

Umbilical venous blood pH: a useful aid in the diagnosis of asphyxia at birth

S W D'SOUZA, P BLACK, J CADMAN, AND B RICHARDS

Department of Child Health, St Mary's Hospital, Manchester; Department of Computation, University of Manchester Institute of Science and Technology

SUMMARY Umbilical venous blood, and umbilical arterial blood pH, PO_2 , PCO_2 , and base excess were determined in 453 term infants at birth. The results indicate that umbilical venous blood pH, and umbilical arterial blood pH are significantly related to each another. Acidosis, as defined by an umbilical venous blood pH <7.27 , is associated with a lower PO_2 , a raised PCO_2 , and a reduced buffer base when compared with PO_2 , PCO_2 , and buffer base associated with a normal pH (7.27-7.42), or alkalosis (pH >7.42). The infant's condition at birth was recorded using modified Apgar scores, in which the gradings were vigorous (5-6), intermediate (3-4), or depressed (0-2). In the neonatal period, neurological abnormalities occurred in infants who had been in a depressed condition at birth in the presence of acidosis. Other infants, who had been in a depressed condition with a normal pH or alkalosis and the remaining infants who had an intermediate or a vigorous condition at birth, did not manifest neurological abnormalities in the neonatal period. Our findings suggest that measurement of umbilical venous blood pH, whose values correlate well with those of umbilical arterial blood pH, in infants who are in a depressed condition at birth improves the clinical assessment of the severity of asphyxia.

Asphyxia in the fetus is generally the result of partial oxygen deprivation during labour, and fetal blood pH is used as an indicator of asphyxia.¹⁻³ The seriousness of such intrauterine asphyxia in the pathogenesis of hypoxic-ischaemic brain damage in newborn infants is shown by Brown *et al.*,⁴ who reported that fetal distress had occurred in 65% of infants with neonatal neurological abnormalities. Further evidence is provided by D'Souza and Richards⁵ in infants with a history of fetal distress who manifested deviant neurological signs in the neonatal period and cerebral palsy in later childhood. Impairment of cerebrovascular autoregulation has been suggested in newborn infants who have sustained asphyxia.⁶ Thus, postnatal episodes of systemic hypotension may reduce cerebral blood flow which could add a postnatal component to the hypoxic-ischaemic injury at birth.

Apgar scores are lower as a result of intrauterine asphyxia but there is an apparent discrepancy between Apgar scores and the severity of acidosis at birth, as determined by pH measurements on umbilical arterial blood.⁷ With improved resuscitation most term infants in a depressed condition at birth, as reflected by fairly low Apgar scores at

1 minute, seem to recover by 5 minutes, but there is some uncertainty about the risk of brain damage due to intrauterine asphyxia in such infants.

In the present study, we investigated the distribution of pH values in umbilical arterial blood and umbilical venous blood collected at delivery. Since umbilical arterial blood represents blood coming from the fetus the pH of this blood is a measure of fetal acidosis. Umbilical venous blood is in contact with the placenta and the pH of this blood is influenced by the condition of the placenta and its ability to carry out respiratory gas exchange and the exchange of metabolites—such as lactate—between fetal and maternal blood. We studied the relationship of umbilical venous blood pH to umbilical arterial blood pH to determine the accuracy with which fetal acidosis at birth can be predicted from knowledge of umbilical venous blood pH, since it is often much easier to obtain a blood sample from the umbilical vein than from the umbilical artery. We further determined PO_2 , PCO_2 , and base excess in blood samples from the umbilical artery and umbilical vein and investigated changes in these indices in relation to umbilical venous blood pH. In the clinical assessment of the infant's condition at birth a

modified Apgar score was used to avoid observer errors in the assessments of muscle tone and reflex excitability.⁸ A significant relationship between modified Apgar scores and fetal distress has been reported.⁸ Meconium-stained liquor, fetal bradycardia, and fetal tachycardia were associated with lower modified Apgar scores which suggest that the modified Apgar score is reduced by fetal hypoxia.

Methods

Altogether 453 mothers, who had normal singleton pregnancies and were in labour after a gestational period of 39 to 42 weeks, were chosen. Labour in all mothers was supervised by one person (P B), who also assisted at delivery.

Umbilical arterial blood and umbilical venous blood.

Within 30 seconds of delivery, a segment of umbilical cord was clamped at both ends. Arterial and venous blood was collected separately into heparinised 1 ml polyethylene syringes (by P B who was skilled in this procedure). Blood pH, P_{O_2} , and P_{CO_2} were measured immediately after a blood sample was collected, using Astrup apparatus. Blood was collected in EDTA containers for arterial, and venous blood haemoglobin determination. This information together with pH and P_{CO_2} was used in estimating base excess.

Infants. The infant's condition at birth was assessed by a subset of the Apgar scoring method.⁸ Scores 0, 1, or 2 were given respectively when respiration was absent, gasping, or regular; when heart-rate was absent, ≤ 100 , or >100 beats a minute; or when colour was white, blue, or pink. Each baby could score a maximum of 6. Infants were routinely weighed and received a general medical examination. Records were kept of their progress in the lying-in wards, including neurological abnormalities and the results of investigations. On leaving hospital infants with acidosis and those who were in a depressed condition at birth were followed up at a local welfare clinic.

Statistics. Student's *t* test was used when comparing mean values, and the χ^2 test or Fisher's exact test when comparing numbers (proportions) of infants in the various categories. The distribution of umbilical venous blood and arterial blood was examined and the relationship of venous blood pH to arterial blood pH was determined by linear regression analysis.

Results

Fifty infants were born by forceps delivery and the remaining 403 infants by a normal cephalic vaginal delivery. Most mothers had received one or two doses of pethidine (150 mg) intramuscularly during labour, but none had received general anaesthesia. Birthweights ranged from 3227 to 3680 g, and all birthweights were appropriate for gestational age.

Distribution of umbilical venous blood pH and umbilical arterial blood pH. Fig. 1 shows, for umbilical venous blood, a mean pH of 7.344 with a standard deviation of 0.067 and, for umbilical arterial blood, a mean pH of 7.265 with a standard deviation of 0.079. The distribution of pH values in umbilical venous blood and umbilical arterial blood is skewed to the left (venous blood skewness -0.197 ; arterial blood skewness -0.399).

Relationship of umbilical venous blood pH to umbilical arterial blood pH. This relationship is statistically highly significant ($r=0.7447$; $P<0.00001$). Fig. 2 shows the regression line and 95% confidence limits drawn through 453 observations on umbilical venous blood pH and umbilical arterial blood pH. The regression equation is: $pH(\text{arterial blood}) = 0.86 \cdot pH(\text{venous blood}) + 0.86$.

Umbilical arterial blood pH, gases, and base excess in infants with acidosis, a normal pH, and alkalosis.

On the basis of umbilical venous blood pH there are three groups of infants: those with a normal pH, those with acidosis, and those with alkalosis. Normal pH is defined as 7.27 to 7.42, this range being plus or minus 1 standard deviation and it includes 7.4 which is the accepted 'normal' value for adults. Hence our choice of the word normal is not inappropriate. There are 367 values within the normal

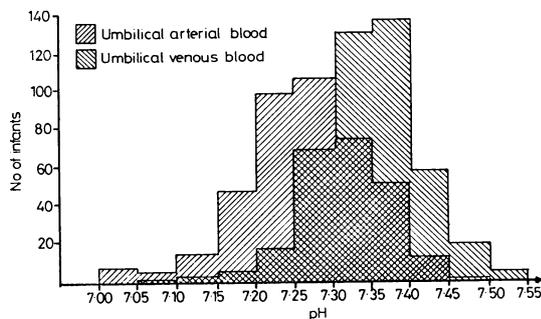


Fig. 1 Distribution of umbilical venous blood pH and arterial blood pH at birth.

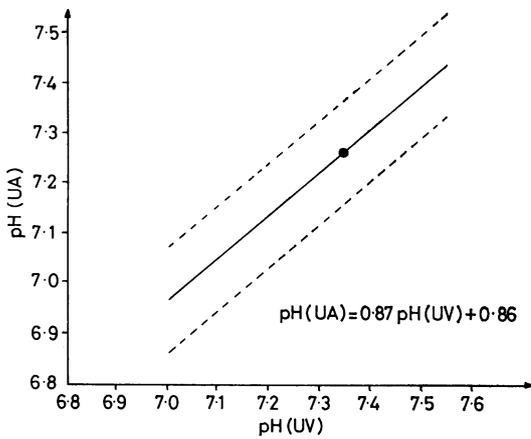


Fig. 2 Relationship between umbilical venous blood pH and umbilical arterial blood pH at birth. Regression line and 95% confidence limits drawn through 453 observations. The mean UV pH and mean UA pH occurs at the ● on the graph.

Table 1 Mean (\pm SD) umbilical arterial blood pH, gases, and base excess in infants with acidosis, a normal pH, and alkalosis

Umbilical arterial blood	Umbilical venous blood		
	Acidosis (pH < 7.27) n = 43	Normal pH (pH 7.27–7.42) n = 367	Alkalosis (pH > 7.42) n = 43
pH	7.14 \pm 0.07***	7.27 \pm 0.06	7.36 \pm 0.05***
Po ₂ (mmHg)	15.05 \pm 6.61*	17.23 \pm 6.40	17.34 \pm 5.05
Pco ₂ (mmHg)	50.42 \pm 15.60**	42.34 \pm 12.20	34.16 \pm 10.14***
Base excess (mmol/l)	-8.20 \pm 4.16***	-3.76 \pm 4.16	-1.30 \pm 4.63**

Levels of significance compared with normal pH *P < 0.05, **P < 0.01, ***P < 0.001.

pH range. Forty-three umbilical venous blood pH values less than 7.27—that is less than 1 standard deviation below the mean—were classified as acidotic. The remaining 43 pH values > 7.42—that is more than 1 standard deviation above the mean—were classified as alkalotic. Table 1 shows that with acidosis there is a reduction in Po₂, a rise in Pco₂, and a reduction in buffer base. Similar changes in relation to pH had taken place in umbilical venous blood.

Modified Apgar scores and umbilical venous blood pH. Modified Apgar scores at 1 minute and at 5 minutes after birth were not related statistically to umbilical venous blood pH, using the χ^2 test. Twenty-four infants were in a depressed condition (modified

Table 2 Neonatal neurological abnormality

Infant	Birth	Neonatal
A	Forceps delivery	Severe hypotonia, lethargy, and tremor.
Gestational age 41 weeks	Modified Apgar scores: one minute 1; five minutes 6	Fed by a nasogastric tube. Jaundice, maximum serum bilirubin 212 μ mol/l.
Birthweight 3640 g	pH (UA) 7.03 pH (UV) 7.19	Discharged on day 5
B	Normal delivery	Jittery, cyanotic episodes, and feeding difficulties. Single umbilical artery.
Gestational age 41 weeks	Modified Apgar scores: one minute 2; five minutes 6	Discharged on day 5
Birthweight 4000 g	pH (UA) 7.04 pH (UV) 7.26	

UA = umbilical artery, UV = umbilical vein.

Apgar scores 0–2) at birth, 3 (12%) had acidosis, 19 (80%) had a normal pH, and the remaining 2 (8%) infants had alkalosis. In the neonatal period, 2 of 3 infants with a history of a depressed condition and acidosis at birth manifested a neurological abnormality (Table 2). These deviant neurological signs were present for 48 to 72 hours after birth. This is in contrast to our findings in the 21 remaining infants with a history of a depressed condition at birth, with a normal pH or alkalosis, who did not manifest neurological abnormalities in the neonatal period (P < 0.022, Fisher's exact test). The results of investigations in the 2 infants with neonatal neurological abnormalities excluded hypoglycaemia, hyponatraemia, hypocalcaemia, and infection, but the history of a depressed condition at birth with acidosis suggests that the deviant neurological signs were owing to intrauterine asphyxia.

A total of 429 remaining infants of the 453 studied had an intermediate condition (modified Apgar scores 3–4), or a vigorous condition (modified Apgar scores 5–6) at birth. In these 429 infants 40 (9%) had acidosis, 348 (81%) had a normal pH, and the 41 (10%) remaining infants had alkalosis at birth, but in the neonatal period none of these infants manifested a neurological abnormality.

At follow-up, during a 2-year period, the 2 infants who had recovered from neonatal neurological abnormalities appeared to be developing normally. The other infants, who were in a depressed condition or acidotic at birth, also appeared to be making normal progress.

Discussion

Most infants with acidosis at birth appear to be in a vigorous or intermediate condition which raises the possibility that such acidosis is not entirely fetal in origin. Indeed, several studies have previously shown that there is movement of H⁺ ions and lactate across

the placenta from mother to fetus.⁹⁻¹² Most of this maternal acidosis which takes place in the second stage of labour is to some extent due to expulsive and ventilatory efforts by mothers during uterine contractions.¹³ Consequently, the downwards trend in fetal pH shows increasing steepness as delivery approaches.^{3 14 15} In this type of acidosis derived from the mother, buffer reserves in the newborn infant may be impaired and a lowered affinity of haemoglobin for oxygen, because of acidosis, may reduce the O₂ carrying capacity of fetal blood. However, the favourable progress during a 2-year period of acidotic infants in a vigorous condition or an intermediate condition at birth suggests that this acidosis is of uncertain clinical significance.

Reduced vigor, or a depressed condition at birth may be induced by conditions other than intrauterine asphyxia—such as the administration of pethidine, or anaesthetic drugs, to mothers in labour since these drugs cross the placenta and depress the infant's respiration at birth.^{16 17} Pethidine administered to our mothers in labour may have contributed to a depressed condition at birth in infants with acidosis, a normal pH, or alkalosis. By lowering the modified Apgar score, pethidine changes the relationship of modified Apgar scores to pH which then proves to be statistically not significant.

The neonatal progress of infants with a depressed condition at birth and acidosis has shown that in this subgroup of depressed infants there is a greater risk of brain damage. It is tempting to suggest that acidosis in such infants reflects a greater severity of fetal O₂ deprivation and a reliance on anaerobic glycolysis, while the lower modified Apgar scores (0-2) appear to indicate that homeostatic mechanisms for maintaining vital functions are impaired by intrauterine asphyxia.

In the asphyxiated fetus the sympathetic nervous system and circulating catecholamines produced by stimulation of the adrenal glands appear to be important in sustaining vital functions. Raised catecholamine levels have been observed in umbilical arterial blood at birth in infants who suffered asphyxia.¹⁸ Circulating catecholamines and the sympathetic nervous system could have a role in reducing the rate of fall in the Apgar score due to asphyxia in the following way: (1) improving the performance of the hypoxic myocardium,¹⁹ which maintains normal heart-rate; and (2) activating carotid body chemoreceptors,²⁰ which stimulate respiration and cause arousal, and as a result there is an improvement in muscle tone and an increase in reflex excitability.

In support of this hypothesis Lagercrantz¹⁸ has shown that the catecholamine surge at birth is less in

infants with acidosis (umbilical arterial blood pH 7.09-7.20) and a depressed condition (Apgar score below 7) than in infants with a similar pH but in better condition at birth (Apgar score above 7). Infants with a depressed condition at birth and acidosis seem less able to mobilise catecholamines to overcome the deleterious effects of asphyxia. It is our impression that these infants have more problems as a result of the asphyxia since 2 out of 3 cases in our study manifested deviant neurological signs in the neonatal period.

In the present study, we have little objective evidence of the severity of intrauterine asphyxia in those infants who are in a depressed condition at birth except for meconium-stained liquor in one case. In this case, continuous fetal heart rate monitoring was undertaken because of meconium-stained liquor but the findings on the fetal heart trace were of uncertain significance, and at birth the umbilical venous blood pH was within the normal range. Since the mothers selected for study had an uneventful pregnancy and were in labour at term, the risks of intrauterine asphyxia are usually considered to be slight. Furthermore, assuming that resuscitation is adequate, since all depressed infants at birth had recovered 5 minutes later, the only evidence relating the neurological sequelae to the severity of asphyxia at birth is the umbilical venous blood pH. The pH values in those depressed infants who later manifested neurological abnormalities were some of the lowest recorded in this study.

In routine clinical practice it is more convenient to obtain a sample of umbilical venous blood than it is to obtain a sample of umbilical arterial blood, since the umbilical vein is a fairly large blood vessel. Thus, errors due to a reduction in blood pH and oxygen tension resulting from delay in obtaining umbilical arterial blood is reduced. Moreover, a study on the relationship of umbilical arterial blood pH, and venous blood pH, to the neurological condition of infants in the neonatal period has shown that reduced umbilical venous blood pH values are as good a predictor of deviant neurological signs as are reduced umbilical arterial blood pH values.²¹ Our findings suggest that the measurement of umbilical venous blood pH in infants who are in a depressed condition should improve the clinical assessment of these infants at birth by focusing attention on those at greater risk from the damaging effects of asphyxia.

Finally, it is worth commenting that we have deliberately used the modified Apgar score (with a maximum score of 6) rather than the full Apgar score (with a maximum score of 10) because we feel that the assessment of muscle tone and reflex excitability is more subjective compared with the

remaining components of the Apgar score. Notwithstanding this, our findings are comparable with the observations recently reported²² especially in regard to those infants who are acidotic or depressed in terms of Apgar score, but not both simultaneously, and who escaped being neurologically abnormal in the neonatal period. Further, if that writer sees the Apgar score as a 'blunt instrument' on account of its inability to diagnose early asphyxia we suggest that this could be due to the lack of correlation between the Apgar score and pH. Clearly, the usefulness of the Apgar score can be improved by bringing to bear on the problem *two* blunt instruments—namely Apgar score and pH.

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References

- ¹ Beard R W, Morris E D, Clayton S G. pH values of foetal capillary blood as an indicator of the condition of the foetus. *J Obstet Gynaecol Br Commonw* 1967; **74**: 812–22.
- ² Hon E H, Khazin A F, Paul R H. Biochemical studies of the fetus. II. Fetal pH and Apgar scores. *Obstet Gynecol* 1969; **33**: 237–55.
- ³ Pearson J F. Maternal and fetal acid-base balance. In: Beard R W, Nathanielsz P W, eds. *Fetal physiology and medicine*. London: Saunders, 1976: 492–509.
- ⁴ Brown J K, Purvis R J, Forfar J O, Cockburn F. Neurologic aspects of perinatal asphyxia. *Dev Med Child Neurol* 1974; **126**: 567–80.
- ⁵ D'Souza S W, Richards B. Neurological sequelae in newborn babies after perinatal asphyxia. *Arch Dis Child* 1978; **53**: 564–9.
- ⁶ Hill A, Volpe J J. Hypoxic-ischemic brain injury in the newborn. *Semin Perinatol* 1982; **6**: 25–41.
- ⁷ Sykes G S, Molloy P M, Johnson P, *et al*. Do Apgar scores indicate asphyxia? *Lancet* 1982; **i**: 494–6.
- ⁸ D'Souza S W, John R W, Richards B, Milner R D G. Fetal distress and birth scores in newborn infants. *Arch Dis Child* 1975; **50**: 920–6.
- ⁹ Vedra B. Acidosis and anaerobiosis in full term infants. *Acta Paediatr Scand* 1959; **48**: 60–9.
- ¹⁰ Vedra B. Partial anaerobiosis in the human fetus. *Am J Obstet Gynecol* 1963; **86**: 1088–92.
- ¹¹ Rooth G, Nilsson J. Studies on foetal and maternal metabolic acidosis. *Clin Sci* 1964; **24**: 121–4.
- ¹² Daniel S S, Adamsons K, Jr, James L S. Lactate and pyruvate as an index of prenatal oxygen deprivation. *Pediatrics* 1966; **37**: 942–53.
- ¹³ Pearson J F, Davies P. The effect of continuous lumbar epidural analgesia on the maternal acid-base balance and arterial lactate concentration during the second stage of labour. *J Obstet Gynaecol Br Commonw* 1973; **80**: 225–9.
- ¹⁴ Bretscher J, Saling E. pH values in the human fetus during labor. *Am J Obstet Gynecol* 1967; **97**: 906–11.
- ¹⁵ Kubli F W. Influence of labor on fetal acid-base balance. *Clin Obstet Gynecol* 1968; **11**: 168–91.
- ¹⁶ Roberts H, Caine K M, Percival N, Snow P, Please N W. Effects of some analgesic drugs used in childbirth. *Lancet* 1957; **i**: 128–32.
- ¹⁷ Moya F, Thorndike V. The effects of drugs used in labor on the fetus and newborn. *Clin Pharmacol Ther* 1963; **4**: 628–53.
- ¹⁸ Lagercrantz H. Letter: Asphyxia and the Apgar score. *Lancet* 1982; **i**: 966.
- ¹⁹ Downing S E, Gardner T H, Rocamora J M. Adrenergic support of cardiac function during hypoxia in the newborn lamb. *Am J Physiol* 1969; **217**: 728–35.
- ²⁰ Jansen A H, Purves M J, Tan E D. The role of sympathetic nerves in the activation of the carotid body chemoreceptors at birth in the sheep. *J Dev Physiol* 1980; **2**: 305–21.
- ²¹ Huisjes H J, Aarnoudse J G. Arterial or venous umbilical pH as a measure of neonatal morbidity? *Early Hum Dev* 1979; **3**: 155–61.
- ²² Anonymous. The value of the Apgar score. *Lancet* 1982; **i**: 1393–4.

Correspondence to Dr S W D'Souza, Department of Child Health, St Mary's Hospital, Hathersage Road, Manchester M13 0JH.

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