Interactive CardioVascular and Thoracic Surgery

Comparison of lateral tunnel and extracardiac conduit Fontan procedure

Jeong Ryul Lee, JaeGun Kwak, Kwan Chang Kim, Sun Kyoung Min, Woong-Han Kim, Yong Jin Kim and Joon Ryang Rho

Interact CardioVasc Thorac Surg 2007;6:328-330; originally published online Mar 15, 2007;
DOI: 10.1510/icvts.2006.146928

doi:10.1510/icvts.2006.146928

INTERACTIVE CARDIOVASCULAR AND THORACIC SURGERY

Interactive CardioVascular and Thoracic Surgery 6 (2007) 328–330

www.icvts.org

Institutional report - Congenital

Comparison of lateral tunnel and extracardiac conduit Fontan procedure

Jeong Ryul Lee[a,b,*], Jae Gun Kwak[a], Kwan Chang Kim[a], Sun Kyoung Min[a], Woong-Han Kim[a], Yong Jin Kim[a], Joon Ryang Rho[a]

[a]*Department of Thoracic and Cardiovascular Surgery, Seoul National University Children's Hospital, Seoul National University College of Medicine, Seoul National University Clinical Research Institute, 28 Yongon-dong, Jongro-gu, Seoul 110-744, South Korea*
[b]*Seoul National University Hospital, Medical Research Institute Xenotransplantation Research Center, South Korea*

Received 17 October 2006; received in revised form 20 February 2007; accepted 20 February 2007

Abstract

The purpose of this study was to compare the outcomes of lateral tunnel (LT) and extracardiac conduit (ECC) Fontan procedures at a single institution. From April 1995 to December 2006, 165 Fontan procedures were performed (67 LT, 98 ECC). Pre-, intra- and postoperative variable values were compared between two different techniques. Operative mortality was 5 (3 LT, 2 ECC). Immediate postoperative transpulmonary gradient (LT 8.5±ECC 2.5 vs. 6.6±2.4 mmHg) and central venous pressure (LT 18.3±3.8 vs. ECC 15.6±2.4 mmHg) showed significant difference ($P<0.001$). The LT patients had a higher incidence of sinus node dysfunction in the postoperative period (22.4% vs. ECC 11.2%; $P=0.05$). Mean follow-up was 74.1±31.5 months in LT, and 31.7±28.1 months in ECC patients. There was one late death. Actuarial survival at 10 years is 92% for LT, and 89% for ECC patients ($P=0.796$). The LT and ECC, both, showed comparable early and mid-term outcomes in operative morbidity and mortality, postoperative hemodynamics, survival. Use of ECC for modified Fontan operation reduces the risk of sinus node dysfunction and shows better outcome of immediate postoperative hemodynamics.

Keywords: Congenital heart disease; Single ventricle; Fontan procedure

1. Introduction

Fontan operation has undergone many modifications since 1968 when it was introduced for the single ventricle physiology [1]. At present, two types of modifications, lateral tunnel (LT) type and extracardiac conduit (ECC), are commonly used. The LT, it was introduced in 1987 [2], includes placement of an intraatrial baffle. Although many authors had shown the excellent long-term results of this method, this has the probability of postoperative atrial arrhythmias [3–5]. The ECC, introduced in 1990 [6], can avoid the atrial suture lines and atrial distension due to the reduction of chamber cavity.

In this paper, we compared the above two techniques in a single institution, although there was a time gap in between them, by the same surgeons, and reviewed the postoperative hemodynamics, arrhythmias and functional status in both techniques.

2. Material and methods

From April 1996 through December 2006, 165 consecutive Fontan procedures were performed at the Seoul National University Children's Hospital. Of 165 patients, 67 were LT, 98 ECC. The decision between the LT and ECC approach was made based on the periodic trend, the beginning of the study were mainly LT and more recently, ECC. We reviewed hospital records, operative records and clinic records. Hemodynamic values for the first 24 h after operation were obtained from intensive care unit records. Central venous pressure was measured via an internal jugular venous line or subclavian venous line, and common atrial pressure via a transthoracic line placed in the operating room. Transpulmonary gradient was derived as Fontan pressure (central venous pressure) minus common atrial pressure.

Twenty-four hour telemonitoring obtained during in-hospital for observation of arrhythmia, and regular 12-lead ECG were checked in all patients more than on one occasion in hospital. All patients were followed up at OPD, and if supposed to be in arrhythmic state, ECGs were checked again. We also checked the duration of chest tube insertion. All the data from the patients were compared and analyzed between LT and ECC. Sinus node dysfunction was defined as a sinus bradycardia below the heart rate expected for age, a sinus pause or absence of an expected P wave, a slow escape rhythm that originates within atria, a marked sinus arrhythmia with constant variation in the P-P interval, which is likely to be accompanied by sinus bradycardia, and presence of both bradyarrhythmia and tachyarrhythmias at the late visit of OPD, not including any temporary event during hospitalization.

*Corresponding author. Tel.: +82-02-2072-2877; fax: +82-02-764-3664.
E-mail address: jrl@plaza.snu.ac.kr (J.R. Lee).

All Fontan operations were performed via a median sternotomy and utilized standard cardiopulmonary bypass, and mild to moderate hypothermia (28.1±4.0 °C). Aortic cross-clamping was used in all LT patients but not in ECC patients except concomitant intracardiac procedures. In the LT procedures, a polytetrafluoroethylene (PTFE, Gore Tex, W.K. Gore & Associates, Flagstaff, AZ) baffle was sewn inside the right atrium from the opening of inferior vena caval to the superior cavopulmonary junction. A fenestration was placed in one of the suture lines, or in the baffle. The ECC was performed by placing a tube graft between the divided inferior vena cava and the central pulmonary arteries. For extracardiac conduit, PTFE grafts were currently used. A fenestration was placed by side-to-side anastomosis of the ECC to the atrium, or by interposition of a small PTFE tube graft between the ECC and the atrium when it was needed. Another surgeon used a skirt-like shape connector which is made with Gore Tex membrane for avoiding stenosis of the fenestration site. Concomitant procedures were performed including pacemaker implantation or generator change (8), atrioventricular valve repair or replacement (19), cryoablation (31), pulmonary artery angioplasty (30), and coarctoplasty (1).

All patients were managed regarding anticoagulation. According to the surgeon's strategy, some pateints were managed by Coumadin, others by Aspirin. In patients with Coumadin, the international normalized ratio (INR) was maintained between 1.5 and 2.0.

3. Results

There were no characteristic differences between the two groups, age, sex distribution, weight and BSA. Also, TPG, Rp and Qp/Qs showed no significant differences between the two groups. There was a slight difference in preoperative atrioventricular valve regurgitation of more than grade 2, but there was no statistical significance (LT vs. ECC, 6:17 $P=0.08$). Preoperative arrhythmia status was similar in each group (Table 1).

The mean cardiopulmonary bypass time did not differ between groups. Aortic cross-clamping was used in all LT patients and 41.3% of ECC patients. The mean cross-clamping time was significantly longer in the LT group.

Table 1
Patient data

	LT ($n=67$)	ECC ($n=98$)	P-value
Age (months)	47.4±50.6	52.0±66.0	ns
Sex (M:F)	40:27	68:30	ns
Wt (kg)	15.8±11.1	16.7±13.0	ns
BSA (kg/m^2)	0.64±0.29	0.64±0.30	ns
TPG (mmHg)	7.08±5.60	5.44±2.18	ns (0.15)
Rp	2.36±1.20	1.89±0.84	ns
Qp/Qs	0.74±0.27	0.73±0.38	ns
AVVR (>II)	6 (9.0%)	17 (17.0%)	ns (0.09)
Arrhythmia	3 (7.9%)	7 (7.0%)	ns

LT, lateral tunnel Fontan procedure; ECC, extracardiac conduit Fontan procedure; Wt, body weight; BSA, body surface area; TPG, transpulmonary gradient; Rp, pulmonary artery resistance; Qp, pulmonary blood flow; Qs, systemic blood flow; AVVR, atrioventricular valve regurgitation; ns, no significance (not described factors are >0.5 in P-value).

Fenestrations were placed in 86.5% in LT group and 37.8% in ECC group (Table 2).

In the case of postoperative cardiac rhythm, sinus node dysfunction was found in LT patients more than in ECC patients (LT: ECC=15(22.4%): 11(11.2%), $P=0.05$). But pacemaker implantation was performed similarly in both groups. Postoperative atrioventricular valve regurgitation more than grade 2 was observed in 20 patients (11 in LT, 10 in ECC). Immediate TPG and CVP showed significant difference. [(LT 8.5±2.5 vs. ECC 6.6±2.4 mmHg in TPG, $P<0.001$ and LT 18.3±3.8 vs. ECC 15.6±2.4 mmHg in CVP, $P=0.001$). The median duration of mechanical ventilation (LT 18.6±21.0 vs. ECC 23.0±25.3 h), intensive care unit stay (LT 5.5±2.8 vs. ECC 5.4±5.4 days), chest tube drainage (LT 18.0±11.8 vs. ECC 19.7±9.7 days), and hospital stay (LT 26.5±14.6 vs. ECC 25.2±12.2 days) did not show different value in statistics.] Mean follow-up was 74.1±31.5 months in LT, and 31.7±28.1 months in ECC patients.

Overall operative mortality was 5 out of 165 patients (3.0%), three in LT patients (4.5%) and two in ECC patients (2.0%). Among the LT patients, one died due to sepsis, another died after CPB weaning failure and the other died after sudden cardiac arrest at the general ward. Among two ECC patients, one died due to intractable ventricular fibrillation and the other patient died due to CPB weaning failure. There were nine late mortalities, four in LT and five in ECC patients. Cause of death included pulmonary edema, low cardiac output syndrome, bradycardia, protein losing enteropathy and hypoxic brain damage. In the 10-year survival rate, there was no significant difference between the two groups ($P=0.796$). Actuarial survival at 10 years is 92% for LT patients and 89% for ECC patients.

4. Comments

This study compares the results of LT and ECC Fontan procedures performed at a single institution over the last 11 years. The two types of approaches showed very similar operative outcomes, early postoperative hemodynamics, and a mid-term functional status.

The relative merits of the LT and ECC Fontan procedures have been described previously [5, 7]. Introduced in the mid-1980s, the LT creates a tubular path between the inferior vena cava and pulmonary arteries, consisting of prosthetic baffle and a portion of the lateral atrial wall. The LT has favorable hydrodynamic characteristics, ensures unrestricted systemic and pulmonary venous pathways,

Table 2
Operation data

	LT	ECC
CPB (min)	154.4±72.5	147.3±56.2
ACC	67 (100%)	39 (39.8%)
Time (min)	49.9±22.5	36.1±19.7
Fenestration	58 (86.5%)	34 (37.8%)
Co-operation		
PM implantation	4 (5.9%)	4 (4.0%)
AVV repair/replacement	5 (7.4%)	14 (14.3%)
Cryoablation	25 (37.3%)	6 (6.0%)
PA angioplasty	17 (25.3%)	13 (13.3%)

minimizes atrial exposure to high pressure and incorporates growth potential [5, 7]. Recently, excellent long-term outcome has been reported at a mean follow-up of 10.2 years [5]. In contrast, the ECC, introduced in 1990 [6] consists of a tube graft between the inferior vena cava and pulmonary arteries. Like the LT, it provides an efficient pathway for systemic venous flow. In addition, it leaves the entire atrium at low pressure and does not permit the atrial cavity to enlarge, minimizes atrial suture lines and can be performed without aortic cross-clamping. Even though not being currently used, it can also be performed without cardiopulmonary bypass [8]. Because it does not incorporate growth potentiality, the ECC has typically been performed in patients large enough to accept a graft adequate for an adult's inferior vena caval size for the good early and mid-term results [8, 9].

In this series, the LT and ECC had essentially similar operative outcomes. Overall operative mortality was 3.0%. This is similar to those in other recent series of Fontan procedures, with reported mortalities of 2–13% [6, 10–15]. Operative mortality and complication did not differ between LT and ECC patients. We also found no differences between LT and ECC patients in duration of mechanical ventilation, ICU stay, chest tube drainage and hospital stay.

Another useful measure of outcome after a Fontan procedure is the postoperative Fontan pressure. This variable has been found to be predictive of early Fontan failure [5]. Although both groups showed similar operative outcomes, in this series, LT patients showed higher Fontan pressure than ECC patients (18.3 ± 3.8 vs. 15.6 ± 2.4 mmHg, $P < 0.001$). Fenestrations were not performed routinely, and this was not supposed to influence the outcome of operations and had no relationship with immediate postoperative hemodynamics including Fontan procedures and TPG. In our study, ECC patients showed more stable postoperative hemodynamic status.

The LT and ECC approaches also provided comparable mid-term outcomes. There were no significant differences in 10-year survival ($P = 0.796$). All surviving patients were in NYHA class I or II, with no differences between the two groups. This is in concert with other studies documenting good functional status at follow-up after an LT or ECC procedure [9].

There was a similarity between our results and those of the Toronto group with the incidence or arrhythmias in LT and ECC patients. Arrhythmias after Fontan procedure may include sinus node dysfunction and supraventricular tachycardia. Sinus node dysfunction is thought to result from direct injury to the sinus node and/or its blood supply. Atrial incisions and suture lines, increased pressure and dilatation of atrium due to the intraatrial baffle in the LT, may contribute to tachyarrhythmias. In our analysis, sinus node dysfunction was observed more frequently among LT than ECC patients (22.4% vs. 11.2%, $P = 0.05$). This caused implant of permanent pacemakers in two patients in the LT group and three patients in the ECC group in our study. In the Toronto group sinus node dysfunction during the postoperative period in 45% LT vs. 15% ECC patients was observed [10]. The LT procedure was identified as a significant independent risk factor for early postoperative sinus node dysfunction. Especially, the LT after a previous bidirectional Glenn requires reconnecting the superior aspect of the atrium to the pulmonary arteries. This involves dissection, an incision and suturing in the vicinity of the sinus node and artery, which may be obscured by scarring and absence of the superior cavoatrial junction as a landmark. These things are supposed to have contributed to the higher rate of sinus node dysfunction among LT patients.

In summary, this study documents the outcomes of LT and ECC Fontan operations performed over the last 11 years at a single institution. The LT and ECC approaches had comparable early and mid-term outcomes including operative mortality, morbidity, resource use and survival. Use of the ECC procedure for modified Fontan operation could reduce the risk of sinus node dysfunction and improve postoperative hemodynamics in our institution.

References

[1] Fontan F, Baudet E. Surgical repair of tricuspid atresia. Thorax 1971; 26:240–248.
[2] Puga FJ, Chiavarelli M, Hagler DJ. Modifications of the Fontan operation applicable to patients with left atrioventricular valve atresia or single atrioventricular valve. Circulation 1987;76(Suppl III):III53–III60.
[3] Gardiner HM, Dhillon R, Bull C, de Leval MR, Deanfield JE. Prospective study of the incidence and determinants of arrhythmia after total cavopulmonary connection. Circulation 1996;94(Suppl II):II17–II21.
[4] Manning PB, Mayer JE, Wernovsky G, Fishberger SB, Walsh EP. Staged operation to Fontan increases the incidence of sinoatrial node dysfunction. J Thorac Cardiovasc Surg 1996;111:833–840.
[5] Stamm C, Friehs I, Mayer JE Jr, Zurakowski D, Triedman JK, Moran AM, Walsh EP, Lock JE, Jonas RA, del Nido PJ. Long-term results of the lateral tunnel Fontan operation. J Thorac Cardiovasc Surg 2001;121:28–41.
[6] 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 1990;100:228–232.
[7] de Leval MR, Kilner P, Gewillig M, Bull C. Total cavopulmonary connection: a logical alternative to atriopulmonary connection for complex Fontan operations. J Thorac Cardiovasc Surg 1988;96:682–695.
[8] Petrossian E, Thompson LD, Hanley FL. Extracardiac conduit variation of the Fontan procedure. Adv Card Surg 2000;12:175–198.
[9] Haas GS, Hess H, Black M, Onnasch J, Mohr FW, van Son JAM. Extracardiac conduit Fontan procedure: early and intermediate results. Eur J Cardiothor Surg 2000;17:648–654.
[10] Azakie A, McCrindle BW, van Arsdell G, Benson LN, Coles J, Hamilton R, Freedom RM, Williams WG. Extracardiac conduit vs. lateral tunnel cavopulmonary connections at a single institution: impact on outcomes. J Thorac Cardiovasc Surg 2001;122:1219–1228.
[11] Airan B, Sharma R, Choudhary SK, Mohanty S, Bhan A, Chowdhari UK, Juneja R, Kothari SS, Saxena A, Venugopal P. Univentricular repair: is routine fenestration justified? Ann Thorac Surg 2000;69:1900–1906.
[12] Kaulitz R, Ziemer G, Luhmer I, Kallfelz H. Modified Fontan operation in functionally univentricular hearts: preoperative risk factors and intermediate results. J Thorac Cardiovasc Surg 1996;112:658–664.
[13] Mosca RS, Kulik TJ, Goldberg CS, Vermilion RP, Charpie JR, Crowley DC, Bove EL. Early results of the Fontan procedure in one hundred consecutive patients with hypoplastic left heart syndrome. J Thorac Cardiovasc Surg 2000;119:1110–1118.
[14] Gaynor JW, Bridges ND, Cohen MI. Predictors of outcome after the Fontan operation: is hypoplastic left heart syndrome still a risk factor? J Thorac Cardiovasc Surg 2001;121:28–41.
[15] Yoshimura N, Yamaguchi M, Oshima Y, Oka S, Ootaki Y, Tei T, Kido S. Risk factors influencing early and late mortality after total cavopulmonary connection. Eur J Cardiothor Surg 2001;20:598–602.