Extracardiac vs Intra-atrial Lateral Tunnel Fontan: Extracardiac is Better

No it’s not: *(They both have problems)*
Why is it difficult to analyze outcomes after the Fontan procedure?

- Wide range of patient morphology
- Variable pre-Fontan palliation
- Multiple technical modifications of Fontan procedure since 1970
  - First generation: "Atrio-pulmonary"
  - Second generation: "Lateral tunnel"
  - Third generation: "Extra-cardiac conduit"
Surgical repair of tricuspid atresia

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Surgical repair of tricuspid atresia has been carried out in three patients. Two of these operations have been successful. A new surgical procedure has been used, which transmits the whole vena caval blood to the lungs, while only oxygenated blood returns to the left heart. The right atrium is, in this way, "centralized" to direct the inferior vena caval blood to the left lung, the capillary pulmonary arteries receiving the superior vena caval blood through a cavo-pulmonary anastomosis. This technique depends on the size of the pulmonary arteries, which must be large enough and sufficiently low pressure to allow a cavo-pulmonary anastomosis. The indications for this procedure apply only to children sufficiently well developed. Younger children or those whose pulmonary arteries are too small should be treated by palliative surgical procedures.

Only palliative operations (systemic veno-pulmonary arteries anastomoses, systemic arteries to pulmonary arteries anastomoses) have been performed in tricuspid atresia. Although these procedures are valuable, they result in only a partial clinical improvement, because they do not suppress the mixture of venous and oxygenated blood.

We have initiated a corrective procedure for tricuspid atresia, which completely suppresses blood mixing. The entire vena caval return goes arterIALIZED in the lungs and only oxygenated blood comes back to the left heart. The procedure is not an anatomical correction, but would require the creation of a right ventricle, but a procedure of physiological pulmonary flow restoration with suppression of systemic return.
• Use of a valved *RA-PA conduit* was an incremental risk factor for late death by multivariate analysis
• Left atrioventricular valve atresia

Fontan F, Kirklin JW, Fernandez G, Costa F, Naftel DC, Tritto F, Blackstone EH. *Outcome after a “perfect” Fontan operation*  
*Circulation 1990;81:1520-36*
Lateral Tunnel Fontan
(Total Cavopulmonary Connection)

- Right atrial incision
- Division of SVC
- Distal takedown of Blalock shunt w/ enlargement of arteriotomy
- Division of MPA
- Right atrial incision

Jonas RA, Castaneda AR.
J Cardiac Surg 1988; 3:91-96
Lateral Tunnel Fontan
(Total Cavopulmonary Connection)

Gortex baffle
Aortic punch used to create fenestration

Bridges ND et al, Circulation 1990; 82:1681-1689
Bidirectional Glenn Shunt

Bridges ND, Jonas RA et al., Bidirectional cavopulmonary anastomosis as interim palliation for high-risk Fontan candidates

*Circulation* 1990; 82 (suppl IV) IV170-176
Lateral Tunnel After Bidirectional Glenn Shunt

A.

Atrial incision anterior to sinus node

B.
Hemi-Fontan Procedure
Alternative “Hemi-Fontan” procedure

Rodefeld, Huddleston et al
*J Thorac Cardiovasc Surg* 1996; 111:514-526
“Before suture line placement, no dog had inducible atrial flutter. After placement of the suture line, sustained atrial flutter was reproducibly induced in every dog....”
Extracardiac Conduit Fontan Procedure

LONG-TERM RESULTS OF THE LATERAL TUNNEL FONTAN OPERATION

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Ingeborg Friehs, MD
John E. Mayer, Jr, MD
David Zirakowski, PhD
John K. Friedman, MD
Adrian M. Moran, MD
Edward P. Walsh, MD
James E. Lock, MD
Richard A. Jonas, MD
Pedro J. del Nido, MD

Objectives: Completion of a total cavopulmonary anastomosis with an intratrial lateral tunnel is known to yield good early and midterm results. In this study, we sought to determine the long-term outcome (10 years) after a lateral tunnel Fontan procedure.

Methods: Between October 1987 and December 1991, 220 patients (aged 11 months to 32 years) with a wide range of underlying diagnoses underwent a fenestrated or nonfenestrated lateral tunnel Fontan procedure at our institution. Current follow-up information was available for 196 patients (94%, mean follow-up = 10.2 ± 0.6 years). Risk factor analysis included patient-related and procedure-related variables, with death, failure, and bradyarrhythmia or tachyarrhythmia as outcome parameters.

Results: There were 12 early deaths (<30 days or hospital death), 7 late deaths, 4 successful takedown operations, and 4 heart transplantations. Kaplan-Meier estimated survival was 93% at 5 years and 91% at 10 years, and freedom from failure was 90% at 5 years and 87% at 10 years. Freedom from new supraventricular tachyarrhythmia was 96% at 5 years and 91% at 10 years; freedom from new bradyarrhythmia was 88% at 5 years and 79% at 10 years. Three patients had evidence of protein-losing enteropathy. Multivariable risk factors for development of supraventricular tachyarrhythmia included heterotaxy syndrome, atrioventricular valve abnormalities, and preoperative bradyarrhythmia. Risk factors for bradyarrhythmia included systemic venous anomalies. The sole risk factor for late failure was a previous coarctation repair.

Conclusion: The lateral tunnel Fontan procedure results in excellent long-term outcome even when used in patients with diverse anatomic diagnoses. The incidence of atrial tachyarrhythmia is low and mainly depends on the underlying cardiac morphology and preoperative arrhythmia. The good long-term outcome after an intracardiac lateral tunnel Fontan procedure should serve as a basis for comparison with other surgical alternatives. (J Thorac Cardiovasc Surg 2001;121:28-41)
Longterm Survival after Lateral Tunnel Fontan
Longterm Results after Lateral Tunnel Fontan: Freedom from New SVT
Longterm Results after Lateral Tunnel Fontan: Freedom from Bradyarrhythmia
Lateral Tunnel Fontan in the Current Era: Is It Still a Good Option?

John W. Brown, MD, Mark Ruzmetov, MD, PhD, Benjamin W. Deschner, BS,
Mark D. Rodesfeld, MD, and Mark W. Turrentine, MD
Section of Cardiothoracic Surgery, Indiana University School of Medicine, Indianapolis, Indiana

Ann Thorac Surg 2010;89:556-62

- Freedom from new SVT: 98% at 5 years; 95% at 10 years
- Freedom from bradyarrhythmia: 97% at 5 years; 96% at 10 years
- Multivariable risk factors for development of supraventricular tachyarrhythmia included
  - atrioventricular valve abnormalities (p = 0.02), and
  - preoperative bradyarrhythmia (p = 0.01).
92% of 636 patients had the lateral tunnel Fontan

“We have preferred to do the lateral tunnel Fontan at the University of Michigan for a multitude of reasons.”
Conclusions

• The EC and LT operation had comparable early and late mortality, readmission for chylous effusion, preservation of sinus rhythm, and frequency of all neurologic events. The more frequently fenestrated LT cohort used fewer resources.
Hakacova N, Lakomv AM, Kovacikova L. 
Arrhythmias after Fontan operation: comparison of lateral tunnel and extracardiac conduit 

*J Electrocardiol 2008;41:173-7*

- Retrospective analysis of the incidence, types, and duration of rhythm disorders in 101 consecutive patients who received either LT (n = 60) or EC (n = 41)
- Extracardiac conduit as compared with LT does not provide superior outcomes related to the problem of early and 1-year onset arrhythmias
From November 1995 through October 2002, 70 Fontan procedures were performed: 37 LT and 33 ECC

**Conclusions**

- The LT and ECC approaches had comparable early and mid-term outcomes, including operative morbidity and mortality, postoperative hemodynamics, resource use, and mid-term survival and functional status.
- ECC patients had a **higher!!!** incidence of sinus node dysfunction early after operation.

*Ann Thorac Surg. 2003;76:1389-96*
## Arrhythmia after Fontan

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>ECC</th>
<th>Lateral tunnel</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiore et al</td>
<td>2007</td>
<td>Indiana/St. Louis</td>
<td>Non-sinus rhythm</td>
<td>Non-sinus rhythm</td>
<td>15% vs 18%</td>
</tr>
<tr>
<td>Cohen et al</td>
<td>2000</td>
<td>CHOP</td>
<td>13%</td>
<td>13%</td>
<td>N.S.</td>
</tr>
<tr>
<td>Azakie et al</td>
<td>2009</td>
<td>Toronto</td>
<td>7%</td>
<td>23%</td>
<td>&lt; 0.02</td>
</tr>
<tr>
<td>Kumar et al</td>
<td>2003</td>
<td>South Carolina</td>
<td>28%</td>
<td>15%</td>
<td>0.2</td>
</tr>
<tr>
<td>Hakacova et al</td>
<td>2008</td>
<td>Slovakia</td>
<td>Early arrhythmia</td>
<td>54%</td>
<td>N.S.</td>
</tr>
</tbody>
</table>
Why is there a high incidence of arrhythmia with the extracardiac conduit Fontan?

• May be secondary to damage to the Crista terminalis, particularly if the procedure is done off pump…..
• Large atrial cuff
Extracardiac Conduit Fontan Procedure

John Brown in Discussion of “Lateral tunnel Fontan in the Current Era: Is it still a good option?”

Ann Thorac Surg 2010;89:556-62

“We try to use a no-touch technique for the crista terminalis, the atriocaval junction and the blood supply to the SA node. That is a no man’s land for us. You can’t disturb those tissues and expect that the patient is going to remain in sinus rhythm”
The higher densities of adrenergic nerve in the Crista Terminalis play an important role in the genesis of atrial arrhythmia.
# Pleural Effusions and Hospital Stay

<table>
<thead>
<tr>
<th>ECC</th>
<th>Lateral tunnel</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiore et al, 2007 Indiana/St. Louis</td>
<td>Hospital stay</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>25 + 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(33% fenestration)</td>
<td></td>
</tr>
<tr>
<td>Hirsch et al, 2008 U Michigan</td>
<td>Prolonged drainage 33%</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>(35% fenestration)</td>
<td></td>
</tr>
<tr>
<td>Fu Song et al, 2009 Giessen</td>
<td>10 ± 12 w/fenestration</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>13.2 ± 8.8 w/o fenestration</td>
<td></td>
</tr>
<tr>
<td>Kumar et al, 2003 South Carolina</td>
<td>10 days</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>11 days</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(100% fenestration)</td>
<td></td>
</tr>
<tr>
<td>Azakie et al, 2001 Toronto</td>
<td>8 days</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>11 days</td>
<td></td>
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<tr>
<td></td>
<td>(77% fenestration)</td>
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</table>
Why do many centers doing the extracardiac conduit suggest that a fenestration is not necessary?

• Because it’s technically challenging to keep a fenestration open with a standard ECC Fontan
## Summary of Advantages and Disadvantages

### ECC vs Lateral Tunnel

<table>
<thead>
<tr>
<th>ECC</th>
<th>Lateral tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technically simpler, more easily reproducible with variable patient morphology</td>
<td>Judgment required</td>
</tr>
<tr>
<td>“Minimizes” atrial suture lines</td>
<td>Heavier atrial suture burden</td>
</tr>
<tr>
<td>No atrial tissue at high pressure</td>
<td>Thin strip of atrial tissue at high pressure</td>
</tr>
<tr>
<td>Difficult to fenestrate</td>
<td>Easy to fenestrate</td>
</tr>
<tr>
<td>No catheter access to atrium</td>
<td>Catheter access to atrium available</td>
</tr>
<tr>
<td>No growth potential</td>
<td>Grows</td>
</tr>
<tr>
<td>Avoids CPB + X-clamp</td>
<td>Short clamp time, CPB mandatory</td>
</tr>
</tbody>
</table>
Extracardiac conduit Fontan is not better than the Intra-atrial Lateral Tunnel Fontan
Acknowledgements

- Medical illustrator      Becky Dodson
- Powerpoint creator     Laura Young
- Research               TK Susheel Kumar MD
Why is it difficult to analyze risk factors for Fontan outcome?

• Wide range of patient morphology
• Variable pre-Fontan palliation
• Multiple technical modifications of Fontan procedure since 1970
  – First generation: “Atrio-pulmonary”
  – Second generation: “Lateral tunnel”
  – Third generation: “Extra-cardiac conduit”
  – **Fourth generation: “Intra/extracardiac conduit with fenestration”**
The “Intra/Extracardiac Conduit” Fenestrated Fontan

Atrial incision avoids
✓ Sinus node
✓ Crista terminalis
✓ Sinus node artery
The “Intra/Extracardiac Conduit” Fenestrated Fontan

- Ring-supported Goretex conduit
- Goretex suture tacks atrial wall to conduit
- Fenestration in short intra-atrial segment
The “Intra/Extracardiac Conduit” Fenestrated Fontan
The Intra/Extracardic conduit Fontan
Results of Intra/Extracardiac Conduit:
First 7 patients at Children’s National Medical Center

- 6/7 patients in Sinus rhythm at latest follow-up, one with “low atrial rhythm”
- 2/7 patients had transient early sinus node dysfunction
- EP team have commented on markedly lower incidence of early post-op junctional rhythm relative to lateral tunnel
Conclusions

• The intra/extracardiac conduit combines the advantages of both the Extracardiac conduit and the Lateral Tunnel and has fewer of the disadvantages