SHORT REPORT

Peripheral oxygenation in term neonates

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Arch Dis Child Fetal Neonatal Ed 2007;**92**:F51–F52. doi: 10.1136/adc.2005.089037

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.[1–3] 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:

$$DO_2 = \text{Hbflow} \times 4 \times SaO_2;\ VO_2 = \text{Hbflow} \times 4 \times (SaO_2 - SvO_2)$$

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 1 Details of 50 healthy neonates

	Measurement		
Parameter	**1**	**2**	**p Value**
Age (h)	20.7 (9.6)	82.9 (20.9)	<0.001
Weight (g)	3298 (448)	3262 (442)	NS
Lower arm circumference (cm)	9.4 (0.7)	9.4 (0.8)	NS
Upper arm circumference (cm)	10.7 (1.0)	10.4 (1.0)	NS
Mean arterial pressure (mm Hg)	50.5 (5.3)	56.4 (4.4)	<0.001
Heart rate/min	114 (12)	113 (12)	NS
Arterial saturation (%)	96.6 (1.8)	96.6 (1.2)	NS
Temperature rectal (°C)	37.0 (0.3)	37.0 (0.2)	NS
Temperature peripheral (°C)	34.5 (1.0)	34.2 (0.9)	NS

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

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

Measurement			
Parameter	**1**	**2**	**p Value**
Haemoglobin flow (μmol/100 ml/min)	3.5 (1.7)	3.6 (1.60)	NS
Oxygen delivery (ml O_2/kg/min)	1.89 (0.93)	1.93 (0.85)	NS
Oxygen consumption (ml O_2/kg/min)	0.57 (0.30)	0.74 (0.33)	0.005
Fractional oxygen extraction	0.32 (0.13)	0.38 (0.08)	0.018
Mixed venous oxygenation	0.65 (0.13)	0.60 (0.08)	0.019
Tissue oxygenation index (%)	67 (5)	61 (6)	<0.001

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[4] and muscular activity.[1] 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,[5] 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,[4 5] 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.[1]

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.[3] An influence of the haemoglobin concentration[2] 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.

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Competing interests: None declared.

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Accepted 7 March 2006

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