

Short reports

Improved accuracy of continuous measurement of arterial oxygen tension in sick newborn infants

Criteria for reading and recalibrating the electrode

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SUMMARY Improved accuracy of continuous arterial oxygen tension (PaO_2) measurement is obtained if allowance is made for the response time of the electrode. Recalibration is necessary only when PaO_2 measured in a blood sample differs from the electrode value by more than ± 11.5 mmHg (1.5 kPa).

During the last 6 years continuously-recording intravascular oxygen electrodes have been developed (Parker *et al.*, 1971; Harris and Nugent, 1973; Goddard *et al.*, 1974). These instruments have shown that the arterial oxygen tension (PaO_2) in sick newborn babies may fluctuate widely, and that analysis of intermittent blood samples is often a poor reflection of the changes taking place. The ideal continuously-recording oxygen electrode would be accurate and reliable, and would not introduce any hazards that do not already exist with an umbilical arterial catheter (Kollmeyer and Tsang, 1974). Accuracy depends on the initial calibration against blood analysis of PaO_2 , while reliability depends on knowing when to recalibrate.

Of the various electrodes that have been developed only one is commercially available.* We have devised a technique that greatly improves the accuracy of this instrument and we also report our criteria for recalibrating the electrode.

The instrument

The electrode is attached to the end of a 5 French gauge (1.67 mm) dual-lumen polyvinylchloride catheter. One lumen has a side hole and is used for blood sampling, fluid infusion, and pressure measure-

ment. The other lumen contains the leads from the polarographic oxygen electrode which are connected to a battery-powered amplifier. A meter displays the reading of PaO_2 . An optically-coupled recording unit enables a continuous chart record of PaO_2 to be made. The output current of each electrode is tested before the catheter is individually packed and sterilised.

After the catheter has been inserted there is a gradual change in sensitivity of the electrode caused by membrane thickening as water is absorbed, and it is recommended that the electrode be calibrated after 15-30 min. The meter is read and a sample of blood is withdrawn for PaO_2 measurement. When the result is known the meter reading is adjusted by the ratio of the blood PaO_2 to the meter PaO_2 . The accuracy of this method of calibration depends on the response time of the system and on any change in PaO_2 just before, or during, blood sampling. The electrodes used in this study had a 95% response time of between 40 and 60 seconds.

Patients

We placed 28 catheters in 24 newborn infants (birthweights between 0.6 and 3.6 kg, mean 2.15); each required an indwelling arterial catheter for clinical management. Most infants were born prematurely, with a mean gestational age of 34 weeks (range 24-44). 15 had birth asphyxia, 5 developed severe hyaline membrane disease, and 5 severe haemolytic disease; 4 had meconium aspiration, 2 polycythaemia, and one each, diaphragmatic hernia, delayed resorption of lung fluid, and viral pneumonia. Three infants died in the neonatal period.

We obtained consent from the parents to use this

*G. D. Searle & Co. Ltd., High Wycombe, Bucks.

type of catheter instead of the standard polyvinyl-chloride umbilical arterial catheter†; often this was obtained some days before birth if there was premature labour or if elective caesarean section was planned.

Methods

We have already described our technique for catheterisation of umbilical arteries (Kitterman *et al.*, 1970). No alteration in our routine procedure was made and during this initial evaluation we did not rely on the continuous reading of P_{aO_2} for clinical management, but continued to sample blood at least every 4 hours for measurements of P_{aO_2} , P_{aCO_2} , and pH (Radiometer PHM72).

The electrode was calibrated as soon after insertion as possible and a continuous record of P_{aO_2} made on a polygraph recorder (Grass model 7A). From this record it was apparent that P_{aO_2} was fluctuating, often by as much as 20 mmHg (2.7 kPa), even when the baby was sleeping and breathing quietly. In these circumstances if blood is sampled for analysis of P_{aO_2} , the meter will read the correct value only after the response time of the electrode has elapsed. The meter reading at the time blood is being sampled will not reflect actual P_{aO_2} and this discrepancy may lead to unnecessary recalibration. During this study we read the meter at the time blood was sampled and then we allowed for the response time of the electrode and read it again 45 seconds after blood sampling. The Radiometer electrode value for P_{aO_2} was compared with the meter readings and the differences calculated. When the difference, even after allowing for the response time, was greater than 10 mmHg (1.34 kPa) we repeated the blood sample. In most cases the discrepancy between the meter reading and the P_{aO_2} in this second sample was <10 mmHg but if it again exceeded 10 mmHg we recalibrated the electrode. This decision was based on our feeling that when a discrepancy of >10 mmHg exists between the predicted value (catheter electrode) and actual value (Radiometer) of P_{aO_2} , then the usefulness of the electrode for regulating oxygen and artificial ventilation, and for safely reducing the frequency of blood sampling is seriously diminished.

Results

Four of the 28 electrodes did not activate. The mean time to initial calibration of the remaining 24 electrodes was 74 minutes (range 18–240). Delay was in most cases due to a very unstable P_{aO_2}

†Argyle Umbilical arterial catheter ALOE Medical Co. St Louis.

immediately after birth and during resuscitation.

The catheters were in place for between 2 and 135 hours (mean 43). During this time haematocrit varied between 18 and 72%, P_{aCO_2} between 15 and 88 mmHg (2–11.7 kPa), and pH between 7.06 and 7.57. The P_{aO_2} meter was read at the time of blood sampling and 45 seconds later on 408 occasions. Eight electrodes were recalibrated, 7 once, one twice. Mean time between calibrations was 38 hours.

Fig. 1 shows the correlation between the P_{aO_2} values from the blood sample and the meter reading of the P_{aO_2} electrode (a), at the time of sampling and (b) 45 seconds later.

The relation between P_{aO_2} recorded by the Radiometer electrode and the catheter electrode is described by the equations:

- (a) Simultaneous reading
 $y = 8.35 + 0.86x$ ($r = 0.867$. SE of regression = 9.15)
- (b) Reading at 45 seconds
 $y = 2.29 + 0.97x$ ($r = 0.948$. SE of regression = 5.84).

The value of P_{aO_2} read at 45 seconds is a significantly better estimate of the true P_{aO_2} value ($F = 2.45$, $P < 0.001$). When this reading of P_{aO_2} at 45 seconds (Fig. 1 (b)) is used to predict the true P_{aO_2} value, the meter reading has 95% confidence limits for regression of ± 11.5 mmHg (1.5 kPa). This compares with a value of ± 17.9 mmHg (2.4 kPa) for the reading in the time of sampling (Fig. 1 (a)).

The differences between individual values for P_{aO_2} read by the electrode at 45 seconds and the Radiometer P_{aO_2} value ranged from 0 to ± 21 mmHg (2.8 kPa) within the preset limits of two consecutive values >10 mmHg (our criteria for recalibration). The SD of the differences was ± 5.6 mmHg (0.75 kPa). Fig. 2 shows an example of one electrode's performance plotted to show the variation in the prediction of actual P_{aO_2} and an example of recalibration. The 95% confidence limits for regression of ± 11.5 mmHg (1.5 kPa) defines the limits that may be used without the need to repeat a blood sample.

Discussion

Continuous recording of P_{aO_2} in sick newborn infants is potentially a method by which oxygen tension may be kept within safe limits while, at the same time, reducing the number of blood samples taken and hence the need for transfusion of blood.

To achieve this, the electrode when accurately calibrated must remain stable, and the frequency of recalibration be reduced to a minimum. An unduly long response time can lead to incorrect calibration,

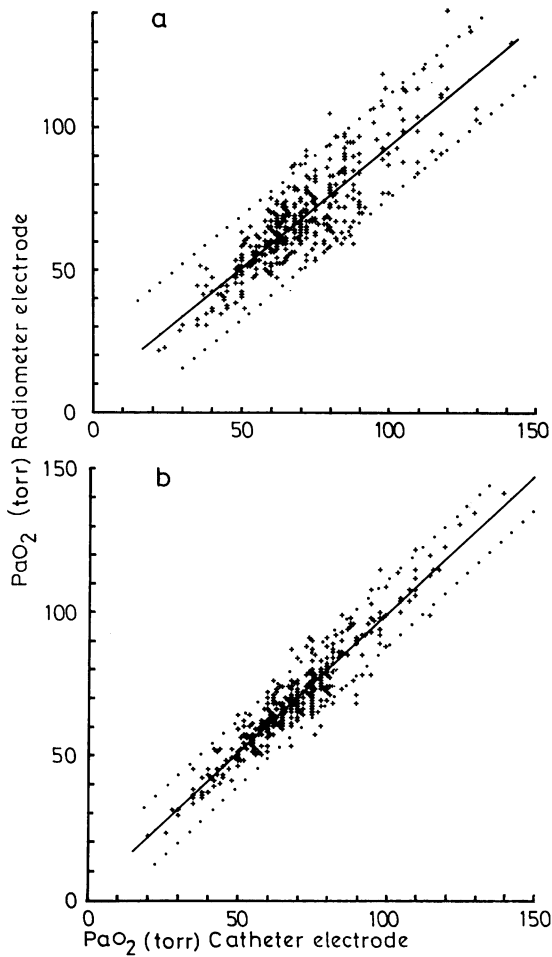


Fig. 1 Relation between PaO_2 reading from catheter electrode and PaO_2 in a blood sample measured by Radiometer electrode. (a) Electrode reading at time of blood sampling. (b) Electrode reading 45 seconds after blood sampling. 95% confidence limits are shown. Conversion: 7.5 torr (7.5 mmHg) = 1kPa.

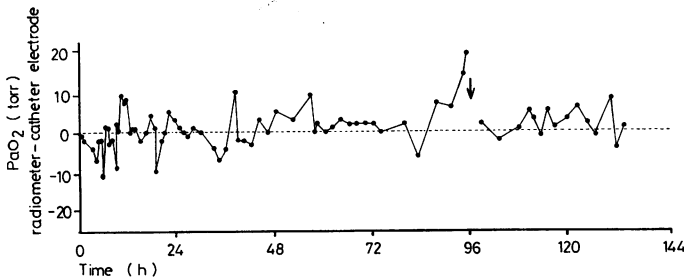


Fig. 2 Example of sequential difference between PaO_2 reading from catheter electrode and PaO_2 in blood sample measured by Radiometer electrode. Electrode recalibrated at arrow.

especially if PaO_2 is changing during sampling. In a preliminary study of this problem, Rolfe (1976) using a similar electrode, reported differences of -13 to +19% despite recalibrating the electrode after each of 6 blood samples during a 3-hour period.

We have shown that greater accuracy and therefore a reduced frequency of recalibration may be obtained by allowing for the response time of the system by reading the meter 45 seconds after blood sampling.

When used in this way recalibration is only

required when the meter reading differs from PaO_2 in a blood sample by more than ± 11.5 mmHg (95% confidence).

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Haemorrhage responsive to vitamin K in a 6-week-old infant

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SUMMARY A 6-week-old breast-fed infant presented with vomiting, jaundice, and irritability. Haemorrhage occurred after lumbar puncture, and a coagulation abnormality which responded to vitamin K was found. It would seem prudent to estimate the prothrombin time before invasive procedures in breast-fed infants of this age, or to give vitamin K to such infants when doubt exists about previous vitamin K administration.

Case report

A term baby boy weighing 3450 g was delivered after spontaneous onset of labour to a primagravid mother. Apgar scores were 3 at one minute and 5 at five minutes. He was resuscitated with oxygen delivered by face mask. Mild, presumed physiological jaundice developed on day 3 but otherwise the neonatal period was uneventful. Neither mother nor baby received vitamin K. He was breast fed. Slight jaundice persisted after his discharge on day 5 but he remained well until admission at 6 weeks with a 2-day history of nonprojectile vomiting after feeds

without haemorrhage. For 5 days there had been slight irritability on handling, but sleep, feeding, and bowel function were all normal. The icterus had intensified. There was no history of maternal or infant drug ingestion, but both parents had developed upper respiratory tract infections 5 days previously.

On admission the baby was afebrile, slightly jaundiced, mildly dehydrated, and irritable on handling. Weight was on the 50th centile with length and head circumference on the 90th centile for age. The anterior fontanelle was full but not tense. Systematic and neurological examination, including fundoscopy, were normal. No clinical evidence of pyloric stenosis was detected. Initial investigations included a haemoglobin of 9.1 g/dl, a white blood count (WBC) of $9.2 \times 10^9/l$ (9200/mm³) (neutrophils 35%, lymphocytes 65%), and a platelet count of $360 \times 10^9/l$ (360 000/mm³). The film contained a few atypical lymphocytes. Serum electrolytes were within normal limits. Serum total bilirubin was 90 $\mu\text{mol/l}$; 5.3 mg/100ml (direct 39 $\mu\text{mol/l}$; 2.3 mg/100ml). Full infection screen, including CSF analysis, showed no evidence of a bacterial infection.