The Relationship of Arterial Blood pH and pCO_2 to the Viability of the Newborn Piglet

G. C. B. Randall*

SUMMARY

Clinical observations were made on the majority of 749 newborn piglets from 75 litters and the blood pH and pCO_2 levels in samples taken from an umbilical artery were determined in 299 of these piglets. A method of individual clinical assessment was developed which reduced the effect of subjective error on the evaluation of viability at the time of delivery. Blood samples were collected from the umbilical artery prior to the onset of respiratory movements and it was found that increased acidemia and hypercapnia were associated with reduced viability. The pH values in severely depressed piglets were between 6.50 and 6.95 and pCO_2 values between 105 and 185 mm Hg, whereas in the fully viable animals, the ranges were 7.10-7.42 and 46-75 mm Hg respectively. It was concluded that a large proportion of the mortality and reduced viability at the time of delivery could be attributed to intra-uterine asphyxia.

RÉSUMÉ

L'auteur a effectué des observations cliniques sur la plupart de 749 porcelets naissants, issus de 75 portées; il a déterminé les concentrations sanguines de pH et de pCO_2, en utilisant des échantillons de sang prélevés dans l'artère ombilicale, chez 299 de ces porcelets. Il a développé une méthode d'évaluation clinique individuelle réduisant l'effet de l'erreur subjective dans l'évaluation de la viabilité, au moment de la naissance. Il a prélevé les échantillons de sang dans l'artère ombilicale, avant le début de mouvements respiratoires, et il a trouvé qu'une acidémie et une hypercapnie accrues étaient associées à une réduction de la viabilité. Chez les porcelets gravement déprimés, les valeurs du pH se situaient entre 6.50 et 6.95 et celles du pCO_2, entre 105 et 185 mm Hg; par contre, la moyenne de ces valeurs se situait respectivement entre 7.10-7.42 et 46-75 mm Hg, chez les porcelets bien vivants. L'auteur a conclu qu'on peut attribuer à l'asphyxie intrautérine, au moment de la naissance, une grande proportion de la mortinatalité et de la réduction de la viabilité.

INTRODUCTION

A definite relationship between the acid-base balance of umbilical blood and the clinical condition of the newborn infant was demonstrated by James *et al* in 1958 (8). This finding was compatible with those of earlier studies in animals in which asphyxia resulted in both respiratory and metabolic acidosis (3, 19). Interest in fetal acid-base studies was further stimulated when Saling (18) introduced a technique for sampling fetal capillary blood prior to and during delivery which enabled obstetricians to obtain details of fetal acid-base balance during labour.

Although a large volume of information relating to acid-base balance is presently available for the human infant, similar studies in the domestic animals have been limited. Acid-base values of venous blood from normal neonatal calves and from two calves in which delivery was delayed by dystocia have been presented by Moore (12). Detailed studies were made by Rossdale into the acid-base equilibrium of normal newborn foals (16) and of those affected by a neonatal respiratory distress syndrome (17). On the basis of *post-mortem* lesions and blood lactic acid levels,

*Animal Pathology Division, Health of Animals Branch, Canada Department of Agriculture, Animal Diseases Research Institute, P.O. Box 1400, Hull, Quebec.

Randall and Penny (14,15) suggested that asphyxia during parturition was an important factor in the etiology of stillbirth in the pig. In the present study blood pH and pCO_2 were determined in newborn piglets and a system for evaluating the viability of the piglet at parturition is proposed.

MATERIALS AND METHODS

ANIMALS

Seventy-five Yorkshire sows from an institutional herd were observed during parturition. The method of management of the sows during pregnancy and parturition was typical of many in use at the present time. In this herd all sows farrowed their first litters over a four-week period in March-April and their second litters in September-October and were then marketed. The farrowings observed were from 22 second-litter sows and 53 gilts. In the first 22 litters an attempt was made to collect a sample from every pig in the litter. During the second farrowing season, samples were collected from at least three normal piglets in each litter and from any depressed piglets in these litters.

COLLECTION OF BLOOD SAMPLES

A total of 318 samples were collected from 299 piglets during this study. All blood samples were collected during the period of apnea preceding the onset of respiration. To collect blood the umbilical cord was ruptured and one umbilical artery was cut with a scalpel approximately 2 cm from the umbilicus. Blood was collected in a heparinised glass capillary tube[1]. The tube was filled either by holding it closely against the proximal end of the cut artery and allowing it to fill by arterial flow or by capillary flow from the centre of the large bead of blood which commonly formed in the incision. Caution was taken to ensure that the sample did not become contaminated with air during or after collection. After collection a steel pin was placed into the tube which was then sealed with plasticene. The sample was then mixed by moving the pin within the tube with a magnet and stored in melting ice. The sample size from each piglet was approximately 125 μl. The umbilical cord was ligated with umbilical tape after collection of the sample.

MEASUREMENTS

Samples were analysed within two hours of collection and all analyses were made at 38°C. The pH and pCO_2 measurements were made with a PHM71 acid-base analyser[2] and the following electrodes: for pH, a glass capillary micro-electrode[3] and for pCO_2, a Severinghaus-type electrode[4]. The pCO_2 electrode was calibrated with gas mixtures of known carbon dioxide content and the pH electrode with two high-precision standard buffers[5]. In general only one sample could be taken prior to the onset of respiration but in the majority of severely depressed piglets duplicate samples were obtained. In some animals it was not possible to obtain sufficient blood to carry out a full analysis and in such cases a pH determination only was carried out.

VIABILITY SCORING SYSTEM

The scoring system which is in common use for the evaluation of the viability of the human infant (1) was used as a model for the system described. Observations were made on five parameters: namely respiration, heart rate, muscle tone, attempts to stand and colour; zero, one or two points were assigned to each parameter on the basis of a clinical evaluation. The criteria for each parameter were determined from earlier observations on parturition in the pig (13) and are illustrated in Table I. Assessment of the clinical status of each piglet was made during the first minute following delivery.

Post-mortem examinations were performed on all stillborn piglets. Those piglets whose internal organs were in a state of autolysis and degeneration were classified as *pre-partum* deaths and were assumed to have died in the days immediately prior to parturition. Stillborn piglets showing no degenerative changes were classified as *intra-partum* deaths. A detailed description of *post-mortem* lesions in *pre-partum* and *intra-partum* stillbirths has been given elsewhere (14).

[1]Radiometer, Copenhagen.

[2]Radiometer, Copenhagen.

[3]Radiometer electrode No. G298A.

[4]Radiometer electrode No. E5037.

[5]Radiometer, Copenhagen.

TABLE I. Clinical Criteria and Viability Scoring of Newborn Piglets

Criterion	Clinical Observation	Score
Quality of Respiration	Absent	0
	Apneic for 15 seconds, with continued dyspnea and irregularity	1
	Strong respiratory efforts within 15 seconds and establishment of normal rhythm	2
Heart rate	Absent	0
	< 120 per min	1
	> 120 per min	2
Muscle tone	Flaccid	0
	Poor	1
	Good	2
Attempts to stand	None within five min	0
	Within five min	1
	Within one min	2
Colour	Pallid	0
	Cyanotic	1
	Pink	2

RESULTS

In the 75 litters observed, 749 piglets were born. The mean litter size for the 53 gilts was 9.7 piglets and 10.9 for the 22 second litter sows. The mean duration of gestation was 115.3 days.

The number of piglets in different score classes is shown in Table II. Piglets scoring 8-9 (9.3% of those scored) were generally slower in getting to their feet but were otherwise comparable with piglets scoring 10 (79.8%).

Piglets scoring 6-7 points (3.3%) usually had dyspnea, poor muscle tone, cyanosis and were sluggish in getting to their feet. It was noticeable that such piglets were weaker than their litter mates during the first few hours of life and had difficulty in finding and maintaining a teat.

Piglets scoring 1-5 (4.1%) could be subdivided into two groups. The first comprised five piglets which were extremely depressed at birth. Respiration was established with difficulty in these piglets and a regular respiratory rhythm was not established until 15 min after delivery. In four cases the piglets did not attempt to stand until one hour after delivery and were unsteady for several hours. The second, and larger group, was made up of animals in which the only signs of life were a slow heart beat and occasional weak respiratory gasps in a few piglets. The heart rate was always less than 120 per min (mean 44)

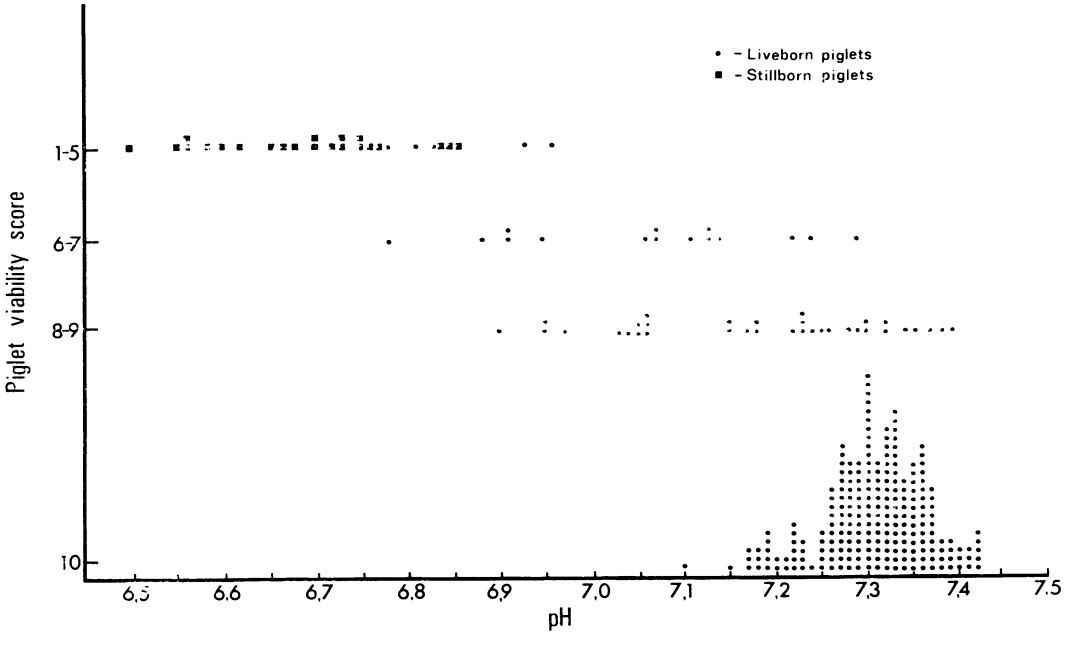

Fig. 1. Relationship between the pH of arterial blood samples at the time of delivery and the viability score of the newborn piglet. Individual symbols represent the value for each piglet sampled.

TABLE II. The Distribution of Newborn Piglets in Different Viability Classes

Viability Point Score (max. 10)	Number of Piglets Recorded
10	582
8-9	68
6-7	24
1-5	30
0	25
Unscored	20
Total	749

and persisted for 5.3 min on average. Respiration was always limited to less than five gasps. *Post-mortem* findings in such piglets were similar to those described by Randall and Penny for *intra-partum* stillbirths (14). Piglets showing no evidence of viability (score 0) could also be divided into two groups. The first contained 12 mummified piglets and *pre-partum* stillbirths while the second group of 13 piglets were classified as *intra-partum* deaths at *post-mortem* examination.

Gasping may occasionally occur during delivery of a piglet but generally respiratory movements do not begin until approximately ten seconds after delivery (13). Initially the piglet makes strong irregular gasps which appear to clear the upper respiratory tract and are followed by rapid shallow respiratory movements before a regular respiratory rhythm is established. The first few gasps were not considered to be respiratory in terms of gaseous exchange and samples from piglets which had made one or two gasps only were included with those taken during the period of apnea. Care was taken to exclude samples from piglets which had gasped more than three times or in which rapid breathing was established.

The individual pH and pCO_2 determinations are illustrated in Figs. 1 and 2 and the mean values for each viability group are summarized in Table III. Mean values for the different viability classes during the two farrowing seasons were not significantly different and the data relating to the two seasons were pooled.

There was some correlation between clinical assessment and arterial blood pH within the group of piglets scoring 1-5 points. The pH values for the five piglets in which respiration was established (Fig. 1) were at the upper end of the range and it was also noted that the heart rate in the stillborn piglets was related to the pH of the arterial blood. The heart action in piglets with a blood pH between 6.50 and 6.70 was

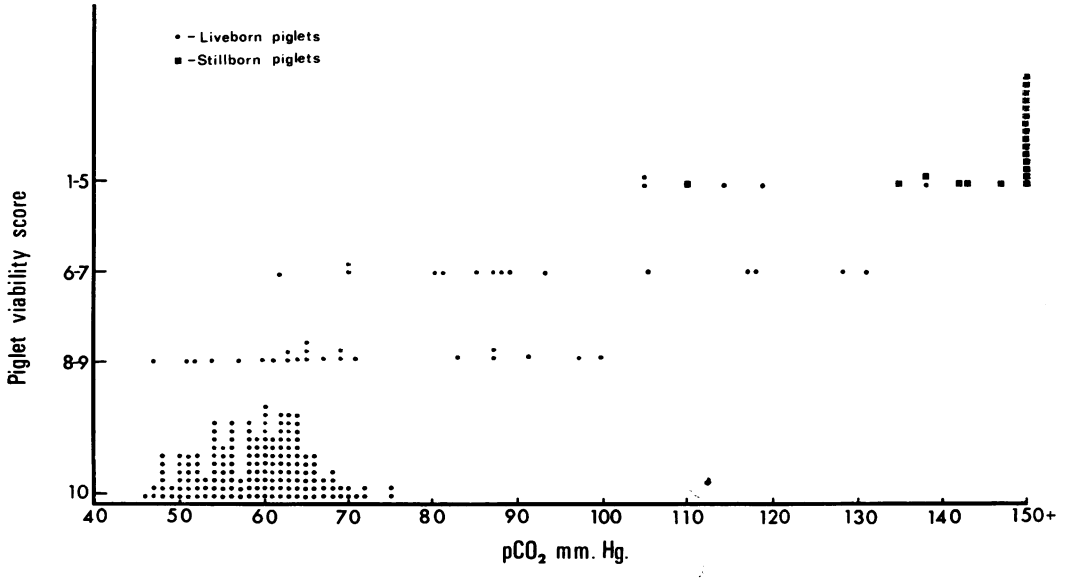

Fig. 2. Relationship between the pCO_2 of arterial blood sampled at the time of delivery and the viability score of the newborn piglet. Individual symbols represent the value for each piglet sampled.

TABLE III. Mean Levels (± s.e.) of pH and pCO_2 in Umbilical Arterial Blood in Newborn Piglets of Varying Viability

Viability Score	pH	No. of Piglets Sampled	pCO_2 (mm Hg)	No. of Piglets Sampled
10	7,31 ± 0,004	223	58,8 ± 0,49	161
8-9	7,18 ± 0,023[c]	34	69,1 ± 3,2	22
6-7	7,06 ± 0,037[d]	15	93.4 ± 5,6[d]	15
1-5[a]	6,86 ± 0,031[d]	5	116,0 ± 6,0[d]	5
1-5[b]	6,69 ± 0,039[d]	22	156,4 ± 4,4[d]	21

[a]Respiration established with subsequent survival for > 5 min
[b]*Intra-partum* stillbirths
[c]Significantly different ($p < 0.05$) from value for piglets scoring 10
[d]Significantly different ($p < 0.01$) from value for piglets scoring 10

irregular and varied from fibrillation with spasmodic beats to slow regular beats at a rate of 30 per minute. In piglets with a pH of 6.70 - 6.80 the heart rate varied from 30-90 per minute and in those piglets in which the pH was above 6.80 the range was 84-150 per minute.

DISCUSSION

A major problem in a study of this nature is the influence of subjective variation between observers as to the viability of the animal. In general, it is still necessary to rely on observational criteria for a rapid clinical assessment of viability in the neonate. In 1958, in an attempt to reduce the variability in the evaluation of the human neonate, Apgar *et al* (1) introduced a system which has become widely accepted in human obstetrics. This system was used as a model for scoring the viability of the newborn piglet although it was modified so as to be more applicable to the piglet. It is accepted that imperfections may be present in such a system but the observation of a small number of fixed criteria removes many subjective errors and permits a rapid evaluation of the piglet's viability.

It would have been preferable to obtain the blood samples under strictely anaerobic conditions; however, this was not practical under the present experimental conditions. Kubli *et al* (11) concluded that the changes occurring in blood pH and pCO_2 resulting from loss of CO_2 to the atmosphere during the careful collection of the sample into a capillary tube were minimal.

At the completion of delivery, both the pH and pCO_2 of blood samples taken from the umbilical arteries of piglets scoring 10 were higher than those reported in infants (2, 10, 11) and it is possible that higher levels of bicarbonate may be present in piglets' blood at birth. High levels of bicarbonate in the blood of fetal piglets of 106 days of gestation were reported by Cummings and Kaiser (4). It seems probable that the piglet is subjected to a short period of asphyxiation during the terminal stages of delivery, as has been observed in the human infant (7) and in the horse (16), and that the pH and pCO_2 values of normal piglets at birth reflect the subsequent state of acidemia. However, since the delivery period in the pig is short, the average interval between the delivery of individual piglets being about 15 min (9, 13), the degree of hypoxia to which the piglet is subjected should be slight.

In this study there was a definite relationship between reduced viability scores and increases in both blood hydrogen-ion concentration and pCO_2. Mean values for both parameters were significantly different between viability classes. However, it can be seen (Figs. 1 and 2) that some overlapping between the values for different classes was present. This overlapping was more marked in animals with a score of six or more. These results are similar to those in man where a strong association between increasing acidemia and hypercapnia in the neonate is generally associated with intra-uterine asphyxiation (2, 8) and fetal distress. Several workers have, however, indicated that it is difficult to forecast the Apgar score (1) of the infant from a blood sample taken just prior to delivery (2, 6, 20). One probable explanation for the variability in pH and pCO_2 values

in those piglets scoring 8-9 is that the scoring system used is not specific for asphyxia and piglets with no marked acid-base disturbance were weak for some other reason.

In this study it was not possible to obtain maternal values for comparison with fetal values. It was felt that samples collected from normal piglets in any litter should indicate any possible influence of maternal acid-base disturbance on fetal values and comparison of pH and pCO_2 values of depressed piglets with those of their normal litter mates should be a close estimate of variations in the degree of asphyxiation. Occasionally piglets with a high viability score were found to have a relatively severe acidosis at birth, the etiology of which was not determined.

The severity of the acidemia and hypercapnia in piglets scoring 1-5 was more marked than that reported for similar human infants (6, 8). The pH and pCO_2 values observed were similar to those in fetal lambs which had been asphyxiated by occlusion of the umbilical cord (5). All piglets with a score of 1-5 and a large proportion of those scoring 6-7 were delivered with the umbilical cord already ruptured and it is possible that the extremely high pCO_2 and low pH levels in the blood of these piglets may have resulted in part from an inability to transmit excess hydrogen-ions and carbon dioxide to the maternal circulation.

Marked acidemia and hypercapnia were present in the blood of the majority of piglets scoring seven or less indicating that these piglets had been subjected to asphyxiation prior to or during delivery. These results support the earlier suggestion (14) that asphyxia during parturition is an important factor in the etiology of stillbirth in the pig. Furthermore, since it is apparent that asphyxiation during delivery may directly influence the viability of the piglet for several hours after delivery, some consideration should be given to its importance as an adverse influence on the piglet's ability to survive the hazards of its perinatal environment.

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