Comparison of shunt types in the Norwood procedure for single-ventricle lesions.

- MBT N= 275, RVPA N= 274
- 12 months outcome
  - RVPA: 68 deaths and 4 transplantations (26.3%)
  - MBT: 91 deaths and 9 transplantations (36.4%)
  - 95% CI, −17.8 to −2.4, p= 0.01

- All follow-up period
  1. The difference was no longer significant at all follow-up (Log-rank, p= 0.06)
  2. When cases who had shunt crossover (MBT 25, RVPA 32) were taken into account, the overall transplantation-free survival rate was higher in the RVPA (p= 0.02)
Comparison of shunt types in the Norwood procedure for single-ventricle lesions.

- MBT N= 275, RVPA N= 274
- Treatment effect differed in the period before and the period after 12 months (P=0.02, Nonproportional-hazards test)

“....the negative factors related to use of the RVPA shunt including damage to the right ventricle from the ventriculotomy and smaller pulmonary arteries become evident later (after stage II)....”
Comparison of shunt types in the Norwood procedure for single-ventricle lesions.

<table>
<thead>
<tr>
<th></th>
<th>RVPA</th>
<th>MBT</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norwood Hospitalization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPR (%)</td>
<td>13</td>
<td>20</td>
<td>0.04</td>
</tr>
<tr>
<td>Unintended interventions (n,rate)</td>
<td>4(1.5)</td>
<td>15(5.5)</td>
<td>0.01</td>
</tr>
<tr>
<td>Composite of serious adverse events (n,rate)</td>
<td>98(36)</td>
<td>133(48)</td>
<td>0.02</td>
</tr>
<tr>
<td>Norwood-Stage II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unintended interventions (n,rate)</td>
<td>96(41.2)</td>
<td>56(25.6)</td>
<td>0.01</td>
</tr>
<tr>
<td>Complications (n,rate)</td>
<td>515(221)</td>
<td>367(168)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Stage II-12mos</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complications</td>
<td>145(72)</td>
<td>81(46)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Fig. 3
Comparison of shunt types in the Norwood procedure for single-ventricle lesions.

<table>
<thead>
<tr>
<th></th>
<th>RVPA</th>
<th>MBT</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>After Norwood</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVESV (median, ml/m2)</td>
<td>44.2</td>
<td>50.1</td>
<td>0.001</td>
</tr>
<tr>
<td>EF (%)</td>
<td>48.5± 7.6</td>
<td>44.5 ± 7.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Before Stage II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVEDV (median, ml/m2)</td>
<td>105.2</td>
<td>113.4</td>
<td>0.009</td>
</tr>
<tr>
<td>RVESV (median, ml/m2)</td>
<td>57.9</td>
<td>63.2</td>
<td>0.004</td>
</tr>
<tr>
<td>rPAD (mm)</td>
<td>5.4 ± 1.7</td>
<td>6.1 ± 2.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nakata Index (mm2/m2)</td>
<td>145</td>
<td>169</td>
<td>0.009</td>
</tr>
<tr>
<td>ratio of dis. To prox. IPAD</td>
<td>1.3 ± 0.6</td>
<td>1.1 ± 0.3</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Fig. 4
Stenting of the arterial duct and banding of the pulmonary arteries: basis for combined Norwood stage I and II repair in hypoplastic left heart.


- 1998-2000
- N= 11
- Survived to Norwood + BDG: 8
- Survival rate after Norwood + BDG : 82%
- Follow up: 6m-3y
- Fontan completion: 0

Fig. 5
Fifteen-year single center experience with the "Giessen Hybrid" approach for hypoplastic left heart and variants: current strategies and outcomes. (Schranz D et al. Pediatr Cardiol. 2015;36:365-73)

- 1998-2013
- Undergo Norwood+BDG: 89
- Survivor: 81 after Norwood+BDG
- 53 survivor after Fontan without HTx (60%)
- 20 awaiting Fontan

- AA 58vs AS 49: no significance
- lPA stenting: 38% (34 of 89)
- With vs without lPA stenting: no significance

Fig. 6

- 2004-2012
- N= 54
- Survival 59%(@8yrs)
- Survive after Fontan: 19 (35%)
- The cumulative PA intervention rate: 50%
- Out of indication for Fontan: 6
  - Reason: lPA stenosis
- Risk factor for failure to reach Fontan: LPA size (p= 0.01, univariate)
Use of mathematical modeling to compare and predict hemodynamic effects between hybrid and surgical Norwood palliations for hypoplastic left heart syndrome. Modeling of Congenital Hearts Alliance (MOCHA) Investigators. (Circulation. 2011:13;124(11 Suppl):S204-10)

- Both systemic and cerebral oxygen deliveries were considerably poorer in the hybrid model

  “...Diastolic runoff through the ductal stent can occur and can cause flow reversal in the brachiocephalic circulation...”

- both Norwood models demonstrated higher ventricular performance than the hybrid model
Is a hybrid strategy a lower-risk alternative to stage 1 Norwood operation?  

- 2005-2014
- North America, 20 institutions
- N= 564 (Risk-adjusted)
- NW-RVPA 222, NW-BT 232, HS1P 110
- 4 years survival  
  NW-RVPA: 76%
  HS1P: 61%
  NW-BT: 60%
- Better overall survival after NW-RVPA

Fig. 9
Is a hybrid strategy a lower-risk alternative to stage 1 Norwood operation?

- NW-RVPA 88, HS1P 88 (propensity score matching)
- 4 years survival
  - NW-RVPA 75%
  - HS1P 59% \( (p = 0.008) \)
- Risk factor in the multivariable model: BW
- HS1P: Survival advantage for neonates with lower BW
  - (vs NW-RVPA: <2.0, vs NW-BT: <3.0)

- Hospital mortality after Norwood: 40.0% (2004) to 15.6%(2010) ($P = 0.0055$)

“...In the past decade, the right ventricle–pulmonary artery conduit represented one of most important advances in the surgical technique of the Norwood procedure...”

“... encouraging results from bilateral PA banding with or without stenting of the ductus arteriosus for the management of HLHS could contribute to the increase in annual numbers of PA banding and the recent decrease in the annual number of Norwood procedures in neonates. ....”