Non-invasive Cardiac Output measurement during BxB Gas Exchange

Learn more (Quark CPET/RMR/PFT & K4 b²)

Cardiac Output ($Q_t$) can be accurately estimated from VO$_2$ during exercise in normal subjects and in patients with various degrees of cardiac insufficiency by measuring the Anaerobic Threshold or the VO$_2$peak.

This solution provides a simple and low cost assessment of Cardiac Function (Cardiac Output and Stroke Volume) in response to exercise that is independent of disturbed lung physiology and acid-base changes during exercise.

Importance of Cardiac Function Evaluation

Cardiac function evaluation is an important component of Cardio Pulmonary Exercise Test (CPET), especially when heart failure and chronic pulmonary disease coexist in the same patient. CPET is a useful tool to distinguish if reduced exercise tolerance is due to either cardiac or ventilatory impairment.

Heart failure can be described as the inability of the heart to deliver oxygen to metabolizing tissues in accordance with their oxygen requirements. This can be due to impairment of systolic function (impaired myocardial contractility) or of diastolic function (abnormal myocardial stiffness during filling); both types of impairment yield to a reduced systolic output and thus to a reduced Cardiac Output ($Q_t$).

Measurement of Cardiac Function

The severity of cardiac (and circulatory) failure is usually evaluated using two criteria: maximum oxygen uptake (VO$_2$max) and anaerobic threshold (AT).

Exercise Functional Classification based on VO$_2$ max and AT

<table>
<thead>
<tr>
<th>Class</th>
<th>VO$_2$ max</th>
<th>AT</th>
<th>CImax</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: little or no impairment</td>
<td>&gt;20</td>
<td>&gt;14</td>
<td>&gt;8</td>
</tr>
<tr>
<td>B: mild to moderate impairment</td>
<td>16-20</td>
<td>11-14</td>
<td>6-8</td>
</tr>
<tr>
<td>C: moderate to severe impairment</td>
<td>10-15</td>
<td>8-11</td>
<td>4-6</td>
</tr>
<tr>
<td>D: severe limitation</td>
<td>&lt;10</td>
<td>&lt;8</td>
<td>&lt;4</td>
</tr>
</tbody>
</table>

CImax: Maximum Cardiac Index (l/min/m$^2$)

Prior non-invasive methods of estimating Cardiac Output ($Q_t$), such as inert gases or CO$_2$ re-breathing methods (Indirect Fick method), required sophisticated equipment, considerable technical expertise and subject cooperation during the needed breath holding manoeuvres. Moreover, these methods were likely to be invalid during exercise in patients with heart and lung disease with varying degree of ventilation-perfusion mismatching and lactic acidemia.

Non-Invasive Cardiac Output Estimation

Cardiac output is the volume of blood being pumped by the heart in the time interval of one minute and can be expressed with the following equation:

$$Q_t = Stroke~Volume~(SV) \times Heart~Rate~(HR)$$

Being stroke volume (SV) the volume of blood pumped from one ventricle of the heart with each beat.

The Fick principle has been applied to the measurement of cardiac output and...
it involves calculating the oxygen consumed over a given period of time from measurement of the oxygen concentration of the venous blood and the arterial blood:

\[ Q_t = \frac{O_2 \text{Uptake (VO}_2\text{)}}{\text{Arteriovenous Content Difference [C(a-vDO}_2\text{)]}} \]

Because both HR and VO\text{2} can be easily measured during standard incremental Cardio Pulmonary Exercise Testing, both Q\text{t} and SV could be accurately quantified if the simultaneous C(a-vDO\text{2}) could be estimated.

The C(a-vDO\text{2}) has been demonstrated to increase linearly as a function of % maximal VO\text{2} (VO\text{max}), both in normal subjects and in patients with various degrees of cardiac insufficiency. This linear relationship can be described by the following equation:

\[ C(a-vDO\text{2}) = 5.72+10.5*(\frac{VO_2 \text{max}}{VO_2}) \]

Assuming this relationship and considering the Fick equation, Stringer et al. have demonstrated that it is possible to estimate Cardiac Output non-invasively throughout exercise.

If C(a-vDO\text{2}) can be directly measured, the value can be introduced manually on the software in order to measure Cardiac Output with the Fick Method.

**Cardiac Output calculation with CPET Suite**

COSMED software automatically calculates Qt (Cardiac Output, l/min) and SV (Stroke Volume, ml) during an incremental exercise test and makes the trend available for all kind of visualization and printing functions.

The calculation of Qt is based on the assumption that SV is extrapolated by the VO\text{2} uptake trend.

The software allows also the real measurement of Cardiac Output (resolving the Fick equation directly) by entering the value of C(a-vDO\text{2}) in all the circumstances when arterial-venous content difference could be routinely measured, as it happens in Cat-labs with in-bed patients under catheterization.