

## Comparison of capillary and arterial blood gas measurements in neonates

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**SUMMARY** One hundred and fifty eight paired arterial and capillary blood samples were obtained from 41 sick preterm infants in their first week of life and the pH, and PCO<sub>2</sub>, and PO<sub>2</sub> concentrations were measured. Half of the capillary samples were obtained from unwarmed heels and half from heels warmed to 40°C. A potentially significant discrepancy (arbitrarily defined as 0.05 units for pH, 1 kPa for PCO<sub>2</sub>, and 3 kPa for PO<sub>2</sub>) was found in 19 (24%) of cases for pH, in 9 (11%) for PCO<sub>2</sub> and in 21 (26%) for PO<sub>2</sub>. Warming the heel produced no significant improvement in results. We conclude that capillary blood provides satisfactory measurements of pH and PCO<sub>2</sub> for all but the most critical purposes, but that the usefulness of capillary PO<sub>2</sub> estimations is limited to the exclusion of hypoxia.

Blood gas analysis is often performed for neonates on blood samples taken either from arteries or capillaries, but there have been few publications comparing the results obtained from these two sources in babies. Studies by Gandy *et al*<sup>1</sup> in babies weighing over 2000 g at birth, and by Koch *et al*,<sup>2</sup> and MacRae *et al*<sup>3</sup> in healthy term babies, showed that the pH and PCO<sub>2</sub> measurements of arterial and capillary blood collected from warmed heels were similar after the first few hours of life. Arterial and capillary PO<sub>2</sub> measurements showed a less strong association. Gandy *et al*<sup>1</sup> found a poor correlation, and Glasgow *et al*<sup>4</sup> and Usher<sup>5</sup> found that the correlation was reasonable only when the arterial PO<sub>2</sub> was below 8 kPa. Winquist *et al*,<sup>6</sup> using histamine iontophoresis to arterialise capillary blood, showed a close correlation in preterm babies over 5 days old, and Corbett *et al*<sup>7</sup> and Desai *et al*<sup>8</sup> described a good correlation between arterial and capillary PO<sub>2</sub> using the dorsal surfaces of the finger and the scalp, respectively, as the sources of capillary blood.

In only one of the publications cited<sup>6</sup> were ill preterm babies studied; and that was in 1970 when babies in the neonatal intensive care unit were considerably more mature than they are today. We therefore felt that an up to date investigation of the association between arterial and capillary blood gas measurements was warranted.

A questionnaire sent to 42 neonatal units showed that more than half relied on capillary samples for most of their blood gas estimations. One third of the

units attempted to warm the site from which the blood was taken before sampling. Twenty nine of the respondents thought that capillary PO<sub>2</sub> measurement was of no value, 11 thought that it was reliably 2–3 kPa below the arterial value, and two thought that it accurately reflected the arterial PO<sub>2</sub>. The present study was designed to compare capillary blood gases taken from unwarmed heels and from heels warmed to 40°C with arterial gases to find out whether the capillary measurements were sufficiently accurate to be used in clinical practice.

### Patients and methods

One hundred and fifty eight paired arterial and capillary blood samples were obtained from 41 preterm babies, median gestational age 30 weeks (range 23–34). All were between 3 hours and 7 days old and had indwelling umbilical arterial catheters. At the time of sampling each baby had a normal central temperature (36.8°–37.2°C) and a mean arterial blood pressure above 30 mm Hg. Thirty five of the babies had respiratory distress syndrome, and 57% were receiving muscle relaxants at the time of sampling. All capillary samples were obtained when capillary puncture was performed for Dextrostix measurement—this is routine practice as our arterial lines are perfused with dextrose. The study was approved by the local ethical committee.

The first pair of samples from each infant comprised an arterial sample and a capillary sample taken simultaneously from an unwarmed heel

(group 1). The second pair comprised an arterial sample and a capillary sample taken simultaneously from a heel warmed in water at 40°C for five minutes before sampling (group 2). The capillary samples were taken from the medial and lateral borders of the heel using an Autolet; a 200 µl sample of blood was collected into a heparinised tube. Arterial samples were collected after a 2 ml 'dead space' volume had been removed from the line. All samples were analysed on a Radiometer ABL 300 blood gas analyser within five minutes of being taken. The machine's precision was tested by analysing 10 consecutive samples from the same source. The standard deviations for pH, PCO<sub>2</sub> and PO<sub>2</sub> were 0.001, 0.04 kPa, and 0.3 kPa, respectively.

Confidence intervals are reported for the data that approximated to a normal distribution. The results for PO<sub>2</sub> have a skewed distribution and were analysed by Kendall's S test, a non-parametric, distribution free method.

### Results

Seventy nine paired samples were obtained for each group. For each of the measured variables we studied the distribution of arterial and capillary measurements, the distribution of the differences between paired arterial and capillary measurements (referred to as 'discrepancies'), and the proportion

of results in which it was thought that the discrepancy was of potential clinical importance, (0.05 units of pH, 1 kPa for PCO<sub>2</sub>, and 1, 2, and 3 kPa for PO<sub>2</sub>).

The distribution of pH measurements is shown in fig 1 and the discrepancies between arterial and capillary measurements in table 1. There was no significant difference in mean discrepancy between the two groups (95% confidence intervals -0.006 to +0.014 units; the 5% significance figure of +0.004 lies within this interval). This suggests that warming the heel had little beneficial effect on pH measurement. Overall, 28 of 158 (18%) of the paired samples were discrepant by more than 0.05 units of pH (that is, about a 12% difference in hydrogen ion concentration).

Table 1 *Discrepancy between arterial and capillary pH measurements in paired samples taken from unwarmed heels (group 1) and warmed heels (group 2)*

	Group 1 (n=79)	Group 2 (n=79)
Mean (SD) discrepancy (arterial minus capillary value)	0.005 (0.035)	0.001 (0.033)
95% confidence intervals	-0.06 to 0.07	-0.06 to 0.07
No (%) of results in which discrepancy exceeded 0.05 units	19 (24)	9 (11)

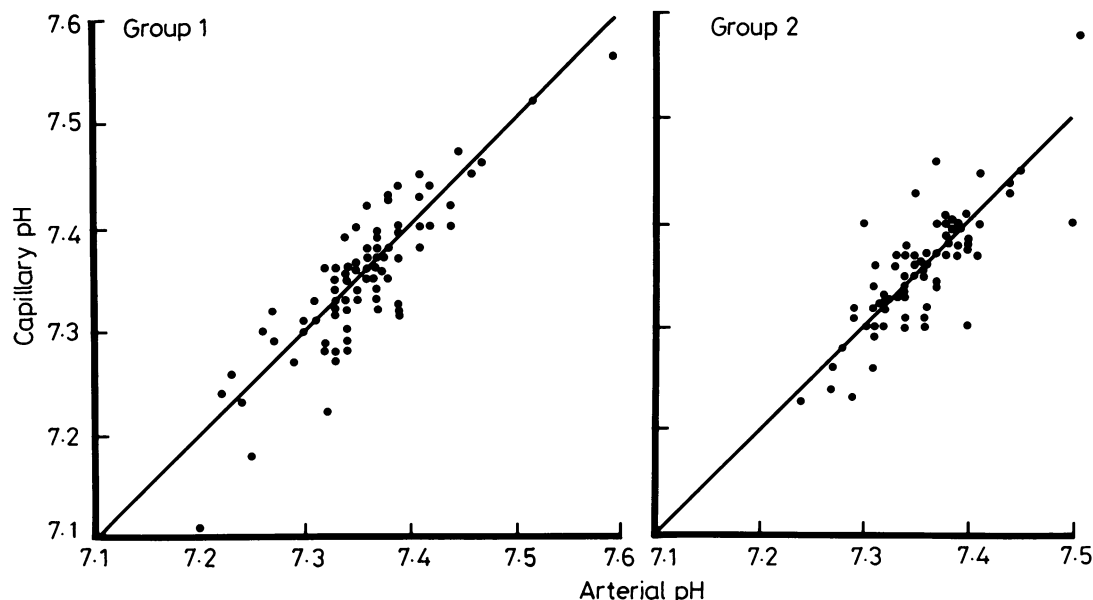


Fig 1 pH of arterial and capillary blood in paired samples taken from unwarmed heels (group 1) and warmed heels (group 2) with line of identity.

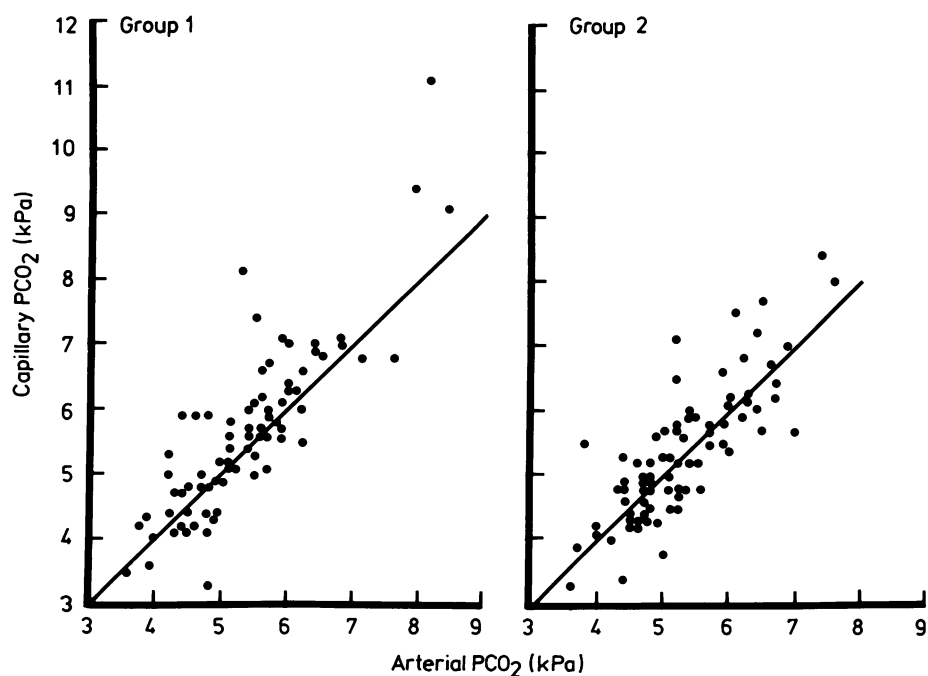


Fig 2  $PCO_2$  of arterial and capillary blood in paired samples taken from unwarmed heels (group 1) and warmed heels (group 2) with line of identity.

The distribution of  $PCO_2$  measurements is shown in fig 2 and the discrepancies between arterial and capillary measurements are shown in table 2. The difference in the mean discrepancy between the two groups was not significant at the 5% level (95% confidence intervals  $-1.1$  to  $+1.5$  kPa; the 5% significance figure of  $-0.21$  lies within this interval), indicating that warming the heel had little effect. Overall, 15 of 158 (10%) of the paired samples were discrepant by more than 1 kPa.

The distribution of  $PO_2$  measurements is shown in fig 3, and the discrepancies between arterial and

capillary measurements in table 3 and fig 4. A comparison of the discrepancies between the two groups showed no significant difference at the 5% level, again suggesting that warming the heel made little difference ( $S=1036$ ; variance(s)=3944 and 312; SD 1.8;  $p>0.1$ ).

### Discussion

The merits of sampling capillary blood for analysis of blood gases are that it is technically easier and less likely to result in serious complications than arterial catheterisation or puncture, and that sites are available when arterial sites are not, but it is a clinically useful technique only if the blood gas measurements obtained are a sufficiently accurate guide to the arterial measurements. In this study the arterial blood gas measurements were taken as the 'gold standard' by which capillary measurements were judged. To what extent the discrepancies reported are methodological (for example, diffusion of  $CO_2$  from capillary blood during sampling), or physiological is uncertain, but a standard capillary blood sampling procedure was used and more attention was probably paid to good technique than can usually be guaranteed, and so the study is

Table 2 Discrepancy between arterial and capillary  $PCO_2$  measurements in paired samples taken from unwarmed heels (group 1) and warmed heels (group 2)

	Group 1 (n=79)	Group 2 (n=79)
Mean (SD) discrepancy (arterial minus capillary value)	$-0.26$ kPa (0.7)	$-0.05$ kPa (0.65)
95% confidence intervals	$-0.42$ to $+0.1$ kPa	$-0.18$ to $+0.08$ kPa
No (%) of results in which discrepancy exceeded 1 kPa	9 (11)	6 (8)

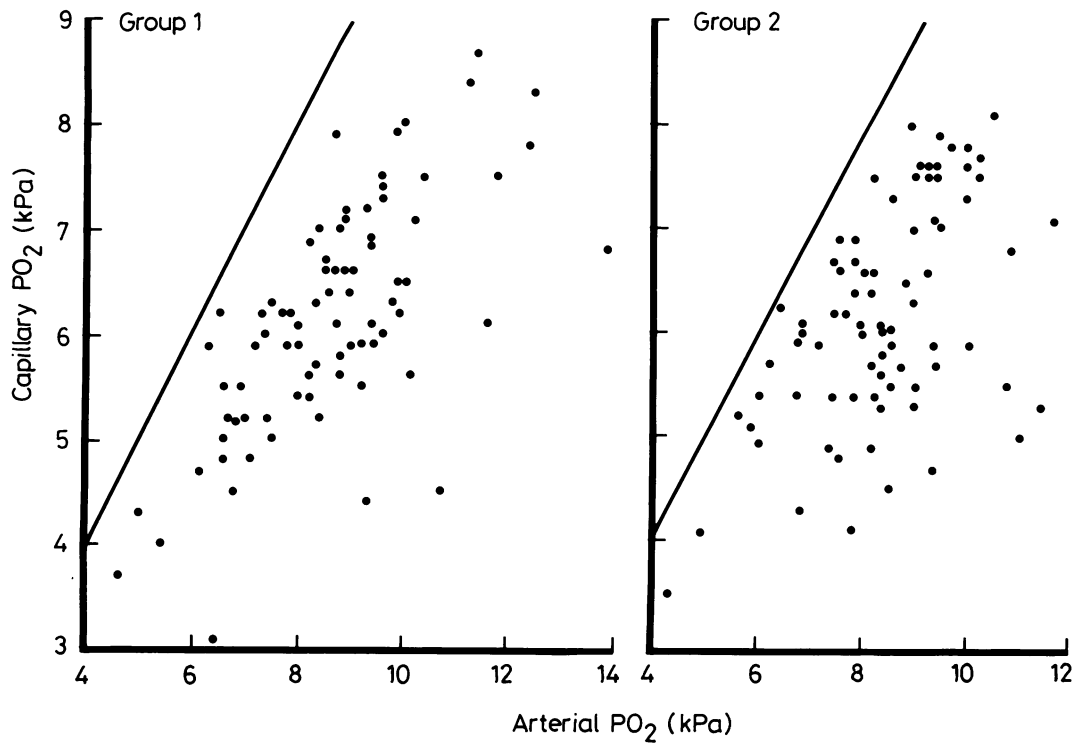


Fig 3 PO<sub>2</sub> of arterial and capillary blood in paired samples taken from unwarmed heels (group 1) and warmed heels (group 2) with line of identity.

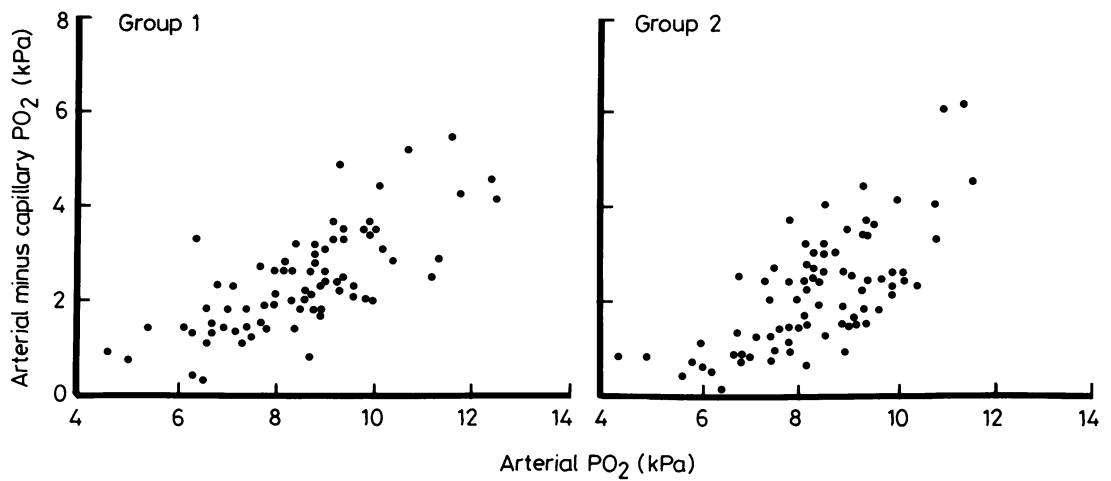


Fig 4 Discrepancy between arterial and capillary PO<sub>2</sub> measurements in samples taken from unwarmed heels (group 1) and warmed heels (group 2) and arterial PO<sub>2</sub> measurements in the two groups.

## Comparison of capillary and arterial blood gas measurements in neonates 747

Table 3 Discrepancy between arterial and capillary PO<sub>2</sub> measurements in paired samples taken from unwarmed heels (group 1) and warmed heels (group 2)

	Group 1 (n=79)	Group 2 (n=79)
Mean (SD) discrepancy (arterial minus capillary value)	2.47 kPa (1.20)	2.17 kPa (1.25)
Range	0.3 to 7.2 kPa	0.1 to 6.1 kPa
No (%) of results in which discrepancy exceeded:		
1 kPa	74 (94)	59 (75)
2 kPa	47 (59)	42 (53)
3 kPa	21 (27)	16 (20)

representative of what happens in practice. It is unlikely that a consensus could be reached among paediatricians as to what is a 'sufficiently accurate' guide to arterial measurements, and undoubtedly this also depends on the state of the patient. From the results of this study we contend that in acutely ill preterm babies, for whom no effort is spared to maintain meticulous homeostasis, capillary blood analysis may not reflect any arterial blood gas variable with sufficient accuracy.

In less critical circumstances the measurements of pH and PCO<sub>2</sub> derived from capillary blood were satisfactory, but there is limited clinical usefulness in the association between arterial and capillary PO<sub>2</sub> measurements. The tendency for the discrepancy in PO<sub>2</sub> to diminish as lower figures were approached, and the fact that capillary PO<sub>2</sub> never exceeded arterial PO<sub>2</sub>, confers some value on capillary blood gas analysis as a means of excluding hypoxia. Hyperoxia, on the other hand, is difficult to exclude by capillary blood gas analysis. It is tempting to interpret fig 3 as suggesting that arterial PO<sub>2</sub> measurements above 11 kPa are unlikely as long as the capillary PO<sub>2</sub> is kept below about 6 kPa, but this

is to extrapolate beyond the limits of the data as there are not enough babies with excessively high arterial PO<sub>2</sub> measurements to support this conclusion.

In this study warming the heel made no significant difference to the discrepancy between arterial and capillary measurements of any of the variables. It may be that temperatures above 40°C would be more effective in arterialising capillary blood, but we were concerned about the possibility of damaging the skin.

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