Simple and versatile method for measuring oxygen consumption in infants

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SUMMARY A simple, rapid, and accurate method for measuring oxygen consumption in infants is described. Expired gas is entrained in a stream of air drawn through a gently applied face mask. Oxygen consumption is derived from (1) gas flow rate, measured with a flowmeter, and (2) the fall in oxygen concentration of the gas mixture, measured with a paramagnetic analyser. A measurement can be made at the bedside within 2 minutes without disturbing the infant. In 17 mature 2-day-old neonates mean oxygen consumption was 6.52 ml/kg per min, SD 0.90, similar to that previously reported using less simple methods.

Measurements of oxygen consumption (\( \text{VO}_2 \)) have been very helpful in physiological studies of the newborn, for example in determining the optimal conditions for a thermoneutral environment in term and preterm infants (Hill and Rahimtulla, 1965; Scopes and Ahmed, 1966; Hill and Robinson, 1968; Bhakoo and Scopes, 1974). They have also proved valuable in the investigation of infants undergoing cardiac catheterisation (Fixler et al., 1974) and cardiac surgery (Owen-Thomas and Meade, 1975), and in the evaluation of the effects of treatment, e.g. postoperative management (Ito et al., 1976) and phototherapy (O. Smales, unpublished, 1976).

Methods previously reported for measuring \( \text{O}_2 \) consumption usually disturb the infant, are frequently time-consuming, and use relatively complicated and expensive equipment. We describe a simple method for measuring \( \text{O}_2 \) consumption accurately and quickly with portable apparatus.

**Patients and methods**

A constant flow system is used and \( \text{O}_2 \) consumption is derived by the application of the Fick principle. A clear plastic mask with a soft foam-lined rim is gently applied to the face covering the nose and mouth (Figs. 1, 2). The mask is connected to a coaxial circuit through which air is drawn at a constant flow rate. The expired gas from the infant is entrained in the gas stream drawn into the central tube. The gas is dried by silica gel before passing through a flowmeter (Rotameter). Part of the flow (0.3 l/min) is pumped to a paramagnetic oxygen analyser (Servomex 0A272) and allowed to escape to atmosphere; the remainder is drawn to waste through a needle valve and pressure regulator into a
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A small reservoir is placed between the pump and analyser to smooth out breath-by-breath changes in gas concentration. The volume of the reservoir is adjusted so that a steady reading is obtained within 120 seconds.

A secure airtight seal between the mask and infant is not essential. The high sample flow rate (equal to twice the approximate peak expired flow rate of the neonate) and slight subatmospheric pressure within the mask ensure that expired gas cannot escape from the mask; if a leak is present between the mask and infant, air is drawn into the mask. Since ambient air is drawn through the system additional humidification is not usually necessary; if this is essential, as part of a study of heat balance for instance, this is easily achieved by the insertion of a low resistance humidifier in the inspiratory limb of the system.

If measurements are required of the effects of critical changes in environmental factors, the mask and coaxial circuit may be replaced by a conventional head box or hood.

**Laboratory verification.** In order to check the accuracy and linearity of response of the system, O₂ consumption was simulated by the injection of a steady flow of N₂ into the central tube of the coaxial circuit. N₂ entered the circuit at a range of flows from approximately 50 to 250 ml/min. The true flow rate was derived using a wet-gas meter (Parkinson and Cowan Type B) and stop-watch. Appropriate corrections were applied for temperature pressure and humidity.

**Clinical measurements.** O₂ consumption was measured in 17 healthy, term 2-day-old babies, while they were sleeping clothed in their cots 2–3 hours after feeds. The studies were made in an environment of moderate humidity which was carefully maintained within the neutral temperature range for each baby, meeting Hey’s (1971) criteria for thermal neutrality.

**Results**

**Laboratory verification.** The correlation between measured and simulated V̇O₂ is shown in Fig. 3. The 95% confidence limits of the measured values are virtually constant at approximately ± 1·5 ml/min over the range 10–50 ml/min.

**Clinical measurements.** The mean V̇O₂ was 6·52 ml stpd/kg per min, SD 0·90. These values accord with figures obtained by other workers using both closed and open-circuit techniques (see Table). The infants’ ages ranged from 32 to 60 hours, mean 48 hours; their mean weight was 3·12 kg, SD 0·5.
retention in all but the smallest neonates; this cannot be excluded by measurements of CO₂ concentration in mixed expired gas obtained from a T-piece arrangement. The Servomex OA272 analyser used in the present system is ideal for this type of investigation and obviates the need for additional amplification, recording, and calibration equipment.

The present method can be quickly and repeatedly performed from within minutes of birth and produces accurate results without disturbing the infant. The equipment is relatively simple, inexpensive, and portable. The measurement of O₂ consumption by this method has many potential applications in special-care nurseries and paediatric wards. We have used it to make several hundred measurements of O₂ consumption in neonates and infants in the labour wards, special care nursery, and in the follow-up of older infants as outpatients.

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References

Table Comparative values of \( \dot{V}_O_2 \) in neonates

<table>
<thead>
<tr>
<th>Published reports</th>
<th>Age (h)</th>
<th>No. of babies</th>
<th>( \dot{V}_O_2 ) (ml/kg per min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present method</td>
<td>32–60</td>
<td>17</td>
<td>6.52±0.90</td>
</tr>
<tr>
<td>Hill and Rahimtulla (1965)</td>
<td>48–96</td>
<td>16</td>
<td>6.70±0.70</td>
</tr>
<tr>
<td>Hill and Robinson (1968)</td>
<td>33–47</td>
<td>11</td>
<td>6.44±1.21</td>
</tr>
<tr>
<td>Ito et al. (1976)</td>
<td>1w</td>
<td>39</td>
<td>5.96±0.77</td>
</tr>
</tbody>
</table>

Discussion

Other methods (Hill and Rahimtulla, 1965; Hill and Robinson, 1968; Scopes and Ahmed, 1966; Stoker et al., 1973; Fixler et al., 1974; Smales, 1978) involve placing the infant in a sealed box or collecting expired air from a hood or tightly applied mask to avoid leakages. The high fresh gas flow used in our method not only ensures that expired gas does not escape past leaks at the rim of the mask (Evans et al., 1977) but also ensures that rebreathing of expired gas does not occur. At gas flows of less than twice the minute volume, rebreathing is likely to occur (Willis et al., 1975). Assuming, in the neonate, a minute volume of 300 ml/kg per min the fresh gas flow should therefore exceed 600 ml/kg per min. The use of lower fresh gas flows (500 to 1000 ml/min; Smales, 1978) will almost certainly result in CO₂

Fig. 3 Correlation (unconstrained regression line with 95% confidence limits of a single observation) of measured \( \dot{V}_O_2 \) and simulated \( \dot{V}_O_2 \). Equation: \( y=0.991x + 0.19; \ r=0.9991 \).


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