [13-16]: OPCABG in the non-stop jumping for vascular anastomosis, intraoperative cardiac fixation and multiple heart movements of the heart to interfere with hemodynamics, vascular anastomosis will also cause anastomosis Blood supply myocardial ischemia, so anesthesia and intraoperative management to ensure that myocardial blood supply occupies a very important position, especially in the maintenance of systemic oxygen supply and demand balance, the patient's postoperative follow-up play a direct role. Coronary heart disease surgery in anesthesia in the basic principles of hemodynamics regulation is to maintain myocardial oxygen supply and demand balance, to avoid myocardial ischemia, to ensure that the vital organs to obtain appropriate blood and oxygen supply [17]. In order to avoid myocardial ischemia to maintain myocardial oxygen supply and demand balance should be as much as possible to maintain hemodynamic stability, and reduce myocardial oxygen consumption, while avoiding oxygen reduction. Therefore, anesthesia induction and maintenance during the rational use of anesthetics and cardiovascular drugs to maintain circulation stability, timely correction of surgical operation caused by hemodynamic fluctuations and arrhythmia, reduce myocardial inhibition and myocardial oxygen consumption, to ensure the balance of myocardial oxygen supply and demand, is the key to the success of anesthesia.

This group of patients selected anesthetic effects on hemodynamics, intraoperative vascular anastomosis when moving the heart gently, and in the anastomosis CX, DIA and RCA appropriate adjustment of the patient position, according to the monitoring indicators and intraoperative heart Filling the state to adjust the infusion rate or diuretic, these methods to a certain extent, to avoid the violent fluctuations in hemodynamic parameters. The effects of etoposide anesthesia on heart rate, myocardial contractility, systemic resistance and preload were less. Analgesic use of sufentanil, the analgesic effect of fentanyl is about 7 to 10 times, the body's stress response than the fentanyl [18]. Propofol has a more pronounced vasodilator effect, can significantly reduce the SVR and reduce the patient's preload. The whole process of intravenous infusion of nitroglycerine and dopamine, dilation of coronary artery, to maintain blood pressure stability, to increase myocardial oxygen supply, reduce cardiac work also played a very important role [19]. Nitroglycerin can expand the coronary artery, increase coronary blood flow, selectively reduce the preload, reduce oxygen consumption, increase oxygen supply, is conducive to myocardial oxygen supply and demand balance, the expansion of peripheral arteries and venous effect, can reduce the return to heart, The preload, SVR and PVR, because of its low binding rate with plasma protein, so there will be no accumulation phenomenon. Dopamine 1~3 μg/(kg•min) mainly excited DA1 receptor, dilated kidney and gastrointestinal blood vessels, increased renal blood flow; dopamine 3~8 μg/(kg•min) when the β1+β2+DA1 receptor excitatory Maine, increased heart rate, increased myocardial contractility, increased CO, increased SVR, increased PVR, and initiation of alpha vasoconstriction, due to its positive muscle strength and contraction of the combined effect of blood vessels, commonly used to maintain blood pressure [20].

The heart blood supply comes from the left and right coronary arteries and their branches. Left anterior descending coronary artery is a direct continuation of the left coronary artery, the supply of left ventricular anterior wall, part of the right anterior wall and anterior wall. When the closed anterior descending artery after anastomosis after the blood supply to the region can be restored. But the surgeon in the CX, DIA and RCA blood vessels on the heart of the move, will cause greater changes in hemodynamics, due to the appropriate cycle of anesthesia management, especially the appropriate expansion of capacity, so in the CX, DIA and RCA When the hemodynamic changes are not obvious, which is different from the previous literature [21,22]. This group of patients with coronary artery stenosis>95% were only 24.8%, most of the collateral circulation has not yet formed, intraoperative blockage of the anastomosis prone to hemodynamic decompensation, anesthesia during the maintenance of myocardial proper oxygen for anesthesia of the key, and hemodynamic stability of the oxygen for the heart is very important. In this study, we observed that RVEF, CCO and CCI were significantly higher than those before operation, and PCWP, SVR and SVRI were lower than those before operation. It was possible to pay attention to the fixation of cardiac fixation device and minimize cardiac compression. In the case of CX, DIA and RCA, the above changes were not obvious, and may be related to the operation of light surgery and intraoperative circulation management properly. SvO_2 is the reaction of the body oxygen and oxygen balance of the comprehensive indicators, can determine the organization of perfusion and oxygenation. Its normal value is 75% (65%~85%). SvO_2>65% for the oxygen reserve appropriate, SvO_2 50%~60% for the oxygen reserve is limited, SvO_2 35%~50% oxygen reserve shortage [23]. This group of patients anesthesia and surgery process SvO_2 are 60% to 80%, indicating that the body metabolic state normal, anesthesia management did not cause oxygen supply and oxygen consumption imbalance. PvO_2 is also the reaction of the body oxygen supply and oxygen consumption of the comprehensive index, the normal value is about 40 mmHg, less than 35 mmHg can be considered to exist tissue hypoxia. This group of patients PvO_2 is about 40 mmHg, indicating no tissue hypoxia.

Blood lactate monitoring is the gold standard for assessing systemic perfusion and oxygen metabolism, and its rise reflects an increase in oxygen demand or low tissue perfusion. It is often associated with hemodynamic changes, such as the presence of tissue hypoperfusion or hypoxia, blood lactate levels will be significantly increased. For OPCABG surgery, blood lactate levels can reflect cardiac output, can be used to assess oxygen supply or oxygen delivery, and even assess the prognosis of high-risk patients [24,25]. A sharp reduction in oxygen delivery is often associated with a rapid increase in blood lactate levels. Similarly, the return to normal oxygen delivery will also increase the level of elevated blood lactate to normal [26]. For OPCABG surgery, the dynamic changes in lactate can be used as an important indicator to guide perioperative treatment and assess the effectiveness of treatment. In this study, although in the anastomotic RCA and surgery when the arterial and venous blood LAC decreased or increased significantly before, but its values are within the normal range, which also shows that this group of anesthesia due to maintain hemodynamic stability, which ensuring the body's oxygen supply and oxygen consumption in a balanced situation.

The key to the success of OPCABG is to maintain hemodynamic stability and to ensure that the oxygen supply and demand balance (control of heart rate, proper handling of heart discharge occurs when the low cardiac output), in the anastomosis of blood vessels before the implementation of ischemic preconditioning can improve myocardial Ischemic tolerance is conducive to keeping the circulatory state stable. OPCABG perioperative anesthesia management should note the following: Coronary heart disease anesthesia and perioperative management principle is to maintain the balance of myocardial oxygen supply and demand, to avoid increased myocardial oxygen consumption, heart rate control and blood pressure, heart rate and systolic blood pressure product (rate-Pressure vaccine, RPP) ≤ 12000, to maintain the stability of hemodynamics. Correct assessment of cardiopulmonary function, adequate preparation before anesthesia, anesthesia before the medication should be reasonable and appropriate, so that patients eliminate tension, full sedation, and strive into room was drowsiness, heart rate control in the <70 times/min, blood pressure control in the normal range. Anesthesia induced smooth, depth appropriate to reduce the high stress response. Intraoperative monitoring of cardiac function, through ECG, MAP, CVP, HR, PCWP, CCO, SVR, PVR, SvO_2, arterial blood gas, blood, biochemistry and other indicators at any time to understand the heart pump function, to maintain good tissue perfusion and oxygen supply. Moving heart and placement of cardiac fixation, sudden drop, and arrhythmia should be suspended operation, the heart reset, while adjusting the patient position to reduce the heart shift. Ischemic preconditioning refers to the heart after a short period of ischemia, can make myocardium for a long time follow-up and then resistant to ischemia, is an endogenous myocardial protection. Repeated movement of the heart several times with ischemic preconditioning. The use of vasoactive drugs to make the cycle stabilized. Intraoperative infusion should be appropriate to avoid increased before the burden, due to excessive cardiac filling is not conducive to surgical operation, and increase myocardial oxygen consumption; infusion is too small blood circulation instability. Coronary heart disease patients often use diuretics, body potassium content decreased, prone to hypokalemia, anesthesia surgery should pay attention to observe the urine output at any time, and maintain serum potassium>4 mmol/L. Low potassium can increase myocardial excitability, easy to cause ventricular fibrillation, surgery should be based on blood electrolytes monitoring results potassium. Placed Swan-Ganz catheter can monitor the left and right cardiac function and its front and rear load, for the operation of cardiac function monitoring, maintenance and determine the capacity of a positive guide, especially for patients with poor heart function should be routinely implemented.

1970 Swan-Ganz invented a floating catheter, anesthesia for cardiac surgery on hemodynamics monitoring laid an important foundation [27], and later Sharif found that the thermal dilution method of CO than the actual change to be delayed 5~15 min. This delay cannot reflect the OPCABG intraoperative hemodynamic real-time changes, it should be based on the time of the heart was filling the state of a comprehensive analysis to carry out anesthesia treatment [28]. Halvorsen et al. [29] divided the OPCABG vascular anastomosis into two periods: placed the position of the heart and fixed with a fixation for 1; occlusion of the coronary artery for 2, they found that the most significant changes in hemodynamics occurred in the first phase, which is consistent with Shinn [30] and Mishra [31]. In this study, the time taken for the collection of specimens is at the end of the anastomotic coronary artery, according to the above point of view is collected before 5~15 min when the data, that is, the maximum change in hemodynamic changes, so the collected data that can explain the problem. In addition, the Swan-Ganz catheter is the right heart catheter, whose hemodynamic monitoring is affected by the intrathoracic pressure. Patients with positive pressure ventilation in the chest when the positive pressure increases, increased hemodynamics value, while the end of the pressure when the pressure rise before the optimal hemodynamic monitoring point, so the pressure value should be in the end of breath read, the details of this study has not been reported in the literature. In addition, intraoperative compression of the heart, myocardial ischemia, valve insufficiency, severe myocardial contraction weakness, severe mitral regurgitation, right ventricular dilatation and severe tricuspid regurgitation can lead to severe hemodynamics Variety. Transesophageal Echocardiography (TEE) is the most sensitive indicator of intraoperative myocardial ischemia, which provides reliable information in a timely and accurate manner. We have now implemented this monitoring and found that it is more beneficial to ensure patient safety.

OPCABG Surgical anesthesia is more demanding for anesthesiologists than traditional CABG anesthesia, such as controlling heart rate, blood pressure, anteroposterior load, and maintaining hemodynamic stability in anastomotic coronary vessels, CABG is more challenging, but if you can grasp the principle of anesthesia of OPCABG surgery (control capacity, timely use of vasoactive drugs and positive inotropic drugs to maintain circulation and stability, pay attention to the use of crown drugs, effective prevention and treatment of myocardial ischemia), according to Surgery at different stages of timely regulation of hemodynamics, to maintain a stable cycle, you can ensure the safety of anesthesia, so that patients successfully through the perioperative period. Our current anesthesia treatment program has been clinically proven to be safe and effective. With the continuous development of anesthesiology, there will be more ideal to reflect the changes in hemodynamics monitoring methods; it will make OPCABG surgery as one of the conventional cardiac surgery.

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