the heart by infusing the cardioplegic solution under aortic occlusion by means of the balloon throughout the procedure. Even though the balloon catheter passes through the aortic valve, significant aortic valve insufficiency is not likely to occur because of the small caliber of the balloon catheter. We believe that the clinical application of this double-lumen aortic occlusion catheter will protect the myocardium in patients with a thoracoabdominal aortic aneurysm or distal descending aortic aneurysm who undergo the operation through the left thoracotomy with DHCA.

REFERENCES

1. Kouchoukos NT, Wareing TH, Izumoto H, Klausling W, Abboud N. Elective hypothermic cardiopulmonary bypass and circulatory arrest for spinal cord protection during operations on the thoracoabdominal aorta. *J Thorac Cardiovasc Surg* 1990;99:659-64.
2. Rokkas CK, Sundaresan S, Shuman TA, Palazzo RS, Nitta T, Despotis GJ, et al. Profound systemic hypothermia protects the spinal cord in a primate model of spinal cord ischemia. *J Thorac Cardiovasc Surg* 1993;106:1024-35.
3. Kouchoukos NT, Daily BB, Rokkas CK, Murphy SF, Bauer S, Abboud N. Hypothermic bypass and circulatory arrest for operations on the descending thoracic and thoracoabdominal aorta. *Ann Thorac Surg* 1995;60:67-77.
4. Okita Y, Takamoto S, Ando M, Morota T, Kawashima Y. Utilization of triple-lumen balloon catheter for occlusion of the ascending aorta during distal aortic arch surgery with hypothermic circulation technique through left thoracotomy. *J Card Surg* 1995;10:699-702.

MODIFIED HEMI-FONTAN PROCEDURE ON THE BEATING HEART

Franz-Xaver Schmid, MD, Friedrich Wippermann, MD, Christoph Kampmann, MD, Michael Hilker, MD, and Hellmut Oelert, MD, Mainz, Germany

Indication, timing, and type of surgical intervention in patients with single ventricle physiologic condition are a continuing challenge. For patients who have significant risk factors for a poor Fontan outcome, the bidirectional cavopulmonary anastomosis has been shown to be an effective staging procedure by providing pulmonary blood flow without volume loading of the single ventricle.^{1,2} It offers the benefit of a relatively simple surgical approach and can be performed as a closed procedure with the heart beating on partial cardiopulmonary bypass. However, later completion of the Fontan circulation can only be accomplished by extensive dissection of the cardiac end of the superior vena cava and of the right atrium. Additionally, there may be an increased risk for arrhythmias and phrenic nerve palsy. Therefore the so-called hemi-Fontan procedure, including an anastomosis between both ends of the divided superior vena cava and the pulmonary artery in conjunction with an intraatrial patch occlusion of the cavoatrial junction, was introduced.³ This procedure involves opening of the right atrium during a short period of aortic crossclamping and cardioplegic arrest and

Fig 1. Schematic display of the operative procedure: Proximally eversion is facilitated by dissection and mobilization of the full length of the superior vena cava (SVC). RPA, Right pulmonary artery; MPA, main pulmonary artery; RA, right atrium.

From the Departments of Cardiothoracic Surgery and Pediatric Cardiology, Johannes Gutenberg-University Hospitals, Mainz, Germany.

Received for publication July 16, 1998; accepted for publication July 30, 1998.

Address for reprints: Franz-Xaver Schmid, MD, Department of Cardiothoracic Surgery, University Hospitals, Langenbeckstrasse 1, D-55131 Mainz, Germany.

J Thorac Cardiovasc Surg 1999;117:188-90

Copyright © 1999 by Mosby, Inc.

0022-5223/99 \$8.00 + 0 12/54/93616

may increase the overall risk of the operation. We developed an alternative technique for a hemi-Fontan procedure on cardiopulmonary bypass without the requirement for aortic crossclamping.

Technique. The operation is performed through a median sternotomy incision. Cardiopulmonary bypass is established by aortic perfusion and drainage via cannulation of the right atrium and the innominate vein. Clamps are placed on the

superior vena cava with some distance superior to the cavoatrial junction and just below the innominate vein orifice. The superior vena cava is transected at the level of the superior margin of the right pulmonary artery. The cut edges of the cardiac end of the divided superior vena cava are everted with gentle axial traction. The venous stump is kept everted until a patch is sutured within the superior vena cava near its entrance site to the right atrium (Fig 1). After complete internal occlusion, the eversion is reduced. The operation is completed with the creation of a total cavopulmonary connection with anastomosis of the cranial and cardiac end of the divided superior vena cava into a longitudinal incision in the superior and inferior aspect of the right pulmonary artery. Thus a hemi-Fontan circulation is established (Fig 2). Subsequent completion of the Fontan procedure requires the excision of the patch from within the right atrium and construction of the lateral atrial tunnel.

Patients and results. From June 1, 1996, to April 30, 1998, 14 infants with hypoplastic left heart syndrome who survived the Norwood procedure (including pulmonary artery to ascending aorta anastomosis with homograft augmentation of the aortic arch, atrial septectomy, and placement of a 3.5-mm modified right Blalock-Taussig shunt) underwent a modified hemi-Fontan operation as an intermediate stage for an eventual Fontan procedure at our institution. The hemi-Fontan operation was performed at a mean age of 7.6 ± 5.4 months (range, 3 to 14 months). Mean bypass time was 68.9 minutes (range, 40 to 127 minutes). All surgical procedures were performed while the heart was beating. Oxygen saturation after discontinuation of cardiopulmonary bypass was 83.1% (75% to 88%). There was no operative death. The early postoperative course was smooth in all patients, with weaning from the ventilator and discharge to the ward between 2 and 6 days after the operation. The youngest patient in this series had significant pleural effusions and required chest tube drainage for 5 days. Chylothorax occurred in one patient.

Three weeks of a fat-free diet was required for cure. No arrhythmias occurred, and no antiarrhythmic medication became necessary.

After a period of 8, 12, and 13 months of follow-up in 3 patients, the hemi-Fontan circulation was converted to a complete Fontan circulation by placement of an intra-atrial baffle. During the short follow-up period, no complications occurred. All patients are alive and well.

Comment. The hemi-Fontan operation (functional bidirectional cavopulmonary anastomosis) has proved to be a safe and effective preparatory stage for a Fontan procedure, especially in young and high-risk candidates.⁴ The technical modification that is reported here offers several potential advantages. The total cavopulmonary anastomosis can be performed on normothermic cardiopulmonary bypass with the heart beating. Avoiding myocardial ischemia may be of substantial importance in patients with increased surgical risk, as are patients experiencing second-stage palliation of hypoplastic left heart syndrome.⁵ The absence of intra-atrial suture lines by performing an extracardiac occlusion of the superior vena

Fig 2. Lateral angiogram reveals wide patency of the cavo-pulmonary anastomoses and closure of the cavoatrial junction. The angiogram was performed during follow-up study before Fontan completion. Bidirectional pulmonary blood flow is noted.

cava at its right atrial junction and the avoidance of extensive dissection at the time of the Fontan completion may contribute to decrease the incidence of atrial arrhythmias. Moreover, creation of the inferior cavopulmonary anastomosis is facilitated because it can be performed when the clamp at the cardiac end is already released.

An adequate length of the cardiac end of the superior vena cava is critical for its eversion. Ligation and division of small venous branches draining to the superior vena cava and of the azygos vein allow extensive mobilization of the superior vena cava. Azygos continuation of the inferior vena cava may significantly reduce the length of the vein available for the anastomosis. Thus the vascular clamp has to be placed near the cavoatrial junction, with the sinus node at risk for damage. In this situation we do not recommend our modified surgical procedure.

In patients with an additional left superior vena cava, this also is anastomosed to the pulmonary artery in an end-to-side fashion but is oversewn at its cardiac end. Moreover, ensuing completion of the Fontan circulation after the aforementioned hemi-Fontan modification can also be performed easily as a total extracardiac cavopulmonary procedure.

In conclusion, the hemi-Fontan operation can be accomplished without cardiac arrest and low operative morbidity and mortality in the setting of hypoplastic left heart syndrome and in most patients with a functional single ventricle. Long-term follow-up of this technique will provide further information on its potential advantages.

REFERENCES

1. Albanese SB, Carotti A, Di Donato RM, et al. Bidirectional cavopulmonary anastomosis in patients under two years of age. *J Thorac Cardiovasc Surg* 1992;104:904-9.
2. Hopkins RA, Armstrong BE, Serwer GA, et al. Physiologic rationale for a bidirectional cavopulmonary shunt. *J Thorac Cardiovasc Surg* 1985;90:191-8.
3. Jacobs ML, Rychik J, Rome JJ, et al. Early reduction of the volume work of the single ventricle: the hemi-Fontan operation. *Ann Thorac Surg* 1996;62:456-62.
4. Lamberti JJ, Spicer RL, Waldman JD, et al. The bidirectional cavopulmonary shunt. *J Thorac Cardiovasc Surg* 1990;100:22-30.
5. Jonas JA. Intermediate procedures after first stage Norwood operation facilitate subsequent repair. *Ann Thorac Surg* 1991;52:696-700.

IN SITU IMPLANTATION OF A PROSTHETIC SYSTEMIC ATRIOVENTRICULAR VALVE IN CORRECTED TRANSPOSITION

Amir Elami, MD, Arthur Pollak, MD, and Gideon Merin, MD, *Jerusalem, Israel*

Tricuspid valve abnormalities are common in patients with corrected transposition of the great arteries (C-TGA).¹⁻³ Anatomic abnormalities include Ebstein's malformation, straddling, dysplasia, or simply inferior displacement of the coaptation point. As a consequence, systemic atrioventricular valve insufficiency is common, occurring in up to 33% of patients with C-TGA.^{3,4} This valvular dysfunction is significant in that its presence or development negatively affects survival, whether treated surgically or not.^{1,4,5} Systemic (right) ventricular dysfunction often coexists in these patients, making it difficult to define the relative contribution of each abnormality to the progression of heart failure and shortening of survival. In contrast to normally located regurgitant tricuspid valves, where even in the presence of Ebstein's anomaly over 50% can be repaired successfully, left-sided tricuspid valves need to be replaced in most cases. The conventional technique of valve replacement involves excision, with loss of the continuity between the valve annulus, valve tissue, chordae, and ventricular wall. Preservation of the subvalvular apparatus has been shown to maintain left ventricular performance after mitral valve replacement in both animal models and clinical studies. We applied this concept to 2 patients with C-TGA and tricuspid regurgitation requiring tricuspid valve replacement (TVR).

Clinical summaries

PATIENT 1. This patient was born in June 1990. During the first year of his life, he was hospitalized frequently because of pulmonary infections as the result of congestive heart fail-

ure. Echocardiography identified C-TGA, a membranous ventricular septal defect, a patent foramen ovale, mild pulmonary stenosis, and significant tricuspid regurgitation caused by Ebstein's anomaly. Although dilated, right ventricular (systemic) function was normal. At 3.5 years of age, he underwent closure of the patent foramen ovale and ventricular septal defect, with implantation of a permanent atrioventricular (DDD) pacemaker because of intermittent complete atrioventricular block. Because he had normal right ventricular function at that time, it was decided to withhold surgical intervention for the tricuspid valve. After this procedure he remained asymptomatic for 12 months. He then started to have shortness of breath, and cardiac enlargement was evident, despite full medical treatment of congestive heart failure. Echocardiography at 5 years of age revealed moderate deterioration of systolic right ventricular function with fractional shortening (FS) of 18%. Subsequently, he underwent TVR. The septal leaflet of the valve was displaced downward, and the annulus was dilated, thereby precluding leaflet coaptation. A 27-mm St Jude Medical prosthesis (St Jude Medical, Inc, St Paul, Minn) was implanted into the tricuspid valve annulus. This was achieved by interrupted stitches that ran from the atrial aspect through the annulus and around the free edge of each leaflet and then into the prosthesis sewing ring. The leaflets were therefore folded along the annulus. When examined 1 month later, he denied any symptoms. Echocardiography revealed improvement in right ventricular function (FS, 23%) with a normally functioning prosthetic valve. In addition, he regained sinus rhythm. During his last follow-up visit, 29 months after TVR, echocardiography demonstrated a normal size-for-age systemic ventricle with mildly reduced systolic function (FS, 25%).

PATIENT 2. This patient was initially diagnosed at the age of 6 months as having situs inversus and dextrocardia. A heart murmur was also noted. In November 1992, when she was 53 years old, she started having shortness of breath on exertion. Echocardiographic findings failed to diagnose C-TGA but were instead read as severe "mitral regurgitation," moderate "tricuspid regurgitation," and normal-size "left ventricle."

From the Departments of Cardiothoracic Surgery and Cardiology, Hebrew University, Hadassah Medical School, Jerusalem, Israel.

Received for publication Aug 14, 1998; accepted for publication Sept 2, 1998.

Address for reprints: Amir Elami, MD, Department of Cardiothoracic Surgery, Hadassah University Hospital, PO B 12000, Jerusalem 91120, Israel.

J Thorac Cardiovasc Surg 1999;117:190-1

Copyright © 1999 by Mosby, Inc.

0022-5223/99 \$8.00 + 0 12/54/94222