BLOOD AND PHYSIOLOGICAL VARIABLES IN THOROUGHBRED FOALS DURING THE FIRST 24 HOURS OF LIFE

Víctor H. Parraguez
Ignacio Coloma
Raquel Riquelme
Aníbal J. Llanos
Carolina Escobar

PARRAGUEZ[1], V.H.; COLOMA[1] , I.; RIQUELME[1], R.; LLANOS[2] , A. J.; ESCOBAR[1], C. Blood and physiological variables in thoroughbred foals during the first 24 hours of life. *Arq. ciên. vet. zool. UNIPAR,* 5(2): p. 169-176, 2002.

ABSTRACT: Blood and physiological variables with clinical importance were studied in newborn Thoroughbred foals. Arterial blood samples were taken from 15 foals at 0, 1, 2, 4, 8, 16 and 24 hours after birth. From this samples, PaO_2, $PaCO_2$, pH, hemoglobin concentration, hemoglobin saturation with O2 and hematocrite were measured. Simultaneously, rectal temperature, heart rate and breathing rate were also measured. Rectal temperature increased from 37.5 ± 0.1 ºC (time 0) up to 38.3 ± 0.1 ºC (24 hours). Heart rate was highest 1 hour after birth (139.0 ± 6.5 beats/min) and remained between 90-97 beats/min after 4 hours. Respiratory rate was high at time 0 (57 ± 4.6 breaths/min), with a minimum at 8 hours (38 ± 3.8 breaths/min) and then raised again. PaO2 had a minimum value of 62.8 ± 6.4 mm Hg at time 0, increasing up to 89.1 ± 5.0 mm Hg at 24 hours. PaCO2 had a maximum value of 51.3 ± 1.8 mm Hg at time 0, remaining in 42-43 mm Hg between 2 and 8 hours, increasing subsequently. Blood pH had little variation and was between 7.371 and 7.407. Hemoglobin concentration had the highest value of 15.1 ± 0.8 g/dl at the first hour of life and descended afterwards. Hemoglobin saturation with O_2 increased gradually from 96.4 ± 2.9 % at time 0 to 100.8 ± 1.3 % at 24 hours. Hematocrite was between 36.4 and 40.0 % and was statistically different (33.8 ± 1.5 %; $p < 0.05$) only at 16 hours.
KEY WORDS: foal, newborn adaptations, blood gas, physiological variables

VARIABLES SANGUÍNEAS Y FISIOLÓGICAS EN POTRILLOS FINA SANGRE DE CARRERA DURANTE LAS PRIMERAS 24 HORAS DE VIDA

PARRAGUEZ, V.H.; COLOMA, I.; RIQUELME, R.; LLANOS , A. J.; ESCOBAR , C. Variables sanguíneas y fisiológicas en potrillos Fina Sangre de carrera durante las primeras 24 horas de vida. *Arq. ciên. vet. zool. UNIPAR,* 5(2): p. 169-176, 2002.

RESUMEN: Variables fisiológicas y sanguíneas con importancia clínica fueron estudiadas en potrillos F.S.C. recién nacidos. Se extrajo sangre arterial a las 0, 1, 2, 4, 8, 16 y 24 horas desde el nacimiento, midiéndose PaO_2, $PaCO_2$, pH, concentración de Hemoglobina, saturación de Hemoglobina con O_2 y hematocrito. Simultáneamente se midió temperatura rectal, frecuencia cardíaca y frecuencia respiratoria. La temperatura rectal aumentó de 37.5 ± 0.1 ºC (tiempo 0) a 38.3 ± 0.1 ºC (24 horas). La mayor frecuencia cardíaca se registró 1 hora después del nacimiento (139.0 ± 6.5 lat/min), permaneciendo entre 90-97 lat/min después de las 4 horas. La frecuencia respiratoria fue mayor en el tiempo 0 (57 ± 4.6 resp/min), con un mínimo a las 8 horas (38 ± 3.8 resp/min), aumentando posteriormente. PaO_2 tuvo un valor mínimo de 62.8 ± 6.4 mm Hg en el tiempo 0, aumentando a 89.1 ± 5.0 mm Hg a las 24 horas. $PaCO_2$ tuvo un valor máximo de 51.3 ± 1.8 mm Hg en el tiempo 0, manteniéndose en 42-43 mm Hg entre las 2 y 8 horas, aumentando posteriormente. El pH sanguíneo varió escasamente, oscilando entre

[1] DVM MSc; , Facultad de Ciencias Veterinarias y Pecuarias, Universidad de Chile - Casilla 2, Correo 15, La Granja, Santiago, Chile. Tel: (56 2) 678 5548; Fax: (56 2) 678 5526. vparragu@abello.dic.uchile.cl
[2] Pharm. Chem Facultad de Medicina, Universidad de Chile. Casilla 2, Correo 15, La Granja, Santiago, Chile.

7.371 y 7.407. La concentración de Hemoglobina tuvo el mayor valor (15.1 ± 0.8 g/dl) en la primera hora, descendiendo posteriormente. La saturación de Hemoglobina con O_2 aumentó desde 96.4 ± 2.9 % (tiempo 0) hasta 100.8 ± 1.3 % (24 horas). El hematocrito osciló entre 36.4 y 40.0 %, siendo estadísticamente distinto solo a las 16 horas (33.8 ± 1.5 %; $p < 0.05$).

PALABRAS CLAVE: potrillo, adaptaciones del recién nacido, gases sanguíneos, variables fisiológicas

VARIÁVEIS SANGÜÍNEAS E FISIOLÓGICAS EM POTROS PSI DURANTE AS PRIMEIRAS 24 HORAS DE VIDA

PARRAGUEZ, V.H.; COLOMA, I.; RIQUELME, R.; LLANOS , A. J.; ESCOBAR , C. Variáveis sangüíneas e fisiológicas em potros PSI durante as primeiras 24 horas de vida. *Arq. ciên. vet. zool. UNIPAR,* 5(2): p.169-176, 2002.

RESUMO: Variáveis fisiológicas e sangüíneas de importância clínica foram estudadas em potros PSI recém-nascidos. O sangue arterial foi colhido às 0, 1, 2, 4, 8, 16 e 24 horas depois do nascimento, aferindo-se PaO_2, $PaCO_2$, pH, concentração de Hemoglobina, saturação de Hemoglobina com O_2 e hematócrito. Simultaneamente aferiu-se a temperatura retal e as freqüências cardíaca e respiratória. A temperatura retal aumentou de 37,5 ± 0,1 °C (tempo 0) a 38,3 ± 0,1 °C (24 horas). A maior freqüência cardíaca registrou-se uma hora depois do nascimento (139,0 ± 6,5 bat/min), permanecendo entre 90-97 bat/min depois das 4 horas. A freqüência respiratória foi maior no tempo 0 (57 ± 4,6 resp/min), com um mínimo às 8 horas (38 ± 3,8 resp/min), aumentando posteriormente. A PaO_2 teve um valor mínimo de 62,8 ± 6,4 mm Hg no tempo 0, aumentando para 89,1 ± 5,0 mm Hg às 24 horas. A $PaCO_2$ teve um valor máximo de 51,3 ± 1,8 mm Hg no tempo 0, mantendo-se em 42-43 mm Hg entre 2 e 8 horas, aumentando posteriormente. O pH sangüíneo variou pouco, oscilando entre 7,371 e 7,407. A concentração de Hemoglobina teve o maior valor (15,1 ± 0,8 g/dl) na primeira hora, baixando posteriormente. A saturação de Hemoglobina com O_2 aumentou de 96,4 ± 2,9 % (tempo 0) até 100,8 ± 1,3 % (24 horas). O hematócrito oscilou entre 36,4 e 40,0 %, sendo estatisticamente distinto somente às 16 horas (33,8 ± 1,5 %; $p<0.05$).

PALABRAS-CHAVE: potros, adaptações do recém nascido, gases sangüíneos, variáveis fisiológicas

Introduction

During intrauterine life, the fetus receives all he needs for living from its mother. Birth implicates adaptation to the new environment, a process which is critical for survival. Exposure to hostile conditions is an immediate consequence of birth, which in horses may result in a high mortality rate, up to 22 % under extensive management. The primary event that must happen is breathing and for that, the lungs must complete a transition from being a collapsed, liquid filled organ to becoming an airfilled structure responsible for a sufficient gas exchange for the entire body (KOTERBA, 1990).

Cardiorespiratory disturbances are one of the main causes of death in neonates of all species. In Chile there is about 5% of mortality during the first 3 days of life in foals, and eventhough there are no studies about it, it seems that hypoxemia is one of the main causes. Newborn foals have some characteristics, different from neonates of other species, which make it difficult for the clinician to diagnose a respiratory distress: their breathing pattern is very soft and difficult to observe and the gums don't take the classic bluish hue until the hypoxemia is already approaching to the irreversible point (HAYES, 1994).

During the first day of life, several changes occur in the foal. Compared with adult horses, transient systemic arterial hypoxemia, hypercapnia and acidosis are present at birth (ROSSDALE, 1968). It is very important to recognize the changes that take place during the first day of life before ill foals can be interpreted. Measuring arterial blood gases is an excellent and direct way to diagnose and monitor respiratory diseases. Any foal with suspected perinatal hypoxemia should have an arterial gas determination on initial examination. This procedure should be repeated periodically to control the evolution of blood gases avoiding a progressive hypoxemia and hypercapnia (PALMER, 1994). Other important blood parameters that should be monitored to have a complete view of the metabolic status of the foal are the hemoglobin concentration, hemoglobin saturation with oxygen and pH.

The main goal of this study was to determine how arterial partial pressure of oxygen (PaO_2), arterial partial pressure of carbon dioxide ($PaCO_2$), pH, hemoglobin (Hb) concentration, Hb saturation with oxygen (sat Hb), hematocrite, rectal temperature, heart and breathing rate, change during the first 24 hours of life in normal delivered Thoroughbred foals. This information, systematically obtained from frequent samples, will contribute to improve the clinical diagnosis and management of neonatal diseases or maladjustment.

Materials and Methods

Fifteen Thoroughbred foals born in the "Haras San Patricio" (central zone of Chile; 70º59´00´´W, 33º40´30´´S; 680 feet above see level), between August and November of 1999, were used in this study.

The protocol consisted in measuring PaO_2, $PaCO_2$, pH, Hb concentration, sat Hb and hematocrite from arterial blood samples and rectal temperature, heart and breathing rate. This was performed at: 0, 1, 2, 4, 8, 16 and 24 hours after birth, considering time 0 as the first 10 minutes after the umbilical cord was cut.

Blood samples were collected from the lateral palmar digital artery with the foal restrained in lateral recumbence, having previously shaved and cleaned the site of puncture. One ml of blood was taken at each time with a syringe flushed with heparin solution (1000 I.U./ml). Any bubble in the sample was immediately removed and gas measurement was done promptly.

Arterial gases (O_2 and CO_2), pH, sat Hb and Hb concentration were measured using a Radiometer blood gas analyzer. For hematocrite, the blood samples were centrifuged at 800 g for 3 minutes in microhematocrite tubes.

A statistical analysis for repeated measurements was performed using a general linear model procedure and Duncan´s multiple range test for each variable to see if there were any significant differences between times. A significant difference was considered when $p < 0.05$. In addition, correlation analysis between variables was performed using the Pearson coefficient (SNEDECOR & COCHRANE, 1967). Sex of the newborns was not considered as a variation factor, because this characteristic is not significant as a risk factor for foal survival (HAAS *et al*, 1996). Results are presented as average ± standard deviation (X ± SD).

Results

Newborn foals involved in this study were selected from normal pregnancies and parturitions, after a gestation period of 344 ± 8 days, considered as normal for Thoroughbred horses (DÍAZ & DÍAZ, 1989; BERNARD & REIMER, 1994).

Rectal temperature had an average of 37.9 ± 0.04 ºC during the first day of life. The newborn had the lowest rectal temperature during the first 10 minutes (37.5 ± 0.1 ºC). It raised with time reaching the highest value of 38.3 ± 0.1 ºC 24 hours after birth (Fig. 1).

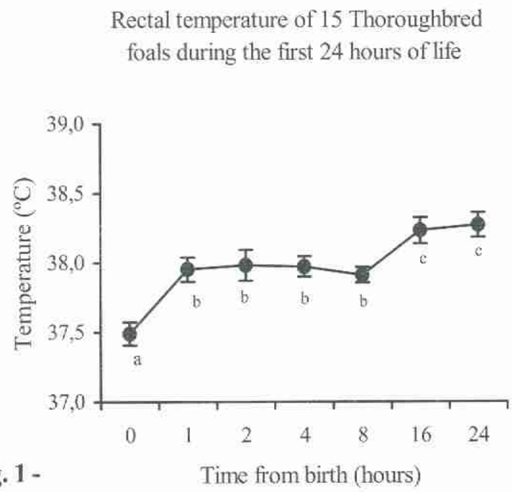

Fig. 1 -

*different letters indicate significant differences ($p \leq 0.05$)

Heart rate was low at time 0 (89.0 ± 9.1 beats/min), reaching the highest value 1 hour after birth (139.0 ± 6.5 beats/min), decreasing during the following hours and stabilizing after 4 hours between 90 and 97 beats/min (Fig. 2). The average from measurements obtained during the 24 hours was 103 ± 2.8 beats/min.

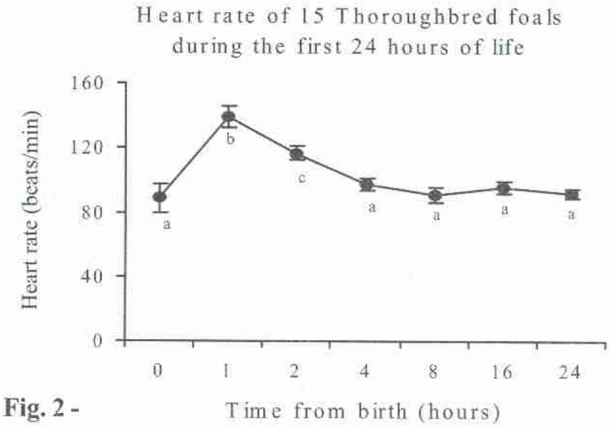

Fig. 2 -

*different letters indicate significant differences ($p \leq 0.05$)

Respiratory rate had an opposite pattern to the heart rate. It was high at the beginning of the study (57.0 ± 4.6 breaths/min), decreasing gradually until 8 hours after birth, reaching 38.0 ± 3.8 breaths/min. It increased at 16 hours and finally dropped at 24 hours (Fig. 3). The average for the day was 48.0 ± 1.7 breaths/min.

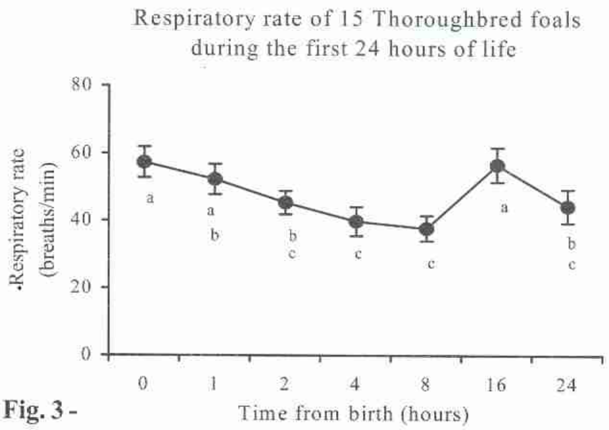

Fig. 3 -

*different letters indicate significant differences ($p \leq 0.05$)

PaO_2 average for the first 24 hours was 80.0 ± 4.3 mm Hg with an increasing from time 0 (62.8 ± 6.4 mm Hg) to 24 hours, when it reached a value of 89.1 ± 5.0 mm Hg (Fig. 4).

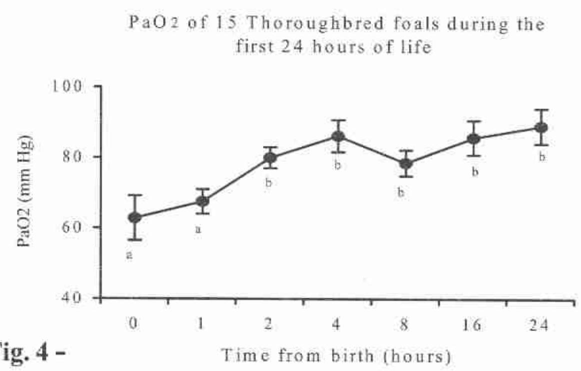

Fig. 4 -

*different letters indicate significant differences ($p \leq 0.05$)

$PaCO_2$ had the maximum value during the first 10 minutes of extrauterine life (51.3 ± 1.8 mm Hg), then from hour 2 it decreased remaining between 42 and 43 mm Hg until hour 8. Afterwards, it increased again reaching 47.4 mm Hg at 24 hours (Fig. 5). The average for the period was 45.8 ± 0.7 mm Hg.

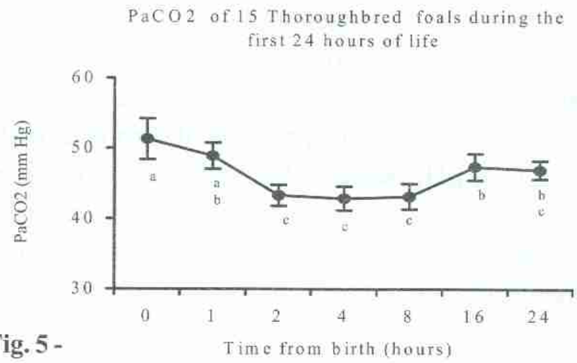

Fig. 5 -

*different letters indicate significant differences ($p \leq 0.05$)

The pH for the first 24 hours of life was 7.393 ± 0.01, being the parameter with less variation, eventhough there were significant differences between some values, the variation range was narrowed, remaining between 7.371 and 7.407 (Fig. 6).

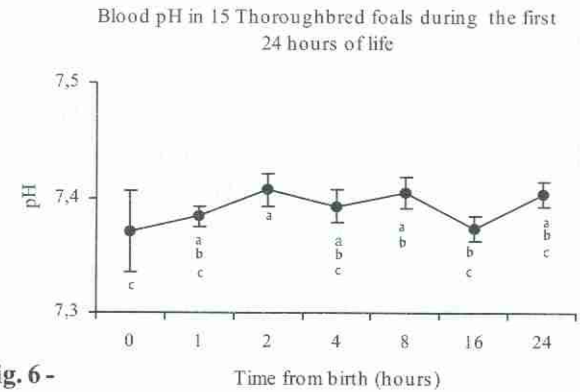

Fig. 6 -

*different letters indicate significant differences ($p \leq 0.05$)

Hb concentration for the period was 15 ± 0.3 g/dl. It had a maximum value of 15.2 ± 1.1 g/dl at time 0 and decreased gradually up to 12.11 ± 0.5 g/dl with a minor increase, but not significant, at 24 hours (12.73 ± 0.5 g/dl) (Fig. 7).

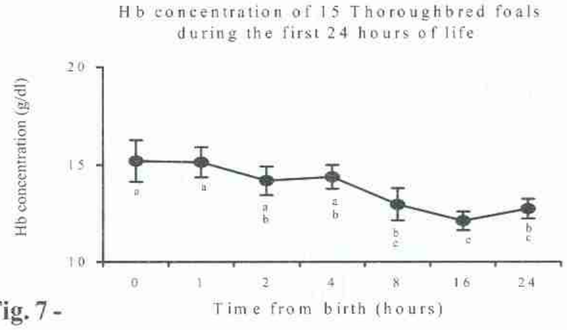

Fig. 7 -

*different letters indicate significant differences ($p \leq 0.05$)

The sat Hb increased gradually during the first day of life, but after 2 hours the differences were not statistically significant ($p > 0.05$), reaching the highest value of 100.8 ± 1.3 % at 24 hours (Fig. 8). The average for the 24 hours was 99.3 ± 0.5 %.

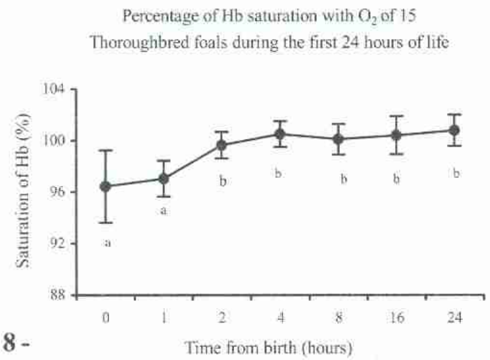

Fig. 8 -

*different letters indicate significant differences ($p \leq 0.05$)

Hematocrite of the foals had little variation during the first 24 hours of life. Only at 16 hours there was a significant decrease (33.8 ± 1.5 %; $p < 0.05$) and the average for the first day of life was 38.3 ± 0.7 % (Fig. 9).

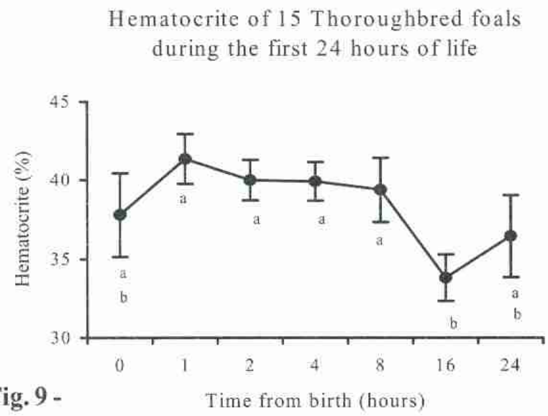

Fig. 9 -

*different letters indicate significant differences ($p \leq 0.05$)

Correlation test showed a direct and significant association ($p < 0.05$) between the following variables: time-temperature; time-PaO_2; Hb concentration-heart rate; sat Hb-PaO_2; sat Hb-pH and Hb concentration-hematocrite. There was an inverse and significant association between time-heart rate, time-Hb concentration, time-sat Hb, PaO_2-$PaCO_2$ and PaO_2-Hb concentration (Table 1).

Table 1 - Correlation between blood and physiological variables in foals during the first 24 hours of life in the "Haras San Patricio" (central zone of Chile)

Variables	r^2	P
Hematocrite-Hb concentration	0.588	0.0001
PaO_2-Sat Hb	0.568	0.0001
Time-Temperature	0.477	0.0001
Sat Hb-pH	0.424	0.0001
Time-PaO_2	0.363	0.0007
Heart rate-Hb concentration	0.229	0.0388
Time-Sat Hb	0.214	0.0506
Time-Hb concentration	- 0.366	0.0007
Time-Hematocrite	-0.309	0.0052
Time-Heart rate	-0.293	0.0028
PaO_2-Hb concentration	-0.257	0.0208
PaO_2-$PaCO_2$	-0.217	0.0490

Discussion

Newborn foals experience many changes in an attempt to adapt to extrauterine life. During the first 10 minutes of life, rectal temperature was low, but as the foal started to shiver and make the first attempts to stand, it raised in a consistent manner until 24 hours of life. There are two facts that could explain the initial hypothermia. First, that the mare gives birth at night when the environmental temperature (15-20 ºC) is much lower than the intrauterine and second, foals are born covered with amniotic fluid whose evaporation produces an important heat loss. Some hours after birth, rectal temperature raised as the environmental temperature did, together with the fact that the foal had been moving and feeding many times. Similar changes had been previously reported, eventhough those values for body temperature were obtained at an environmental temperature of 21 ºC (STEWART *et al*, 1984), suggesting that a decrease of 5 ºC in environmental temperature, do not deteriorate thermoregulation ability in full-term newborn foals.

Equine neonate heart rate has been described as extremely variable (REEF, 1985).

However, results of the present study show a clear and consistent pattern between individuals, allowing to a lower variation specially from 2 hours of life. Furthermore, heart rate values obtained at all times were higher than those reported by MADIGAN (1988), being the main difference at 2 hours of life, although the author had not measured before. The lower value obtained in our study (before 10 minutes of extrauterine life) is consistent with the range described at this time (YAMAMOTO *et al*, 1991; MACPHERSON *et al*, 1997), but higher than the value reported by BERNARD & REIMER (1994) for immediate postpartum period. In addition, the significant increase of heart rate observed during the first hour of life seems to be consistent with the pattern described for the first 10 minutes after birth (YAMAMOTO *et al*, 1991) or the next several hours (BERNARD & REIMER, 1994; MACPHERSON *et al*, 1997). Heart rate was stabilized from 4 hours at values considered as normal for the first week of life (BERNARD & REIMER, 1994). The described changes are related to the degree of hypoxemia and cardiac depression during labor (YAMAMOTO et al, 1991), but it can also be influenced by environmental conditions after birth, so it must be interpreted together with other parameters. On the other hand, neonate heart rate was always higher than in the adult (about 2.3 folds) during the first 24 hours of life. In adults and neonates the cardiovascular system regulates the oxygen supply to the tissues with variations in cardiac output and blood flow distribution according to proper metabolism (DELIVORA-PAPADOPOULUS & GIACOMO, 1992). The increase in metabolic demands at birth involves necessarily a greater cardiac output, which results from a combination of different mechanisms, including an increase of heart rate (SERWER, 1992), which is consistent with changes observed in the newborn foal.

Respiratory rate of the foals initially was high, but diminished with time until 16 hours when this increased again. A new decrease was observed at 24 hours. Values obtained for the variable during the first hour of life are in the range described by BERNARD & REIMER (1994), LANE (1996) and MACPHERSON *et al* (1997). However, the average for subsequent time was higher than those reported as normal for this period (ROSSDALE, 1970; KOTERBA *et al*, 1985; BERNARD & REIMER, 1994) and about 3 folds greater than in the adult horse (DUNLOP, 1994), but coincides with values described in foals of 2 or 7 days of age (KOTERBA, 1990). Several environmental and pathological conditions may influence the oxygen consumption and respiratory rate in newborns, but according to SERWER (1992), a cold environment is in large part responsible for a greater oxygen requirement in the newborn, compared with the fetus, and can establish notable variability in oxygen consumption between normal newborns. This situation would be a probable explanation to the differences observed in the foal respiratory rates between our work and those of ROSSDALE (1970), KOTERBA *et al* (1985) and BERNARD & REIMER (1994). The obtained changes in respiratory pattern were closely related with arterial gases, specially carbon dioxide concentration, which triggers the onset of respiration at parturition and regulate respiratory dynamics subsequently. Besides, the oxygen consumption of foals is higher than in adults, so requires a greater minute ventilation. The high breathing rate at birth could be necessary to adjust frequency and depth so alveolar ventilation can be achieved with a minimum respiratory effort (STEWART *et al*, 1984).

The newborn foals showed an initial hypoxemic, hypercapnic and lightly acidemic state, which was normalized at 2 hours, showing a rapid adaptation to the new environment. PaO_2 and $PaCO_2$ changes were similar to those described by HODGSON (1987) and KOTERBA (1990), although PaO2 were lightly superior in our study. The increase in PaO_2 showed parallelism with the percentage curve of hemoglobin saturation with PaO_2. In addition, all the values described in the present study for arterial gases at different times during the first 24 hours of life, are consistent with previously reported by different authors (KOSCH *et al*, 1984; MACPHERSON *et al*, 1997; VAALA, 1994; ROSSDALE, 1970; ROSE & HODGSON, 1983; KOTERBA *et al*, 1985). Furthermore, although the arterial gas patterns show a highly efficient newborn foal adaptive mechanisms, 24 hours of life seems to be insufficient to reach normal adult values (DUNLOP, 1994; MILNE *et al*, 1975; LITTLEJOHN, 1969). This situation may be explained because, at birth, the lungs of the foal are still immature and the number and size of alveoli increase with age. Additionally, the circulatory changes that occur at birth and the lack of an adequate function of the thoracic wall, make the newborn foals liable to suffer alveolar collapse and develop pulmonary shunts (DUNLOP, 1994).

Hematocrite and hemoglobin concentration are very important variables, because their relation with blood gas transport. An adequate knowledge and interpretation of this variables by the clinician, in addition to what was described previously, is fundamental during evaluation of newborns well being, specially in foals, in which anemia is a common clinical sign (VAALA, 1994). Hematocrite and hemoglobin concentration showed discrete changes during the first 24 hours of life and were in the ranges described previously (HARVEY *et al*, 1984; HARVEY, 1990; BECHT & SEMRAD, 1985; BERNARD & REIMER, 1994). A general tendency to decrease was observed, however at 16 hours, a significant decrease occurred in both variables. The experimental design of this study did not allow an explanation for such decrease. However, considering the mechanism of passive antibody transfer in neonatal foals, a possible explanation would be intended. Intestinal absorption of colostrum increases from 6 hours after birth, being less efficient at 12 hours and minimal between 18 and 24 hours (BECHT & SEMRAD, 1985; MADIGAN, 1988; ROSSDALE, 1993), so part of the observed change may result from the osmotic effect of absorbed colostral proteins with a blood volume expansion, as suggested by HARVEY (1984). No physiological haemolysis has been described in newborn horses, then this mechanism present in other species may be discarded.

Finally, it is important to point out that, in addition to adequate correlations between blood and physiological variables, most of them had a significant correlation with time, which indicates that the first 24 hours after birth of the foal, correspond to a period of great importance to the foal extrauterine adaptation.

Acknowledgements

We thank Mr. Fernando Coloma, owner of "Haras San Patricio", who made possible this study with his Thoroughbred horses. We also thank the workers of the farm and the Veterinary students Felipe Matus and David Parra for their technical assistance.

References

BECHT, J.L.; SEMRAD, S.D. Hematology, blood typing, and immunology of the neonatal foal. *Vet Clin North Am: Equine Practice*, v. 1, p.91-116. 1985.

BERNARD, W.V.; REIMER, J.M. Examination of the foal. *Vet Clin North Am: Equine Practice*, v. 10, p. 37-66. 1994.

DELIVORA-PAPADOPOULOS, M.; DIGIACOMO, J.E. Oxygen transport and delivery. In: Polin R, Fox W, eds. *Fetal and Neonatal Physiology*. Mexico D.F., Mexico. W Saunders Co. 1992. p. 801-813.

DÍAZ, H.; DÍAZ, A. *Sexualidad y control reproductivo en equinos*. Editorial Ograma. Santiago. Chile. 1989. p.84.

DUNLOP, C.I. Anesthesia and sedation of foals. *Vet Clin North Am: Equine Practice*., v.10, p. 70-73. 1994.

HARVEY, J.W.; ASQUITH, R.L.; MCNULTY, P.K.; KIVIPELTO, J.; BAUER, J.E. Haematology of foals up to one year old. *Equine Vet J*, v. 16, p. 347-353. 1984.

HARVEY, J.W. Normal hematologic values. In: KOTERBA, A.M.; DRUMMOND, W.H.; KOSCH, P.C. eds. *Equine clinical neonatology*. USA: Lea & Febiger. 1990. p. 561-568.

HAAS, S.D.; BRISTOL, F.; CARD, E. Risk factors associated with the incidence of foal mortality in an extensively managed herd. *Can Vet J*, v. 37, p. 91-95. 1996.

HAYES, K. Early action is the key to saving a sick foal. *Modern Horse Breeding*, v. January/February, p. 11-13. 1994.

HODGSON, D.R. Blood gas and acid-base changes in the neonatal foal. *Vet Clin North Am: Equine Practice*, v. 3, p. 617-629. 1987.

KOSCH, P.C.; KOTERBA, A.M.; COONS, T.J.; WEBB, A.I.. Developments in management of the newborn foal in respiratory distress 1: Evaluation. *Equine Vet J*, v.16, p. 312-318. 1984.

KOTERBA, A.M.; DRUMMOND, W.H.; KOSH, P. Intensive care of the neonatal foal. *Vet Clin North Am: Equine Practice*, v. 1, p. 3-34. 1985.

KOTERBA, A.M. Respiratory disease: approach to diagnosis. In: KOTERBA, A.M.; DRUMMOND, W.H.; KOSCH, P.C. eds. *Equine clinical neonatology*. USA: Lea & Febiger. 1990 p. 153-176.

LANE, T.J. *Assesment and care of the newborn foal. Cooperative Extension Service*. Institute of Food and Agricultural Sciences. University of Florida. 1996. Document VM-88. P 7.

LITTLEJOHN, A. Acid-base and blood gas studies in horses II. Tracheal end-tidal and arterial blood gas tensions in horses. *Res Vet Sci*, v. 10, p. 263-266. 1969.

MACPHERSON, M.L.; CHAFFIN, M.K; CARROL, G.L.; JORGENSEN, J.; ARROTT, C.; VARNER, D.D.; BLANCHARD, T.L. Three methods of oxytocin-induced parturition and their effects on foals. *JAVMA*, v. 210, p. 799-803. 1997.

MADIGAN, J.E. Manual of equine neonatal medicine. In: J. E. MADIGAN (Ed). *Live Oak Publishing*. Woodlan, California, U.S.A. 1988. p. 363.

MILNE, D.W.; MUIR, W.W.; SKARDA, RT. Pulmonary arterial wedge pressures: Blood gas tensions and pH in the resting horse. *Am J Vet Res*, v. 36, p. 1431-1434. 1975.

PALMER, J.E. Ventilatory support of the neonatal foal. *Vet Clin North Am: Equine Practice*, v. 10, p. 167-169. 1994.

REEF, V.B. Cardiovascular disease in the equine neonate. *Vet Clin North Am: Equine Practice*, v. 1, p. 117-129. 1985.

ROSE, R.J.; HODGSON, D.R. Effect of intranasal oxygen administration on arterial blood gas and acid base parameters in spontaneously delivered, term induced and induced premature foals. *Res Vet Sci*, v. 34, p. 159-162. 1983.

ROSSDALE, P.D. Blood gas tension and pH values in the normal Thoroughbred foals at birth and the following 42 hours. *Biol Neonate*, v. 13, p. 18-25. 1968.

ROSSDALE, P.D. Some parameters of respiratory function in normal and abnormal newborn foals with special reference to levels of paO2 during air and oxygen inhalation. *Res Vet Sci*, v. II, p. 270-276. 1970.

ROSSDALE, P.D. Clinical view of disturbances in equine foetal maturation. *Equine Vet* J, v. 14, p. 3-7. 1993.

SERWER, G.A. Postnatal circulatory adjustments. In: POLIN, R.; FOX, W. eds. *Fetal and Neonatal Physiology*. Mexico D.F., Mexico: W. Saunders Co. 1992, p. 710-721.

SNEDECOR, G.; COCHRANE, W. *Statistical methods*. Ames. Iowa: The Iowa State University Press. 1967, p. 217.

STEWART, J.H.; ROSE, R.J.; BARKO, A.M. Respiratory studies in foals from birth to seven days old. *Equine Vet J*, v. 16, p. 323-328. 1984.

VAALA, W.E. Peripartum asphyxia. *Vet Clin North Am: Equine Practice*, v. 10, p. 187-218. 1994.

YAMAMOTO, K.; YASUDA, J.; KIMEHIKO, T. Electrocardiographic findings during parturition and blood gas tensions immediately after birth in thoroughbred foals. *Jpn J Vet Res*, v. 39, p. 143-157. 1991.

Recebido para publicação em 19/10/01.
Received for publication on 19 October 2001.
Recibido para publicación en 19/10/01.
Aceito para publicação em 19/12/01.
Acepeted for publication on 19 December 2001.
Acepto para publicación en 19/12/01.