



Acid-base status and blood gas tensions of neonatal buffalo calves under normal and forced calving

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Homeostatic equilibrium in the body depends a lot on the acid base balance of blood (Carlson 1995). Minor alterations in blood pH can alter the cellular functions of the body (Robertson 1989). During delivery the vitality of the fetus is of decisive influence on the choice of obstetrical treatment. Signs of life can be obtained by arousing the inter-digital claw reflex, swallowing reflex, eyeball/eyelid reflex, anal reflex, detection of spontaneous fetal movements, strength and rate of heart beat and tension or pulsations of the umbilical cord vessels (Schuijt and Taverne 1992). In protracted dystocia, alterations in cardio-pulmonary functions may lead to impaired carbon dioxide elimination and tissue perfusion causing disturbances in the acid-base equilibrium of the blood (Gurtler *et al.* 1989). Changes in acid-base balance provide adequate information for the early phase of the disease and therapeutic effectiveness against it (Angelov 2009). Determination of the fetal acid-base status gives additional quantitative information, which is fairly correlated with the vitality of a calf (Schuijt and Ball 1986). The auricular artery and jugular vein blood provides the most accurate information with respect to acid base status of the blood leaving the fetus and returning from the placenta, respectively (Gemelli 2003). However, there is limited information on acid-base parameters in neonatal buffalo calves borne normally or borne in stress due to dystocia. So the present study is aimed to evaluate the acid base status of buffalo fetus at parturition in normal and forced calving.

Selection of animals: Seventeen normally delivered (ND) and 17 forcefully delivered (FD) buffalo calves were included

in the study. FD calves were delivered following correction of malpresentation and forced traction. Dystociac buffaloes had been in labor for 4 to 8 h. The dams of all the calves were in their first to second parity.

Blood collection: Blood samples were taken by the standard method from auricular artery and jugular vein puncture, with the calves in lateral recumbency, under anaerobic conditions immediately at the time of birth and subsequently at 1, 2, 3, 4 and 5 h of life in heparinized vials (10 IU heparin/ml blood). The 5 ml blood samples were capped and placed on ice immediately so as to avoid alteration in blood gas tension. Actual blood pH, partial pressure of carbon dioxide ($p\text{CO}_2$), partial pressure of oxygen ($p\text{O}_2$), actual bicarbonate (HCO_3^-), standard bicarbonate (SBC), actual base excess (ABE) and standard base excess (SBE) were determined by blood gas analyzer within 1 h after sampling at 37°C. The values for pH and base excess were taken as the criteria for recovery from acidemia.

Statistical analysis: The data were analyzed by the use of the statistical package for social sciences system for windows. sionse parameters and the differences between ND and FD for acid-base imbalances and blood changes were tested using 2 × 2 analysis of variance (ANOVA) with significant interaction at 5% level. The significant interactions were tested using Duncan's multiple range test. Differences in mean ($\bar{X} \pm \text{SEM}$) acid-base imbalances and blood changes in the two groups with unequal variances were tested with chi square tests of independence subjected to Bonferroni correction as per the methods described previously (Zar 2008).

The acid-base status and blood gas dynamics in the arterial and venous blood of ND and FD calves are shown in Table 1. Any fluctuation in the acid-base parameters seemed to indicate the dynamic changes occurring due to impending calving.

Blood pH: Blood pH was within the normal limits in the ND calves, however, in FD calves, pH was significantly ($P < 0.05$) lower, both in the arterial and venous blood.

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Table 1. Acid base and blood gas values in arterial (a) and venous (v) blood of neonatal buffalo calves delivered normally and forcefully (mean±SEM)

Group	Unit	Hours after calving										Mean±SEM	
		0		1		2		3		4		5	
Parameter		ND	FD	ND	FD	ND	FD	ND	FD	ND	FD	ND	FD
pH (a)	—	7.37 ±0.02 ^a	6.91 ±0.07 ^b	7.39 ±0.03 ^a	6.93 ±0.04 ^b	7.39 ±0.05 ^a	6.98 ±0.06 ^b	7.39 ±0.01 ^a	7.23 ±0.02 ^c	7.36 ±0.04 ^a	7.35 ±0.08 ^{ac}	7.32 ±0.02 ^a	7.38 ±0.04 ^{ad}
pH (v)	—	7.35 ±0.01 ^a	6.94 ±0.09 ^b	7.36 ±0.04 ^a	6.97 ±0.07 ^b	7.36 ±0.04 ^a	6.99 ±0.08 ^b	7.35 ±0.06 ^a	7.25 ±0.08 ^c	7.36 ±0.05 ^a	7.34 ±0.09 ^{ac}	7.35 ±0.04 ^a	7.45 ±0.04 ^d
pCO ₂ (a)	mm Hg	51.3 ±3.8 ^a	51.5 ±2.5 ^a	45.7 ±2.2 ^b	49.5 ±2.4 ^a	41.0 ±1.6 ^c	45.5 ±2.1 ^b	39.7 ±1.7 ^c	40.3 ±3.2 ^c	38.7 ±1.9 ^c	37.0 ±1.9 ^c	38.0 ±1.2 ^c	36.4 ±2.6 ^c
pCO ₂ (v)	mm Hg	51.5 ±1.3 ^a	59.0 ±2.1 [*]	51.0 ±1.2 ^a	57.7 ±2.6 [*]	50.8 ±1.3 ^a	55.3 ±3.0 [*]	50.5 ±1.0 ^a	53.7 ±2.7 ^a	49.8 ±1.2 ^a	52.0 ±3.2 ^a	48.3 ±1.3 ^b	50.6 ±2.7 ^a
pO ₂ (a)	mm Hg	42.0 ±3.5 [*]	36.3 ±2.7 [*]	51.0 ±1.2 ^a	40.6 ±1.9 ^a	57.3 ±3.0 ^b	44.5 ±3.4 ^{ab}	64.3 ±1.9 ^d	50.5 ±3.7 ^b	67.7 ±1.3 ^d	54.1 ±2.9 ^{bc}	73.0 ±5.6 ^d	57.8 ±2.4 ^c
pO ₂ (v)	mm Hg	35.3 ±1.8 ^a	33.0 ±3.3 ^a	37.8 ±1.7 ^a	34.3 ±2.6 ^a	39.8 ±1.7 ^b	36.5 ±1.8 ^{ac}	40.5 ±1.4 ^{ab}	38.5 ±2.3 ^b	41.3 ±1.5 ^b	39.3 ±2.0 ^{bc}	42.5 ±1.4 ^b	42.3 ±1.8 ^b
HCO ₃ ⁻ (a)	mmol/L	25.8 ±1.3 ^a	24.8 ±1.8 ^a	26.8 ±1.0 ^{ab}	24.6 ±2.1 ^a	26.4 ±1.0 ^{ab}	24.0 ±1.7 ^a	25.9 ±1.5 ^a	23.6 ±1.2 ^a	27.6 ±0.5 ^b	23.4 ±2.0 ^a	28.0 ±1.3 ^b	25.2 ±1.3 ^a
HCO ₃ ⁻ (v)	mmol/L	28.3 ±1.9 ^b	23.7 ±1.8 ^a	28.1 ±1.2 ^b	23.1 ±1.0 ^a	27.7 ±1.1 ^b	24.1 ±1.5 ^a	28.2 ±1.4 ^b	23.1 ±1.3 ^a	27.8 ±1.1 ^b	24.5 ±1.2 ^a	27.9 ±1.8 ^b	24.2 ±1.7 ^a
SBC (a)	mmol/L	24.3 ±1.2 ^a	23.5 ±1.4 ^a	25.5 ±1.8 ^a	23.3 ±1.1 ^a	23.7 ±2.6 ^a	24.0 ±1.3 ^a	24.2 ±1.4 ^a	23.2 ±1.7 ^a	23.0 ±1.7 ^a	23.6 ±1.2 ^a	26.2 ±1.6 ^a	22.8 ±1.8 ^a
SBC (v)	mmol/L	25.9 ±1.8 ^a	22.0 ±3.1 ^a	26.1 ±1.9 ^a	22.1 ±2.8 ^a	25.6 ±1.8 ^a	23.5 ±1.8 ^a	26.0 ±1.1 ^a	22.6 ±1.8 ^a	25.8 ±1.0 ^a	24.8 ±1.2 ^a	25.8 ±1.8 ^a	24.6 ±1.4 ^a
ABE (a)	mmol/L	-1.63 ±0.33 ^a	-0.52 ±0.21 ^b	1.30 ±0.53 ^a	-1.43 ±0.38 ^b	1.80 ±0.70 ^a	-0.50 ±0.23 ^c	0.83 ±0.22 ^a	-1.21 ±0.47 ^b	1.27 ±0.32 ^a	-1.35 ±0.56 ^b	0.97 ±0.23 ^a	-1.16 ±0.46 ^b
ABE (v)	mmol/L	-2.23 ±0.91 ^{ad}	-1.00 ±0.23 ^b	2.38 ±0.95 ^{ad}	-1.17 ±0.48 ^b	1.80 ±0.54 ^a	-0.60 ±0.20 ^c	2.25 ±0.97 [*]	-1.13 ±0.44 ^b	2.50 ±0.62 ^d	-0.77 ±0.13 ^b	1.93 ±0.46 ^d	-1.90 ±0.64 ^b
SBE (a)	mmol/L	-2.60 ±0.66 ^a	-1.25 ±0.53 ^b	2.30 ±0.54 ^a	-1.00 ±0.31 ^b	2.60 ±0.47 ^a	-0.40 ±0.17 ^c	2.10 ±0.53 ^a	-1.32 ±0.52 ^b	2.00 ±0.43 ^a	-1.25 ±0.46 ^b	2.20 ±0.36 ^a	-1.80 ±0.77 ^b
SBE (v)	mmol/L	-2.65 ±0.89 ^a	-0.90 ±0.28 ^b	2.78 ±0.63 ^a	-1.23 ±0.33 ^b	2.18 ±0.43 ^a	-0.60 ±0.13 ^c	2.65 ±0.84 ^a	-1.18 ±0.39 ^b	2.77 ±0.57 ^a	-1.23 ±0.54 ^b	2.30 ±0.69 ^a	-1.10 ±0.40 ^b

*Values in same and succeeding row and column with different superscripts are significantly different (P < 0.05); ND, normally delivered; FD, forcefully delivered. *Samples were obtained from auricular artery (a) and jugular vein (v).

Immediately after delivery, a decrease in pH was observed in FD which increased gradually over the period after calving especially after 4 h whereby the foetuses also tend to become stable. In ND, blood pH was fairly constant and within the normal limits throughout the sampling period suggesting no clinical manifestation of changed acid-base balance because of serious degenerative tissue changes that alter the blood pH (Glowisching and Schlerka 1980). Marked changes in pH reflect acute cellular injury (Zanker *et al.* 2001). This stands true for the calves delivered forcefully which might have resulted in mycote injury of skeletal muscle due to manipulations applied in the process of delivery of fetus in the present study. Blood pH is determined by the ratio between bicarbonate and $p\text{CO}_2$. A decrease in the pH reflects increase in the hydrogen ion concentration that results in acidosis which persisted for nearly 2 h in FD calves. This acidosis appeared more metabolic as appreciable increase in $p\text{CO}_2$ was observed. Neonatal calves delivered forcefully develop metabolic acidosis owing to change in the pH (Rhee *et al.* 1993). Further, injurious effect of traction also corresponded to decrease in the pH through tissue hypoxia immediately after delivery as observed in the current investigation (Owens and Edey 1985). In ND calves, the decrease in pH was not appreciable since the foetuses were delivered quickly and smoothly.

$p\text{CO}_2$ and $p\text{O}_2$: A reversible trend was observed for both the parameters in both cases for the 2 types of blood. While the concentration of $p\text{CO}_2$ was significantly ($P < 0.05$) higher in FD than in ND calves, reverse was true for the $p\text{O}_2$. Large amount of CO_2 is produced by oxidative metabolism. This CO_2 combines with water in the blood-stream resulting in formation of carbonic acid, leading to increase in the secretion of H^+ and decrease in the pH (Carlson and Bruss 2008). Both in arterial and venous blood of FD calves, the $p\text{CO}_2$ values were stable after 2 – 3 h indicating the struggling period of calves for survivability, which was longer in the calves delivered forcefully. The net effect of $p\text{CO}_2$ especially in FD calves resulted in hyperventilation as a result of increased physiological dead space owing to stress and pain at the time of delivery. Hyperventilation arises as the venous $p\text{CO}_2$ rises above 55 mm Hg (Constable 2000). This can be corroborated with increase in $p\text{CO}_2$ levels immediately after delivery, may be due to over stimulation of apneustic centre of medulla oblongata. The compensating response is mediated through respiratory system, which within limits, alters the $p\text{CO}_2$ so as to partially restore the pH toward normal (de Moraes 1992).

As mentioned earlier, the oxygen tensions both in the arterial and the venous blood in ND and FD calves exhibited a much significant ($P < 0.05$) change. Increase in $p\text{O}_2$ over the period of time in both the groups was due to hypercapnea (Berchtold *et al.* 2001). The values in the arterial blood of FD calves displayed a sharp rise after 2 h indicating the compensatory response towards physiological levels. Hypercapnea occurs as the arterial $p\text{O}_2$ falls below 40 mm

Hg (Roussel *et al.* 1998). This appeared true for FD calves immediately after delivery. Not surprisingly, arterial $p\text{O}_2$ values reflected much appreciable rise than the venous $p\text{O}_2$ in both the groups. High arterial blood profiles for $p\text{O}_2$ as compared to venous blood rendered them as true indicators for clinical correlations Carlson (1995).

HCO_3^- and SBC: The metabolic component of acid-base balance is indicated by the bicarbonate concentration. Bicarbonate is usually estimated by determination of the CO_3^{2-} content or total CO_2 of blood samples since it accounts for approximately 95% of the measured total CO_2 , and thus total CO_2 provides a measure of metabolic changes in acid-base balance. In our study, alterations in HCO_3^- and SBC suggested compensatory efforts. Five hours after calving, the mean values of calculated and standard bicarbonate had improved as the animals were in the process of homeostasis. Although nonsignificant, the values were towards lower baseline limit in the FD calves. The bicarbonate measured is decreased in metabolic acidosis. These measurements may indicate the metabolic acid-base status. In fact, any change in carbon dioxide difference between arterial and venous blood may reflect changes in bicarbonate delivery to the tissue (Szenci and Taverne 1988).

Actual and standard base excess or base deficit (ABE and SBE): The base excess or deficit indicates the sum of all the buffer anions in blood under standardized conditions. The negative value indicates the deviation of the buffer base from normal and is generally taken as an indication of the deviation of bicarbonate from normal, which is commonly found in animals suffering from metabolic acidosis (Carlson and Bruss 2008). In our study, a negative value in FD calves was observed indicating acidosis both in the arterial and venous blood. A negative value immediately at calving indicated a mild degree of acidosis even in the calves delivered normally which tend to get stabilized thereafter. Therefore, it can be concluded that base values of a venous and/or arterial blood at the time of birth in calves delivered after traction can be of diagnostic significance.

It is thus, probable that buffalo calves delivered following dystocia have metabolic acidosis which stabilises over a period of time. Determination of blood gas and acid-base parameters in animals experiencing dystocia may act as prognostic indicator of survival of the fetus if given adequate fluid and electrolyte therapy. Hence, monitoring of blood gas, acid-base status and electrolytes should form a mandatory procedure for intensive and critical care in neonates.

SUMMARY

The evaluation of acid-base homeostasis in difficult parturition is vital to clinical recognition of metabolic disorders to provide correct therapeutic measures. The acid-base status and blood gas tensions of buffalo calves delivered normally (n, 17) and delivered through manipulations and

forced traction (n, 17) were studied over a period of 5 h immediately after calving. Changes in the acid-base status and blood gas dynamics were suggestive of metabolic acidosis with some compensation immediately after delivery in normally delivered (ND) calves. The calves delivered through forced extraction (FD) had distinct metabolic acidosis which continued up to 4 h after calving. Decreased oxygen utilization following dystocia was evident which improved over the period of time after calving. Furthermore, wider differences were recorded in the acid-base and blood gas values of metabolic acidosis of arterial and venous capillary blood. These differences found in the levels of acid-base balance between both kinds of blood revealed restricted informative significance in the venous blood.

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