Fontan Deterioration in Pediatric Cardiologist’s View

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Outcomes of Fontan operation

- JTCS 2006:131;172-80 Mitchell ME et al
  - 85%–LT, 15%–EC, 49%–HLHS
  - Median 8.6yr F/U
  - Freedom from death or Tx: 98.0% at 1yr, 94.9% at 5yr, 93.9% at 8yr
  - Cardiac–related rehospitalization: 54.2%
  - NYHA class I or II: 86.7%
  - School performance: 30.2% above average, 39.9% average, 29.8% below average
Factors influencing early and late outcome

- *EJCTS 2007*
- Two commandments
  - Preop impaired ventricular function
  - Elevated pulmonary artery pressure
Late complications associated with Fontan circulation

- Arrhythmia
- Thromboembolism and hepatic dysfunction
- Protein-losing enteropathy
- Worsening cyanosis
Arrhythmia in failing Fontan

- Mechanism:
  - Injury to sinus node or its blood supply
  - Extensive atrial incision and suture line
  - Chronic exposure of atrial myocardium to elevated pressure with subsequent dilatation
  - Underlying anatomic substrate: discordant AV connection, atrial isomerism
  - Hemodynamic factor: AV valvar regurgitation
Arrhythmia in failing Fontan: sinus node dysfunction

- Reduce CO
  - Limiting HR in patients with relatively fixed stroke volume
  - ↓ ventricular filling ↔ junctional rhythm and loss of AV synchrony
Arrhythmia in failing Fontan: sinus node dysfunction

- Children’s Hospital of Philadelphia
  *Circulation* 1998

- 287 patients staged with hemi-Fontan followed by lateral tunnel Fontan, 1990-1995

- Sinus node dysfunction in 7% before and in 15% after hemi-Fontan, in 23% at early post-Fontan, in 44% at 4~7yr F/U after Fontan
Follow-up time (years from Fontan)

Percent (%): SND

0-2y (N=41)  2-4y (N=84)  4-7y (N=95)
• **JTCS 2000**

• Modifications to the cavopulmonary anastomosis do not eliminate early sinus node dysfunction – 30 EC Fontan vs 46 LT Fontan
- **ATS 2004;78:1979-88**
- **New onset arrhythmia after the EC Fontan op compared with LT procedure**
  - 29 LT Fontan (7.9yr), 45 EC Fontan (4.4yr)
  - New onset SVT in early postop EC:LT=11%:38%, during F/U 0%:27%
  - Pacemaker due to bradyarrhythmia, in early postop 34%, during F/U +3 patients in LT group, but none in EC group
• *Int J Cardiol* 2003;88:285-91
• SND after Fontan modifications—fluence of surgical method
  ▪ SND in situs solitus heart, EC 0/16 vs LT 8/26
  ▪ Staged approach—no risk
• *ATS 2003;76:1389-96*
• LT versus EC Fontan procedure: a concurrent comparison
  ▪ Early postop SND EC:LT=27%:8%, at discharge 10%:0%
Arrhythmia in failing Fontan: atrial tachyarrhythmia

- Most common form: IART
- IART mimic AF, but longer cycle length (> 240ms)
- Often poorly tolerated, limit ventricular filling and cardiac output, associated with atrial thrombus formation
- Risk factor:
  - older age Fontan, prior atrial septectomy, PA reconstruction, worse NYHA class
  - Systemic ventricular dysfunction, heterotaxy, anomalous systemic venous drainage, previous BDG

\textit{ATS 2005} \textit{JTCS 1997}
Arrhythmia in failing Fontan: atrial tachyarrhythmia

- Notoriously resistant to antiarrhythmics
- Increased with F/U
- Reported up to 57% *Heart 2000*
- LT Fontan 3-5yr F/U 4.1% *Circulation 1998*
- Efforts minimize risk of arrhythmia
  - Minimize injury to sinus node & its blood supply
  - Minimize atrial incision & suture line particularly in terminal groove
  - Guard against or reduce AV valvar regurgitation
Arrhythmia in failing Fontan: atrial tachyarrhythmia

- Digoxin, amiodarone, sotalol
- Radiofrequency ablation
  - Initial success rate around 80%, recurrence rate greater than 50% at 2yr F/U
  - 3-D mapping system and irrigated-tip ablation catheter, immediate success in >80%, Recur or new arrhythmia 30–45% in 6–12 mon after ablation
    - Heart Rhythm 2005, AJC 2003
- Fontan conversion and arrhythmia surgery
  - Fontan conversion without cryoablation—50～67% clinical recurrence of IART
  - No recurrence after right sided Maze procedure at 2.5yr F/U
Thromboembolism

- Increased risk of thrombosis
  - Atrial arrhythmia
  - Distended and sluggish Fontan pathway
  - Intravascular prosthetic material
  - Hepatic impairment with multiple clotting factor abnormalities: ↓ level of protein C, protein S, antithrombin III
  - Increased platelet reactivity
Thromboembolism

- Exact prevalence: unclear, 3~33%
- Stroke incidence: 2.6% among 645 patients over 15yrs *Pediatr Neurol* 1995
- Freedom from thrombus 92%, 90%, 84%, 82% at 1, 3, 8, 10yr after Fontan *ATS 2001*
Thromboembolism

- Ligation of pulmonary trunk leaving blind cul-de-sac distal to pulmonary valve: worrisome substrate for occurrence of thromboembolism
- The role of long-term antiplatelet or anticoagulation therapy: poorly defined
Protein-losing enteropathy

• 3~15% of Fontan patients
• Sx: fatigue, peripheral edema, pleural and pericardial effusion, ascites, chronic diarrhea
• Dx: low serum albumin, increased fecal α₁-antitrypsin levels
• Mediated by chronically elevated central venous pressure
Fontan Operation

- Arrhythmia
- Systolic/Diastolic Dysfunction

Chronic Low Cardiac Output

- Increased Angiot II
- Inflammation

Increased Mesenteric Vascular Resistance

Mesenteric Hypoperfusion in Conjunction with Venous Congestion

Break in Intestinal Mucosal Integrity-PLE
Protein-losing enteropathy

- Other risk factor: longer CPB time, morphologic RV anatomy *AJC 2001*
- In patients with generalized edema, 5yr survival rate $\approx 50\%$, 10yr $1/5$ *JTCS 1998*
Protein-losing enteropathy

• Multiple therapeutic approach:
  - Dietary modification with high protein, high MCT
  - Afterload reduction agent
  - Inotropic agent
  - Heparin
  - Albumin infusion
  - Octreotide
  - Prednisone
  - Pacing on significant SND
  - Atrial fenestration
  - Fontan revision
  - Cardiac transplantation
Worsening cyanosis

- In absence of atrial fenestration, SpO2 ≥ 94%
- Common cause:
  - Progressive deterioration of ventricular function with or without AV valve regurgitation
  - Shunting through baffle leak or residual interatrial communication
  - Pulmonary vein compression by giant RA or aorta
  - Systemic venous collateralization
  - Pulmonary AV malformation
  - Pulmonary pathology
  - Hepatic venous connection to CS or LA
  - Rt-to-Lt interatrial shunt via small thebesian vein
  - Diaphragmatic paresis
Effectiveness of Carvedilol for Congestive Heart Failure that Developed Long after Modified Fontan Operation

Naoko Ishibashi · In-Sam Park · Yukiko Takahashi · Mitsunori Nishiyama · Yasue Murakami · Katsuhiko Mori · Shigekazu Mimori · Makoto Ando · Yukihiro Takahashi · Toshio Nakanishi

• 27yr old man
• Intractable CHF due to severe ventricular dysfunction
• Carvedilol 2mg/day → 30mg/day
• ↓ atrial pressure and improved ventricular function
**β-blocker on heart failure**

- **Mechanism**
  - Suppression of oxygen consumption
  - Upregulation of β-adrenergic receptor
  - Antiarrhythmic effect
  - Reduction of cardiac norepinephrine
  - Improvement of ventricular diastolic function
Carvedilol

• Potent nonselective $\beta$-blocker
• $\alpha_1$-adrenergic receptor blocker: vasodilating effect
• Antioxidant effect
→ a primary drug for treatment of CHF
Bosentan induces clinical, exercise and hemodynamic improvement in a pre-transplant patient with plastic bronchitis after Fontan operation

- *J Heart Lung Transplant* 2005;24:1174–6
- 14yr old boy with high pulmonary artery pressure
Fontan experience

- Total 45 patients
  - Median F/U 4yr 11mon
- Age: 1yr 9mon~ 24yr, median 2yr 11mon
- Body wt: 10.0~63.8kg, median 12.8kg
• **Underlying conditions**
  - Tricuspid atresia 13
  - Isomeric heart 6, RAI 5/LAI 1
  - Common inlet ventricle 5, RV 3/ LV 2
  - Mitral atresia or stenosis/LV hypoplasia 6
  - PA IVS 4
  - DILV 3
  - Ebstein 2
  - HLHS 1
  - DORV/ MV straddling 1
  - Others 4
• **Op methods**
  - Lateral tunnel procedure: 6
  - Extracardiac conduit TCPC: 38
    - 18mm, 2; 19mm, 7; 20mm, 26; 22mm, 2; 24mm, 1
  - Hepatic vein inclusion after Kawashima: 1
  - Staged with BCPC except 3 cases
  - Right Maze in 2 patients

• **No early mortality, 1 late mortality**

• **Intractable chylothorax 3**

• **Pacemaker in 2, antiarrhythmics in 1**
Follow-up by specialized team

• Regular surveillance
  ▪ Thorough clinical history
  ▪ Physical examination
  ▪ Resting oximetry
  ▪ 12-lead EKG
  ▪ Chest X-ray
  ▪ Echocardiography
  ▪ CBC, LFT, serum protein/albumin
  ▪ Occasional Holter monitoring