

Cardiopulmonary Bypass in Surgery for Interrupted Aortic Arch

Huimin Huang, MD; Demin Zhu, MD; Hong Chen, MD; Wei Wang, MD; Wei Zhang, MD; and Weiding Fu, MD

Department of Cardiothoracic Surgery, Shanghai Children's Medical Center, Xinhua Hospital, Shanghai Second Medical University, Shanghai, China

Abstract: Interrupted aortic arch is a complicated congenital heart defect. Because of its anatomic features, the conventional cardiopulmonary bypass (CPB) procedure is not suitable for the surgery of this type of lesion. Thus, we conducted a retrospective study of CPB in surgery for the disease. Ten patients with interrupted aortic arch underwent surgery by one of three different CPB methods, including profound hypothermia with circulatory arrest in four cases, profound hypothermia with low flow rate in five cases, and normothermia in one case. In profound hypothermic CPB, both ascending aorta and main pulmonary artery were cannulated. Through these two cannulas, the flow was pumped to the upper and lower body separately to cool down the body temperature. After cooling, the main pulmonary artery cannula was removed and interrupted aortic arch was corrected either under low flow rate perfusion or under circulatory arrest. After this, the other intracardiac lesions were repaired under conven-

tional CPB. At the end of CPB, one patient demonstrated third-degree atria-ventricular block and required reinstituting CPB and a second procedure to repair the ventricular septal defect (VSD). In the intensive care unit, one patient developed lung infection and dyspnea after extubation that required intubation and mechanical ventilation for another several days. Another patient required 3 days of peritoneal dialysis caused by low cardiac output, hyperkalemia, and oliguria. All patients survived. The mechanical ventilation times were from 8 hours to 8 days and stays in the intensive care unit were from 4 to 12 days. Profound hypothermic cardiopulmonary bypass either with low flow rate or with circulatory arrest is equally the preferable choice for the surgery of interrupted aortic arch. **Keywords:** interrupted aortic arch, cardiopulmonary bypass, profound hypothermia. JECT. 2004;36:358–360

Interrupted aortic arch (IAA) is a complicated congenital heart defect (1–3). From October 1999 to June 2003, 11 patients diagnosed with IAA underwent surgery in our hospital; they comprised approximately 0.27% of the patients receiving operations in this period. With the exception of one case who was operated without the use of cardiopulmonary bypass (CPB), the other 10 patients underwent radical operations under CPB. Because of the anatomic features of this type of defect, the CPB procedure is very different than the standard methods used in operations for other congenital heart defects.

MATERIALS AND METHODS

Patients

Ten pediatric patients were retrospectively studied in this trial. The ages of the patients were from 4 months to 9 years: three were younger than 1 year of age, three were from 1 to 3 years, and the other four were older than 3 years of age. The weights of the patients were from 6 to 31

kg: Six were less than 10 kg, 3 were from 10 to 15 kg, and the other was greater than 15 kg. All the patients were diagnosed by two-dimensional echocardiography, catheterization, and angiocardiology. Besides the IAA defect, all the patients presented with cardiac lesions, such as ventricular septal defect (VSD) and patent ductus arteriosus (PDA). Most of the patients also had various degree of pulmonary hypertension (Table 1).

Cardiopulmonary Bypass

Three different types of CPB methods were used for these patients. Four patients underwent profound hypothermia with circulatory arrest, five patients underwent profound hypothermia with low flow rate, and one patient underwent normothermic CPB.

Profound Hypothermia With Circulatory Arrest After mediastinotomy, the ascending aorta and main pulmonary artery were cannulated, and both cannulas were connected to the bypass circuit by a three-way adaptor. The right atrium also was cannulated and was connected to the bypass circuit as usual. As soon as the left and right pulmonary arteries were occluded, the CPB was initiated, and blood was cooled down. During the cooling period, some pump volume flowed through the ascending aorta catheter to the coronary artery, brain, and upper arms vessels,

Address correspondence to: Huimin Huang, Department of Cardiothoracic Surgery, Children's Medical Center, Xinhua Hospital, Shanghai Second Medical University, 1678, Dongfang Road, Shanghai (200127), China. E-mail: wenfeik@online.sh.cn

Table 1. Preoperative demographic data.

Number	Sex	Age	Weight (kg)	Diagnosis
1	Male	1 yr. 9 mon.	10	IAA(A), VSD, PDA, PH
2	Male	3 yr. 9 mon.	12	IAA(A), VSD, PDA, PH
3	Male	9 yr. 2 mon.	31	IAA(A), residual of fifth aortic arch
Stenotic				
4	Female	3 yr. 5 mon.	14	IAA(B), PDA, LSVC, PH
5	Male	7 mon.	6	IAA(B), VSD, PDA, PH
6	Female	3 yr. 2 mon.	13	IAA(A), VSD, PDA, PH
7	Female	1 yr. 5 mon.	10	IAA(B), right vagosubclavian artery
8	Male	6 mon.	7	IAA(A), VSD, PDA, PH
9	Female	1 yr. 2 mon.	8	IAA(A), VSD, PDA, PH
10	Female	4 mon.	6	IAA(A), VSD, PDA, PH

whereas other pump volume flowed through main pulmonary artery catheter to the descending aorta to perfuse the lower body area. When the rectal temperature had been cooled down to 18 to 20°C, the circulation was arrested. The aortic root was then crossclamped, and heart was suppressed by St Thomas crystalloid cardioplegia solution. The main pulmonary artery cannula was removed, and both the left and right pulmonary arteries were released. PDA was dissected. The proximal end of it was closed, and the distal end of it was anastomosed to the side of ascending aorta. After the anastomosis, the superior vena cava and inferior vena cava were cannulated, and CPB was reinstituted. Both vena cava also were crossclamped, and then the other intracardiac defects were repaired under CPB. During the anastomosis of IAA, the head—arm vessels were occluded to prevent the air embolus in the intracranial blood vessels. CPB time for the patients was 67.7 ± 18.0 minutes, aortic root crossclamping time was 62.7 ± 15.3 minutes, and circulatory arrest time was 40.7 ± 10.9 minutes.

Profound Hypothermia With Low Flow Rate The cannulation of both ascending aorta and main pulmonary artery and their connection to the CPB circuit were the same as those used in profound hypothermia with circulatory arrest. Superior vena and inferior vena cava were cannulated and were connected to the bypass circuit as usual. After the left and right pulmonary arteries were occluded, the CPB was initiated and blood was cooled down. As with the profound hypothermia group with circulatory arrest, some pump volume flowed through the ascending aorta cannula to the coronary artery, brain, and upper arms vessels, whereas the other pump volume flowed through the main pulmonary artery cannula to the descending aorta to perfuse the lower body area. After cooling down to the 22 to 25°C in the rectum, the main pulmonary artery cannula was occluded and then was removed. Both left and right pulmonary arteries were released. The descending aorta was clamped and flow rate was decreased to 30 milliliters per minute per kilogram

body weight. PDA was dissected. The proximal end of it was closed and distal end of it was anastomosed to the side of ascending aorta except one case with right vagosubclavian artery, in which the distal end of dissected PDA was anastomosed to the left carotid artery. After the anastomosis of IAA, the descending aorta was released and flow rate was increased. Afterwards, the aortic root was clamped and heart was suppressed by cardioplegia solution. Other intracardiac defects were then repaired. CPB time, aortic root crossclamping time, and descending aorta crossclamping time were 119.8 ± 48.6 minutes, 54.5 ± 17.9 minutes, and 45.2 ± 13.6 minutes, respectively.

Normothermic CPB One of the patients was complicated with a residual of fifth aorta arch, which was stenotic. This patient accepted normothermic CPB for the operation. After mediastinotomy, the ascending aorta and right atrium were cannulated and CPB was initiated as usual. The residual of the fifth aorta arch was incised longitudinally and was expended by Gore-Tex patch. CPB lasted 58 minutes and crossclamping time of descending aorta was 31 minutes. The flow rate during descending aorta crossclamping was 30 milliliters per minute per kg body weight.

RESULTS

The operative procedure and CPB for all the patients were successful and ran smoothly. After we released the aortic root, the hearts of all the patients resumed sinus rhythms spontaneously except one, in whom a third-degree heart block occurred. Reinstitution of CPB was needed to redo the repair of VSD in this case. Several days after operation, this patient also resumed sinus rhythm. In the intensive care unit, one patient had a lung infection and dyspnea after extubation and required reintubation and mechanical ventilation for another several days. One patient required 3 days peritoneal dialysis because of low cardiac output, hyperkalemia, and oliguria. The other patients recovered smoothly. No deaths were observed in this group of patients. The mechanical ventilation were from 8 hours to 8 days and intensive care unit (ICU) stays were from 4 to 12 days.

DISCUSSION

Methods of CPB in surgery for IAA are not the same as those in surgery for other cardiac defects because the descending aorta must be clamped and the lower body area perfused by blood from the descending aorta is ischemic during the anastomosis of the interrupted aortic arch (3,4). We used to manage the CPB much different from that which is reported here for the repair of this type of lesion. In the previous method, there were two steps in the operation. First, the IAA was repaired without CPB under

normothermia through a left intercostal space incision. Then, the other intracardiac defects were repaired through the median incision under the conventional CPB and cardiac arrest (5). This method is troublesome and not safe because the clamping of descending aorta might induce spinal cord and kidneys ischemia and other complications. Thus, this method was discontinued.

Most of the cases in this report underwent surgery under the hypothermic CPB with circulatory arrest or with low flow rate. Because of the anatomic feature, the hypothermic CPB with circulatory arrest or with low flow rate used in this type of defect has some different aspects.

No matter which of these two methods is chosen, both the ascending aorta and main pulmonary artery should be cannulated to supply the pump flow to upper and lower body areas through these two cannulas, respectively, to cool the body temperature equally. During this period, the left and right pulmonary arteries should be clamped to prevent the flow going through the lung, which could induce severe lung side effects.

If the hypothermia with low flow rate was used, main pulmonary artery cannula could be removed after the rectum temperature reached 22 to 25°C, and then the flow rate should be decreased to 20 to 30 milliliters per minute per kilogram body weight because the pump flow at that time perfused only the heart, brain, upper limbs, and other upper body area. After the anastomosis of IAA, the descending aorta crossclamping should be released and whole body perfusion restored. Of course, the flow rate should be increased immediately to resume the whole body perfusion. Moreover, the aortic root should not be clamped during the anastomosis of IAA to maintain the coronary artery perfusion. Only after the completion of this procedure, the aortic root was crossclamped to further repair the other intracardiac lesions thereby limited the heart ischemic time.

If the profound hypothermia with circulatory arrest was used, the head—arm vessels should be occluded during the anastomosis of IAA to prevent the intracranial air

embolus (4). Furthermore, the CPB should be reinstituted as the anastomosis of IAA is completed. The repairing of the other intracardiac lesions could be done under conventional CPB to limit the circulatory arrest time and decrease the brain complication produced by brain ischemia during the circulatory arrest.

IAA is a rare and complicated congenital heart defect. Profound hypothermic CPB with circulatory arrest or with low flow rate should be recommended in the surgery for this type of lesion (6). In our practice, for those infants or younger children, in whom the anastomosis of IAA was difficult, the circulatory arrest was adopted; otherwise, the low flow rate was used. In this report, three of four patients with circulatory arrest were younger than 1 year of age, and the five patients with low flow rate were older.

One patient, who was complicated with a residual of fifth aortic arch, received normothermic CPB. In that case, the stenotic fifth aortic arch was expanded using a Gotex patch under the condition of descending aorta occlusion. If the child was old enough and the crossclamping duration of descending aorta is suspected to be limited in a safe range, the normothermic CPB could be attempted. Otherwise, the profound hypothermic CPB should be the choice in the surgery for this type of lesion.

REFERENCES

1. Jahangiri M, Zurakowski D, Mayer JE, et al. Repair of the truncal valve and associated interrupted arch in neonates with truncus arteriosus. *J Thorac Cardiovasc Surg.* 2000;119:508–14.
2. Watanabe T, Tajima K, Sakai Y, et al. Everting closure for interrupted aortic arch, ventricular septal defect, and severe subaortic stenosis. *Thorac Cardiovasc Surg.* 1998;46:33–6.
3. Hata H, Shiono M, Sezai Y, et al. One-stage repair of interrupted aortic arch and aortopulmonary window. *Ann Thorac Surg.* 1998;65:829–31.
4. Castaneda AR, Jonas RA, Mayer JE, et al. *Cardiac Surgery of the Neonate and Infant.* 1st ed. Philadelphia: Saunders; 1994: 353–62.
5. Huang HM, Zhu DM, Chen H, et al. Different cardiopulmonary bypass method in operations for interrupted aortic arch. *Chin J Clin Thorac Cardiovasc Surg.* 2003;10:80.
6. Jonas RA, Elliott MJ. *Cardiopulmonary Bypass in Neonates, Infants and Young Children.* 1st ed. Oxford: Butterworth-Heinemann; 1994: 138–9.