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Extracardiac versus Intra-Atrial Lateral Tunnel Fontan: Extracardiac is Better – Yes, it is!

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The LT and EC Fontan were first performed in the 1980s.

- Lateral tunnel
- Extracardiac
Also in the 1980s, there were two new “power cars” on the market: De Lorean DMC-12 and Ferrari F40. The race began...
FONTAN MOTOR SPEEDWAY (circa 1990)
As time progressed and the cars make their laps...

- Long CPB and cross-clamp times
- Inferior hemodynamics
- Potential for RA dilation
- Increased atrial arrhythmias
- Potential for stroke
- Higher operative mortality (3%)

VS.

- No cross-clamp, shorter CPB
- Superb hemodynamics
- Procedure of choice for Fontan Conversions
- Operative mortality (1%)
FONTAN MOTOR SPEEDWAY (circa 2000)
The extracardiac conduit Fontan operation using minimal approach extracorporeal circulation: Early and midterm outcomes

OBJECTIVE: Our approach to the extracardiac conduit Fontan operation has evolved over time from full-pump, to partial-pump, to completely off-pump. This study is designed to report our overall experience with the extracardiac conduit Fontan operation and to evaluate the evolution in bypass technique on postoperative outcomes.

METHODS: From September 1992 to April 2005, 285 patients, median age 4.5 years (1.4-44 years), median weight 16 kg (9.4-94 kg), underwent a primary extracardiac conduit Fontan procedure. Early and late outcomes were analyzed for the entire cohort and for 2 patient groups depending on whether an oxygenator was used in the bypass circuit (166 patients; 58%) or not (119 patients; 42%).

RESULTS: Early failure (including death and takedown) occurred in 7 patients (2.5%). Prevalence of new early postoperative sinus node dysfunction necessitating a permanent pacemaker was 0.4%, and that of new tachyarrhythmias necessitating discharge home on a regimen of antiarrhythmia medications was 2.5%. Ten-year actuarial freedom from Fontan failure, new sinus node dysfunction necessitating a permanent pacemaker, and reoperation for conduit thrombosis or stenosis was 90%, 96%, and 98% respectively. Fenestration rate was lower (P = .001) in the no-oxygenator group (8%) than in the oxygenator group (25%). Patients in the no-oxygenator group had lower intraoperative Fontan pressure (12.0 +/- 2.3 vs 13.5 +/- 2.4 mm Hg, P < .001), common atrial pressure (4.6 +/- 1.8 vs 5.3 +/- 1.8 mm Hg, P = .003), and transpulmonary gradient (7.5 +/- 2.1 vs 8.3 +/- 2.2 mm Hg, P = .013) than did the oxygenator group.

CONCLUSIONS: The extracardiac conduit Fontan operation coupled with minimal use of extracorporeal circulation is associated with favorable intraoperative hemodynamics, low fenestration rate, minimal risk of thrombosis or stenosis, and minimal early and late rhythm disturbance.

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Clinical outcome of 193 extracardiac Fontan patients
The first 15 years

OBJECTIVES: We sought to evaluate the mid-term outcome of hospital survivors with extracardiac Fontan circulation.

BACKGROUND: Few data exist about the mid-term and long-term results of the extracardiac Fontan operation.

METHODS: From November 1988 to November 2003, 221 patients underwent an extracardiac Fontan procedure as primary (9 patients) or secondary (212 patients) palliation, at a mean age of 72.2 months (range 13.1 to 131.3 months). A total of 165 of 193 early survivors underwent programmed noninvasive follow-up evaluations and at least one cardiac catheterization.

RESULTS: The overall survival, including operative deaths, was 85% at 15 years. Freedom from late failure among hospital survivors is 92% at 15 years. A total of 127 of 165 survivors (77%) were in New York Heart Association functional class I. The incidence of late major problems was 24% (42 major problems in 36 of 165 patients): 19 patients had arrhythmias (11%), 5 patients had obstruction of the extracardiac conduit (3%) and 6 of the left pulmonary artery (3.5%), and 5 patients experienced ventricular failure (3%), leading to heart transplantation in 3 patients. Protein-losing enteropathy was found in two patients (1%). The incidence of late reinterventions was 12.7% (21 of 165 patients, including 15 epicardial pacemaker implantations). Four patients died (2.3%), two after heart transplantation.

CONCLUSIONS: After 15 years of follow-up, the overall survival, the functional status, and the cardiopulmonary performance of survivors of the extracardiac Fontan procedure compare favorably with other series of patients who underwent the lateral tunnel approach. The incidence of late deaths, obstructions of the cavopulmonary pathway, reinterventions, and arrhythmias is lower than that reported late after other Fontan-type operations.

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Midterm surgical results of total cavopulmonary connection: Clinical advantages of the extracardiac method

OBJECTIVE: We evaluated the midterm surgical outcomes of intra-atrial lateral tunnel and extracardiac conduit total cavopulmonary connection to clarify the clinical superiority. 

METHODS: Patients (n = 167) underwent total cavopulmonary connection (88 with lateral tunnel and 79 with extracardiac conduit) from November 1991 to March 1999. Survival, incidence of reoperation and late complications, exercise tolerance, hemodynamic variables, and plasma concentration of natriuretic peptide type A were compared. In the lateral tunnel group, time-related change in lateral tunnel size was investigated for its relationship to postoperative arrhythmias.

RESULTS: The 8-year survival was 93.2% in the lateral tunnel group and 94.9% in the extracardiac conduit group. Seven reoperations were performed in the lateral tunnel group but none in the extracardiac conduit group. Supraventricular arrhythmias developed in 14 patients (15.9%) in the lateral tunnel group and in 4 patients (5.1%) in the extracardiac conduit group (P = .003). Freedom from cardiac-related events was 72.5% in the lateral tunnel group and 89.8% in the extracardiac conduit group at 8 years (P = .0098). Hemodynamic variables and exercise tolerance were similar in both groups but plasma natriuretic peptide type A concentration, a parameter of atrial wall tension, was higher in the lateral tunnel group. In the lateral tunnel group, intra-atrial tunnel size increased by 19.4% during the 44.2-month interval and the percent increase in tunnel size was an independent predictor of supraventricular arrhythmias.

CONCLUSIONS: The midterm survival, hemodynamic variables, and exercise tolerance were 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. In the lateral tunnel group, careful observation is required to monitor the relationship of the dilating tendency of the intra-atrial lateral tunnel and the development of late complications.
Results of staged total cavopulmonary connection for functionally univentricular hearts; comparison of intra-atrial lateral tunnel and extracardiac conduit

Objectives: This study aims to compare the outcome of the two co-existing modifications of staged total cavopulmonary connection (TCPC) - the intra-atrial lateral tunnel (ILT) and the extracardiac conduit (ECC). Methods: We included 209 patients after staged TCPC (102 ILT and 107 ECC), operated on between 1988 and 2008. Medical and surgical records were reviewed for (1) patient demographics and cardiac anatomy; (2) pre-Fontan procedures; (3) pre-Fontan haemodynamics and cardiac functional status; (4) operative details; (5) postoperative hospital course; (6) follow-up information on arrhythmias and thrombo-embolic events; (7) post-Fontan interventions; and (8) clinical status at last follow-up until June 2008. Results: Median follow-up duration was 4.3 years (interquartile range 1.5-7.4 years). At 6-year follow-up, freedom from Fontan failure (i.e., mortality or re-operations for Fontan failure) was 83% for the ILT and 79% for the ECC groups (p=0.6); freedom from late re-operations (other than re-operations for Fontan failure) was 79% for the ILT and the ECC groups and freedom from arrhythmias was 83% for the ILT, and 92% for the ECC groups (p=0.022). Multivariable Cox regression analysis identified intensive care unit stay and cardiopulmonary bypass time as risk factors for Fontan failure, but they were not strong predictors. Right ventricular morphology was identified as a risk factor for arrhythmias. The occurrence of thrombo-embolic events was low with no difference between the ILT and the ECC groups, and irrespective of the postoperative use of anticoagulant or anti-platelet aggregation therapy. At most recent follow-up, sinus rhythm was present in 70% of patients; in 23% of the patients, ventricular function was found to be moderately or severely impaired at echocardiography. Conclusions: Outcome after staged ILT- and ECC-type Fontan operations is good, with comparable freedom from late re-operations and freedom from Fontan failure at 6-year follow-up. The incidence of arrhythmias was significantly lower in the ECC group. Right ventricular morphology was identified as a risk factor for arrhythmias.

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“Freedom from arrhythmias was significantly higher in patients with an ECC, analyzed up to 6 years after Fontan completion.”

OBJECTIVE: In a total cavopulmonary connection (TCPC) with an extracardiac conduit, the future development of stenosis in the venous pathway and distortion of the pulmonary artery according to the somatic growth of the patients is a major concern for surgeons and pediatricians. METHODS: Thirty patients who underwent extracardiac TCPC (EC-TCPC) between 1990 and 1998 and who had received at least two postoperative angiograms were enrolled in this study. To evaluate the postoperative change in the anastomosis, the cross-sectional area of the venous root at three different points was measured on the first and second angiograms after the EC-TCPC. Further, to evaluate the somatic growth of the autologous tissue, 12 patients who grew more than 10 cm in height after the completion of the EC-TCPC were selected and we measured the length of the pulmonary artery, length of the artificial graft, length between the branching point of the hepatic vein and artificial graft’s anastomotic site to the inferior vena cava, and the pressure gradient across the grafts during the follow-up, and the pressure gradient across the grafts during the follow-up, and the pressure gradient across the grafts during the follow-up, and the pressure gradient across the grafts during the follow-up, and the pressure gradient across the grafts during the follow-up. RESULTS: The cross-sectional area at each point did not change during the follow-up, and the pressure gradient across the grafts has not been observed. The diameter of the pulmonary artery and length of the inferior vena cava above the hepatic vein insertion grew similarly during the follow-up. CONCLUSIONS: The mid-term clinical results after the completion of the EC-TCPC, including the somatic growth of the venous pathway, were satisfactory.

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Measurements of cross sectional area

- Cross-sectional area unchanged at follow-up
- No focal stenosis
- No incidence of thromboembolism

Measurements of length

- PA diameter and IVC length grew similarly during follow-up
- No deformities of PA

Optimal conduit size of the extracardiac Fontan based on energy loss and flow stagnation

BACKGROUND: In the extracardiac Fontan operation, larger conduits are used when considering the patients' growth rate. However, larger conduits may cause inefficient flow due to turbulence or stagnation, resulting in late problems such as thrombosis or stenosis. Our objective was to reveal the physiologic effects of respiration and exercise using numerical models, based on the energy loss and flow stagnation, and to determine optimal conduit size. METHODS: For the Fontan operation, conduits from 14 to 22 mm were created based on angiographic data from 17 Fontan patients (mean age, 36.0 months; mean body surface area, 0.53 m²). Respiratory-driven flow of the superior and inferior vena cava was determined at rest and during exercise on two levels (0.5 and 1.0 W/kg) by magnetic resonance imaging flow studies. Flow stagnation was defined as the volume of the region where flow velocity was less than 0.01 m/second at both the expiratory and inspiratory phases. Conduit size was 14 mm, 16 mm, and 22 mm; 4.199 mW during 1.0 W/kg exercise. Stagnation volume at the expiratory phase increased with an increase of conduit size (14 mm, 9.20% vs 22 mm, 33.9% conduit volume at rest).

CONCLUSIONS: Fontan circulation is a low-energy system even during exercise. Larger conduits were proven to have redundant spaces, thus 16 and 18 mm conduits were optimal.

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Has the LT Fontan gone down the same road as...
...the DeLorean DMC-12?
EC Fontan wins!
And the winners are!
Extracardiac Fontan

- Superb hemodynamics
- No cross-clamp required
- Avoids extensive RA suture lines
- Avoids elevated RA pressures
- Very low operative mortality (1%) 
- Fewer postoperative arrhythmias
- Lower incidence of CVA
- Procedure of choice for Fontan conversion