

Management of Peripheral Extracorporeal Circulation in the Surgical Treatment of Tricuspid Valve Disease by Thoracoscopy

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Abstract—Objective: To elucidate the management of peripheral extracorporeal circulation (cardiopulmonary bypass) to protect the cardiac function and reduce the surgical trauma and complications in tricuspid valve operation by thoracoscopy. **Methods:** A clinical data analysis of 255 subjects (87 males and 168 females; mean age of 42.7 ± 15.2 years; average weight of 55.3 ± 13.3 Kg) was performed, which with surgical indications of tricuspid regurgitation underwent the total thoracoscopy assisted tricuspid valve operation (16 cases with De Vega annuloplasty; 40 cases with Kays annuloplasty; 174 cases with artificial valve annuloplasty; 3 cases with artificial chordae; 4 cases with edge to edge; 18 cases with tricuspid valve replacement). All patients were treated with peripheral approach of extracorporeal circulation, which was established through the arteria femoralis and femoral vein intubation combined with the superior vena cava (internal jugular vein) percutaneous intubation. **Results:** Under peripheral cardiopulmonary bypass (CPB) for thoracoscopic tricuspid valve operations, all patients were with unobstructed drainage, good exposure and effective myocardial protection. There was no refractory cardiac resuscitation, multiple organ injury following ischemia-reperfusion and other serious complications, and there was no intraoperative confirmation of median sternotomy, 5 cases with re-thoracotomy for hemostasis. Clinical data was described as follows: the average operation time was 185.3 ± 58.6 min, CPB time was 116.7 ± 44.1 min, aortic cross-clamp (ACC) time was 93.7 ± 61.4 min (248 cases), endotracheal intubation time was 12.6 ± 3.6 hours, thoracic drainage was 237.3 ± 308.9 ml, and mean postoperative hospital stay was 5.3 ± 2.6 days. The incident rate of no using blood products during the hospitalization was 81%. **Conclusion:** It was entirely feasible that the thoracoscopic tricuspid valve operations were on the basis of the peripheral CPB established through the arteria femoralis and femoral vein intubation combined with the internal jugular vein percutaneous intubation. Thus, peripheral CPB could be the preferred method of establishing extracorporeal circulation for all kinds of minimally invasive cardiac surgeries.

Index Terms—Extracorporeal circulation, peripheral cardiopulmonary bypass, tricuspid valve operation, annuloplasty, thoracoscopy

I. BANKGROUND

Minimally invasive cardiac surgery by thoracoscopy was considered as another major technological revolution since the advent of extracorporeal circulation, and the development of which has benefited from contributions of the establishment of peripheral cardiopulmonary bypass (CPB). Currently, the mainstream methodology in peripheral CPB is based on the intubation of the peripheral vascular, such as femoral artery, femoral vein, axillary artery, subclavian vein and internal jugular vein. Under peripheral CPB, although there are still some limits in the types of minimally invasive cardiac surgeries, the surgical treatment of tricuspid valve disease can be carried out smoothly in some heart surgery centers with mature technology, most of them were obtained good clinical effects.

The functional tricuspid regurgitation may occur mostly secondary to the left heart valve disease or the morphological change in tricuspid annulus induced by atrioventricular septal defect (AVSD), right ventricular dysfunction and pulmonary hypertension [1, 2]. Partial of tricuspid regurgitation is derived from the abnormalities of tricuspid valve, such as congenital endocardial cushion defect, Ebstein malformation, infective endocarditis and so on. Tricuspid stenosis is common in rheumatic heart disease with the change in tricuspid valve and chordae, and most cases are complicated by tricuspid regurgitation of different degrees [3, 4]. It is worth noting that some of the patients underwent cardiac surgery suffer from severe tricuspid regurgitation postoperatively, and the patients who need surgical treatment are increased [5, 6]. Therefore, the development of the surgical treatment of tricuspid valve disease by thoracoscopy has been attempted.

In this study, The CPB was established through the intubation of femoral artery, femoral vein and internal jugular vein, being applied to various types of 255 cases underwent the tricuspid valve operation by thoracoscopy to sum up the experiences of clinical practice.

II. METHODS

Clinical Data

From January 2014 to November 2016, 255 patients with surgical indications of tricuspid regurgitation were involved in the study (87 males and 168 females; mean age of 42.7 ± 15.2 years; average weight of 55.3 ± 13.3 Kg), which underwent total thoracoscopy assisted tricuspid valve operation in Guangdong Cardiovascular Institute and the First Affiliated Hospital of Jinan University, China. Among them, seven patients underwent tricuspid valve re-operation, 248 patients in the first trial operation for tricuspid valve disease included 167 cases with atrial septal defect and tricuspid regurgitation, 73 cases with mitral valve disease and tricuspid regurgitation, 4 cases only with tricuspid regurgitation and 4 cases with other diseases and tricuspid regurgitation. All subjects could be divided into three groups according to the severity of tricuspid regurgitation: 85 patients with severe tricuspid regurgitation, 83 patients with moderate tricuspid regurgitation and 87 patients with mild tricuspid regurgitation. Inclusion criteria were determined by color Doppler echocardiography, electrocardiogram and chest X-ray radiography. Exclusion criteria included the severe adhesion of pleura and heart, sick sinus syndrome, peripheral vascular disease, coronary heart disease and hyperthyroidism.

Operation method

All operations were performed under general anesthesia with left-sided double lumen endobronchial Tube. The external defibrillation electrode patch was adhered at the apex and right scapula. After systemic heparinization, the drainage of superior vena cava was established through the percutaneous intubation (14 to 18 Fr) of right internal jugular vein, and right inguinal femoral arterial intubation (16 to 20 Fr) and femoral venous intubation (22 to 28 Fr) were set up for peripheral CPB. Re-operations for the seven patients were performed with heart-beating by not clamping the ascending aorta, and no clamping the superior and inferior vena cava simultaneously to keep the operation

field clear. While other 248 patients were obtained the operations with aortic cross-clamp (ACC) and clamping of superior vena cava, some patients without clamping of inferior vena cava. Subsequently, Tomas warm blood cardioplegia perfusion was interruptedly perfused every 20 minutes through the perfusion cannula inserted in root of aorta during the operation. All the operations were under total thoracoscopy, which included 16 cases with De Vega annuloplasty, 40 cases with Kays annuloplasty, 174 cases with artificial valve annuloplasty, 3 cases with artificial chordae, 4 cases with edge to edge and 18 cases with tricuspid valve replacement.

Statistical analyses

The measured results were processed using the SPSS statistics software package (ver. 12.0; SPSS Inc. Chicago, Illinois, USA). A normal distribution was obtained using the normality test. Data expresses as the mean \pm standard deviation for numerical data and n (%) for categorical data.

III. RESULTS

Firstly, peripheral CPB benefited to thoracoscopic tricuspid valve re-operation without the difficulties from deep and narrow operation area (as shown in Figure 1), and which could provide good surgical conditions, such as clear operation field (as shown in Figure 2). Secondly, all patients under peripheral CPB had no complications of death, arrhythmia, pneumothorax, paravalvular leakage, cardiac rupture, neurology and others. Of 248 patients underwent the operations with aortic cross-clamp (ACC), the situation of heart resuscitating was described as follow. There were 239 cases (96.4%) with spontaneous heart re-beat after releasing the aortic clamp, five cases (2%) with electric defibrillation for one time, three (1.2%) for two times, and one (0.4%) for three times. Thoracotomy was performed for hemostasis in 5 cases. The baseline data of the operations were shown in Table 1. The relevant data of intubation were shown in Table 2.

TABLE 1
BASELINE DATA OF THE OPERATIONS.

Mean operation time (min)	CPB time (min)	ACC time (min)	Tracheal intubation time (H)	Thoracic drainage (ml)	Postoperative hospital stay (D)	Rate of no using blood products
185.3 \pm 58.6	116.7 \pm 44.1	93.7 \pm 61.4	12.6 \pm 3.6	237.3 \pm 308.9	5.3 \pm 2.6	81.0%

TABLE 2
RELEVANT DATA OF INTUBATION.

Weight (kg)	Femoral artery catheterization (Fr)	Pressure of Max pump (mmHg)	Femoral vein catheterization (Fr)	Jugular vein catheterization (Fr)	Max CVP (mmHg)
30-40	16-18	198	20-22	16	5
40-50	16-20	211	22-26	16	6
50-60	18-20	205	26-28	16	8
60-70	20-22	215	28	16	8
>70	20-22	219	28	16	11

IV. DISCUSSION

With the progress of extracorporeal circulation technology, CPB through peripheral arteriovenous catheterization has been more and more used in clinical practice. Because the incision of total thoracoscopy-assisted cardiac surgery is very small, it can only be conducted by using the arteria femoralis and femoral vein intubation combined with the superior vena cave percutaneous intubation. In our center, we found that the effects of all types of totally thoracoscopic valvuloplasty were good and peripheral CPB was in stable operation.

To the femoral artery intubation, the intubation diameter was determined by the weight of the patients and the condition of arteria femoralis. For patients with large weight, the thinner catheterization could result in excessive pump pressure and limited perfusion flow. However, the catheterization of excessively large diameter would cause the difficulty in decannulation, even could injure the endarterium and affect the distal perfusion of homolateral lower limbs. There was one case that the replacement of artificial vascular had been performed for difficulty in removing the intubation. And, more remarkable, although the femoral artery was larger before intubation, it was not uncommon for the reduction of the diameter of femoral artery because of the spasm after intubation. With regard to patients with severe mismatch between body weight and the diameter of femoral artery, the contralateral femoral artery could be explored and CPB was set up with bilateral femoral arteries if necessary. In this study, four patients underwent peripheral CPB through bilateral femoral arteries. The intubation of the femoral artery should be inserted into the descending aorta as much depth as possible aiming to avoid the excessive pumping pressure caused by the femoral artery spasm. Thus, multiple plaques, ulcer and tortuous appeared at the site of the descending aorta, iliac artery and femoral artery, should be considered as the contraindications of peripheral CPB.

The choice of the intubation diameter of femoral vein varied with different individuals. For the suitable size, the cases with vacuum-assist venous drainage, and even the part of cases with natural drainage can achieve good effect. The tip of catheterization was posited just below the opening of the inferior vena cava, with moderate reverse trendelenburg position, some patients did not even need to be clamped the inferior vena cava. In this study, we adopted the femoral vein intubation combined with the internal jugular vein percutaneous intubation for venous drainage, the internal jugular vein could be completely clamped, and central venous pressure (CVP) was monitored as an indicator of drainage within the allowable range. Thus, the drainage method was reliable and the operation field was better than using diode. It was worth noting that, for patients with the weight over 70kg, even if using the maximum diameter of catheterization (28Fr) for femoral venous drainage was unable to meet the operation requirement and must be with the vacuum-assist venous drainage.

For all types of the thoracoscopic cardiac operations, peripheral CPB should not only ensure the unobstructed drainage, but also consider the problem whether which was adequate for the tissue perfusion or not. It should be noted that the peripheral CPB was established only through the arteria femoralis and femoral vein intubation combined with the superior vena cave (internal jugular vein) percutaneous intubation, in the case of long CPB time, the peripheral CPB had poorer perfusion of cerebral tissue and the distal limb tissues than that of central CPB. Therefore, in the preoperative assessment, the operation time needed to be estimated. For those minimally invasive cardiac surgeries with long operation time, peripheral CPB should be considered carefully to reduce the incidence of complications associated with CPB, taking the risks of tissue perfusion into consideration.

Furthermore, hypothermy was an effective method for myocardial protection during cardiac arrest. However, ice could not be used to cooling the heart in thoracoscopic operation. Thus, we did not choose HTK cardioplegia for myocardial perfusion once a time, but interrupted perfusion of Tomas warm blood cardioplegia was performed every 20 minutes through the perfusion cannula inserted in root of aorta during the ACC, which could maintain hypothermy on heart. The success rate of spontaneous heart re-beat was high after releasing the aortic clamp, and there was no occurrence of severe low cardiac output syndrome.

Currently, there are growing numbers of patients suffering from tricuspid valve disease, and annuloplasty is performed as much as possible in the surgical treatment of tricuspid valve disease. The usual procedure of annuloplasty included Devage annuloplasty, Kay annuloplasty and artificial valve annuloplasty [7-9]. In addition, the severe tricuspid insufficiency secondary to cardiac surgery has seriously affected the quality of patients' life, and the positive surgical treatment has been paid more and more attention. However, the patients who underwent the re-operation of median sternotomy had a mortality rate of 5% to 26% at the 30 days follow-up [10], in the term, the thoracoscopic tricuspid valve re-operation with peripheral extracorporeal circulation has obvious advantages. It had achieved a fairly good curative effect with midterm follow-up that tricuspid valve re-operation was performed through right thoracic approach including right anterolateral small incision and thoracoscope assisted right small incision [11]. In this study, we had performed the total thoracoscopy assisted tricuspid valve re-operation under peripheral CPB for seven patients (3 cases with artificial valve annuloplasty; 4 cases with tricuspid valve replacement), which all achieved satisfactory outcomes after surgical treatment. Moreover, the thoracoscopic tricuspid valve re-operation led to a lowering of the pain perception of the patients in comparison with the first operation. The re-operation procedure we performed was not clamping the aorta and vena cava, thus, we did not need to separate the pericardial adhesion, right atrium was incised directly from the pericardium. During operation, peripheral CPB

was run under the vacuum-assist femoral vein drainage (negative pressure adjusted at about 15 to 30 mmHg) and Esmolol was injected to control heart rate of 20 beats/min, these could provide a clear operation field (Figure 1). For the severe adhesion of pleura and heart in the tricuspid valve re-operation, surgeons and patients are more conservative in the past, which could easily cause right heart impairment and severe pulmonary hypertension, even the damage of organs, such as liver and kidney in the long run. Hence, all the above resulted in a significant increase in the risk of re-operation. However, with the mature of the technology of total thoracoscopy assisted cardiac operation with peripheral CPB, it is expected to reduce the risk of this type of surgery and to improve the prognosis.

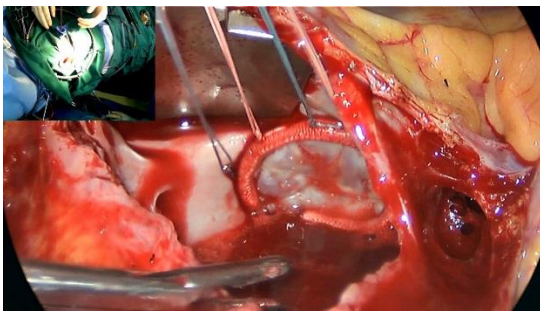


Figure 1. Peripheral CPB was helpful to tricuspid valve re-operation by totally video assisted thoracoscopy without the difficulties from deep and narrow operation area.

In summary, the basic principle of totally thoracoscopic surgery with peripheral CPB was the same as the open heart surgery [11]. Our study suggested that the tricuspid annuloplasty by thoracoscopy could be used in complex surgical treatment of tricuspid valve lesion, peripheral CPB could keep the operation field clear with the good exposure of valve and subvalvular apparatus (Figure 2). Thus, it was entirely feasible that the thoracoscopic tricuspid valve operations were on the basis of the peripheral CPB established through the arteria femoralis and femoral vein intubation combined with the internal jugular vein percutaneous intubation.

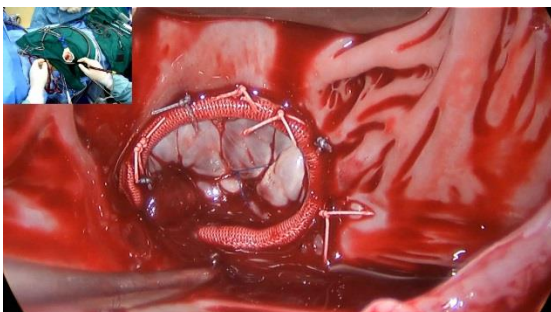


Figure 2. Peripheral CPB in the surgical treatment of tricuspid valve disease by thoracoscopy could provide good surgical conditions.

V. CONCLUSION

Based on clinical practice, we vigorously supported the widespread application of the peripheral extracorporeal circulation established through the arteria femoralis perfusion combined with the intubation

drainage of the femoral vein and internal jugular vein for total thoracoscopy assisted cardiac operation. There was no increase in CPB time and ACC time, the drainage was unobstructed and the operation field was well expose during operation, and it could be the preferred method of establishing extracorporeal circulation with good myocardial protection for all kinds of minimally invasive surgeries for tricuspid valve diseases.

ETHICAL APPROVAL

This study was approved by the human research ethics committee of Jinan University, Guangzhou, China, as well as those of co-operating hospitals and was performed in accordance with the principles of the Declaration of Helsinki.

INFORMED CONSENT

Written informed consent was obtained from all participants.

COMPETING INTERESTS

This work was performed in collaboration with Guangdong Cardiovascular Institute. Ming-Jie Mai is the archiater of Guangdong Cardiovascular Institute. The authors declare that they have no conflicts of interest.

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