Impact of loading conditions on ventricular function in Ebstein anomaly of the tricuspid valve

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Introduction

- Rare CHD
- 3-5/100,000 live births
- <1% of CHD
- 7% less than 1 year-old at diagnosis
- Most common congenital lesion of the tricuspid valve
Anatomic characteristics

• Adherence of the septal and posterior leaflets to the underlying myocardium with downward displacement of the septal leaflet (>8 mm/m² BSA)

• Redundancy, tethering and fenestration of the anterior leaflet

• Dilation of the RA, « atrialized » portion of the right ventricle, the true annulus and the RV
Tricuspid regurgitation

RV dysfunction

Atrialized RV (passive reservoir)

Dilation of the true tricuspid annulus

Right atrium and ventricle dilation

Decreased forward flow through PV

Decreased LV filling
The spectrum of Ebstein anomaly

**Mild anomaly**
- Asymptomatic

**Moderate**
- Arrhythmia
- Progressive cyanosis
- Decreasing exercise tolerance
- Fatigue
- Right-sided heart failure

**Severe anomaly**
- Neonatal/Fetal
- Cyanosis
- Cardiomegaly
- Regurgitant TV
- Right heart failure
- Functional pulmonary atresia
Indications for surgery

Traditional indications for intervention

- Decrease in exercise tolerance
- Heart failure
- Increase in cyanosis
- Arrhythmia

ESC guidelines (2010)

- >Moderate TR + NYHA >II
  and/or arrhythmia
  and/or deteriorating exercise tolerance
- **Progressive right heart dilatation** and/or **RV dysfunction** and/or cardiomegaly on X-ray regardless symptoms

*Baumgartner H, EHJ 2010*
Cone repair

• Mobilisation of the anterior and inferior leaflets detached from their position in RV
• Clockwise rotation and suture to the septal margin of the anterior leaflet
• Septal leaflet (if present) delaminated and incorporated in cone
• Annuloplasty
• Right atrium plicated and ASD closed (if present)

GOSH study: Objective

- Few deaths after Cone repair
  
  *Anderson HN, Congenital Heart Disease 2013*

- Before Cone operation, RV is exposed to high preload and low afterload

- Cone repair reduces TR and the tricuspid valve is repositioned to its anatomic annulus

  ⇒ Change in loading conditions: less preload and higher afterload

- Investigate the adaptation of right (RV) and left ventricles (LV) to change in loading conditions after Cone repair
### GOSH study: Population (N=17)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>15 ±6.7</td>
</tr>
<tr>
<td>Weight</td>
<td>48 ±13</td>
</tr>
<tr>
<td>CPB time</td>
<td>131±16</td>
</tr>
<tr>
<td>CX Time</td>
<td>21±10</td>
</tr>
<tr>
<td>Maze</td>
<td>2</td>
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<tr>
<td>Deaths</td>
<td>0</td>
</tr>
<tr>
<td>NYHA</td>
<td>2.2±0.5</td>
</tr>
<tr>
<td>Pre-operative arrhythmia</td>
<td>5/17</td>
</tr>
<tr>
<td>Length of Follow-up (m)</td>
<td>17 ±12</td>
</tr>
</tbody>
</table>

- Retrospective study
- 2 centers (GOSH and Heart Hospital)
- From 2009 to 2014
GOSH study: Material and methods

- Echocardiography in 3 periods
  - Pre-operative
  - Early post-operative: <30 days after operation
  - Mid-term post-operative: median 8 ± 10 months

- Conventional echocardiographic parameters
  - 2D strain for LV and RV
  - Time to systolic peak corrected by HR
Results: Better clinical status and increased LV filling

**NYHA**

- **Pre op:** 2
- **Post op:** 1

\[p = 0.010\]

**Tricuspid Regurgitation**

- **Pre op:** 4
- **Post op:** 2

\[p < 0.001\]

**GOSH Score**

- **Pre op:** 1.2
- **Post op:** 1.0

\[p = 0.007\]

**LV end-diastolic diameter Z-scores**

- **Pre op:** -0.5
- **Post op:** -1.0

\[p = 0.002\]

**GOSH score:** \((RA + aRV)/(fRV + LA + LV)\)

Results: LV function

No change in LV function estimated by conventional parameters but significant decrease of LV 2D strain in post-operative period.
**Results : RV function**

- Visually altered RV function
- Decreased TAPSE and RV FAC

in post-operative period
Results: RV function (2)

- **RV 2D Strain** could not be performed in most patients due to technical issues:
  - highly dilated with a thin wall atrialised RV in pre-op
  - not good enough quality picture in post-op
**Results : Septal contraction**

<table>
<thead>
<tr>
<th>Means</th>
<th>Group of EA patients</th>
<th>Control group</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>16.47 ± 6.73</td>
<td>15.71 ± 6.95</td>
<td>0.061</td>
</tr>
<tr>
<td>Pre-operative basal septum 2D strain</td>
<td>-16.96 ± 2.74</td>
<td>-19.86 ± 2.00</td>
<td>0.018</td>
</tr>
<tr>
<td>Post-operative basal septum 2D strain</td>
<td>-14.44 ± 3.32</td>
<td>-19.86 ± 2.00</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Results: LV time to systolic peak

No significant change in LV time to systolic peak corrected by HR

**Global time to systolic peak**

- Pre op
- Post op

**Global TTP corrected by HR**

- Pre op
- Early post
- Mid-term post

p=0.121

p=0.074
Main results

- Better LV filling

- Decreased LV function in early post-operative period with a trend to later recovery

- No change in LV time to systolic peak but seems reduced

- Decreased RV function
Hypothesis for RV dysfunction

- Competent valve, lower preload
- Dyskinetic “re-ventricularised” myocardial wall and septum
- Remodelation or Intrinsic Cardiomyopathy?
Histology: atrialized RV

- Functional part of the RA
- Wall almost always very thin
- Often posterior wall aneurysmal dilation
- Endocardium is thick, fibrous and smooth
- Occasionally completely devoid of myocardium

Atrialized RV (2)

25 year-old specimen of EA
Atrialized RV
Extensive interstitial fibrosis

Normal heart
More organised myocardial architecture and less interstitial fibrosis

Functional RV

- 10 EA hearts (with/without RV dilation) vs 10 controls
- Dilated RV: thinner with less fibers
- Same fiber density and fiber diameter in all groups
- No difference of % of myocardium between the 3 groups

Functional RV (2)

- 6 neonates vs controls
- Reduced wall thickness
  \[3 \pm 0.2 \text{ mm vs } 4.2 \pm 0.2 \text{ mm}, \ p < 0.01\]
- Reduced individual fiber diameter
  \[7.2 \pm 0.3 \mu \text{m vs } 11.4 \pm 0.6, \ p < 0.001\]
- Increased fibrous content
  \[29.3 \pm 2.6\% \text{ vs } 8.7 \pm 1.1\%, \ p < 0.001\]

Histological changes in EA: congenital or acquired?

- 3 fetal/10 perinatal/3 adults
- 9 isolated/7 with associated lesions
- Versus controls

- Section of the atrialized RV and functional RV
- Macroscopic findings, endocardial thickness and interstitial fibrosis

Histological changes in EA: congenital or acquired?

- Fetal and neonatal cases: normal interstitial fibrosis in both ventricle except for one case of EA with PS

- Adult cases: 2/3 cases had increased interstitial fibrosis in the atrialized RV and one had interstitial fibrosis in the LV

- No correlation between histological changes and degree of displacement or increase in the circumference of the TV

⇒ Fibrosis may be acquired
Conclusion

- Encouraging early surgical results with Cone repair:
  - Decreased TR
  - Improvement of the clinical status

- LV myocardial mechanics appears better than preoperatively

- Continuing impairment of RV function may reflect intrinsic myocardial dysfunction likely due to myocardial deficiency

- What will be the long term adaptation of the ventricles to these new load conditions?