Pectus excavatum: Cardiopulmonary Consequences and Treatment

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Background

• Pectus excavatum (PE)

Congenital deformity of the chest wall with posterior displacement of the inferior part of the sternum.
Background Cardiopulmonary Consequences

Cardio-pulmonary problems associated with Pectus excavatum (PE)

- Patients frequently complain about exercise intolerance, shortness of breath.

There is no consensus regarding the consequences of PE and the surgical correction on cardio-pulmonary function.
Background Cardiopulmonary Consequences

Cardio-pulmonary problems associated with Pectus excavatum (PE)

Cochrane Collaboration 2014: “Many questions related to pectus excavatum such as ... the impact on cardiopulmonary function... remain in debate. The clinical presentation of this condition is widely variable.”

Jayaramakrishnan 2013: 19 studies with different surgical techniques
  preoperative: reduced cardiac function and pulmonary function
  postoperative: modest improvements in pulmonary function and cardiac function

Maagaard 2013: “Before operation, FEV1 and maximum cardiac index were lower in patients compared with healthy, age-matched controls. ... After 3 years and bar removal, cardiopulmonary function in patients during ... had normalized.”
Background Cardiopulmonary Consequences

Pectus excavatum (PE)  ➔ cardiac impairment?
Background Cardiopulmonary Consequences

- Compression of the underlying cardiac chambers, in particular the right atrium (RA) and the right ventricle (RV), between the depressed sternum and the spine

Impression, rotation or even dislocation of the right heart chambers
Background Cardiopulmonary Consequences

• Additional anatomical and functional information on the impact of PE may help to understand the complains of the affected patients and guide clinical decision-making.

• Cardiac Magnetic Resonance Imaging (CMR)

cardiac morphology and function in patients with PE before surgical correction
Objective Cardiopulmonary Consequences

• Single center prospective evaluation in adolescents and adults *
• 2002 - 2014

• CMR for cardiac examination in patients referred for surgical correction of PE and reporting about exercise intolerance were prospectively enrolled.
  – right and left ventricle volumes and function, stroke volume and cardiac output, mass of the left ventricle

• Transthoracic Echocardiography (TTE) and Exercise test
• Quantification of Pectus excavatum severity with Haller Index

* Results presented at the 52nd Annual Meeting STS 2016, Phoenix
Methods Cardiopulmonary Consequences

- CT scan and cardio-pulmonary work-ups (exercise test, CMR)
Methods Cardiopulmonary Consequences

• 1.5 T or a 3 T whole body clinical MRI system
• Cardiac synchronization from 3 electrodes placed on the left anterior hemithorax

• Biventricular volumes and systolic function, indexed left ventricular mass as well as cardiac output were obtained and correlated with PE severity, as assessed by Haller index.
Results Cardiopulmonary Consequences

- n = 91
- ♂ 85%
- Age 22 years (13-70)
- BMI 20.9 ± 2.4
- Haller Index 4.8 (2.4 to 12.4)

- n = 55 (60%) TTE
- n = 67 (74%) Exercise Test
Results Cardiopulmonary Consequences

Rotation of the heart to the left, as well as impression, elongation and in some cases dilatation of the right heart chambers were observed.

RV was increased in 80 % with mid ventricular enlargement in 47.5 %.
Results Cardiopulmonary Consequences
Results Cardiopulmonary Consequences

<table>
<thead>
<tr>
<th>Ventricular mass, function and volumes of RV</th>
<th>Absolute</th>
<th>Indexed (absolute/BSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDV (ml)</td>
<td>177.6±39.8 (87-283)</td>
<td>95±18.4 (43-150)</td>
</tr>
<tr>
<td>ESV (ml)</td>
<td>80.9±23.7 (18-151)</td>
<td>43.4±11.7 (11-80)</td>
</tr>
<tr>
<td>SV (ml)</td>
<td>96.9±40.7 (47-163)</td>
<td>52.2±8.4 (36-75)</td>
</tr>
<tr>
<td>Cardiac output (L)</td>
<td>7.1±1.5 (3.5-12.1)</td>
<td>3.8±0.7 (2.5-6.0)</td>
</tr>
<tr>
<td>EF (%)</td>
<td>55.5±6.8 (43-79)</td>
<td>NA</td>
</tr>
</tbody>
</table>
Results Cardiopulmonary Consequences

No relevant anatomical changes of the left cardiac chambers.

Significant inverted correlation between indexed LV mass (g/m²) in CMR and Haller index ($p < 0.001$).

<table>
<thead>
<tr>
<th>LV Mass (g)</th>
<th>Absolute</th>
<th>Indexed (absolute/ BSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>108.6±25.5</td>
<td>58.3±10.2</td>
</tr>
<tr>
<td></td>
<td>(42-171)</td>
<td>(29-79)</td>
</tr>
</tbody>
</table>
Results Cardiopulmonary Consequences

![Graphs showing the relationship between Indexed LV mass (g/m²) and Maximal exercise capacity (watts) with p < 0.001 and R = 0.6, and VO2max (ml/min) with p < 0.001 and R = 0.5.](image)

- Maximal exercise capacity (watts) vs Indexed LV mass (g/m²): p < 0.001, R = 0.6
- VO2max (ml/min) vs Indexed LV mass (g/m²): p < 0.001, R = 0.5
# Results Cardiopulmonary Consequences

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1 (L)</td>
<td>4.0±0.7</td>
</tr>
<tr>
<td>FVC (L)</td>
<td>4.7±1.1</td>
</tr>
<tr>
<td>FVC (% from predicted)</td>
<td>90.5±15</td>
</tr>
<tr>
<td>VO2\text{max} (ml/min/kg)</td>
<td>38.7±6.8</td>
</tr>
<tr>
<td>VO2\text{max} (% from predicted)</td>
<td>86.2±15.3</td>
</tr>
<tr>
<td>Maximal exercise capacity (Watt)</td>
<td>214.3±56.6</td>
</tr>
<tr>
<td>Maximal exercise capacity (% from predicted)</td>
<td>94±21.3</td>
</tr>
</tbody>
</table>
Conclusions Cardiopulmonary Consequences

• Patients with PE have normal cardiac function, volumes and left ventricular mass.

• Anatomical changes of the right heart chambers are commonly observed, but did not result in an impairment of cardiac volumes and function.

• Elongation and mid ventricular dilatation were also documented and may correspond to a compensatory mechanism finally enabling normalization of the cardiac volumes.
Conclusions Cardiopulmonary Consequences

- The Haller index inversely correlates with LV mass measured by CMR.

Physical deconditioning, reflected by lower left ventricular mass, may contribute to exercise intolerance in patients with pectus excavatum.
Conclusions Cardiopulmonary Consequences

• Examinations
  – CT
  – Lung function test
  – (Exercise test)
  – (TTE, CMR)
Conclusions Cardiopulmonary Consequences

Background: Treatment

Surgical correction of the Pectus excavatum ???

Mental aspects !!!

Improvement of quality of life ???
Donald Nuss: Pectus Bar = Nuss Procedure

- Nuss D et al.
  A 10 years review of a minimally invasive technique for correction of pectus excavatum
Background Treatment

- Nuss procedure -

- Primarily developed for children

Results in adults?
Objective Treatment

• Single center report in adolescents and adults

• Autumn 2002 → 2014, n = 129

Long-term follow-up including quality of life?
Results Treatment

• Long-term observation - Satisfaction with appearance

![Graph showing satisfaction levels over time.](chart.png)
Results Treatment

- Long-term observation - Quality of life

![Graph showing quality of life over time]

- % of patients reporting:
  - much better
  - better
  - same
  - worse

- Time points:
  - 3 months
  - 12 months
  - 36 months
Results Treatment

Patient before and after Nuss procedure
Results Treatment

Patient before and after Nuss procedure
Conclusions

Cardiopulmonary Consequences and Treatment

Improved quality of life and improved motivation to exercise…
Outlook
Cardiopulmonary Consequences and Treatment

• Improvement of quality of life – self-image, participate in sports …

• Training frequency needs to be integrated as a key factor in the preoperative assessment of PE and further investigations systematically comparing physical activity before and after surgical PE correction are required.

• Further investigations of patients with PE and cardio-pulmonary co-morbidities are required.