Cases Report

Extracardiac Conduit versus Lateral Tunnel for Total Cavopulmonary Connections

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Objective: *Compare the surgical outcomes of the lateral tunnel and the extracardiac conduit total cavopulmonary connections at a single center during a 10-year period.*
Material and Method: *From October 1995 through October 2005, 27 total cavopulmonary connections (TCPC) were performed: fourteen patients were the lateral tunnel and thirteen patients were the extracardiac conduit. Prior superior cavopulmonary connective surgery and fenestration surgery were done more often in the group with extracardiac conduit.*
Results: *Operative mortality was 29% in the lateral tunnel and no operative mortality in the extracardiac conduit ($p < 0.05$). The cause of deaths in three patients was significant AV valve regurgitations and one was small pulmonary artery index. All patients in both groups were in NYHA class I and 2 and no patients with supraventricular arrhythmias were detected in the two groups during the follow-up period. There was only one patient in the lateral tunnel who developed thromboembolism from irregular warfarin taking.*
Conclusion: *The extracardiac conduit had lower mortality than the lateral tunnel. However, there was no difference in early and mid-term complications.*

Keywords: *Fontan procedure, Tricuspid valve, Atresia*

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Total cavopulmonary connections are based on the concept that a systemic venous pressure is an adequate driving force for pulmonary blood flow and a pumping right ventricle is unnecessary. It has become one of the standard procedures for a wide variety of complex congenital heart diseases. In 1988, De Leval et al reported that the hemodynamic advantages of the lateral tunnel TCPC is better than atriopulmonary connection[1]. In 1990, Marcelletti et al described the extracardiac conduit TCPC procedure by using an extracardiac conduit from the inferior vena cava to the pulmonary artery[2]. Both the lateral tunnel and the extracardiac conduit TCPC procedures are favorable options for many cardiac surgeons, which of the two modifications of the total cavopulmonary connection is still controversial. Currently, the extracardiac conduit TCPC is achieved with or without cardiopulmonary bypass and it provides superior hemodynamics, especially with the use of conduit-superior vena cava offset[3]. The authors have performed both the lateral tunnel and the extracardiac conduit TCPC in Ramathibodi Hospital. In the younger aged children (younger than 6 years old) the lateral tunnel TCPC was preferable and the extracardiac conduit TCPC for the children who were older than 6 years. The objective of the authors' retrospective study was to compare the early and mid-term surgical outcomes between the lateral tunnel TCPC and the extracardiac conduit TCPC.

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Material and Method

Consecutive patients (n = 27) who underwent modified Fontan procedure at Ramathibodi Hospital from October 1995 to October 2005 were enrolled in the

present study. Fourteen patients underwent the lateral tunnel TCPC and thirteen patients underwent the extracardiac conduit TCPC. The lateral tunnel TCPC have been performed since 1995 and after 2000, the authors began the extracardiac conduit TCPC. At the beginning, the fenestration was created only in the high-risk patients, until after 2000 it was routinely done in all patients of both groups. In patients with cyanosis and were less than 2 years of age was done by palliative modified Blalock Taussig shunt and Glenn shunt procedure was considered when the patients were more than 2 years. The lateral tunnel TCPC was performed in children younger than 3 years old. The authors considered the extracardiac conduit TCPC in children older than 6 years old. The mean age and weight at operation was 8.1 $\pm$ 6 years (3-21 years) and 21 $\pm$ 12 kg (11-54 kg) in the lateral Tunnel TCPC group and 8.8 $\pm$ 1.8 years (6-12 years) and 21.3 $\pm$ 5.43 kg (13-31 kg) in the extracardiac conduit TCPC group.

Operative techniques

Lateral tunnel TCPC was done by cardiopulmonary bypass and cardioplegic arrest. The superior vena cava was anastomosed to both the superior surface and the inferior surface of the pulmonary artery. Intra-atrial buffling with a polytetrafluoroethylene (PTFE) was achieved by a longitudinal atrial incision, to route the blood flow from the inferior vena cava to the superior vena cava orifice, which was connected to the inferior surface of the pulmonary artery. Extracardiac conduit TCPC was done with cardiopulmonary bypass support without cardioplegic arrest. The superior vena cava was connected to the superior surface of pulmonary artery and a polytetrafluoroethylene at least 16 mm. in diameter was connected from the inferior vena cava to the inferior surface of the pulmonary artery.

There were four patients in the lateral tunnel and 11 patients in the extracardiac conduit TCPC who had underwent previous Glenn shunt operations. The interval of Glenn shunt procedure to total cavo pulmonary connection was 45 $\pm$ 33 months. Fenestration (5 mm in diameter) was created in four patients in the lateral tunnel and 11 patients in the extracardiac conduit TCPC. The pulmonary arterioplasty was performed in one patient from each group. All patients in both groups were taking warfarin postoperatively to prevent thromboembolism by maintained INR level at 2.3-2.8.

All patients had been followed up in a regular basis with a median duration of 60 months, with ECG, chest radiographs, echocardiograms, and blood sampling.

Statistical analysis

Continuous data were compared using student's t-test and categorical data were compared using Fisher's exact test or Chi-square test as appropriate. Data are shown as mean $\pm$ SD. Statistical significance was defined as p-value less than 0.05.

Results

Medical records, operative records, postoperative records, echocardiograms, and preoperative cardiac catheterization records were reviewed. The characteristics of the present study operation are summarized in Table 1, and preoperative hemodynamic variables are shown in Table 2. The pulmonary artery index showed no significant difference between the lateral tunnel TCPC and the extracardiac conduit TCPC (284.2 $\pm$ 182 vs. 264 $\pm$ 79.8 mm^2/m^2, $p = 0.74$). There was no difference in the other preoperative hemodynamic variables measured between them except the extracardiac conduit had a previous Glenn shunt procedure more than the lateral tunnel group ($p < 0.001$).

There were two major differences between the patients in the lateral tunnel TCPC and the extracardiac conduit TCPC groups. First, the previous Glenn shunt was done more in the extracardiac conduit than in the lateral tunnel TCPC (84.6% and 21.4%, $p < 0.001$). Second, fenestration was done more in the extracardiac conduit than in the lateral tunnel group (100% and 28.5%, $p < 0.01$). The anatomic diagnosis, degree of AV valve regurgitation, as well as ventricular morphology, did not differ in the two groups. Meanwhile, the cardiopulmonary bypass time showed no difference in the two groups but in the extracardiac conduit TCPC aortic clamp was unnecessary except to perform intracardiac repairs or in case of difficulty occur. All preoperative parameters such as diameter of the right pulmonary artery, the left pulmonary artery, the descending aorta, and the pulmonary artery index did not differ in either group. All patients underwent cardiac catheterization prior to total cavopulmonary connection; the mean values of variables measured at cardiac catheterization were essentially identical in the two groups.

Early outcome

There were four hospital deaths (29%) in the lateral tunnel group and no hospital death in the extracardiac TCPC group ($p < 0.05$). There was significant difference in the mortality. There was no difference in the other complications of both groups. The surgical outcomes are summarized in Table 3.

Table1. Characteristics of the study population

	Lateral tunnel	Extracardiac conduit	p-value
Number	14	13	
Age	8.1 ± 6	8.8 ± 1.8	0.73
Sex (M/F)	7/7	9/4	
Diagnosis			0.395
TA	5 (35.7%)	3 (23%)	
SV	6 (42.8%)	6 (46.1%)	
PA-IVS	2 (14.2%)	1 (7.6%)	
DORV	1 (7.1%)	0 (0%)	
Heterotaxy syndrome	0 (0%)	3 (23%)	
Prior procedure			
BT-shunt	9/14 (64.2%)	4/13 (30.7%)	0.122
Glenn shunt	3/14 (21.4%)	11/13 (84.6%)	0.001
Regurgitation of AV valve			
Mild to moderate	2/14 (14.2%)	5/13 (38.4%)	0.152
Concomitant procedure			
Fenestration	4/14 (28.5%)	13/13 (100%)	0.001
PA plasty	1/14 (7.14%)	1/13 (7.7%)	0.999
PA banding	-	1/13 (7.7%)	0.481
Ventricular morphology			
RV	3 (21.4%)	6 (46.1%)	
LV	7 (50%)	6 (46.1%)	0.342
Unconfirmed	4 (28.5%)	1 (7.6%)	
CPB time (min)	158 ± 26	161 ± 144	0.951
ACC time (min)	83 ± 25	-	

Abbreviations : TA – Tricuspid atresia, SV – Single ventricle, PA-IVS – Pulmonary atresia with intact ventricular septum, DORV – Double outlet right ventricle, AV – Atrioventricular valve, PA – Pulmonary atresia, RV – Right ventricle, LV – Left ventricle, CPB – cardiopulmonary bypass, ACC – Aortic cross clamp time

Table2. The preoperative parameters between the lateral tunnel and the extracardiac conduit TCPC group

	Lateral tunnel	Extracardiac conduit	p-value
Number	14	13	
Age (y)	8.1 ± 6	8.8 ± 1.8	0.73
BW (kg)	21 ± 12	21.3 ± 5.43	0.935
Body surface area	0.79 ± 0.3	0.82 ± 0.14	0.74
Pulmonary artery index	284.2 ± 182	264.3 ± 79.8	0.74
McGoon ratio	1.98 ± 0.5	2.13 ± 0.26	0.42
Mean PA pressure	10.6 ± 2.3	12.8 ± 3	0.06
Left atrial pressure	8.1 ± 2.5	8.7 ± 3.4	0.63
Trans pulmonary gradient	4.1 ± 2	4.3 ± 2.1	0.81

The overall operative mortality of the lateral tunnel TCPC was 29%. All patient deaths were the lateral tunnel without the fenestration. Two patients had high central venous pressure above 30 mmHg, and the other two had pulmonary edema from significant AV valve regurgitation. The authors found that there was no significant difference of postoperative pericardial effusion and pleural between the lateral tunnel TCPC and the extracardiac conduit TCPC. One patient in the extracardiac conduit TCPC had perioperative cerebral air embolism with good recovery.

Follow-up assessments

The incidence of early and late deaths, reoperations, and late complications (protein-losing enteropathy, systemic thromboembolism, and supraventricular arrhythmias) were compared in the two groups. There was no late death in the presented

Table3. Compare the surgical outcomes between the lateral tunnel TCPC and the extracardiac conduit TCPC procedure

	Lateral tunnel	Extracardiac conduit	p-value
Number	14	13	
Survives	10 (71%)	13 (100%)	
Deaths	4 (29%)	0 (0%)	0.03
Complications	5 (35.7%)	6 (47%)	0.58
Pleural effusion	3 (21.4%)	5 (38.5%)	0.33
Pericardial effusion	1 (7%)	1 (7.7%)	0.99
Arrhythmias	1 (7%)	0 (0%)	0.99
Others	1 (7%)	1 (7.7%)	0.99

patients. One patient in the extracardiac conduit was readmitted by massive pericardial effusions at three weeks after discharge and treated by subxyphoid drainage. There were 3 patients (21.4%) in the lateral tunnel TCPC and 5 patients in the extracardiac conduit (38.5%) who developed postoperative pleural effusion and all resolved by conservative treatment. One patient in the lateral tunnel developed systemic thromboembolism, irregular warfarin usage may have been the cause. All alive patients in both groups were in NYHA Class 1 and 2. One patient in the lateral tunnel TCPC developed postoperative supraventricular tachycardia and was treated with a short term of an antiarrhythmic drug.

Discussion

In 1988, de Leval[1] proposed the total cavopulmonary connection by the lateral tunnel as an alternative procedure to Fontan operation and described advantages in hemodynamic and reduction of the atrium complications. In 1990, Marcelletti et al[2] described an extracardiac conduit TCPC procedure by using an extracardiac conduit from the IVC to the pulmonary artery. In 1992, Laschinger et al[4] described a new extracardiac TCPC by using an extracardiac epicardial lateral tunnel. In their technique, the extracardiac epicardial lateral tunnel was constructed of the native epicardial atrial wall and Gore-Tex graft[4]. There were modifications of TCPC since 1990. However, both the lateral tunnel TCPC and the extracardiac conduit TCPC have become the standard procedure for total cavopulmonary connection. Kumar et al compared the clinical outcomes between the lateral tunnel TCPC and the extracardiac conduit TCPC[5]. they found that the lateral tunnel had favorable hydrodynamic characteristics, ensured unrestricted systemic and pulmonary venous pathway, minimized atrial exposure to high pressure, and incorporated growth potential but the extracardiac conduit TCPC leaves the entire atrial at low pressure, minimizes atrial suture lines, and can be performed both with and without aortic cross-clamping, sometimes can also be performed without cardiopulmonary bypass[6,7]. The extracardiac conduit TCPC provides advantages in patients with anomalies of systemic and pulmonary venous drainage, such as those with heterotaxy syndrome but it had a high incidence of sinus node dysfunction[5]. In Ramathibodi Hospital, the selection between the two techniques of TCPC depended on patient age and limitation of patient anatomy. The authors considered the lateral tunnel TCPC for the younger children (younger than 6 years) and the extracardiac conduit TCPC for the older children (older than 6 years). The authors have never used Gore-Tex conduit less than 16 mm in diameter. The present study showed that the two important factors had effected on the surgical outcomes. First, the previous Glenn shunt procedure in the extracardiac conduit TCPC was more than in the lateral tunnel TCPC. Second, the fenestration in the extracardiac conduit TCPC was more than in the lateral tunnel also. The authors believed in the advantage of fenestration[9] and the staged procedure which brought the benefits on cardiovascular adaptation to the complete Fontan circulation. Although the mortality in the extracardiac conduit TCPC was less than in the lateral tunnel TCPC ($p < 0.05$), the authors can't conclude which one is better because of the difference of additional procedure and staged procedure. The authors also found that it was unreliable for the measurement of pulmonary artery pressure immediate after cardiopulmonary bypass and early post operative period and currently the authors perform the fenestration in all patients with TCPC.

In summary, the present study documents the outcomes of the lateral tunnel and the extracardiac conduit TCPC performed concurrently over the last 10

years at a single institute. The two approaches were compared by early and mid-term outcomes including operative mortality and morbidity, preoperative parameters, surgical outcomes, mid-term results, and functional status. The extracardiac conduit had a lower mortality although there was no difference in the complications. However, the authors cannot conclude which one is better because of the difference in concomitant procedures that affected the surgical outcomes. Therefore, the two standard techniques of total cavopulmonary connections were still both the lateral tunnel and the extracardiac TCPC and the choice depended on the patient's anatomy, patient age, and preference of surgeon. The authors recommended that the fenestration and the staged procedure had benefits on cardiovascular adaptation and on the surgical outcomes, especially in high-risk patients rather than two surgical techniques.

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การผ่าตัด total cavopulmonary connection ด้วยวิธีการใช้ extracardiac conduit กับ lateral tunnel

สุกษม อัตนวานิช, ภาณุวัฒน์ เลิศสิทธิชัย

การศึกษาเปรียบเทียบวิธีการผ่าตัด total cavopulmonary connection ด้วยวิธีการใช้ extracardiac conduit และวิธีการทำ lateral tunnel ในช่วงเวลา 10 ปี ที่โรงพยาบาลรามาธิบดี โดยเริ่มจากเดือนตุลาคม พ.ศ. 2538 จนถึงตุลาคม พ.ศ. 2548 ในผู้ป่วยที่ได้รับการทำผ่าตัด total cavopulmonary connection จำนวน 27 ราย โดย 14 ราย ได้รับการทำผ่าตัดโดยวิธีการทำ lateral tunnel และ 13 ราย ได้รับการทำผ่าตัดด้วยวิธีการใช้ extracardiac conduit ในพวกที่ได้รับการทำผ่าตัดด้วยวิธีการใช้ extracardiac conduit โดยได้รับการทำผ่าตัดขั้นแรกด้วยการทำผ่าตัดต่อหลอดเลือดดำใหญ่ส่วนบนเข้ากับหลอดเลือดแดงพัลโมนารี่ มีจำนวนมากกว่าในกลุ่มพวกที่ทำ lateral tunnel ($p < 0.001$) ยังพบว่าได้รับการทำ fenestration มากกว่าในกลุ่มพวกที่ทำ lateral tunnel ($p < 0.001$) อัตราการเสียชีวิตในกลุ่มที่ทำ lateral tunnel เป็นร้อยละ 29 แต่ในกลุ่มที่ใช้ extracardiac conduit ไม่มีอัตราการเสียชีวิต ($p < 0.05$) สาเหตุการเสียชีวิตพบว่ามี 3 ราย เกิดจากการรั่วของลิ้นเอตริโอเวนตริคูล่า และ 1 ราย เกิดจากขนาดของหลอดเลือดแดงพัลโมนารี่มีขนาดเล็ก การติดตามผลในผู้ป่วยที่รอดชีวิตพบว่าอยู่ใน functional class I และ II และไม่พบว่ามีปัญหาจากการเต้นของหัวใจผิดจังหวะ ผู้ป่วย 1 ราย ในกลุ่มของ lateral tunnel เกิดภาวะก้อนเลือดอุดตัน จากการกินยาละลายเลือดไม่สม่ำเสมอ จึงสรุปว่า พวกที่ได้รับการทำผ่าตัดด้วยวิธี extracardiac conduit มีอัตราการตายที่ต่ำกว่าในกลุ่ม lateral tunnel แต่ไม่มีความแตกต่างในเรื่องภาวะแทรกซ้อนในระยะแรกและระยะกลางของการติดตามผล