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ARTERIAL ACID-BASE MEASUREMENTS IN 1—3 DAYS OLD PIGLETS*

By

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ANDRÉN, BIRGITTA: *Arterial acid-base measurements in 1—3 days old piglets.* Acta vet. scand. 1982, *23*, 581—591. — A method of percutaneous arterial blood sampling in piglets has been developed and determinations of arterial pH, pCO_2, pO_2, BE, HCO_3^-, LA and Hb have been performed in 121 piglets 1—3 days of age. The validity of these measurements has been tested and proved valid for clinical practice with the exception of pO_2 and LA values. The correlations with age were statistically significant but poor and therefore the mean values are presented as reference values. These were: pH: 7.423±0.082, pCO_2: 4.98±0.74 kPa, BE: 0.4±4.1 mmol/l, HCO_3^-: 23.0±3.2 mmol/l and Hb: 88±14 g/l.

arterial blood; acid-base; piglet.

In order to evaluate the metabolic disorders in piglet diseases particularly diarrhoea, acid-base determinations are of great value. There are, however, few investigations reported concerning acid-base metabolism in piglets. From studies of umbilical arterial blood pH and pCO_2 (partial pressure of carbon dioxide) *Randall* (1971) concluded that hypoxia during parturition could cause high piglet mortality and reduced viability at the time of delivery.

Arterial blood gas tensions and pH values (*Randall* 1972) and venous acid-base determinations (*Wilhelm et al.* 1977) in piglets from birth to 2 days of age suggested that a moderate metabolic and respiratory acidosis, presented at birth, was corrected in a few hours.

Piglets with diarrhoea had lower venous pH and BE (base excess) values than normal piglets (*Kutas & Szabó* 1971).

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In acid-base evaluations arterial blood is preferable to venous (*Siggaard-Andersen* 1974). Catheterization of an artery is, however, inconvenient in clinical practice and therefore it was the purpose to test the validity of acid-base measurements of arterial blood collected by percutaneous arterial puncture. In addition reference values for pH, pCO_2, pO_2 (partial pressure of oxygen), BE, HCO_3^- (bicarbonate), LA (lactic acid) and Hb (haemoglobin) in piglets 1—3 days of age are presented.

MATERIAL AND METHODS

Animals

A total of 121 piglets, 1—3 days of age, from 24 litters, selected at random, were used in this study. Swedish Landrace, Yorkshire or mixed breed were represented. The piglets were divided into 2 groups. Group I consisted of piglets used for percutaneous sampling. This group contained 113 animals reared at conventional farms. Each piglet in this group was used only once. Group II consisted of 8 experimental piglets (aged 12—72 h), bred in the Department of Medicine I. They were sampled by arterial catheterization, 2—4 times each at 12—24 h interval. The total number of samples collected was 27.

All piglets were allowed to suckle their dams freely. They were all considered healthy since no clinical signs of illness either of the dam or of the piglets were noted. The age distribution of the piglets at the time of sampling is presented in Table 1.

Table 1. Number of piglets and ages when sampled in Group I and II.

	Age at sampling		
Group	12—24 h	25—48 h	49—72 h
I	48	34	31
II	16	7	4

Sampling procedure

Group I (percutaneously sampled piglets). To minimize excitement during sampling the piglet was held as gently as possible in a supine position with its neck stretched forwards and its forelimbs stretched backwards to expose the jugular fossa. The carotid artery was punctured with a 0.8×35

mm needle fitted to a syringe (B Arterial Blood Sampler, Radiometer, Copenhagen). The dead space of the syringe and needle was previously filled with heparin solution (5000 IU/ml). The needle was inserted at a point 1.5—2 cm cranial to the manubrium sterni and 1—1.5 cm lateral to the midline and directed approximately towards the elbow tip of the opposite side. A criterion of arterial puncture was that the syringe was filled automatically in a continuous stream with blood. If the arterial puncture was not successful within 60s the piglet was let loose for a couple of minutes' rest before the next attempt. The syringe was filled within 30s with 1 ml blood. After sampling the syringe was sealed with a metal cap and placed in icewater until analysis within 2 h. 0.3 ml of the sample was used for haemoglobin determination and 0.1 ml was mixed with 1 ml perchloric acid and used for LA determination. After blood sampling the rectal temperature was measured.

Group II (catheterized piglets). In the newborn piglet one of the carotid arteries was catheterized after skin incision and the vessel located and exposed by blunt dissection during local anaesthesia. The cannula used was a 20 cm long nylon cannula with an outer diameter of 1.02 mm (Portex; Hythe, Kent). About 3 cm of its length was inserted in the cardiac direction in the artery and the rest secured to the body with adhesive tape so that the free end of the cannula to which a three-way stopcock (K-69 Pharmaseal) was attached, was placed at the back of the piglet. Blood collection was then possible with the animal standing. After the first portion had been discarded about 1 ml of blood was drawn in a heparinized 2 ml disposable syringe (Mediplast). It was then sealed with a metal cap and kept in icewater until analysed within 20 min. The cannula was rinsed and filled with heparinized saline solution between each sampling. The blood samples were collected at 12, 24, 48 and 72 h after birth and handled in the same way as those of Group I.

Analysing procedure

The arterial blood was analyzed for pH, pCO_2 and pO_2 in an automatic acid-base analyzer (IL 413 or IL 613 Instrumentation Laboratory S.p.A. Milan). Both instruments were equipped with the same electrodes. The IL 413 was calibrated manually and the IL 613 automatically every twentieth minute. The composition

of the 2 gas mixtures used as calibrating standards was 5 % CO_2, 12 % O_2, 83 % N_2 and 10 % CO_2, 90 % N_2 respectively analyzed to the nearest 0.05 % (AGA, Stockholm). The BE and HCO_3^- values were calculated from the Siggaard-Andersen nomogram. The BE values were determined at the actual haemoglobin concentration which was measured spectrophotometrically as cyanmethemoglobin. The values for pH, pCO_2 and pO_2 were determined at 37°C and corrected to the individual body temperature. Once weekly the IL 413 and IL 613 were checked with ampoules of a gas equilibrated buffer solution (IL Blood Gas Control). The reproducibilities of pH, pCO_2 and pO_2 measurements were tested with duplicate determinations and expressed as correlation coefficients which varied between 0.89—0.98.

Blood LA was determined enzymatically (Boehringer Mannheim GmB UV test).

The disposable syringe and the B 109 Arterial Blood Sampler were tested for the possibility of gas diffusion during storage in icewater. The pO_2 values rose on average 0.4 kPa and 0.2 kPa respectively for each syringe while the pCO_2 values were 0.22 kPa and 0.14 kPa lower respectively after 3 h of storage in icewater.

Statistical analyses, by standard methods (*Colton* 1974), included differences between mean values tested by Student's t-test and regression analysis by the method of least squares.

RESULTS

The correlations of pH, pCO_2, pO_2, BE, HCO_3^-, Hb and LA with age in each group are shown in Table 2. The values for pH, BE, HCO_3^-, and Hb of Group I were inversely correlated and pCO_2 positively correlated to age. The pH and Hb values of Group

Table 2. Correlation with age of pH, pCO_2, pO_2, BE, HCO_3^-, Hb and LA of Group I and II.

Group		pH	pCO_2	pO_2	BE	HCO_3^-	Hb	LA
I	r*	—0.51	0.25	0.24	—0.31	—0.39	—0.24	—0.07
	P**	<0.001	<0.01	<0.05	<0.001	<0.001	<0.01	>0.05
II	r	—0.55	0.30	0.05	—0.47	—0.37	—0.68	0.11
	P	<0.01	>0.05	>0.05	<0.05	>0.05	<0.001	>0.05

* r = correlation coefficient.

** P = level of probality of r different from zero.

Table 3. Comparison of the standard deviation (s) of pH, pCO_2, pO_2, BE, HCO_3^-, Hb and LA as a function of age (regression) and independently of age (mean) in Group I and II.

Group		pH	pCO_2	pO_2	BE	HCO_3^-	Hb	LA
I	s (regression)	0.069	0.72	2.1	3.9	2.9	14	1.8
	s (mean)	0.081	0.74	2.2	4.1	3.2	14	1.8
II	s (regression)	0.037	0.41	1.8	2.1	1.9	10	1.5
	s (mean)	0.045	0.43	1.8	2.4	2.0	14	1.5

Table 4. The mean values and standard deviation (s) of pH, pCO_2, pO_2, BE, HCO_3^-, Hb and LA of Group I and II.

		I	P*	II
pH	n	113		27
	mean	7.423	>0.05	7.423
	s	0.081		0.045
pCO_2 kPa	n	113		26
	mean	4.98	>0.05	4.80
	s	0.74		0.43
pO_2 kPa	n	113		27
	mean	8.5	<0.001	10.4
	s	2.2		1.8
BE mmol/l	n	113		26
	mean	0.4	>0.05	-0.4
	s	4.1		2.4
HCO_3^- mmol/l	n	113		26
	mean	23.0	>0.05	22.6
	s	3.2		2.0
Hb g/l	n	112		27
	mean	88	>0.05	90
	s	14		14
LA mmol/l	n	36		27
	mean	4.7	<0.001	2.0
	s	1.8		1.5

* P: level of probability of difference between the mean values.

II were also inversely correlated to age while pCO_2, BE and HCO_3^- were not. No correlation was found between age and LA or pO_2 in either group. No significant differences were found between the 2 groups regarding the regressions of pH, pCO_2, BE, HCO_3^- and Hb on age.

The standard deviations of the regressions of pH, pCO_2, pO_2, BE, HCO_3^-, Hb and LA on age and those independantly of age in the 2 groups coincided with the exception of pH in both groups and Hb in Group II (Table 3).

In Table 4 the mean values and s for pH, pCO_2, pO_2, BE, HCO_3^-, Hb and La of respective groups are presented. No significant differences between the mean values of the parameters of the 2 groups were found except for pO_2 and LA but the variations were throughout larger in Group I as indicated by the larger standard deviations.

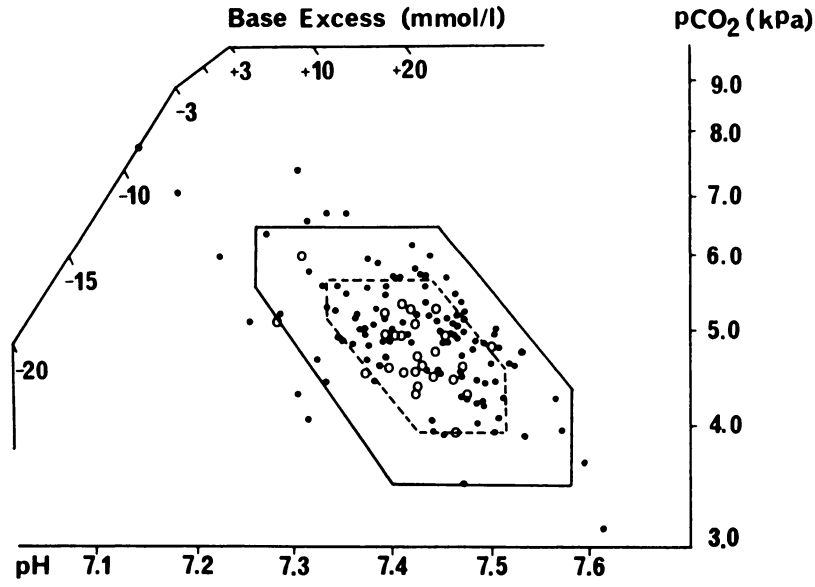

Figure 1. The distribution of the acid-base status of piglets put in the Siggaard-Andersen nomogram.

● Group I
○ Group II

The normal variations of respective group is shown by the hexagons which are derived from the mean values and twice the standard deviations of pH, pCO_2 and BE.

———— Group I
– – – – – – Group II

All the acid-base measurements of the piglets in both groups are plotted in the Siggaard-Andersen nomogram (Fig. 1). The normal variations are shown by the hexagons which are derived from the mean values ± 2 s of pH, pCO_2 and BE.

DISCUSSION

The acid-base calculations in this study were based upon the Siggaard-Andersen nomogram constructed for human arterial blood. The applicability of the nomogram has been tested on calf, cattle, sheep and pig arterial blood and proved valid (*Lebeda & Bouda* 1969, *Phillips* 1970, *Scott & McIntosh* 1975).

The BE values in this study were calculated at the actual haemoglobin concentration. *Rooth & Thalme* (1970) and *Rooth & Jacobsson* (1971) pointed out that in fetal or infant blood the BE values of extracellular fluid (BE_{ECF}) were more valid than those of plasma (BE_p) or blood (BE_B) since the relatively larger extracellular space of infants may cause variations in the BE values. As the ECF is considered to be about 3 times the plasma volume the BE_{ECF} is often calculated at a haemoglobin concentration of 50 g/l which represents approximately one third of the total haemoglobin concentration of human blood (*Monti & Rooth* 1970). A comparison between the BE_B values of this study and calculated corresponding BE_{ECF} values did not show any significant differences ($P > 0.05$). Consequently there seems to be no advantage in using BE_{ECF} instead of BE_B for clinical work.

The value of using arterial instead of venous blood for accurate acid-base determinations is well established. Arterial blood drawn from an indwelling arterial catheter should give the most accurate values possible and thus these values from piglets of Group II represent the reference values of pH, pCO_2, pO_2, BE, HCO_3^-, Hb and LA in this study.

The influence on age of acid-base, Hb and LA values were tested in Group II and the correlations, although statistically significant, were poor (Table 2). Largely, the same relationships were found in Group I. In addition, as shown in Table 3, the standard deviations of the acid-base variables, Hb and LA values of Groups I and II as a function of age and independantly of age were compared and the differences were small. Accordingly there was little improvement in evaluating these variables by considering the age during 12—72 h after birth in piglets. Subse-

quently the mean values of pH, pCO_2, pO_2, BE, HCO_3^-, Hb and LA of both groups were compared and no significant differences were observed with the exception of the pO_2 and LA values (Table 4). There are considerable sources of error connected with percutaneous arterial blood sampling in piglets which may explain the differences in pO_2 and LA values and the relatively larger variations of the values of Group I (Fig. 1).

Piglets are by nature difficult animals to restrain quietly. Anxiety or excitation during blood sampling may cause changes in pCO_2 or pO_2 values due to hyperventilation or apnoea (*Siggaard-Andersen* 1974).

The influence of posture and excitement of acid-base variables has been tested in 11 piglets (*Andrén* unpublished). The LA values were significantly influenced both by changes in posture and of excitement and this may be due to increased cathecolamine secretion (*Ganong* 1975). This may be one reason why the LA values of Group I were higher than those of Group II. Changing posture lowered the pO_2 values and excitement during percutaneous sampling in a supine position may depress the pO_2 values further. This seems to indicate that excitement during sampling may be of greater importance than changes in posture. The other acid-base variables were unaffected by both excitation and change in posture.

Another explanation for the pO_2 difference between the 2 groups may be venous admixture in samples of Group I. This possibility cannot be completely disregarded when sampling percutaneously. Venous admixture can occur in two ways. First the needle may pass through the jugular vein before entering the artery. This will fill the needle with venous blood by capillary action. This error, however, may be neglected since the volume of the needle is only approximately 2.4 % of the whole sample volume. Secondly, the blood sample may consist of venous blood. The construction of the syringe "B 109 Arterial Blood Sampler" does not permit filling unless there is a positive pressure in the vessel in which the needle is situated. In a supine position during sampling the piglet is occasionally screaming and struggling and the resulting increase of the intraabdominal pressure may cause a pressure rise in the jugular vein enough to fill the syringe with venous blood.

Although the method of percutaneous sampling using the B 109 Arterial Blood Sampler is subjected to disadvantages it

may be considered acceptable for clinical purposes. Even if the validity is disputable in evaluating a single sample the diagnostic evaluation of a population of samples should be valid. The values for pO_2 and LA cannot, however, be regarded as valid. It is also important that the piglet is handled as gently as possible during sampling to minimize excitation. Care should also be taken that the syringe is filled in a constant flow and not coincident with abdominal strains.

The acid-base values of the piglets in this study correspond well to those of *Randall* (1972) who considered the adjustement of the umbilical arterial acid-base status to adult values to be completed a few hours after birth. This author considered these

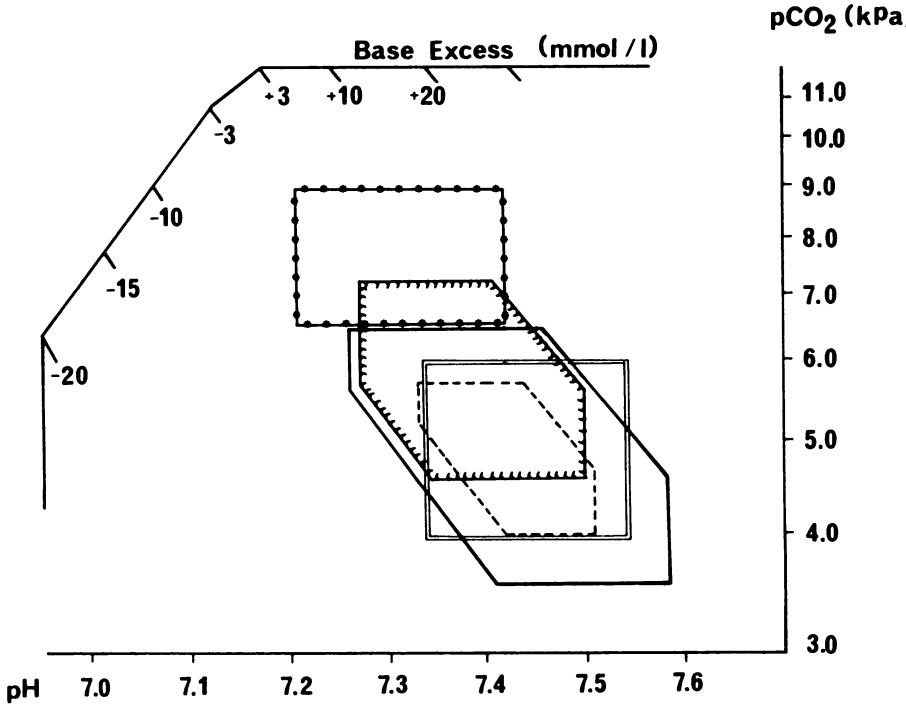

Figure 2. Acid-base measurements in piglets reported by different authors represented as hexagons and rectangels derived from the mean values for pH, pCO_2 and BE ± 2 s and put in the Siggaard-Andersen nomogram.

——— Group I (1—3 days old piglets)
– – – – – – Group II (1—3 „ „ „)
●●●●●●●●● *Randall* 1972 (newborn piglets)
═══ *Randall* 1972 (24 h old piglets)
‹ ‹ ‹ ‹ ‹ ‹ ‹ *Wilhelm et al.* 1977 (24 h old piglets)

relatively low pO_2 values, (lower than those found in our Group II), may be due to excitement of the animal during sampling. Anatomical differences in the vessels of the umbilicus can cause uncertainty of the catheter position (*Hakkarainen* pers. comm.) which may also explain the lower pO_2 values.

Other studies of the acid-base balance of piglets 2—3 days of age have been performed on venous blood (*Kutas & Szabó* 1971, *Wilhelm et al.* 1975) and as expected these results differ from ours mainly with respect to the pH, pO_2 and pCO_2 values which were lower (pH and pO_2) and higher (pCO_2) respectively compared to ours.

The different acid-base values are illustrated and compared to ours in the Siggaard-Andersen nomogram (Fig. 2). Venous blood used for acid-base determinations will move the values towards the upper left corner of the nomogram. This will spuriously indicate a respiratory acidosis. All the values of the newborn piglets (*Randall* 1972) are found outside and to the upper left of those found in our study.

Acid-base values of newborn calves correspond well to those of piglets (*Schlerka et al.* 1979) while in 1—3 day old children the pH and pCO_2 values of arterial blood are slightly lower than those of piglets (*Koch & Wendel* 1968).

It is, however, difficult to compare results obtained from different authors since various techniques in analyzing and blood sampling have been used.

REFERENCES

Colton, T.: Statistics in Medicine. Little, Brown and Company, 1974.

Ganong, W. F.: Review of Medical Physiology. 7th Ed. LMP Los Altos, California 1975.

Koch, G. & H. Wendel: Adjustement of arterial blood gases and acid-base balance in the normal newborn infant during the first week of life. Biol. Neonat. 1968, *12*, 136—161.

Kutas, F. & J. Szabó: Effect of diarrhoea on the water and acid-base balance in piglets with enteric colibacillosis. Acta Vet. Acad. Sci. Hung. 1971, *21*, 117—125.

Lebeda, M. & J. Bouda: The applicability of Siggaard-Andersen's nomogram for the venous blood of cattle. Vet. Med. (Praha) 1969, *14*, 75—80.

Monti, M. & G. Rooth: Respiratory compensation to metabolic acid-base disturbances. Scand. J. clin. Lab. Invest. 1970, *26*, 381—383.

Phillips, G. D.: The assessment of blood acid-base parameters in ruminants. Brit. vet. J. 1970, *126*, 325—331.

Randall, G. C. B.: The relationship of arterial blood pH and pCO_2 to the viability of the newborn piglet. Can. J. comp. Med. 1971, *35*, 141—146.

Randall, G. C. B.: pH values and blood-gas tensions in the normal piglet during the first 48 hours of life. Biol. Neonat. 1972, *20*, 68—73.

Rooth, G. & L. Jacobson: The value and validity of base excess $_{ECF}$ in perinatal acid-base studies. Scand. J. clin. Lab. Invest. 1971, *28*, 283—286.

Rooth, G. & B. Thalme: Validity of buffer base and base excess in perinatal acid-base studies. Amer. J. Obstet. Gynec. 1970, *108*, 282—287.

Schlerka, G., W. Petschenig & J. Jahn: Untersuchungen über die Blutgase, den Säure-Basen-Haushalt, Elektrolytgehalt, einige Enzyme und Inhaltsstoffe im Blut neugeborene Kälber. (Investigations on blood-gases, acid-base-relationship, electrolytes, some enzymes and other parameters in blood from newborn calves). Dtsch. tierärztl. Wschr. 1979, *86*, 95—100.

Scott, D. & G. H. McIntosh: Changes in blood composition and in urinary mineral excretion in the pig in response to acute acid-base disturbances. Quart. J. exp. Phys. 1975, *60*, 131—140.

Siggaard-Andersen, O.: The Acid-Base Status of the Blood. 4th Ed. Munksgaard, Copenhagen 1974.

Wilhelm, U., H. Maurer-Schweizer & K. Walser: Blutgasverhältnisse und Säure-Basen-Haushalt bei neugeborenen Ferkeln nach ungestörtem Geburtsverlauf. (pH value, gas-tension and base excess in the venous blood of newborn piglets). Berl. Münch. tierärztl. Wschr. 1977, *90*, 92—95.

SAMMANFATTNING

Arteriell syra-bas mätning hos 1—3 dygn gamla spädgrisar.

En metod för att ta arteriella blodprov på spädgris has utarbetats och bestämningar av arteriellt pH, pCO_2, pO_2, BE, HCO_3^-, LA och Hb har utförts på 121 spädgrisar i åldrarna 1—3 dygn. Validiteten av dessa bestämningar har prövats och de har visat sig vara användbara för praktiskt kliniskt bruk, med undantag för pO_2- och LA-värdena. Syra-bas värdena var signifikanta men ringa korrelerade till ålder och som referensvärden anegs därför medelvärden. Dessa var: pH; 7,423± 0,082, pO_2; 4,98±0,74 kPa, BE; 0,4±4,1 mmol/l, HCO_3^-; 23,0±3,2 mmol/l och Hb; 88±14 g/l.

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