Experience of Harvard Step Test using for exercise tolerance assessment in children with single ventricle

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True level of heart failure (HF) in children is unknown as there is no universal classification system that includes various HF forms.

Elizabeth Braunlin, M.D., Rebecca Ameduri, M.D., 2010.

According to European study more than 50% of cases in children are connected with CHD, 10 – 19% with cardiomyopathy. Children with HF are 10 – 33% of all “cardiological” admission.

Pathophysiology of Congenital Heart Disease in the Adult: Part I: Shunt Lesions. Robert J. Sommer, Ziyad M. Hijazi and John F. Rhodes, Jr Print.

Annual HF morbidity as a result of CHD is 1-2 in a thousand of liveborn and appears in 15-15% of children with CHD.

Heart failure can appear either with normal hemodynamics that combines with damaged myocardial systolic and diastolic function or with overload of normal myocardium, and also with combination of these two factors.

Elizabeth Braunlin, M.D., Rebecca Ameduri, M.D., 2010.
## Functional classification of chronic heart failure according to Ross R.D. (1987)

<table>
<thead>
<tr>
<th>Class</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>II</td>
<td>Mild tachypnea or diaphoresis with feeding in infants. Dyspnea on exertion in older children.</td>
</tr>
<tr>
<td>III</td>
<td>Marked tachypnea or diaphoresis with feeding in infants. Prolonged feeding times with growth failure. Marked dyspnea on exertion in older children.</td>
</tr>
<tr>
<td>IV</td>
<td>Symptoms such as tachypnea, retractions, grunting, or diaphoresis at rest.</td>
</tr>
</tbody>
</table>
Method of exercise tolerance assessment

- Functional tests:
  - Ruffier Dikson
  - V.V. Gorinevsky test
  - Deshin-Kotov test
  - Andrew Martin test
- Six minute walk test
- Step tests:
  - Single-stage test (Harvard Step Test L. broucha, 1943)
- Cardiac Stress Test
- Treadmill Test
  - Valund-Shestrand submaximal exercise
  - Maximal oxygen consumption estimation
The present description of exercise stress tests can’t be used in our patients considering their age and hemodynamics character. In this regard methods and assessment of exercise tolerance are still relevant in this group of patients.
Patient characteristics

- Initial group: Children at the age of 6-10 years old with CHD SV after total cavopulmonary shunt (n=27).

- Control group: Age-associated healthy children (n=50).
Single ventricle

According to M.L. Jacobs and J.E. Mayer:

- 0.13 in a 1000 of newborn
- 2.5% of all CHDs
- 5.5% of «critical» CHD

SV variants:

- Tricuspid valve atresia
- Hypoplastic left-heart syndrome
- Double Inlet Right Ventricle
- AV canal with unbalanced ventricles
- Mitral atresia
- Complex forms of transposition of great arteries
- Ebstein’s anomaly (крайние формы)
- DTGV with noncommited VSD
- PA with intact ventricular septum
- Multiple VSD

«Double inlet ventricle» - two AV valves or one common AV valve are fully or mainly connected with one of the ventricles.
Physiology and strategy of SV repair

Single ventricle

- Increased pulmonary blood flow
  Sat > 85
  - Coarctation of pulmonary artery
  - Muller’s operation

- Well-balanced pulmonary blood flow
  Sat 75-85%
  - Aortic obstruction
  - Norwoord procedure
  - bidirectional cava-pulmonary anastomosis
    - 4-8 months

- Decreased pulmonary blood flow
  Sat < 75%
  - Blalock-Taussig shunt

Fontan procedure
  3-4 years old, weight > 11 kg
Modified Harvard Step Test

- Runtime: 3 minutes
- Step height: 20 см
- Initially: heart rate, BP, SpO2
- Heart rate at 2d, 3d and 4th minutes during 30 seconds (if the testee lost the necessary pace the test stopped).
- Formula of Harvard Step Test Index (HSTI):
  \[ HSTI = \frac{t \times 100}{(f_1 + f_2 + f_3) \times 2}, \]
  where
  - \( t \) — climbing duration in seconds,
  - \( f_1, f_2, f_3 \) — heart rate at 2d, 3d and 4th minutes during 30 seconds of restoration correspondingly.
- Condensed formula can be used in screening programs:
  \[ HSTI = \frac{t \times 100}{f \times 5.5}, \]
  where
  - \( t \) - climbing duration in seconds,
  - \( f \) – heart rate taking into account the time of test carried out by the patients with heart failure (HF) signs
## Results of modified Harvard Step Test

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>TOTAL PATIENTS (N=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TIME OF TEST EXECUTION</strong></td>
<td></td>
</tr>
<tr>
<td>less than 3 minutes</td>
<td>9 (33%)</td>
</tr>
<tr>
<td>3 minutes</td>
<td>18 (67%)</td>
</tr>
<tr>
<td><strong>HEART RATE CHANGE</strong></td>
<td></td>
</tr>
<tr>
<td>increase 15-20%</td>
<td>22 (82%)</td>
</tr>
<tr>
<td>decrease 5-10%</td>
<td>5 (18%)</td>
</tr>
<tr>
<td><strong>EXECUTION REASONS</strong></td>
<td></td>
</tr>
<tr>
<td>muscle weakness</td>
<td>9 (33%)</td>
</tr>
<tr>
<td>the test is fully executed</td>
<td>18 (67%)</td>
</tr>
<tr>
<td><strong>NYHA</strong></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>7 (26%)</td>
</tr>
<tr>
<td>II</td>
<td>20 (74%)</td>
</tr>
</tbody>
</table>
Standards of index of modified Harvard Step Test (IMHST) in healthy children

<table>
<thead>
<tr>
<th>AGE (years)</th>
<th>BOYS</th>
<th>GIRLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>70</td>
<td>68</td>
</tr>
<tr>
<td>7</td>
<td>73</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>9</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>10</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>
IMHST value in patients with SV

- 15-29 under average: 18%
- 30-44 average: 23%
- 45-59 good: 36%
- 60 and higher excellent: 23%
Conclusion

- Modified Harvard Step Test can be performed to preschool children and children of primary school age with SV after total cavopulmonary shunt to assess ET if spiroergometry is not possible.

- Decrease of exercise tolerance was marked in patients with SV in comparison with control group.