Recent Advances in Pediatric Cardiac Surgery

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Advances in Pediatric Cardiac Surgery

- Diagnostic modalities
  - Prenatal EchoCG, 3D EchoCG, TEE, multi-detector CT, MRI

- Surgical strategies and techniques
  - Early total correction
  - Cardiopulmonary Bypass
    - Ultrafiltration, heparin-bonded circuit
  - Perioperative brain protection
    - Selective cerebral perfusion, brain oxymeter
  - Hybrid approach
  - Robotic / endoscopic surgery

- Mechanical assist device / transplantation

- Perioperative care
Trends in Surgical Results of CHD
Current status of CHD surgery in the U.S.
(from STS database)

No. of patients vs. Mortality (%)

- No. of patients: 2005, 22000, 25000, 27000, 29000

WFSICCM Seoul 2015
Prenatal diagnosis of critical congenital heart disease reduces risk of death from cardiovascular compromise prior to planned neonatal cardiac surgery: a meta-analysis

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*Division of Pediatric Cardiology, Department of Pediatrics, University of Louisville School of Medicine, Louisville, KY, USA; †Child and Adolescent Health Research and Design Support Unit, Department of Pediatrics, University of Louisville School of Medicine, Louisville, KY, USA

<table>
<thead>
<tr>
<th>Study</th>
<th>Odds ratio</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Z-value</th>
<th>P-value</th>
<th>Deaths/Total</th>
<th>Odds ratio and 95% CI</th>
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<td>Bonnet (1990)⁴</td>
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<td>0.108</td>
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<td>Franklin (2002)⁵</td>
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<td>0.339</td>
<td>0/10</td>
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<td>Kipps (2011)⁶</td>
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<td>0.005</td>
<td>2.148</td>
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<td>Raboisson (2009)⁷</td>
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<td>118.873</td>
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<td>0.344</td>
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<td>Trzifa (2007)⁸</td>
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<td>0.672</td>
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<tr>
<td>Pooled analysis</td>
<td>0.363</td>
<td>0.118</td>
<td>1.118</td>
<td>-1.766</td>
<td>0.077</td>
<td>1/20</td>
<td>0.01 0.1 1 10 100</td>
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</tbody>
</table>
Predictive Value of Intraoperative Transesophageal Echocardiography in Complete Atrioventricular Septal Defect

Hyun Koo Kim, MD, PhD, Woong-Han Kim, MD, PhD, Sung Wook Hwang, MD, Jae Young Lee, MD, Jin Young Song, MD, Soo-Jin Kim, MD, and Ki Young Jang, MD

Department of Thoracic and Cardiovascular Surgery, Department of Pediatrics, Sejong General Hospital, Sejong Heart Institute, Bucheon; Department of Thoracic and Cardiovascular Surgery, Clinical Research Institute, Seoul National University Hospital, Seoul, Korea

Background. Intraoperative transesophageal echocardiography and follow-up transthoracic echocardiography have been useful in assessing cardiac function in complete atrioventricular septal defects. However, it has been suggested that a discrepancy exists between intraoperative and postoperative findings, and that intraoperative findings cannot reliably predict long-term results. This study aims to determine whether this discrepancy exists and to assess whether it is possible to predict follow-up results using intraoperative transesophageal echocardiography.

Methods. A retrospective analysis was made in 35 patients who underwent biventricular repair by one surgeon between November 1997 and January 2004. All patients received intraoperative transesophageal echocardiography and follow-up transthoracic echocardiography at 19.1 ± 18.02 months (range, 7 days to 5 years; median, 15.1 months).

Results. In left-sided atrioventricular valve regurgitation, 34.3% (12 of 35) of patients showed discrepancy during follow-up, and 28.6% (10 of 35) showed progression of regurgitation (from grade I to II). In right-sided atrioventricular valve, 11.4% (4 of 35) of patients showed discrepancy, 9.6% (3 of 35) showed progression of regurgitation (from grade I to II).

Conclusions. In complete atrioventricular septal defects, intraoperative transesophageal echocardiography did not show the same findings as that of follow-up transthoracic echocardiography in some cases. However, this discrepancy is not so great as to require reoperation in early to midterm follow-up. Therefore, intraoperative transesophageal echocardiography may be used as a tool to predict durability of surgical results and to decrease the incidence of reoperation in complete atrioventricular septal defects.


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Advances in Diagnostic Modalities

- Multi-Detector CT (MDCT)
- MRI
Partially Unroofed Coronary Sinus: MDCT and MRI Findings

Hyoojin Kim
Yeon Hyeon Choe
Seung Woo Park
Tae Ginak Jun
I-Senik Kang
Ji-Hyuk Yang
Hong Eo
Heung Jae Lee

OBJECTIVE. The purpose of this study was to analyze the MDCT and MRI findings in patients with unroofed coronary sinus syndrome.

MATERIALS

Unroofed coronary sinus syndrome is characterized by the presence of an anomalous coronary sinus that persists from the left atrium, with unroofed roofed coronary sinus.

RESULTS

Criminated from CT and MRI, the left atrium presented an anomalous coronary sinus that persisted on the left side of the patient group with the left atrium syndrome.

CONCLUSION

Fig. 3—50-year-old man with type 1 unroofed coronary sinus (CS) syndrome. RA = right atrium, LA = left atrium, D = defect.
A. Oblique reformed CT image along long axis of CS shows defect in CS and lower part of interatrial septum. Arrow represents direction of flow through defect.
B. Volume-rendered posterior view image shows enlarged CS and communication (arrows) between LA and CS.
C. Cine MR image shows large defect (arrows) in roof of CS.

Fig. 4—38-year-old man with type 2 unroofed coronary sinus (CS) syndrome.
A. Oblique reformed CT image along long axis of CS shows 11-mm defect in middle of roof of CS (asterisk). RA = right atrium, LA = left atrium.
B. Virtual angioscopic reconstruction of CT image in view from LA cavity shows defect in roof of CS (arrow).
C. Surgical photograph shows defect (asterisk) in roof of CS visible through CS orifice (arrow).

Keywords: MDCT, MRI, unroofed coronary sinus
DOI: 10.2214/AJH.09.0089

Received September 17, 2009; accepted after revision April 24, 2010.

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4D flow MRI
Rationale for Early Total Correction

- Early repair can allow normal organ development.
  - Allows growth of new coronary blood vessels, and myocardial development (Bass JL, 2004)
  - Allows normal lung development
- Abolition of cyanosis & hemodynamic problem can promote normal body growth.
- Preoperative hypoxia and increased time to surgical correction is associated with the development of PVL, a specific form of WM injury (Kecskes Z, 2002)
- Immature brain is vulnerable to CPB-induced injury, but early repair can potentially provide better WM development in CHD (Welke KF, 2009) and the potential to improve recovery of the neurodevelopmental delay
- Total correction of CHDs early in life will decrease the health and economic burden of the family
Outcomes of Arterial Switch Operation in Samsung Medical Center

- 2000~2014
- 118 patients
  - Median age 8.5 (1~485) days
  - Median Bwt. 3.4 (2.3~10.3) kg
  - Including 9 patients with arch obstruction
- 1 in-hospital mortality (0.1%)

98.2% at 1yr
97.7% at 10yr
Advances in operative management

▪ Avoidance of total circulatory arrest
  • Selective antegrade cerebral perfusion during arch surgery in CoA, IAA, Norwood etc.

▪ Advances in CPB
  • Ultrafiltration
  • Lower priming volume
    – Miniaturized circuit
  • Lesser degree of hypothermia
  • Higher hematocrit
Outcome of Single-Stage Repair of Coarctation with Ventricular Septal Defect

Seong Ho Cho, M.D.,* Yang Hyun Cho, M.D.,* Tae-Gook Jun, M.D., Ph.D.,* Ji-Hyuk Yang, M.D., Ph.D.,* Pyo Won Park, M.D., Ph.D.,* June Huh, M.D., Ph.D.,† I-Seok Kang, M.D., Ph.D.,† and Heung Jae Lee, M.D., Ph.D.†

*Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea; and †Division of Pediatric Cardiology, Department of Pediatrics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

ABSTRACT  Background: The optimal surgical strategy for coarctation of the aorta (CoA) with ventricular septal defect (VSD) is controversial. The aim of this study is to evaluate the clinical outcome of a single-stage repair of CoA with VSD. Methods: We reviewed 72 patients who underwent single-stage repair for CoA with VSD between January 1995 and December 2007. There were 43 males and 29 females. The median age of the patients was 28 days (range = 3 to 188) and median weight was 3.7 kg (range = 2.16 to 5.6). Deep hypothermic circulatory arrest was used in 22 patients and selective antegrade cerebral perfusion was performed in 43 patients. Results: There were no operative deaths and one late death at a median follow-up of 60 months (range = 16 to 158). Postoperative complications were left main bronchus compression requiring aortopexy in one patient and recoarctation requiring balloon dilatation in one patient. Subaortic stenosis occurred in two patients and surgical repair was performed. Conclusions: One-stage simultaneous repair can be performed with a low risk at an early age. doi: 10.1111/j.1540-8191.2011.01255.x (J Card Surg 2011;26:420-424)
Minimally invasive approach

Conventional sternotomy

Sternotomy with minimal incision
Endoscopic closure of ASD

- 66 patients from 2006 to 2014
- Including 10 valve procedures
- No early or late deaths
- 2 reoperations
**Congenital tracheal stenosis**

**Clinical outcomes of slide tracheoplasty in congenital tracheal stenosis**

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** Department of Pediatrics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea.

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Received 14 September 2013; received in revised form 5 March 2014; accepted 11 March 2014.

**Abstract**

**OBJECTIVES**: Treatment of long-segment congenital tracheal stenosis (CTS) remains challenging. Recently, slide tracheoplasty has become the standard approach in many centres. The aim of this study was to evaluate the clinical outcomes of slide tracheoplasty.

**METHODS**: Between 2004 and 2011, 18 patients underwent slide tracheoplasty in our centre. The median patient age was 2.5 months (range, 18 days–4 years) and the median body weight was 4.2 kg (range, 2.2–17.7) kg at operation. Eleven (61%) patients were on a mechanical ventilator prior to surgery. The median stenotic segment estimated by computed tomography scan was 52% of the length of total trachea (range, 18–81%). Five (28%) patients had proximal bronchial stenosis, 3 (17%) had tracheal bronchus, 2 (11%) had tracheobronchomalacia and 1 (6%) had agenesis of the right lung. Thirteen (72%) patients had a combined cardiac anomaly, including 8 patients with a pulmonary artery sling. Ten (56%) patients had associated extracardiac anomalies. Slide tracheoplasty was performed on cardiopulmonary bypass in all patients, and cardiac lesions were corrected.

**RESULTS**: There was no early death. The patient with agenesis of the right lung died of left bronchial stenosis 3 months after the surgery. Two (11%) patients were reoperated on for tracheal restenosis. In the other 15 patients, the median duration of ventilator support was 8 days (range, 5–34) days and the median duration of hospitalization was 31 days (range, 12–79) days. During the follow-up (median duration of 17 months; range, 2–77 months), 13 (72%) patients were symptom-free and 2 (11%) underwent tracheostomy for tracheomalacia.

**CONCLUSIONS**: Based on this study, slide tracheoplasty seems to be an effective technique for CTS. However, shortening of the trachea after reconstruction may give rise to recurrent obstruction.

**Keywords**: Congenital tracheal stenosis • Tracheal surgery • Pulmonary artery/abnormalities
Technique for combined tracheal bronchus
Near-Infrared Spectroscopy (NIRS)
Pulmonary Vasodilators

- **Inhaled Nitric Oxide**
  - In infants at high risk of pulmonary hypertension, routine use of inhaled nitric oxide after congenital heart surgery can lessen the risk of pulmonary hypertensive crises and shorten the postoperative course, with no toxic effects (Miller OI, Lancet 2000)

- **Phosphodiesterase inhibitor (Sildenafil)**
  - appears to control pulmonary hypertension safely and effectively in children undergoing operations to correct congenital heart defects, particularly when it is given both preoperatively and postoperatively. (Palma G, Tex Heart Inst J 2011)

- **Prostacyclin**

- **Endothelin receptor antagonist (Bosentan)**
Surgical Strategy in Patients with Atrial Septal Defect and Severe Pulmonary Hypertension

Yang Hyun Cho,1 Ta-Soon Jun,1 Ji-Hyuk Yang,1 Pyo Won Park,1 June Huh,2 I-Seok Kang,2 Heung Jae Lee2

1Department of Thoracic and Cardiovascular Surgery, and 2Division of Pediatric Cardiology, Department of Pediatrics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

Patient Characteristics from Preoperative and Postoperative Catheterization

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (y)</th>
<th>SPVR mm Hg</th>
<th>MAPR mm Hg</th>
<th>Qp/Qs</th>
<th>Rp (Wood units)</th>
<th>ERPA/SAP</th>
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<td>36</td>
<td>99</td>
<td>57</td>
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<td>0.79</td>
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<td>2</td>
<td>27</td>
<td>93</td>
<td>55</td>
<td>2.45</td>
<td>2.4</td>
<td>0.38</td>
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<tr>
<td>3</td>
<td>34</td>
<td>179</td>
<td>77</td>
<td>1.3</td>
<td>16.7</td>
<td>0.52</td>
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<tr>
<td>4</td>
<td>27</td>
<td>100</td>
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<td>0.73</td>
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<tr>
<td>5</td>
<td>41</td>
<td>63</td>
<td>37</td>
<td>1.62</td>
<td>1.08</td>
<td>0.38</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>90</td>
<td>47</td>
<td>1.72</td>
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<td>0.70</td>
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<tr>
<td>7</td>
<td>22</td>
<td>83</td>
<td>52</td>
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<td>0.76</td>
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<tr>
<td>8</td>
<td>57</td>
<td>90</td>
<td>48</td>
<td>1.6</td>
<td>12.9</td>
<td>0.37</td>
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<tr>
<td>9</td>
<td>52</td>
<td>75</td>
<td>41</td>
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<tr>
<td>10</td>
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<td>1.38</td>
<td>4.7</td>
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</tr>
<tr>
<td>12</td>
<td>36</td>
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<td>54</td>
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<td>13</td>
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<td>44</td>
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<td>0.51</td>
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Mean ± SD

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<th>Preoperative NYHA class</th>
<th>Postoperative NYHA class</th>
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<tr>
<td>I n = 11</td>
<td>n = 11</td>
</tr>
<tr>
<td>II n = 14</td>
<td>n = 14</td>
</tr>
<tr>
<td>III n = 2</td>
<td>n = 2</td>
</tr>
</tbody>
</table>

SPVR: systemic pulmonary artery pressure; MAPR: mean pulmonary artery pressure; SRA: systolic right atrial pressure; Qp/Qs: pulmonary-to-systemic flow ratio; Rp: pulmonary arterial resistance.

*Preoperative values.
General Postop. Management after Norwood procedure

- Sedation with muscle relaxation
- Open chest
- Inotropes, vasodilator
- PD
- Ventilate to normal pH and pCO₂
  - Rule of 40
    - FiO₂ < 40%, PCO₂ 40 mmHg, PO₂ 40 mmHg
- Calculate Qp/Qs ratio, A-VO₂ difference
  - Qp/Qs = (SaO₂-SvO₂)/(0.97-SaO₂)
  - A-VO₂ = SaO₂ – SVO₂
# Incidence & Mortality after CHD surgery

(from STS database, 2005~2009)

<table>
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<th>Procedure</th>
<th>Incidence #</th>
<th>% of all</th>
<th>Discharge Mortality</th>
</tr>
</thead>
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<td>PDA closure, Surgical</td>
<td>6,381</td>
<td>8.1%</td>
<td>37 / 1,254</td>
</tr>
<tr>
<td>VSD repair, Patch</td>
<td>5,009</td>
<td>6.4%</td>
<td>31 / 4,956</td>
</tr>
<tr>
<td>Delayed sternal closure</td>
<td>3,722</td>
<td>4.7%</td>
<td>2 / 3,705</td>
</tr>
<tr>
<td>Bidirectional cavopulmonary anastomosis (BDCPA) (Bidirectional Glenn)</td>
<td>2,668</td>
<td>3.4%</td>
<td>46 / 2,661</td>
</tr>
<tr>
<td>ASD repair, Patch</td>
<td>2,636</td>
<td>3.3%</td>
<td>2 / 2,615</td>
</tr>
<tr>
<td>Norwood procedure</td>
<td>2,426</td>
<td>3.1%</td>
<td>447 / 2,395</td>
</tr>
<tr>
<td>Mediastinal exploration</td>
<td>2,378</td>
<td>3.0%</td>
<td>24 / 2,361</td>
</tr>
<tr>
<td>AVC (AVSD) repair, Complete (CAVSD)</td>
<td>2,265</td>
<td>2.9%</td>
<td>46 / 2,245</td>
</tr>
<tr>
<td>Shunt, Systemic to pulmonary, Modified Blalock-Taussig shunt (MBTS)</td>
<td>1,957</td>
<td>2.5%</td>
<td>142 / 1,939</td>
</tr>
<tr>
<td>Coarctation repair, End to end, Extended</td>
<td>1,875</td>
<td>2.4%</td>
<td>37 / 1,848</td>
</tr>
<tr>
<td>Pacemaker implantation, Permanent</td>
<td>1,861</td>
<td>2.4%</td>
<td>25 / 1,850</td>
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<tr>
<td>TOF repair, Ventriculotomy, Transanular patch</td>
<td>1,731</td>
<td>2.2%</td>
<td>34 / 1,692</td>
</tr>
<tr>
<td>Arterial switch operation (ASO)</td>
<td>1,469</td>
<td>1.9%</td>
<td>39 / 1,460</td>
</tr>
<tr>
<td>Pacemaker procedure</td>
<td>1,381</td>
<td>1.8%</td>
<td>23 / 1,370</td>
</tr>
<tr>
<td>Aortic stenosis, Subvalvar, Repair</td>
<td>1,365</td>
<td>1.7%</td>
<td>6 / 1,339</td>
</tr>
<tr>
<td>Valvuoplasty, Mitral</td>
<td>1,338</td>
<td>1.7%</td>
<td>11 / 1,323</td>
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<tr>
<td>Fontan, TCPC, External conduit, Fenestrated</td>
<td>1,280</td>
<td>1.6%</td>
<td>20 / 1,272</td>
</tr>
<tr>
<td>RVOT procedure</td>
<td>1,275</td>
<td>1.6%</td>
<td>32 / 1,255</td>
</tr>
<tr>
<td>Valve replacement, Pulmonic (PVR)</td>
<td>1,245</td>
<td>1.6%</td>
<td>5 / 1,223</td>
</tr>
<tr>
<td>Conduit reoperation</td>
<td>1,237</td>
<td>1.6%</td>
<td>12 / 1,227</td>
</tr>
<tr>
<td>TAPVC repair</td>
<td>1,206</td>
<td>1.5%</td>
<td>125 / 1,193</td>
</tr>
<tr>
<td>PA banding (PAB)</td>
<td>1,160</td>
<td>1.5%</td>
<td>121 / 1,141</td>
</tr>
<tr>
<td>Coarctation repair, End to end</td>
<td>1,105</td>
<td>1.4%</td>
<td>7 / 1,099</td>
</tr>
<tr>
<td>Transplant, Heart</td>
<td>1,040</td>
<td>1.3%</td>
<td>51 / 1,038</td>
</tr>
<tr>
<td>Vascular ring repair</td>
<td>905</td>
<td>1.1%</td>
<td>5 / 897</td>
</tr>
</tbody>
</table>
Norwood Stage I Sano modification: RV-PA shunt

- RV-PA conduit instead of BTS
  - Valveless
  - Valved homograft
- More stable postop.
  - No coronary steal, Less PBF
- Good for low volume center

- Requiring incision on the RV which will be systemic ventricle
- Volume loading ← PR
- Poor PA growth → early BCPS
Comparison of Shunt Types in the Norwood Procedure for Single-Ventricle Lesions
High Risk Patients with HLHS

- Birth weight < 2.5kg
- GA ≤ 36 weeks
- Intact/restrictive atrial septum
- Aortic atresia ≤ 2mm
- Metabolic acidosis
- AV valve regurgitation ≥ moderate
- Severe ventricular dysfunction
- Significant extracardiac issues
Hybrid Approach to HLHS

• Less invasive procedures
• Avoid OHS, DHCA in neonates
• Initially stabilize patient to an age appropriate for the “big operation”
  - Control & protect PBF (bilateral PAB)
  - Provide reliable systemic output (PDA stent +/- Reverse shunt)
  - Create unobstructed flow from LA (BAS / stent IAS)
Comprehensive Stage II

- at 3~6months
- Removal of the PDA stent & PA bands
- Repair of the aortic arch & PA
- Division of the aAo with reimplantation into the Pulmonary root
- Main PA-to-reconstructed aorta anastomosis
- Atrial septectomy with removal of atrial stent
### Results of hybrid approach

<table>
<thead>
<tr>
<th>Author, Reference, Date, and Country</th>
<th>No. pts.</th>
<th>Mortality displayed as (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hospital mort.</td>
<td>Interstage mort.</td>
<td>Stage 2 mort.</td>
<td>Transplant-free survival beyond stage 2 (%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BPB</td>
<td>NP</td>
<td>BPB</td>
<td>NP</td>
<td>BPB</td>
</tr>
<tr>
<td>Akintuerk et al,² 2002, Germany</td>
<td>11</td>
<td>0</td>
<td>–</td>
<td>9</td>
<td>–</td>
<td>25</td>
</tr>
<tr>
<td>Pilla et al,¹² 2008, Brazil</td>
<td>15</td>
<td>60</td>
<td>–</td>
<td>17</td>
<td>–</td>
<td>75</td>
</tr>
<tr>
<td>Galantowicz et al,¹³ 2008, USA</td>
<td>40</td>
<td>2.5</td>
<td>–</td>
<td>5</td>
<td>–</td>
<td>9</td>
</tr>
<tr>
<td>Pizarro et al,⁹ 2008, USA</td>
<td>33</td>
<td>14</td>
<td>23*</td>
<td>25</td>
<td>21*</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>14 BPB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19 NP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honjo et al,¹⁰ 2009, Canada</td>
<td>58</td>
<td>21 BPB combined hospital mortality</td>
<td>21 NP* combined hospital interstage mort.</td>
<td>7</td>
<td>7*</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>19 BPB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>39 NP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sakurai et al,¹¹ 2009, Japan</td>
<td>43</td>
<td>6</td>
<td>12*</td>
<td>6</td>
<td>27*</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>18 BPB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 NP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (range)</td>
<td></td>
<td>17.3 (0-60)</td>
<td>17.5</td>
<td>12.4 (5-25)</td>
<td>24</td>
<td>25.3 (7-75)</td>
</tr>
</tbody>
</table>
Alternative strategy

- To reduce PA resistance
  - Bilateral PAB 2.5mm
  - Early debanding $\rightarrow$ Minimal PA distortion

- To enhance lower body perfusion
  - PGE1 $\rightarrow$ Avoidance of PDA stent

- To enhance upper body (cerebral, coronary) perfusion in case of associated CoA
  - Reverse BT shunt

- ASD widening if needed, with the aid of intraop. echoCG
Precise evaluation of bilateral pulmonary artery banding for initial palliation in high-risk hypoplastic left heart syndrome

Kazuo Kitahori, MD, PhD, Arata Murakami, MD, PhD, Tetsuhiro Takaoka, MD, Shinichi Takamoto, MD, PhD, and Minoru Ono, MD, PhD

(J Thorac Cardiovasc Surg 2010;140:1084-91)

- bPAB at 6.6±0.6 days, 2.5±0.4kg
- Norwood at 130±88 days, 4.0±1.1kg
- Banding size (circumference)
  - RPA : Bwt. + 7mm
  - LPA : Bwt. + 7.5mm
Age distribution of patients undergoing surgery for CHD in SMC 2014

Excluding PDA ligation in prematurity

WFSICCM Seoul 2015
Increasing number of GUCH patients

Estimated clinical relevance of CHD in the next years

Changing Proportion of Pediatric & Adult CHD

Heart Transplantation in Children

- Kaplan–Meier survival for recipients (1982 ~ 2012)

- Dipchand AI et al., Registry of the ISHLT: 17th Official Pediatric Heart Transplantation Report 2014
Ventricular Assist Device (VAD)
REMATCH Study (Rose et al. NEJM 2001)

- Randomized Evaluation of Mechanical Assistance for Treatment of Congestive Heart Failure
- 129 end-stage HF pts who were ineligible for cardiac transplantation
- ↓48% in the risk of death
- Significantly improved QOL at 1 yr
Pediatric VAD as a bridge to transplantation

From the Pediatric Heart Transplant Study (PHTS), Circulation, Vol124, Dipchand AI et al. (abstr16269). In: AHA Scientific Sessions 2011

Dipchand AI et al., Registry of the ISHLT: 17th Official Pediatric Heart Transplantation Report 2014
Types of VAD

- Extracorporeal
- Paracorporeal
- Implantable
- TAH

- Centrifugal
- Pulsatile (1\text{st} generation)
- Axial Flow (2\text{nd})
- Rotary Radial Flow (3\text{rd})
Axial Flow Pump – HeartMate II

- 2008 US FDA approval for clinical use as a BTT
- 2010 FDA approval for DT

Table 3: Type of Primary Left Ventricular Assist Device (INTERMACS: June 2006–March 2009)

<table>
<thead>
<tr>
<th>Type</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulsatile</td>
<td>528</td>
<td>48.4</td>
</tr>
<tr>
<td>Intracorporeal</td>
<td>460</td>
<td>42.1</td>
</tr>
<tr>
<td>Paracorporeal</td>
<td>68</td>
<td>6.2</td>
</tr>
<tr>
<td>Continuous flow</td>
<td>564</td>
<td>51.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1092</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

INTERMACS, Interagency Registry For Mechanical Circulatory Support; LVAD, left ventricular assist device.
HVAD (HeartWare Corp.)

FDA approved on November 20, 2012
Pulsatile pump – Berlin Heart Excor

FDA approved on Dec 16, 2011
Emerging Devices in Children

The Jarvik child and infant axial flow VAD

HeartWare MVAD
Transapical miniature axial flow pump
(HeartWare International, Inc., Framingham, MA)

CircuLite infant VAD
(CircuLite, Saddle Brook, NJ)

SynCardia 50-cc total artificial heart
(SynCardia Systems, Tucson, AZ)
Improved Survival After Cardiac Arrest Using Emergent Autoprimeing Percutaneous Cardiopulmonary Support

Kiick Sung, MD, Young Tak Lee, MD, Pyo Won Park, MD, Kay-Hyun Park, MD, Tae-Gook Jun, MD, Ji-Hyuk Yang, MD, and Yi-Kyung Ha, RN

Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

Background. Emergent percutaneous cardiopulmonary support (PCPS) has the potential to rescue patients in cardiac arrest who might otherwise die. We retrospectively reviewed the results of PCPS using preassembled, heparin-coated, and autoprimeing devices in patients in cardiac arrest.

Methods. From November 2003 to July 2005, 22 patients in cardiac arrest underwent PCPS using the Capiox emergent bypass system (Terumo, Tokyo, Japan). The mean ± SD age was 63 ± 14 (range, 31 to 85) years. In six patients, the underlying disease causing cardiac arrest was not diagnosed before PCPS. The procedure involved 14 to 21 Fr percutaneous femoral arterial cannulae and 17 to 28 Fr percutaneous femoral long venous cannulae. The mean duration of cardiopulmonary resuscitation before PCPS was 48.5 ± 29.0 (range, 15 to 143) minutes. An intraaortic balloon pump was used concomitantly in six patients.

Results. Fourteen patients received additional surgical or interventional procedures during PCPS. Thirteen (59%) patients could be weaned off PCPS after 52.3 ± 47.8 (range, 4 to 141) hours of support. Twelve complications occurred in 11 patients, including eight related to PCPS: low perfusion flow (two), gastrointestinal bleeding (two), surgical wound bleeding (one), femoral arterial catheter dislodgement (one), hemolysis with acute renal failure (one), and mitral valve thrombus (one). Nine patients (41%) were discharged from hospital without neurologic complications. The incidence of complications differed in comparisons between patients who survived and did not survive.

Conclusions. The use of preassembled, heparin-coated and autoprimeing devices enabled us to rescue in-hospital cardiac arrest patients who might have died without this procedure.

(Ann Thorac Surg 2006;82:651–6)
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ECMO: Evolving technology

**ECMO**

- **Diffusion membrane with polymethyl pentene**
- **Microporous membrane**
- **Magnetic impeller without friction**
- **Heparin-bonded circuit**
- **Double lumen cannula**

*FIGURE 3.4* The first successful extracorporeal life support patient, treated by J. Donald Hill using the Branson oxygenator (foreground), Santa Barbara. 1971.
## Overall ECLS outcomes

(∼ July 2011, ELSO registry)

<table>
<thead>
<tr>
<th></th>
<th>Total patients</th>
<th>Survived ECLS</th>
<th>Survived discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neonatal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>25,746</td>
<td>21,765</td>
<td>85%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>4,797</td>
<td>2,928</td>
<td>61%</td>
</tr>
<tr>
<td>eCPR</td>
<td>784</td>
<td>496</td>
<td>63%</td>
</tr>
<tr>
<td><strong>Pediatric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>5,457</td>
<td>3,556</td>
<td>65%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>5,976</td>
<td>3,855</td>
<td>65%</td>
</tr>
<tr>
<td>eCPR</td>
<td>1,562</td>
<td>843</td>
<td>54%</td>
</tr>
<tr>
<td><strong>Adult</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>3,280</td>
<td>2,094</td>
<td>64%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>2,312</td>
<td>1,243</td>
<td>54%</td>
</tr>
<tr>
<td>eCPR</td>
<td>753</td>
<td>276</td>
<td>37%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>50,667</td>
<td>37,056</td>
<td>73%</td>
</tr>
</tbody>
</table>

**Overall ECLS outcomes**

WFSICCM Seoul 2015
2009 H1N1 influenza virus infection and necrotizing pneumonia treated with extracorporeal membrane oxygenation

A 3-year-old girl with seasonal H1N1 2009 influenza virus pneumonia was successfully treated with extracorporeal membrane oxygenation (ECMO). This patient was rescued from severe H1N1 pneumonia in South Korea in 2009.
2009 H1N1 influenza virus infection and necrotizing pneumonia treated with extracorporeal membrane
Open Heart Surgery with Heart-Lung Machine since 1953

John Gibbon
30 years later (1983)
CHD surgery in Korea

WFSICCM Seoul 2015
Hà Nội children’s hospital now offers vital open heart surgery

HÀ NỘI — More northern children with heart trouble are expected to get necessary care now that Hà Nội’s National Paediatric Hospital has performed its first open heart surgery.

The first patients receiving the surgery yesterday were five-year-old Nguyễn Thị Thu Thủy and Nguyễn Thị Hoàng Lan, 6, both of whom suffer from congenital heart diseases. Both were reported in good health following the procedure.

Thủy and Lan are two of six patients currently scheduled to receive operations at the hospital, all at no charge. The first four surgeries are being performed by Korean doctors, with the remainder to be conducted by resident doctors at the hospital, with the technical support of the Koreans.

The hospital becomes the fourth medical facility in Việt Nam capable of performing open-heart surgery. Hospital director Nguyễn Thanh Lân said it would now regularly carry out the surgery on children with heart diseases, mostly in northern provinces.

The hospital will waive about 60 per cent of operation fees for these patients, Lân said.

It costs from VND20 million to 30 million to conduct an open-heart surgery on one child.

It’s estimated that about 1 per cent of Vietnamese children with congenital heart diseases need this kind of surgery. Lân said his hospital has had to turn doctors and invest about VND30 billion in modern equipment over the past two years. The other hospitals that perform open-heart surgery are Hà Nội’s Việt Đức Hospital, Hoà Central Hospital, and HCM City’s Heart Institute — VNS.

Heart-to-Heart Project (since 2003)
Summary

- Pediatric cardiac surgery continues to evolve. Improved mortality itself is no longer an acceptable goal. There is now the trend of the expectation of perfection and a zero tolerance for complications. Large efforts are being made to improve its long-term outcome, which will continue to rely on the collaborative work with other subspecialties including anesthesia, cardiology, critical care, neonatology, and neurology.
Thank you for your attention