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Bidirectional cavopulmonary anastomosis without cardiopulmonary bypass

Kardiyopulmoner baypassız bidireksiyonel kavopulmoner anastomoz

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ABSTRACT

Background: In this article, we present the results of an off-pump cavoatrial shunt technique to creat a cavopulmonary bidirectional anastomosis.

Methods: Thirty-eight consecutive patients (18 boys, 20 girls; mean age 14.9±16.8 months; range 4 months to 2.5 years) with univentricular heart physiology underwent an off-pump cavopulmonary bidirectional anastomosis between April 2003 and November 2012. The mean weight during surgery was 8.3±3.6 kg. The mean preoperative oxygen saturation and pulmonary artery pressure were 70.7±9.4% and 14.0±3.8 mmHg, respectively.

Results: There was no surgery-related mortality. The mean superior vena cava clamping time and the mean vena cava pressure during clamping were 24.3±4.7 minutes and 26.9±5.5 mmHg, respectively. There were no postoperative neurological complications or dysrhythmias. The mean postoperative saturation was 85.9±5.9%. There were four postoperative deaths. The mean length of intensive care unit stay was two days. Follow-up echocardiography showed functioning cavopulmonary bidirectional anastomosis without any obstruction.

Conclusion: The cavopulmonary bidirectional anastomosis without cardiopulmonary bypass with the support of a cavoatrial shunt is a feasible and safe method. It also eliminates the adverse effects of cardiopulmonary bypass.

Keywords: Cardiopulmonary bypass; cavopulmonary bidirectional anastomosis; single ventricle.

ÖZ

Amaç: Bu çalışmada bidireksiyonel kavopulmoner anastomoz oluşturmak için atan kalpte kavoatriyal şant tekniğinin sonuçları sunuldu.

Çalışma planı: Nisan 2003 - Kasım 2012 tarihleri arasında tek ventrikül kalp fizyolojisi olan 38 ardışık hastaya (18 erkek, 20 kız; ort. yaş 14.9±16.8 ay; dağılım 4 ay - 2.5 yıl) atan kalpte bidireksiyonel kavopulmoner anastomoz uygulandı. Ameliyat sırasında ortalama vücut ağırlığı 8.3±3.6 kg idi. Ameliyat öncesi ortalama oksijen satürasyonu ve pulmoner arter basıncı sırasıyla %70.7±9.4 ve 14.0±3.8 mmHg idi.

Bulgular: Ameliyata bağlı mortalite görülmedi. Ortalama vena kava superior klemp zamanı ve klemp sırasında vena kava basıncı sırasıyla 24.3±4.7 dakika ve 26.9±5.5 mmHg idi. Ameliyat sonrası nörolojik komplikasyon veya ritim bozuklukları görülmedi. Ameliyat sonrası oksijen satürasyonu %85.9±5.9 idi. Ameliyat sonrası dört hasta kaybedildi. Ortalama yoğun bakım ünitesinde kalış süresi iki gün idi. Takip ekokardiyografisinde herhangi bir tıkanıklık olmaksızın, fonksiyonel bidireksiyonel kavopulmoner anastomoz izlendi.

Sonuç: Kavoatriyal şant desteği ile kardiyopulmoner baypas kullanılmadan bidireksiyonel kavopulmoner anastomozu uygulanabilir ve güvenli bir yöntemdir. Ayrıca, kardiyopulmoner baypasın olumsuz etkilerini de ortadan kaldırır.

Anahtar sözcükler: Kardiyopulmoner baypas; bidireksiyonel kavopulmoner anastomoz; tek ventrikül.

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The bidirectional cavopulmonary anastomosis (BCPA) is a commonly performed procedure for univentricular hearts which leads eventually to single ventricle repair. The BCPA procedure offers an important intermediate palliation in patients with a structurally or functionally univentricular heart, who are ultimately destined to a Fontan circulation.[1] The BCPA procedure is commonly performed using cardiopulmonary bypass (CPB) with early and late satisfactory results. However, using CPB may have some deleterious effects. The BCPA without CPB can be performed using various techniques for decompression of the SVC during the anastomosis.[2] In this article, we report our experiences of an off-pump BCPA procedure with a venovenous shunt to avoid CPB.

PATIENTS AND METHODS

Between April 2003 and November 2012 a retrospective non-randomized comparative study was conducted at Ege University in 57 patients with single ventricle anomalies and 38 patients (18 boys, 20 girls; mean age 14.9±16.8 months; range 4 months to 2.5 years) who underwent BCPA without CPB were included. Our study was conducted in accordance with the principles of Declaration of Helsinki. The study protocol was approved by the local ethics committee.

The inclusion criteria were functional single ventricles with a mean pulmonary artery pressure of <18 mmHg, McGoon ratio of >1.5, non-restrictive atrial septal defect, and no other intracardiac defect requiring correction. Patients with complex congenital cardiac anomalies amenable to biventricular or one and a half ventricular repair, patients <6 months of age, and patients with ventricular outflow tract obstruction or requiring intracardiac repair were excluded from this study. Patients who had persistent left superior vena cava (SVC) were also excluded.

The procedure was performed under general anesthesia. All patients had routine intraoperative monitoring, including five-lead electrocardiogram, pulse oximetry, and capnography for end-tidal carbon dioxide measurement. Venous pressure monitoring was done through a multiport cannula into either femoral vein and a short cannula placed in the internal jugular vein. An invasive arterial pressure line was placed in the radial or femoral artery. After median sternotomy, the thymus was partially resected and the pericardium was opened. The SVC and innominate vein were dissected staying closer to the cava to preserve lymphatic channels. The right branch of the pulmonary artery was dissected up to the hilum and isolated. Patent aortic-pulmonary shunts and ductus arteriosus were identified and dissected. Purse string sutures were placed on the innominate vein at its junction with the SVC. Another purse string suture was placed on the right atrial appendage. After systemic heparinization, the innominate vein and the right atrial appendage were cannulated*, connected through a three way connector and de-aired (*Medtonic DLP right angle single stage venous cannula, Minneapolis, Minnesota, USA). With the shunt open and reversed Trendelenburg position, the SVC was clamped at the right atrial end and divided between the clamps. The right atrial end was oversewn and the right pulmonary artery was clamped with a C-clamp. The SVC was anastomosed to the right pulmonary artery with an end-to-side continuous suturing. The clamps were then released. At the end of the procedure, aortic-pulmonary shunts or patent ductus arteriosus were occluded by ligation.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for windows version 21.0 software program (IBM Corporation, Armonk, NY, USA). Continuous variables are expressed in either mean and standard deviation or median values [interquartile range] based on overall variable distribution. Distributed data were analyzed by the Kolmogorov-Smirnov test. The Mann-Whitney U test was used to analyze quantitative data. A p value of <0.05 was considered statistically significant.

RESULTS

The mean weight during surgery was 8.3±3.6 kg. The mean preoperative oxygen saturation was 70.7±9.4%. The mean hematocrit was 52.2±8.7%. The mean pulmonary artery pressure was 14.0±3.8 mmHg. All patients had cyanosis and dyspnea on exertion. Table 1 shows the various congenital defects. Twelve patients

Table 1. Congenital cardiac defects (n=38)

Diagnosis	n
Tricuspid atresia + pulmonary atresia	16
Tricuspid atresia + hypoplastic right ventricle	9
Atrioventricular septal defect Rastelli type C	8
Mitral atresia + pulmonary atresia + left ventricular hypoplasia	3
Double inlet right ventricle + pulmonary atresia + hypoplastic left heart	1
Pulmonary atresia + tricuspid hypoplasia + intact ventricular septum + right ventricular dependent coronary circulation	1

(31.6%) previously underwent modified Blalock-Taussig shunting, while six patients (15.8%) underwent pulmonary artery banding.

There was no operative mortality. Thirty-four patients were discharged and followed for Fontan completion. There were four late postoperative deaths ranging from 7 to 20 days with a median value of 12.5 days, which were attributed to non-neurological causes (mechanical ventilation-related pneumonia and sepsis). Mechanical ventilation time ranged from 1 to 23 days with a median value of one day. The mean length of intensive care unit stay was two days.

There was no hemodynamic instability during procedures and oxygen saturation was maintained at >65% during clamping. The postoperative saturation was 85.9±5.9%. None of the patients were converted to CPB. There were no postoperative dysrhythmias or bleeding; however, prolonged chest tube duration was seen in five patients due to persistent serous pleural effusion. The mean chest tube duration time was 2.7±3.7 days. No blood products were required perioperatively. All patients showed a well-functioning BCPA without any narrowing of SVC-pulmonary artery anastomosis on repeated echocardiography before discharge. All patients had normal neurological status at the time of discharge and at one and three months during follow-up.

DISCUSSION

The BCPA procedure without CPB has been adopted by many centers using various techniques for decompression of the SVC during the anastomosis.[3] Although some advocated this procedure through right thoracotomy, we often prefer median sternotomy which has the advantages of better exposure and rapid institution of CPB in case of emergency.[2,3]

Avoidance of CPB and aortic cross clamping has the advantages including earlier extubation, less blood products, reduced necessity and duration of inotropic support. Some authors have demonstrated increased pulmonary vascular resistance and hypoxia after CPB and possible development of aortopulmonary shunts after establishing CPB, leading to prolonged pleural effusions.[4-6] On the other hand, we believe there are many factors which affect pulmonary vascular resistance in the postoperative period, including mechanical ventilation, pain, infection, and drug hypersensitivity.

In a study, Lamberti et al.[7] reported BCPA without CPB by establishing temporary venoatrial bypass shunting between the SVC and right atrium. Unlike Lamberti's study, Lal and Mahant[8] described a different technique of venoatrial bypass, where the SVC blood was drained into a reservoir and was pumped into the right atrium with the help of a roller pump. In another study, Murthy et al.[9] performed shunting between the SVC and the pulmonary artery. Venoatrial shunting is challenging to perform in patients who have pulmonary artery hypoplasia. A surgical procedure on the pulmonary artery may also cause distortion, rendering it unsuitable for the Fontan repair. In our study, a venoatrial shunt was used in all patients. The technique was easy to perform and allowed good operative exposure, although there was a mild saturation of peripheral oxygen (SpO_2) decrease, while the SVC was clamped. Of note, the risk of decreased cerebral perfusion with SVC clamping has been a concern with all shunt techniques. The high central venous pressure (CVP) on the clamping period may cause some problems. High CVP values may result in low transcranial pressure gradients, which are defined as the difference between the systolic arterial pressure and the mean jugular venous pressure at a minimum of 30 mmHg.[10] To avoid a significant increase in SVC pressure on clamping and to prevent its adverse effects, it seems reasonable to use a temporary veno-venous shunt, which allows decompression of the SVC and improvement of the cerebral perfusion.[11] Although such reports have documented no significant differences in neurological sequelae after clamping the SVC without the use of any shunt, we believe that clamping the SVC without a temporary shunt may lead to decreased cerebral blood flow and put the brain at risk.[12,13]

In a study, Liu et al.[13] reported that BCPA without CPB was reasonably safe, if SVC pressure after clamping remained at less than 30 mmHg and clamping time was less than 30 minutes. In consistent with these findings, the mean SVC clamping time and SVC pressure after clamping remained at less than 30 minutes and 30 mmHg, respectively, without any neurological complications in our study cohort. In addition, intraoperative coordination with an anesthesiologist remains the mainstay of a successful procedure. Inotropes and volume replacement were used to maintain adequate cerebral blood flow and a higher transcranial pressure gradient during anastomosis.

In conclusion, we suggest that BCPA without CPB perfusion using a temporary extracardiac venovenous shunt is a safe, reproducible procedure, which offers good results. As blood transfusion is not necessarily required, certain problems related to CBP, blood transfusion, and protamine administration can be

eliminated and the cost, therefore, can be reduced. In carefully selected cases, BCPA without CPB is easy to perform with a valid self bypass shunt. In this respect, this study further supports the need for additional prospective randomized and controlled trials.

Declaration of conflicting interests

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