Aortic stiffness index and its relation with cardiac functions in children before and after transcatheter closure of the PDA.

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Patent ductus arteriosus (PDA) causes volume overload of the left side of the heart and predisposes to pulmonary hypertension.

The timing of treatment for congenital heart defects is based on the hemodynamic and anatomic situation, with consideration of myocardial cell adaptation and chamber remodeling (1).

Therefore, it is important to have multiple methods available for follow-up.

The combination of new imaging modalities and measurements of serum levels of natriuretic peptides may allow us to improve the evaluation of cardiac function and timing of interventions (2).
PDA is usually associated with hyperdynamic status, and since there is a vascular shunt between the aorta and pulmonary artery, intrinsic aortic changes occur (aortic stiffness).

Moreover, shunt lesions may be associated with an inflammatory process, and endothelial dysfunction may accelerate the aging of vessels, especially the aorta (aortic stiffness) (3).

In the present study we aimed to evaluate the effect of PDA on aortic stiffness and its relation with cardiac function before and after transcatheter closure of PDA to be used as a tool for monitoring the course of patients with PDA.
Our study population consisted of 60 children, who were planned for transcatheter closure of PDA and 60 age-matched healthy children as a control group.

All patients who have congenital PDA indicated for closure according to European Society of Cardiology guidelines 2011 were included in our study.

**Class I.**

- PDA should be closed in patients with signs of LV volume overload. (Level of evidence C).
- PDA should be closed in patients with PAH but PAP < 2/3 of systemic pressure, and PVR <2/3 of SVR. (Level of evidence C).
- Device closure is the method of choice where technically suitable. (Level of evidence C).
• **Class II a.**
  
  • PDA closure should be considered in patients with PAH and PAP >2/3 of systemic pressure or PVR >2/3 SVR but still net left to right shunt (Qp/Qs >1.5) or when testing (preferably with nitric oxide) demonstrates pulmonary vascular reactivity. (Level of evidence C).
  
  • Device closure should be considered in small PDA with continuous murmur (normal LV and PAP). (Level of evidence C)

• Patients with PDA not suitable for percutaneous closure.

• Patients with Irreversible pulmonary vascular disease (i.e. pulmonary vascular resistance index (PVRI) >7 WU/ m2).

• And those who had associated hemodynamically significant congenital heart disease or a significant residual shunt were excluded from the study.
All the patients were subjected to:

A- Clinical assessment: the following parameters were particularly evaluated:

1- Arterial blood pressure.
2- Body weight (BWT).
3- Oxygen saturation.
4- Functional class (FC).

B- Transthoracic 2D echocardiography and tissue Doppler imaging (TDI):

ECG-gated complete 2D echocardiographic and TDI study was performed with the patient in the supine position using Philips IE 33 on outpatient basis, at baseline before the procedure, and at six months follow-up; and the following parameters were assessed:
• Left ventricular dimensions, volumes, systolic and diastolic function.
• Left atrium dimension and volume.
• PDA size and types.
• Other associated congenital anomalies.
• Pulmonary artery pressure.
• Non-invasive evaluation of aortic stiffness

Non-invasive evaluation of aortic stiffness
Aortic stiffness index (ASI) was calculated from the following equation:

\[ \text{ASI} = \left( \frac{\text{SBP}}{\text{DBP}} \right) \div \left( \frac{(\text{AoSD} - \text{AoDD})}{\text{AoDD}} \right) \times 100 \]  

(86).

- C- BNP measurement:
  for all children in the study and six months after device closure of PDA (for children with PDA only).
• **D- Cardiac catheterization:**
  
  Cardiac catheterization was performed for assessment of pulmonary artery pressure, shunt quantification and PDA device closure.

• **E- Follow up**

  **(clinically and by echocardiography)**

  All cases were followed at six months thereafter and the following parameters were assessed: FC and weight gain, Position of the device and residual shunt, Pulmonary artery pressure, LV systolic and diastolic function, Aortic stiffness and BNP.
Control subjects were examined once. They were normal subjects with normal ECG and echocardiography.

Results

Demographic characteristics of patients and controls:

<table>
<thead>
<tr>
<th>Variables</th>
<th>Patients(n=60)</th>
<th>Control(n=60)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (months)</td>
<td>Mean ±SD</td>
<td>23.7 ± 34.6</td>
<td>31.8 ± 34.4</td>
</tr>
<tr>
<td>sex</td>
<td>M (n, %)</td>
<td>15 (25%)</td>
<td>21 (35%)</td>
</tr>
<tr>
<td></td>
<td>F (n, %)</td>
<td>45 (75%)</td>
<td>39 (65%)</td>
</tr>
<tr>
<td>BWT (kg)</td>
<td>Mean ±SD</td>
<td>12.8 ± 11.4</td>
<td>11.2 ± 4.1</td>
</tr>
<tr>
<td>SBP</td>
<td>Mean ±SD</td>
<td>94.8 ± 9.4</td>
<td>96 ± 8.4</td>
</tr>
<tr>
<td>DBP</td>
<td>Mean ±SD</td>
<td>61 ± 6.9</td>
<td>62.1 ± 6.4</td>
</tr>
<tr>
<td>HR (b/m)</td>
<td>Mean ±SD</td>
<td>99 ± 12</td>
<td>90 ± 11</td>
</tr>
</tbody>
</table>
### ASI and cardiac functions in patients and controls

<table>
<thead>
<tr>
<th>Variables</th>
<th>Patients with PDA (n=60)</th>
<th>Controls (n=60)</th>
<th>P</th>
<th>Pt</th>
<th>p°</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before closure</strong></td>
<td><strong>After closure</strong></td>
<td><strong>Mean ± SD</strong></td>
<td><strong>Mean ± SD</strong></td>
<td><strong>Mean ± SD</strong></td>
<td><strong>Mean ± SD</strong></td>
</tr>
<tr>
<td>ASI</td>
<td>Mean ± SD</td>
<td>8.3 ± 2.7</td>
<td>4.3 ± 1.4</td>
<td>1.6 ± 0.74</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LVEF%</td>
<td>Mean ± SD</td>
<td>59.4 ± 5.3</td>
<td>66 ± 4.2</td>
<td>66.7 ± 3.4</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LVEDD (mm)</td>
<td>Mean ± SD</td>
<td>3.4 ± 0.85</td>
<td>3 ± 0.82</td>
<td>2.8 ± 0.55</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LVESD (mm)</td>
<td>Mean ± SD</td>
<td>2.2 ± 0.37</td>
<td>2.0 ± 0.32</td>
<td>1.9 ± 0.54</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>E/Ea</td>
<td>Mean ± SD</td>
<td>11.2 ± 1.9</td>
<td>6.9 ± 0.88</td>
<td>6.5 ± 1.06</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

### BNP, PAP and FC patients and controls

<table>
<thead>
<tr>
<th>Variables</th>
<th>Patients with PDA (n=60)</th>
<th>Controls (n=60)</th>
<th>P</th>
<th>Pt</th>
<th>p°</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before closure</strong></td>
<td><strong>After closure</strong></td>
<td><strong>Mean ± SD</strong></td>
<td><strong>Mean ± SD</strong></td>
<td><strong>Mean ± SD</strong></td>
<td><strong>Mean ± SD</strong></td>
</tr>
<tr>
<td>BNP</td>
<td>Mean ± SD</td>
<td>59.6 ± 16.1</td>
<td>19.9 ± 5.5</td>
<td>19.8 ± 5.1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>PAP</td>
<td>Mean ± SD</td>
<td>43.5 ± 7.3</td>
<td>23 ± 4.7</td>
<td>23.2 ± 5.1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>FC</td>
<td>Mean ± SD</td>
<td>3.5 ± 0.5</td>
<td>1.1 ± 0.3</td>
<td>1.0 ± 0</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>
Correlation between PDA size and ASI:

Correlation between ASI and time delay of PDA closure:
Correlation between ASI and LVEF before PDA closure:

![Graph showing correlation between ASI and LVEF](image)

Correlation between ASI and LVEDD before PDA closure:

![Graph showing correlation between ASI and LVEDD](image)
Correlation between ASI and BNP before PDA closure:

Correlation between ASI and E/Ea ratio before PDA closure:
Correlation between ASI and PAP before PDA closure:

Multivariate analysis has shown that ASI is the most powerful independent predictor of improvement in LVEF% post-PDA closure ($R^2 = 0.570$).

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>P-value</th>
<th>R</th>
<th>$R^2$</th>
<th>Adjusted R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>69.562</td>
<td>&lt;0.001</td>
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<tr>
<td>age</td>
<td>-0.026-</td>
<td>0.012</td>
<td>0.755</td>
<td>0.570</td>
<td>0.559</td>
</tr>
<tr>
<td>ASI</td>
<td>-0.900-</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BNP</td>
<td>-0.037-</td>
<td>0.158</td>
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</tbody>
</table>
conclusion

Aortic stiffness is significantly elevated in patients with PDA even with small sized PDA and associated with impairment in cardiac functions. After device closure, ASI decreased significantly and was associated with significant improvement in cardiac functions and functional class of patients, 6 months after device closure.

Recommendation

We recommend that ASI might be useful for monitoring the course of patients with PDA before and after intervention.
THANK YOU