c. Four patients with hemodynamic disorders in whom corrected $cpCO_2$ was consistently higher than p_aCO_2. This difference disappeared once the hemodynamic disorders had been corrected.

4. Studies of $cpCO_2$ and cpO_2 traces could perhaps provide better understanding of various pathological respiratory conditions but we feel that it should be linked to that of other parameters, such as alveolar pCO_2.

Conclusions

These findings recorded in a small number of patients must be interpreted with caution, particularly in view of the fact that, in a few cases, two types of traces were observed in the same patient at different times. Nevertheless, they do reveal the advantages and limitations of $cpCO_2$ monitoring:

1. In most cases $cpCO_2$ makes it possible to monitor pCO_2 since it is significantly correlated with p_aCO_2.

2. It ceases to be of value when collapse has occurred. Its deviation from p_aCO_2 is an indirect reflection of hemodynamics and could contribute to its monitoring.

3. In general it can be said that these variations are much smaller than those of cpO_2 and there are relatively few situations in which they can be used as a guide in ventilation.

References

1. Eberhard P, Schäfer R (1981) A sensor for non-invasive monitoring of carbon dioxide. J Clin Eng 6: No 1
2. Severinghaus JW, Bradley AF, Stafford MJ (1979) Transcutaneous pCo_2 electrode design with internal silver heat path. In: Huch A, Huch R, Lucey JF (eds) Birth defects: original article series. Continuous transcutaneous blood gas monitoring, vol XV, no 4. Alan R. Liss, New York, pp 265 – 270

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Transcutaneous pO_2 and pCO_2 Monitoring With a Single Electrochemical Sensor; Its Clinical Use and Advantages in Neonatal Intensive Care

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Our medical Physics Department has designed a sensor which combines into a single device a Clark polarographic O_2 electrode and a Stow Severinghaus CO_2 electrode. Details of the probe's construction have been given [1]. The accuracy of simultaneous estimation of p_aO_2 and p_aCO_2 has been investigated in sick infants [2].

Twenty-two studies were performed on ten newborn infants with respiratory illnesses. All had umbilical artery catheters in situ. The sensor was heated to 44 °C and attached to the infant's abdomen for $3\frac{1}{2}$ to 6 h. p_aO_2 was measured continuously by a Searle intravascular oxygen electrode or estimated by a Dräger transcutaneous oxygen electrode. Several samples of arterial blood were taken through the umbilical artery catheter during the course of each study and their p_aO_2 and p_aCO_2 measured. The initial blood gas values for p_aO_2 and p_aCO_2 were used as in vivo calibration points for $tcPO_2$, as previously described [3] and for $tcPCO_2$.

$tcPO_2$ was compared with p_aO_2 recorded by the intravascular oxygen electrode or by p_aO_2 estimated by the Dräger transcutaneous electrode. $tcPCO_2$ was compared with the p_aCO_2 of samples of arterial blood. The relation between $tcPO_2$ and p_aO_2 after in vitro calibration was $tcPO_2 = 0.95\ p_aO_2 + 11.93$ mmHg ($r = 0.69$, $p < 0.001$) and after in vivo calibration $tcPO_2 = 1.00\ p_aO_2 + 1.27$ mmHg ($r = 0.89$, $p < 0.001$). After in vitro calibration $tcPCO_2 = 0.99\ p_aCO_2 + 9.88$ mmHg ($r = 0.89$, $p < 0.001$) and after in vivo calibration $tcPCO_2 = 0.98\ p_aCO_2 - 2.33$ mmHg ($r = 0.97$, $p < 0.001$.)

The results showed that the sensor gave an estimate of p_aO_2 and p_aCO_2 which was sufficiently accurate for use in the clinical management of newborn infants. The combined $tcPO_2/tcPCO_2$ sensor is now being used routinely in our neonatal intensive care unit. The importance of continuous p_aO_2 or $tcPO_2$ monitoring is already well established. Arterial pCO_2 has often been thought to remain fairly stable, with gradual changes in p_aCO_2 requiring intermittent blood gas monitoring only. However, we have found that $tcPCO_2$ can fluctuate rapidly and unexpectedly.

Due to the profound effect that p_aCO_2 has on cerebral blood flow, continuous monitoring of $tcPCO_2$ has proved invaluable in the clinical management of sick infants. In respiratory illnesses carbon dioxide retention occurs and mechanical ventilation may be required to reduce it. The combined $tcPO_2/tcPCO_2$ sensor enables us to intervene at the appropriate time, preventing p_aCO_2 from reaching dangerous levels, whilst ensuring the blood is still kept well

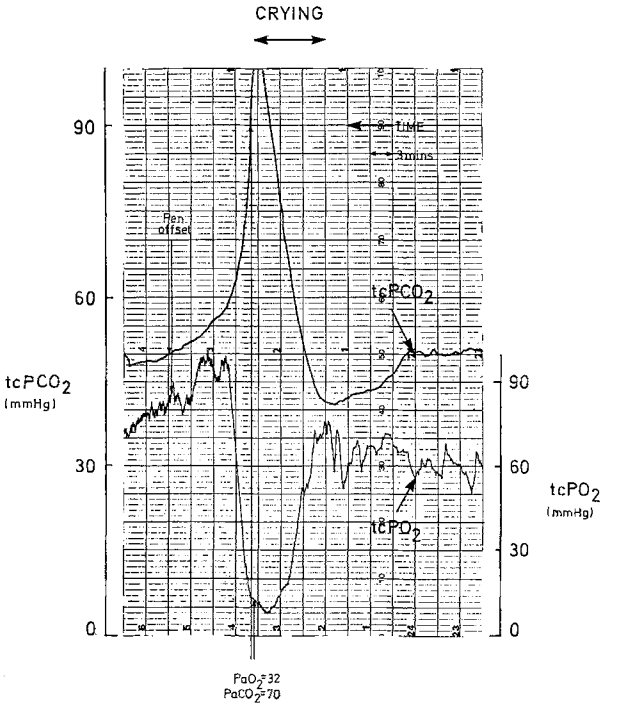

Fig. 1. Simultaneous records of $tcPO_2$ and $tcPCO_2$ recorded by the combined sensor. The infant weighed 2,465 g at 32 weeks of gestation and had severe rhesus haemolytic disease. He was 46 h old at the time of study and was being treated by intermittent mandatory ventilation with 40% O_2. The effect of crying on $tcPO_2$ and $tcPCO_2$ is readily apparent

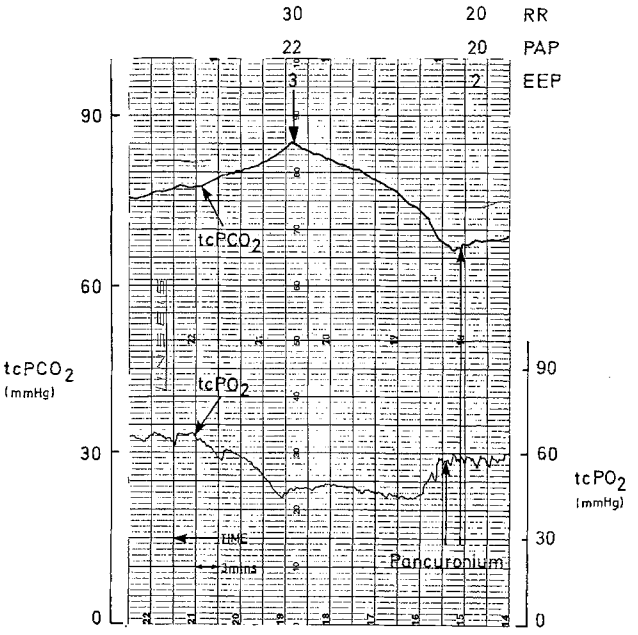

Fig. 2. Simultaneous records of $tcPO_2$ and $tcPCO_2$ recorded by the combined sensor. The records should be read from right to left. The infant weighed 1,070 g at 28 weeks of gestation and had hyaline membrane disease. He was 48 h old at the time of study and was being treated by intermittent mandatory ventilation with 90% O_2. The effect of pancuronium and changes in ventilator settings can be seen.

oxygenated. The level of arterial pO_2 and pCO_2 can then be monitored until suitable ventilator settings have been selected. If an infant's arterial pCO_2 is too low, it can be raised by alterations in ventilator settings, or by introducing a dead space. The effectiveness of such treatment can then be observed. Due to the hazards of prolonged ventilation, it is desirable to wean babies from ventilatory support as soon as possible. Continuous $tcPO_2$ and $tcPCO_2$ monitoring provides useful information in determining when the infant no longer requires ventilation.

Crying and fighting the ventilator are common causes of fluctuating high pCO_2 with low pO_2 (Fig. 1). This behaviour can cause a pneumothorax to occur, which may be followed by intraventricular haemorrhage. The administration of a muscle relaxing drug prevents this struggling but the infant's own respiratory efforts are often reduced, causing arterial pO_2 to fall and pCO_2 to rise. It is therefore important, at this time, to be able to monitor both $tcPO_2$ and $tcPCO_2$ continuously so that ventilation can be increased as necessary to bring arterial pO_2 and pCO_2 back to normal (Fig. 2).

Continuous pO_2 and pCO_2 monitoring is proving extremely valuable for the clinical management of very sick infants.

References

1. Halsall D, Delpy D, Parker D, Whitehead MD, Pollitzer MJ, Reynolds EOR (1980) Transcutaneous pO_2 and pCO_2 measured by a combined electrochemical sensor. In: Rolfe P. Fetal and neonatal physiological measurements. Pitman Medical, Tunbridge Wells, pp 424–429
2. Whitehead MD, Halsall D, Pollitzer MJ, Delpy D, Parker D, Reynolds EOR (1980) Transcutaneous estimation of arterial pO_2 and pCO_2 in newborn infants with a single electrochemical sensor. Lancet, 1:1111–1114
3. Pollitzer MJ, Whitehead MD, Reynolds EOR, Delpy D (1980) Effect of electrode temperature and in vivo calibration on accuracy of transcutaneous estimation of arterial oxygen tension in infants. Pediatrics 65:515–522

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