Peripheral oxygenation in term neonates

G Pichler, K Grossauer, P Klaritsch, J Kutschera, H Zotter, W Müller, B Urlesberger

The aim of this study was to analyse changes in peripheral oxygenation in healthy term neonates within the first week of life with near-infrared spectroscopy and venous occlusion. Oxygen delivery did not change with increasing age. Oxygen consumption and fractional oxygen extraction increased, whereas tissue oxygenation index decreased with increasing age.

Near-infrared spectroscopy (NIRS), in combination with venous occlusion, enables measurements of peripheral oxygenation and perfusion. In the present study, we carried out repeated measurements of peripheral oxygenation in healthy term neonates within the first week of life. The aim was to analyse changes in oxygen delivery (DO$_2$), oxygen consumption (VO$_2$), fractional oxygen extraction (FOE), tissue oxygenation index (TOI), mixed venous oxygenation (SvO$_2$), haemoglobin flow (Hbflow) and vascular resistance, to obtain normal values.

METHODS

NIRS measurements (NIRO 300, Hamamatsu Photonics, Shizuoka, Japan) and venous occlusions were carried out in each of 50 neonates twice within the first week of life. The local ethics committee approved the study.

NIRS measures changes in oxygenated haemoglobin, deoxygenated haemoglobin, total haemoglobin and TOI. Measurements were carried out on neonates in the supine position during sleep after feeding. The two NIRS optodes were placed over the left forearm with a distance of 3.5 cm. Each measurement consisted of at least three venous occlusions lasting 20 s, without movement (artefacts), obtained with a pneumatic cuff placed around the upper arm.

Heart rate and oxygen saturation (haemoglobin; SaO$_2$) were measured by pulse oximetry on the wrist. Central and peripheral temperatures were measured continuously. Mean arterial pressure (MAP) was measured before and after venous occlusions.

Hbflow/min was calculated from the increase in total haemoglobin during the 20-s venous occlusion. Further parameters were calculated as follows:

\[
\text{DO}_2 = \text{Hbflow} \times 4 \times \text{SaO}_2; \quad \text{VO}_2 = \text{Hbflow} \times 4 \times (\text{SaO}_2 - \text{SvO}_2)
\]

where SvO$_2$ = oxygenated haemoglobin/total haemoglobin; FOE = DO$_2$/VO$_2$ and vascular resistance = MAP × haemoglobin concentration/Hbflow. A blood sample was taken from each of 39 neonates within 24 h of the first measurement. VO$_2$ and DO$_2$ are measured in ml/kg/min.$^4$

Hbflow, DO$_2$, VO$_2$, FOE, TOI and SvO$_2$ for each neonate were determined as mean values of the three venous occlusions in each measurement. A paired t test was used for the comparison of the two measurements in each neonate. Vascular resistance was correlated with age and haemoglobin concentration to NIRS parameters by linear regression analysis. Data are mean (standard deviation (SD)).

RESULTS

The 50 neonates (24 boys and 26 girls) had a mean age of 39.5 (SD 1.1) h, a birth weight of 3429 (SD 422) g and an Apgar score of 1/9 to 5/10. The mean haemoglobin concentration in the 39 neonates was 19.8 g/dl (SD 2.7 g/dl).

Table 1 summarises the descriptive data. Only MAP increased with increasing age. Table 2 summarises the data of NIRS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measurement</th>
<th>1</th>
<th>2</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (h)</td>
<td>20.7 (9.6)</td>
<td>82.9 (20.9)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Weight (g)</td>
<td>3298 (448)</td>
<td>3262 (442)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Lower arm (cm)</td>
<td>9.4 (0.7)</td>
<td>9.4 (0.8)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Upper arm (cm)</td>
<td>10.7 (1.0)</td>
<td>10.4 (1.0)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Mean arterial pressure (mm Hg)</td>
<td>50.5 (3.5)</td>
<td>56.4 (4.4)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Heart rate/min</td>
<td>114 (12)</td>
<td>113 (12)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Arterial saturation (%)</td>
<td>96.6 (1.8)</td>
<td>96.6 (1.2)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Temperature rectal (˚C)</td>
<td>37.0 (0.3)</td>
<td>37.0 (0.2)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Temperature peripheral (˚C)</td>
<td>34.5 (1.0)</td>
<td>34.2 (0.9)</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

Values are mean (SD). NS, not significant.

Table 2  Peripheral oxygenation in 50 healthy neonates within the first week of life

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Measurement</th>
<th>1</th>
<th>2</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haemoglobin flow (µmol/100 ml/min)</td>
<td>3.5 (1.7)</td>
<td>3.6 (1.60)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Oxygen delivery (ml O$_2$/kg/min)</td>
<td>1.89 (0.93)</td>
<td>1.93 (0.85)</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Oxygen consumption (ml O$_2$/kg/min)</td>
<td>0.57 (0.30)</td>
<td>0.74 (0.33)</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Fractional oxygen extraction</td>
<td>0.32 (0.13)</td>
<td>0.38 (0.08)</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>Mixed venous oxygenation</td>
<td>0.65 (0.13)</td>
<td>0.60 (0.08)</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>Tissue oxygenation index (%)</td>
<td>87 (8)</td>
<td>81 (6)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

Values are mean (SD). NS, not significant.

Abbreviations: DO$_2$, oxygen delivery; FOE, fractional oxygen extraction; Hbflow, haemoglobin flow; MAP, mean arterial pressure; NIRS, near-infrared spectroscopy; SaO$_2$, oxygen saturation (haemoglobin); SvO$_2$, mixed venous oxygenation; TOI, tissue oxygenation index; VO$_2$, oxygen consumption.
measurements. VO$_2$ increased with increasing age and was associated with an increase in FOE, whereas TOI and SvO$_2$ decreased.

Vascular resistance increased with increasing age ($r = 0.35$, $p = 0.03$). Haemoglobin concentration did not correlate with any parameter.

**DISCUSSION**

Our main finding was a postnatal increase in VO$_2$ and consequently an increase in FOE and a decrease in TOI. VO$_2$ is influenced by the global metabolic rate and muscular activity. Both can be assumed to be the same in all our neonates, as they were sleeping after feeding, and without body movements. Temperature, which influences VO$_2$, also did not change in the present study.

In recent studies, VO$_2$ values were higher in term neonates as measured by NIRS and arterial occlusion, but, in contrast with this study, not all term neonates were measured during sleep. Therefore, different activity states may have influenced measurements. VO$_2$ values were similar to those observed in adults.

The reason for the unchanged DO$_2$ and Hbflow with increasing age despite increasing MAP might be increasing vascular resistance.

This is the first report presenting data on TOI within the first week of life in neonates. TOI behaviour was similar to SvO$_2$ behaviour. An influence of the haemoglobin concentration was not observed in the present study, where haemoglobin concentrations did not differ greatly between neonates.

Taking the present findings into account, NIRS in combination with the venous occlusion method may become important to evaluate peripheral oxygenation in neonates.

**REFERENCES**


**Authors’ affiliations**

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Competing interests: None declared.

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