

# Early and Mid-Term Surgical Results of Total Cavopulmonary Connection

A. Yaghoubi, MD and M. Yousefnia, MD\*

## Abstract

**Objective-** We evaluated the early and mid-term surgical outcomes and complications of intra-atrial lateral tunnel and extracardiac conduit total cavopulmonary connection to clarify the clinical superiority.

**Methods-** Forty patients underwent total cavopulmonary connection (TCPC), 26 with lateral tunnel (LT) and 12 with extracardiac conduit (EC) repair, from July 1992 to June 2004 in two centers. Survival, incidence of reoperation and early complications were compared.

**Results-** The hospital survival was 94.7% in the lateral tunnel group and 100% in the extracardiac conduit group. Seven reoperations were performed in the lateral tunnel group as opposed to three in the extra cardiac conduit group. Functional status of all survivors improved postoperatively. Significant enhancement of O<sub>2</sub> saturation was seen after these operations (mean 72.3% preoperatively, reaching 91.7%). Surgical bleeding in the lateral tunnel repair group was 5.2% and 3.8% for extracardiac conduit repair. Pericardial and pleural effusion was seen in 22% in the lateral tunnel and 17% in the extracardiac conduit group. In addition, whereas chylothorax occurred in 11% in the lateral tunnel, it was not seen in the extracardiac conduit group.

**Conclusions-** The early survival and complications are similar and satisfactory in both lateral tunnel and extracardiac conduit groups. However, the incidence of “cardiac-related” events was significantly less frequent in the extracardiac conduit group. We recommend these procedures, especially EC-TCPC, as an alternative method for patients with complex heart abnormalities who are not candidates for total surgical repair (*Iranian Heart Journal 2007; 8 (3): 16-20*).

**Key words:** total cavopulmonary connection ; complication ; congenital cardiac surgery

Fontan-type operation has been performed in a wide variety of functional single ventricle hearts, and it has evolved from atriopulmonary connection to total cavopulmonary connection (TCPC) on the basis of the theoretical advantages in terms of hydrodynamics and reduction of atrium-related complications.<sup>1-4</sup>

As more patients survive the operation, their long-term functional status has become a major concern.

Currently, the two major modifications of TCPC are the intra-atrial lateral tunnel (LT) method and the extracardiac conduit (EC) method. Be that as it may, controversy has remained in terms of long-term superiority.<sup>5-8</sup>

Received March 22, 2007; Accepted for publication July 5, 2007.

From the Cardiovascular Research Center, Tabriz University of Medical Sciences, Tabriz, Iran and the \*Department of Cardiovascular Surgery, Shaheed Rajaie Cardiovascular Medical Center, Iran University of Medical Sciences, Tehran, Iran.

Address correspondence and reprint request to: Dr. A Yaghoubi, Assistant Professor in Cardiac Surgery, Department of Cardiothoracic Surgery, Shaheed Madani Heart Hospital, Tabriz, Iran. Tel. +98 (411) 3361175 Fax. +98 (411) 3344021 E-mail: [yaghoubia@tbzmed.ac.ir](mailto:yaghoubia@tbzmed.ac.ir)

In this study, we evaluated the early surgical results and complications with the two above-mentioned procedures to provide some data and recommendations on this issue.

## Methods

### Study Group

Forty patients who underwent TCPC in Tehran (Shaheed Rajaie) and Tabriz (Shaheed Madani Heart Centers) from July 1992 to June 2004 were enrolled in this study. Twenty-six patients underwent LT-TCPC and 12 patients EC-TCPC. The age at operation was 10.6 years (SD 5.7 yrs). Follow-up was achieved for all patients, ranging from 3 months to 72 months ( $35.5 \pm 22$  months). Medical records, operative records, all available electrocardiograms, echocardiograms and pre- and post-operative cardiac catheterization records were reviewed. Diagnosis of the study population included tricuspid atresia in 20, tricuspid atresia + TGA in 6, single ventricle + TGA in 6, single ventricle in 2, large VSD in 2, and DORV+PA in 2. Most of the patients enrolled in this study were taking low-dose warfarin and aspirin for hypercoagulability state and angiotensin-converting enzyme inhibitor for cardiovascular protection postoperatively.

### Operative Techniques

All patients underwent TCPC using cardiopulmonary bypass. In LT-TCPC, after cardioplegic arrest, a longitudinal atrial incision was made. Intra-atrial baffling was completed to rout the blood flow from the inferior vena cava orifice, which was connected to the inferior surface of the pulmonary artery. The baffle material was an autologous pericardial patch in all patients. In determining the suture line, careful attention was paid to avoid the crista terminalis and the area close to the sinus node. In EC-TCPC, a connection between the inferior vena cava and the pulmonary artery was established by PTFE straight tube graft in all patients. The

size of the graft was 16-24 mm. The heart was arrested only when intracardiac procedures such as atrioventricular valvoplasty, atrial septectomy, etc. were required in this group. Fenestration was created in 2 patients in LT-TCPC group. Eight patients had previously received a PTFE shunt (Gore-Tex).

### Follow-up Assessment

All patients had follow-up assessment with a median duration of 35.5 months, with ECGs, chest radiographs, echocardiogram, and blood sampling every 3-6 months regularly. The incidence of early and late deaths, re-operations, and complications was compared between the two groups, and the overall incidence of these cardiac-related events was also calculated and compared.

### Statistical analysis

Data are expressed by mean  $\pm$  standard deviation. Actuarial survival and freedom from cardiac related events were estimated by the Kaplan-Meier method with the log-rank test. Statistical analysis was performed with SPSS software (Chicago, Ill.).

## Results

### Surgical Outcome

There were two hospital deaths in the LT-TCPC group. A 13-year-old boy with single ventricle underwent LT-TCPC and developed severe heart failure after the operation and died. Another case, a 7-year-old girl developed respiratory and heart failure and expired. The overall incidence of death was 5.3% in the LT-TCPC group and zero in the EC-TCPC group. The estimated survival at 35.5 months after surgery was 94.7% in the LT group and 100% in EC group.

### Re-operation

There were 9 re-operations in the patients: 2 for thoracic duct ligation in LT-TCPC (1 case with fenestration and one without fenestration, persistent chylothorax), 1 case

with EC-TCPC for sternal re-wiring, and 2 cases for control of post-operative bleeding in each group. One case developed RA clot formation one year after LT-TCPC, which was converted to EC-TCPC. Two patients underwent conversion to EC-TCPC because of lateral tunnel stenosis 5 and 7 years after the first operation. One case underwent balloon dilatation of the anastomosis.

### Other complications

There were 12 cases of pleural effusion as the most common early complication: 8 in the LT group and 4 in the EC group. Pericardial effusion also occurred in 4 patients: 2 in each group, which was treated conservatively. Ascitis developed in 1 patient in the EC group. Three patients in the LT group developed AF rhythm. Junctional rhythm developed in 3 cases: one in the EC and 2 in the LT group. One patient in the EC group had permanent pacemaker implantation due to third-degree AV block. Two cases from the EC group developed LA dilatation.

	LT-TCPC	EC-TCPC
Pleural effusion	8	4
Pericardial effusion +pleural effusion	2	2
bleeding	1	1
Pleural and pericardial effusion + ascitis	0	1
Pleural effusion+ chylothorax	1	0
chylothorax	1	0
Rhythm disturbance	5	2

The overall incidence of cardiac-related events (death, re-operation and arrhythmia) was higher in the LT group.

### Discussion

Since de Leval proposed an alternative procedure to the Fontan-type operation,<sup>4</sup> several modifications have developed to obtain a more efficient Fontan circulation.<sup>6,8,11</sup> However, clinical information regarding the long-term outcomes after these procedures is

still limited. Stamm and associates<sup>15</sup> reported long-term results of the LT-TCPC, showing an estimated survival of 91% at 10 years with good functional status.<sup>16</sup> Our study, that of Nakano and associates and reports by others<sup>1,7,14,16</sup> showed excellent early and mid-term outcomes of EC-TCPC with low mortality and morbidity. Nonetheless, more clinical information is necessary to discuss the long-term benefits and problems of these modifications.

In this study, early and mid-term survival, complications and functional status were equally satisfactory in both groups. Be that as it may, the incidence of cardiac related events was significantly higher in the LT-TCPC group than that in the EC-TCPC group. The incidence of arrhythmias was higher in patients with LT-TCPC, and multivariable analysis revealed that the LT procedure itself was a predictor of postoperative arrhythmia. This result concurs with the recent reports from Azakie and collages<sup>3</sup> and Overoutski and collagues<sup>13</sup> inasmuch as LT-TCPC is an independent predictor of early and intermediate postoperative atrial arrhythmias and that EC-TCPC decreases these arrhythmias. With regard to the cases of re-operation in the LT-TCPC group, 2 reoperations (2 symptomatic patients with anastomotic stenosis who underwent EC-TCPC conversion) could theatrically have been avoided if EC-TCPC had been employed at the initial surgery. Thus, mid-term cardiac related morbidities were more frequent in the LT-TCPC group, with a higher incidence of arrhythmias and re-operations.

Without a significant difference, the functional status of nearly all patients improved in both groups.

A number of studies have been done to investigate the unique features of the Fontan circulation, and it is well known that the efficiency of systemic venous blood flow largely affects the Fontan circulation. Fogel and associates<sup>5</sup> showed that the driving force for the systemic venous blood to move into the pulmonary circulation was largely cardiac

dependent. Ascutto and associates<sup>2</sup> implied that pressure loss from energy dissipation caused by flow turbulence within the systemic venous pathway could impair cardiac performance when a single ventricle must support both systemic and pulmonary circulations. This kind of flow turbulence may occur when the intra-atrial lateral tunnel dilates markedly. According to the energetics, EC-TCPC can provide more energetically efficient Fontan circulation because of the lack of disparity in the cross-sectional area of the systemic venous pathway. Indeed, Lardo and coworkers<sup>10</sup> showed that fluid power loss in the systemic venous pathway was significantly lower with EC-TCPC compared with LT-TCPC.

In addition to the advantages of EC-TCPC mentioned above, our experience and that of others with successful conversion of failed LT-TCPC to EC-TCPC<sup>12,16,17</sup> can provide an additional rationale for use of the EC-TCPC as a procedure of choice.

However, EC-TCPC contains several unresolved potential disadvantages. Thrombus formation, related to both the use of foreign material and a hypercoagulability state after the Fontan-type operation<sup>9</sup> is a major concern, because complete endothelialization could never be expected for a PTFE tube graft.<sup>16</sup> In our experience, however, 1 case of atrial thrombus occurred in the LT-TCPC group, which was converted to EC-TCPC. We should also carefully monitor the possible risk of mismatch of the artificial graft associated with the patient's growth.

### Conclusion

In conclusion, our data indicate clinical advantages of EC-TCPC in terms of the incidence of cardiac events, although mid-term survival rates were similar and satisfactory in both patients with LT-TCPC and patients with EC-TCPC. Careful observation is required to monitor the tunnel and stenosis in the LT group.

### References

1. Amodeo A, Galletti L, Marianeschi S, Picardo S, Giannico S, Renzi PD. Extracardiac Fontan operation for complex cardiac anomalies: seven years experience. *J Thorac Cardiovasc Surg.* 1997; 114: 1020-30.
2. Ascutto RJ, Kydon DW, Ross-Ascutto NT. Pressure loss from flow energy dissipation: relevance to Fontan-type modification. *Pediatr Cardiol* 2001; 22: 110-5.
3. Azakie A, McCrindle BW, Arsdell GV, Benson LN, Coles J, Hamilton R. Extracardiac conduit versus lateral tunnel cavopulmonary connection at a single institution: impact on outcomes. *J Thorac Cardiovasc Surg* 2001; 122: 1219-28.
4. DeLeval MR, Kilner P, Gewillig M, Bull C. Total cavopulmonary connection: a logical alternative to atriopulmonary connection for complex Fontan operations. Experimental studies and early clinical experience. *J Thorac Cardiovasc Surg.* 1998; 96: 682-95.
5. Fogel MA, Weinberg PM, Hoydu A, Hubbard A, Rychik J, Jacobs M. The nature of flow in the systemic venous pathway measured by magnetic resonance blood tagging in patients having the Fontan operation. *J Thorac Cardiovasc Surg.* 1997; 114: 1032-41.
6. Gundry SR, Razzuk AJ, del Rio MJ, Shiri G, Baily LL. The optimal Fontan connection: a growing extracardiac lateral tunnel with pedicled pericardium. *J Thorac Cardiovasc Surg* 1997; 114: 552-8.
7. Haas GS, Hess H, Black M, Onnasch J, Mohr FW, Van Son JAM. Extracardiac conduit Fontan procedure: early and intermediate results. *Eur J Cardiothorac Surg* 2000; 17: 648-54.
8. Hashimoto K, Kurosava H, Tanaka A, Yamagishi M, Koyanagi K, Ishii S. Total cavopulmonary connection without the use of prosthetic material: technical considerations and hemodynamic consequences. *J Thorac Cardiovasc Surg.* 1995; 110: 625-32.
9. Jahangiri M, Kreutzer J, Zurakowski D, Bacha E, Jonas RA. Evaluation of hemostatic and coagulation factor abnormalities in patients undergoing the Fontan operation. *J Thorac Cardiovasc Surg* 2000; 120: 778-82.

10. Lardo AC, Webber SA, Friehs I, del Nido PJ, Cape EG. Fluid dynamic comparison of intra-atrial and extracardiac total cavopulmonary connection. *J Thorac Cardiovasc Surg* 1999; 117: 697-704.
11. Marcelletti C, Corno A, Giannico S, Marino B. Inferior vena cava-pulmonary artery extracardiac conduit. A new form of right heart bypass. *J Thorac Cardiovasc Surg* 1998; 100: 228-32.
12. Marcelletti CE, Hanley FL, Mavroudis C, McElhinney DB, Ablla RF, Marianeschi SM, et al. Revision of previous Fontan connection to total extracardiac conduit Fontan modification. *J Thorac Cardiovasc Surg* 2000; 119: 340-6.
13. Overotski S, Dahnert I, Alexi-Meskishvili V, Nurnberg JH, Hetze D, Lange PE. Preliminary analysis of arrhythmias after the Fontan operation with extracardiac conduit compared with intra-atrial lateral tunnel. *Thorac Cardiovasc Surg* 2001; 49: 334-7.
14. Petrossian E, Reddy VM, McElhinny DB, Akkersdijk GP, Moor P, Parry AJ. Early results of the extracardiac conduit Fontan operation. *J Thorac Cardiovasc Surg* 1999; 117: 688-96.
15. Stamm C, Friehs I, Mayer JE Jr, Zurakowski D, Friedman JK, Moran AM. Long-term results of the lateral tunnel Fontan operation. *J Thorac Cardiovasc Surg* 2001; 121: 28- 4116.
16. Toshida N, Hideaki K, Shiro I, Yuichi S, Hiroya U, Koichi S. Mid-term surgical results of total cavopulmonary connection: clinical advantages of the extracardiac conduit method. *J Thorac Cardiovasc Surg* 2004; 127: 730-6.
17. Van Son JAM, Mohr FW, Hamsch J, Schneider P, Hess H, Hass GS. Conversion of atriopulmonary or lateral tunnel cavopulmonary anastomosis to extracardiac conduit Fontan modification. *Eur J Cardiothorac Surg* 1999; 15: 150-7.