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Clinical responses to acute blood loss in goats

Respostas clínicas à perda sanguínea aguda em caprinos

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Abstract

The response to blood loss is directly related to the degree of hemorrhage, but for the caprine species some aspects still need to be investigated. Therefore, the present study aimed to assess the clinical and hemodynamic effects of acute blood loss in goats. Eight healthy, adult male crossbred goats were subjected to external jugular puncture to remove 30% of the total blood volume. A physical examination and blood gas, biochemical, and hematologic analyses were performed at baseline, before blood loss (T0), and after one (T1h), six (T6h), 12 (T12h), 24 (T24h) and 72 (T72h) hours, and eight (T8d), 16 (T16d), 24 (T24d) and 32 (T32d) days after the acute blood loss event. The goats presented with tachycardia, tachypnea, and hyperthermia one hour after blood loss with a return to normal physiological values at T6h. Packed cell volume was decreased at T1h and red cell counts at T12h, both returning to baseline at T24d. There was a reduction in total protein and albumin levels at T1h, both remained below baseline levels until T16d and T8d, respectively. The serum calcium concentration decreased over the period T1h to T24h and glucose increased over the period T1h to T6h. The values of pH, TCO_2, bicarbonate, and base excess were lower at T1h, while lactate increased markedly at this time. The pCO_2 value only was reduced at T24h. Systolic (PS), diastolic (PD), and mean (PM) pressures were decreased at T1h. Acute loss of 30% of blood volume in goats caused changes in clinical, blood gas, and biochemical parameters, which were restored over a six-hour period, while hematologic changes were more persistent, with baseline values restored only after 24 days.

Key words: Shock. Blood gas. Hypovolemia. Blood.

Resumo

A resposta clínica à perda de sangue está diretamente relacionada ao grau de hemorragia, mas para a espécie caprinas alguns aspectos ainda precisam ser investigados. Deste modo o presente estudo teve como objetivo avaliar os efeitos clínicos e hemodinâmicos da perda aguda de sangue em caprinos. Oito caprinos adultos, mestiços, hígidos, foram submetidas a punção jugular externa para remoção de 30%

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do volume total de sangue. Foi realizado exame clínico e análises hematológicas, hemogasométricas e bioquímicas no momento basal, antes da perda de sangue (T0), e uma (T1h), seis (T6h), 12 (T12h), 24 (T24h) e 72 (T72h) horas e oito (T8d), 16 (T16d), 24 (T24d) e 32 (T32d) dias após. As cabras apresentaram taquicardia, taquipneia e hipertermia uma hora após a perda de sangue com retorno aos valores fisiológicos em T6h. O volume globular diminuiu em T1h e a contagem de células vermelhas em T12h, ambos retornando valores basais em T24d. Houve uma redução nos níveis de proteína totais e albumina em T1h, e ambos permaneceram abaixo dos níveis basais até T16d e T8d, respectivamente. A concentração sérica de cálcio diminuiu durante o período T1h para T24h e a glicose aumentou no período T1h a T6h. Os valores de pH, TCO2, bicarbonato e excesso de base foram menores em T1h, enquanto o lactato aumentou acentuadamente neste momento. O pCO2 foi reduzida somente em T24h. As pressões sistólica (PS), diastólica (PD) e média (PM) diminuíram em T1h. A perda aguda de 30% do volume sangüíneo em cabras causou alterações nos parâmetros clínicos, hemogasométricos e bioquímicos, que foram restaurados ao longo de um período de seis horas, enquanto que as alterações hematológicas foram mais persistentes, com valores basais restaurados somente após 24 dias.
Palavras-chave: Choque. Hemogasometria. Hipovolemia. Sangue.

Introduction

Considerable blood loss may occur due to trauma, surgery, and obstetric intervention, as well as parasitic diseases. These conditions are more common during gestation and lactation, causing more cases of anemia and decreasing productivity of the animals (ABDALLA; ABDELATIF, 2008, 2010). A severe hemorrhage can occur within a few minutes or over several hours, and can threaten homeostasis by decreasing total blood volume, which can lead to hypovolemia, cardiovascular collapse, shock, and death (HAUPTMAN, CHAUDRY, 1998).

Sudden blood losses are initiated by a traumatic event and are followed by endocrine-metabolic responses and failure to maintain homeostatic mechanisms, causing decreased tissue perfusion (MANTOVANI et al., 2002). In these cases, clinical signs such as mucosal pallor, tachycardia, and weak pulse pressure are observed due to the decrease in circulating blood volume (DUTTON, 2003). The reduced tissue perfusion stimulates a series of complex events that trigger changes to cellular metabolism, which can lead to organ failure (CUNNINGHAM, 2004).

An animal's response to blood loss is directly related to the degree of bleeding. Reduction in the order of 10 to 15% of total blood volume is associated with minimal signs of shock, whereas a decrease of 20% to 35% is associated with the clinical syndrome of hypovolemic shock. Losses above 40% can be fatal (HAUPTMAN, CHAUDRY, 1998). However, regardless of the blood volume lost, compensatory mechanisms are activated in an attempt to maintain blood pressure and tissue perfusion (ABDALLA; ABDELATIF, 2008; DORR et al., 1986; SAEEDI et al., 2013; STARR et al., 2002; WIJFFELS et al., 2007).

Abdalla and Abdelatif (2008) evaluated the loss of 15 and 30% of blood volume in goats and observed a decrease in packed cell volume and hemoglobin concentration and an increase in rectal temperature. However, it is still necessary to investigate other parameters such as blood pressure, acid-base balance, as well as the efficiency of the hematopoietic and compensatory mechanisms involved in the restoration of homeostasis, following blood loss in goats. Furthermore, there are no studies of acute blood loss in mixed breed goats raised in the northeast region of Brazil, that present a high rusticity (COSTA et al., 2010). The objective of this study was to evaluate the clinical outcomes in goats subjected to acute blood loss with a 30% reduction in total blood volume.

Material and Methods

The experiment was approved by the Committee on Ethics in the Use of Animals of the Federal Rural

Semiarid University (Protocol nº 23091.000419 / 2013-18).

Eight healthy, castrated male goats weighing 34.75±4.3 kg, were included in the study. The animals were allocated to two collecting pens of 20 m^2 each, where they remained for an adaptation period of 30 days. At the beginning of the adaptation period the animals were dewormed (Cydentin, Zoetis, Campinas, SP) and treated with a coccidiostatic drug (Coccifin, Ouro fino, Cravinhos, SP). Each week during the adaptation period and throughout the experiment, fecal egg counts per gram (ECG) were calculated. Results were negative at all evaluation times. Animals were fed a diet of 70% Tifton hay and 30% commercial concentrate (Max Caprinos, DuRancho, Pesqueira, PE), offered twice a day and calculated as 2.7% of body weight on a dry matter basis. The goats also received mineral mixture (Caprinofós, Tortuga, SP) and water *ad libitum*.

After the adaptation period, the animals were subjected to acute blood loss by external jugular puncture, and 30% of total blood volume (calculated as 8% of body weight) was removed. For blood collection, the animals were manually restrained in the right lateral decubitus position and subjected to cervical antisepsis followed by jugular vein puncture, using a 14G catheter attached to a blood bag. Blood was withdrawn using gravity and the volume removed per animal was monitored using an analytical balance (model AS-2000C) with a sensitivity of 0.01 g, using a ratio of 1 mL of blood equals 1 g (SILVERTHORN, 2010). Blood withdrawal was performed early in the morning from the animals, which were kept in individual pens where the ambient temperature did not exceed 28 °C during the trial period. Removal of blood took 10 ± 2 minutes and 834 ± 11 g of blood per animal was withdrawn.

Clinical signs and the blood gas, hematological, and biochemical parameters were evaluated at predetermined times (T): T0 (immediately before blood loss), one (T1h), six (T6h), 12 (T12h), 24 (T24h), 72 (T72h) hours, and eight (T8d), 16 (T16d), 24 (T24d), and 32 (T32d) days after blood withdrawal. However, systolic, diastolic, and mean pressures were assessed only at times T0 (immediately before blood loss), T1 (immediately after blood loss), and one (T1h), six (T6h), and twelve (T12h) hours after the blood loss, due to the invasiveness of this procedure.

In the clinical evaluation, the heart rate, respiratory rate, temperature, and the capillary refill time (CRT) were measured according to Pugh (2005). For blood gas evaluation, venous blood samples collected using heparinized syringes were analyzed immediately in a portable hemogasometer (i-STAT, Abbott, Illinois, USA), using commercial CG4+ cartridges. This analyzed pH, oxygen pressure (pO2), carbon dioxide pressure (pCO2), oxygen saturation (SO2), bicarbonate (HCO-3), base excess (BE), and total carbon dioxide (TCO2). We did not include data on pO2 and oxygen saturation (SO2) since the blood collected was venous.

For the biochemical evaluation, blood samples were collected in vacuum tubes without anticoagulants, and serum was obtained by centrifugation to determine the activity of aspartate aminotransferase (AST): oxaloacetate hydrazone (REITMAN; FRANKEL, 1957), gamma-glutamyl transferase (GGT): p-nitroanilide (SZASZ, 1969), and concentrations of urea: urease (TOMAS, 1998) creatinine: picric acid (BARTELS; BOHMER, 1972), total protein: biuret (TOMAS, 1998), albumin: bromocresol green (JOHNSON et al., 1999), non-ionizable calcium: arsenate (BAGINSKI et al., 1973), glucose: glucose oxidase (BARHAM; TRINDER, 1972), and lactate: L-lactate dehydrogenase (SHIMOJO et al., 1989). Biochemical measurements were performed using an automatic biochemical analyzer (Rx Daytona, Randox®, Antrim, UK), with commercial kits from the same brand.

Blood samples were collected in vacuum tubes with ethylenediaminetetraacetic acid (EDTA) for the determination of packed cell volume, number of red blood cells, number of leukocytes, and hemoglobin concentration. The counts of red blood cells and leukocytes were performed manually in a Neubauer chamber by macrodilution, using a physiological solution for counting red cells with a 1:40 dilution and Turk's reagent for leukocyte count at a 1:21 dilution (JAIN, 1993). Measurement of packed cell volume was obtained by centrifugation of a microhematocrit tube, where the samples were centrifuged at 12,500 g for 15 minutes and then read on a microhematocrit table (JAIN, 1993). The total hemoglobin concentration was determined by the cyanmethemoglobin method, and a subsequent spectrophotometer reading was performed at 540 nm (HENDRIX, 2005).

The systolic, diastolic, and mean arterial pressures were measured by the invasive method, through cannulation of the auricular artery with a 22G catheter, with the pressure transducer positioned at heart level as a "zero" reference and coupled with a portable monitor (model DX 2020, Dixtal Collaborative Evolution, Manaus, AM).

Data were analyzed for normal distribution by the Shapiro-Wilk test. The variables that showed normal distribution were subjected to an analysis of variance using the procedure PROC MIXED for repeated measures in time. Where there were significant differences ($p < 0.05$) between the times, comparisons were made between those with the mixed-mean test. The Wilcoxon test was used to evaluate the CRT data, which had a non-normal distribution. Statistical analysis was performed using the statistical program SAS (version 9.3., SAS Institute Inc., Cary, NY, USA).

Results and Discussion

The removal of 30% of the total blood volume by jugular venipuncture was an efficient method for causing acute anemia in goats, with total hemoglobin reduced below reference values (8-12 g/dL) in as little as 1 hour, and a decrease in packed cell volume below reference values (22-38%) from six hours after blood loss (JAIN, 1993).

Tachycardia and tachypnea were observed one hour after blood withdrawal (Table 1), caused by a physiological response to reduced blood volume as the animals attempted to maintain cardiac output and tissue perfusion. In a previous study, goats subjected to a loss of 15 and 30% of blood volume had increased heart and respiratory rates, with the intensity of the increase dependent on the degree of blood loss (ABDALLA; ABDELATIF, 2008). In this study, respiratory rate was five times higher than baseline one hour after blood loss, while Abdalla and Abdelatif (2008) observed an increase four times higher than baseline. Similar to this study, they reported a decrease in respiratory rate six hours after acute blood loss (ABDALLA; ABDELATIF, 2008). Heart rate, despite showing a less accentuated increase, was more affected by the loss of blood volume, returning to baseline values at least 12 hours after acute loss.

Hyperventilation is one of the main responses to acute blood loss because the respiratory system is highly sensitive to the concentration of hydrogen ions produced when there is a reduction in oxygen transport. This was evident by the significant reduction in blood pH at T1h ($P < 0.05$), as well as its return to baseline values at T6h. Heart rate regulation, however, is affected not just by a reduction in oxygenation but is also dependent on humoral mechanisms, based on the action of vasopressin and renin-angiotensin (ABDALLA; ABDELATIF, 2008; LIPINSKA et al., 2004). But in our study, it was not possible to determine exactly when the respiratory and cardiac rates returned to baseline, since the evaluations were performed at intervals of six hours.

Table 1. Mean and standard deviation of heart rate (HR), respiratory rate (RR), rectal temperature (RT) capillary refill time (CRT), packed cell volume (PCV), red blood cell count (RBC), total hemoglobin concentration (Hb), and number of leucocytes in goats subjected to phlebotomy (30% blood volume loss) at times T0 (immediately before blood loss), one (T1h), six (T6h), 12 (T12h), 24 (T24h), 72 hours (T72h), and eight (T8d), 16 (T16d), 24 (T24d), and 32 (T32d) days after blood withdrawal.

Time	Parameters							
	HR (beat/min)	RR (mov/min)	RT (°C)	CRT (sec)	PCV (%)	Hb (g/dL)	RBC (x10^6/µL)	Leucocytes (x10^3/µL)
T0	80^{def}±18.0	18.0^{d}±3.0	38.5^{d}±0.4	1.9^{cb}±0.1	27^{a}±2.9	8.7^{a}±0.9	14.7^{a}±1.6	8.8^{ab}±2.4
T1h	149^{a}±26.0	101^{a}±2.0	40.0^{a}±0.2	2.6^{a}±0.5	22^{bc}±3.9	7.0^{bc}±1.2	13.0^{abc}±1.4	8.6^{b}±2.2
T6h	128^{ab}±19.0	22^{d}±5.0	39.2^{c}±0.5	2.5^{a}±0.5	18^{ecd}±2.4	5.8^{ecd}±0.7	12.1^{abc}±2.3	12.4^{ab}±3.7
T12h	118^{bc}±16.0	22^{d}±4.0	39.2^{bc}±0.4	2.2^{ab}±0.4	17^{ed}±2.5	5.4^{bc}±0.8	10.8^{bcd}±1.5	12.9^{ab}±3.5
T24h	98^{cd}±14.0	23^{cd}±6.0	39.2^{c}±0.3	2.4^{ab}±0.5	17^{ed}±2.2	5.4^{c}±0.7	11.2^{abc}±2.2	11.6^{ab}±2.5
T72h	100^{cd}±12.0	24^{cd}±6.0	39.3^{cb}±0.3	2.2^{ab}±0.4	16^{e}±2.4	5.1^{cb}±0.8	10.4^{bcd}±1.6	9.1^{ab}±2.4
T8d	87de±9.0	36^{b}±12.0	39.9^{ab}±0.2	2.1^{ab}±0.5	19^{ecd}±2.7	6.1^{ab}±0.9	10.2^{bcd}±2.6	11.9^{ab}±3.1
T16d	76^{def}±6.0	35^{cb}±9.0	39.4^{abc}±0.3	1.7^{c}±0.2	21^{bcd}±2.3	6.7^{abc}±0.7	9.5^{cd}±2.9	14.3^{a}±5.3
T24d	63^{ef}±6.0	22^{d}±5.0	38.9^{cd}±0.3	2.1^{ab}±0.2	25^{ab}±1.9	8.0^{cd}±0.6	14.8^{a}±1.95	11.6^{ab}±3.6
T32d	59^{f}±9.0	25^{bcd}±7.0	39.0^{cd}±0.2	1.7^{c}±0.2	25^{ab}±3.7	8.1^{cd}±1.2	13.8^{ab}±2.0	12.2^{ab}±3.8

Different lowercase letters in the same column mean significant difference between times (P<0.05).

There was an average increase of 2 °C in rectal temperature one hour after blood loss (Table 1). Over time, the mean values decreased, but the return to basal temperatures did not occur until T24d. Although rectal temperatures remained within the reference values for the species (38-40 °C) (PUGH, 2005), the occurrence of hyperthermia may be linked to increased peripheral resistance (to maintain pressure), as well as the release of hormones involved in the production of heat, such as adrenocorticotropic hormones and catecholamines (ABDALLA; ABDELATIF, 2008, 2010). The return to basal temperatures occurred only after remission of the anemia (T24d), indicating that acute blood loss interfered with thermoregulation in these animals.

Packed cell volume was decreased at T1h and remained below baseline until T16d, returning to reference values (22-38%) (JAIN, 1993) only after T24d. The hemoglobin concentration was reduced at T1h and remained lower than the reference values (8-12 mg/dL) (JAIN, 2003) until T24d. The number of red blood cells was decreased after T12h and returned to baseline at T24d (Table 1). It is important to note that the values of this parameter were within the reference range for the species after blood loss (8-18 x 10^6/µl).

Although packed cell volume decreased in the first hour, the number of red blood cells decreased only later, probably due to hemodilution, which is a physiological and emergency response to blood loss. During this response, fluid moves from the interstitial space into the blood stream due to the reduction of blood pressure, causing the dilution of blood constituents and increasing blood volume. This process is also accompanied by splenic contraction, which is responsible for increasing the number of red blood cells in circulation (CUNNINGHAM, 2004; ABDALLA; ABDELATIF, 2010). The recovery period from anemia in this study was delayed compared to the recovery of goats that suffered losses of 15% and 30% of blood volume and recovered in six days or two weeks, respectively (ABDALLA; ABDELATIF, 2008). This longer recovery time may result from the way blood loss was calculated. In this study, eight percent of live

weight was used to calculate the percentage of total blood volume, while in the study by Abdalla and Abdelatif (2008) they used the more reliable Evan's blue dye technique.

CRT, a physiological variable used to identify hypoperfusion, was shown to be elevated at T1h, but at T12h there was no difference in relation to baseline. The compensatory processes of hemodilution and splenic contraction likely contributed to the reestablishment of CRT 12 hours after blood loss.

The number of leukocytes remained unchanged in relation to T0 (Table 1) and reference values (4-13 x 10^3/µl), indicating a lack of significant immune response after acute blood loss, a finding similar to other studies (ABDALLA; ABDELATIF, 2008). This differed from a study with sheep (SOUSA et al., 2012), which showed that acute blood loss led to an increased leukocyte count. According to Maier (2000), the initial response of the body to hemorrhagic injury is characterized by activation of the immune system and an inflammatory reaction. Although cortisol concentration was not measured, the goats in this study went through a stress period from T1h to T6h, indicated by a significant increase in HR, RR, and blood glucose concentration. However, this was not reflected in the number of total leukocytes, which are routinely elevated in ruminants under stress (FELDMAN et al., 2000).

The concentrations of total protein, globulin, and albumin (Table 2) were decreased one hour after blood loss, and returned to baseline values at T16d, T24d, and T8d, respectively. Although albumin was reduced, concentrations remained within the reference values for the species (2.7-3.9 g/dL) throughout the study, while total protein (6.4-7.0 g/dL) and globulin (2.7-3.9 g/dL) were below the reference values up to T24d and T24h, respectively (KANEKO et al., 2008). There was a reduction in non-ionizable serum calcium concentration from T1h to T24h, in relation to the baseline (Table 2), although the calcium concentration was below the reference values until T8d (8.9-11.7 mg/dL) (KANEKO et al., 2008). Most calcium in the bloodstream is in the non-ionized form (bound to proteins), with albumin being the major binding protein (BARRÊTO-JÚNIOR et al., 2011). When blood loss occurs, calcium is reduced due to protein loss and as a result of hemodilution. As shown in Table 2, the increase in calcium concentration occurred in parallel with the increase in albumin concentration with values returning to baseline at T8d. These findings are corroborated by Abdalla and Abdelatif (2008) in goats and by Sousa et al. (2012) in sheep.

The glucose concentration increased during the period from T1h to T6h in relation to baseline, and remained above the reference values (50-75 mg/dL) (KANEKO et al., 2008) for the species until T24h. The initial glucose concentration was above the reference values and subsequently increased after the loss of blood, possibly due to the release of cortisol and catecholamines that occurs in animals under stress, which promotes an increase in glucose concentration (DUTTON, 2003).

At T1h and T24h the values of pH, TCO_2, bicarbonate concentration, and base excess (BE) were lower in relation to T0 (Table 3). The values of pH (7.3-7.5), TCO_2 (20.7-30.7 mmol/L), and pCO_2 (34.6-48.8 mmHg) remained within the reference values for the species (STEVENS et al., 1994; NUNES et al., 2014). However, at T24h the value of the BE was below the reference values (-3 to + 11 mmol/L), while bicarbonate was below reference values (25-29.4 mmol/L) (STEVENS et al., 1994; NUNES et al., 2014) from T0. The lactate concentration was increased markedly at T1h and remained above the reference values up to T72h (9.0-12.0 mg/dL) (PUGH, 2005). Reduction in blood volume leads to decreased circulation, causing poor peripheral perfusion of non-vital organs. This increases the production of lactate and H+ ions, resulting in a decrease in pH as observed, because cells in affected organs enter the anaerobic cycle to maintain adequate levels of energy for metabolism

(SHIRES; CANIZARO, 1973; ORTOLANI, 2003). At the baseline, the values of both lactate and glucose were above the reference values, possibly due to the containment stress, since adrenaline stimulates the transformation of hepatic glycogen into glucose, as well as promoting the breakdown of glycogen into lactate in tissues such as muscle (LEHNINGER, 1993).

Table 2. Mean and standard deviation of total protein (TP), albumin, globulin, calcium (Ca), glucose, and lactate from goats subjected to phlebotomy (30% blood volume loss) at times T0 (immediately before blood loss), one (T1h), six (T6h), 12 (T12h), 24 (T24h), 72 hours (T72h), and eight (T8d), 16 (T16d), 24 (T24d), and 32 (T32d) days after blood withdrawal.

Time	Parameters					
	TP (g/dL)	Albumin (g/dL)	Globulin (g/dL)	Ca (mg/dL)	Glucose (mg/dL)	Lactate (mg/dL)
T0	$6.7^{a}\pm0.5$	$3.32^{a}\pm0.2$	$3.38^{a}\pm0.3$	$9.1^{a}\pm0.4$	$82.7^{cde}\pm9.3$	$13.4^{bc}\pm6.3$
T1h	$5.4^{e}\pm0.3$	$2.75^{d}\pm0.1$	$2.65^{de}\pm0.2$	$8.0^{c}\pm0.5$	$252.0^{a}\pm14.1$	$78.6^{a}\pm7.20$
T6h	$5.4^{e}\pm0.3$	$2.85^{cd}\pm0.1$	$2.55^{e}\pm0.2$	$8.2^{bc}\pm0.4$	$153.1^{b}\pm12.6$	$22.7^{b}\pm7.0$
T12h	$5.5^{de}\pm0.2$	$2.90^{bcd}\pm0.1$	$2.60^{de}\pm0.1$	$8.2^{bc}\pm0.4$	$95.9^{c}\pm10.5$	$17.4^{bc}\pm5.7$
T24h	$5.6^{de}\pm0.2$	$2.92^{bcd}\pm0.1$	$2.68^{de}\pm0.1$	$8.1^{bc}\pm0.3$	$91.1^{cd}\pm8.0$	$12.6^{bc}\pm3.8$
T72h	$5.8^{cde}\pm0.2$	$2.97^{bcd}\pm0.1$	$2.83^{cde}\pm0.1$	$8.8^{abc}\pm0.5$	$67.1^{e}\pm7.9$	$9.7^{c}\pm6.8$
T8d	$6.1^{bcd}\pm0.2$	$3.11^{abc}\pm0.07$	$2.99^{bcd}\pm0.1$	$9.1^{a}\pm0.3$	$75.1^{de}\pm6.2$	$14.7^{bc}\pm9.1$
T16d	$5.9^{cde}\pm0.3$	$3.00^{bcd}\pm0.1$	$2.90^{cde}\pm0.2$	$8.9^{ab}\pm0.4$	$76.9^{de}\pm9.7$	$13.0^{bc}\pm5.4$
T24d	$6.3^{abc}\pm0.3$	$3.02^{bcd}\pm0.12$	$3.28^{abc}\pm0.1$	$8.9^{ab}\pm0.5$	$69.0^{e}\pm6.9$	$12.9^{bc}\pm7.0$
T32d	$6.6^{ab}\pm0.3$	$3.15^{ab}\pm0.1$	$3.45^{ab}\pm0.2$	$9.2^{a}\pm0.4$	$70.9^{e}\pm4.7$	$10.7^{bc}\pm3.2$

Different lowercase letters in the same column mean significant difference between times ($P<0.05$).

Table 3. Mean and standard deviation of pH, pCO_2, BE, HCO_3-, and TCO_2 values from goats subjected to phlebotomy (30% blood volume loss) at times T0 (immediately before blood loss), one (T1h), six (T6h), 12 (T12h), 24 (T24h), 72 hours (T72h), and eight (T8d), 16 (T16d), 24 (T24d), and 32 (T32d) days after blood withdrawal.

Time	Parameters				
	pH	pCO_2 (mmHg)	BE (mmol/L)	HCO_3^- (mmol/L)	TCO_2 (mmol/L)
T0	$7.36^{ab}\pm0.03$	$41.1^{a}\pm3.0$	$-2.2^{a}\pm1.8$	$22.9^{ab}\pm1.4$	$24.1^{ab}\pm1.5$
T1h	$7.30^{c}\pm0.04$	$40.9^{ab}\pm2.8$	$-5.6^{bc}\pm2.8$	$20.0^{cd}\pm2.1$	$21.1^{cd}\pm2.2$
T6h	$7.37^{ab}\pm0.03$	$38.5^{ab}\pm2.2$	$-2.1^{a}\pm1.2$	$22.1^{abc}\pm1.1$	$23.1^{abc}\pm1.3$
T12h	$7.38^{ab}\pm0.01$	$36.5^{ab}\pm2.6$	$-3.2^{abc}\pm1.5$	$21.1^{bcd}\pm1.4$	$22.1^{bcd}\pm1.3$
T24h	$7.34^{bc}\pm0.03$	$36.0^{b}\pm3.0$	$-5.7^{c}\pm2.2$	$19.2^{d}\pm1.9$	$20.1^{d}\pm2.0$
T72h	$7.37^{ab}\pm0.02$	$38.4^{ab}\pm3.5$	$-2.3^{ab}\pm2.5$	$22.1^{abc}\pm2.1$	$23.2^{abc}\pm2.3$
T8d	$7.35^{bc}\pm0.03$	$40.9^{ab}\pm2.8$	$-2.8^{abc}\pm1.6$	$22.1^{abc}\pm1.2$	$23.2^{abc}\pm1.4$
T16d	$7.40^{a}\pm0.03$	$38.5^{ab}\pm3.8$	$-0.6^{a}\pm2.6$	$24.5^{a}\pm1.2$	$25.5^{a}\pm1.2$
T24d	$7.38^{ab}\pm0.00$	$36.2^{ab}\pm2.1$	$-3.3^{abc}\pm1.7$	$21.2^{bcd}\pm1.4$	$22.2^{bcd}\pm1.4$
T32d	$7.41^{a}\pm0.02$	$36.1^{ab}\pm3.7$	$-1.0^{a}\pm1.3$	$22.7^{abc}\pm1.7$	$24.3^{ab}\pm1.3$

Different lowercase letters in the same column mean significant difference between times ($P<0.05$).

Because bicarbonate acts as a pH buffer, the low pH caused a decrease in its concentration, resulting in the observed deficit of this compound. Hyperventilation, due an increase in the RR, was responsible for the decrease of TCO_2, while pCO_2 was lower only at T24h.

The systolic, diastolic, and mean pressures were affected similarly throughout the evaluation. At T1h, the values were lower than half of those observed at T0, and lower than the reference values (SP: 107 to 121 mmHg, DP: 71 to 87 mmHg, MP: 85 to 104 mmHg) (DZIKITI et al., 2011). The values recovered at the later times (Table 4). This rapid elevation of pressure occurs due to the immediate release of catecholamines during significant blood loss, causing an increase in peripheral vascular resistance (CUNNINGHAM, 2004). The return of these pressures after T1h to the baseline values, while other parameters indicative of tissue perfusion (CRT, HR, RR, blood pH, TCO_2, BE, and bicarbonate) were still affected, demonstrates that blood pressure is not a good indicator of perfusion. This finding was also reported by Dourado (2010).

Table 4. Mean values and standard deviation of the systolic pressure (SP), diastolic pressure (DP), and mean pressure (MP) of goats subjected to phlebotomy (30% blood volume loss) at times T0 (immediately before blood loss), T1 (immediately after blood loss), one (T1h), six (T6h), and 12 (T12h) hours after blood loss.

Parameters	Times				
	T0	T1	T1h	T6h	T12h
SP (mmHg)	$126^{a}\pm17.0$	$47^{c}\pm16.0$	$106^{ab}\pm20.0$	$102^{ab}\pm21.0$	$96^{b}\pm11.0$
DP (mmHg)	$72^{a}\pm13.0$	$23^{b}\pm17.0$	$63^{a}\pm21.0$	$70^{a}\pm19.0$	$73^{a}\pm13.0$
MP (mmHg)	$97^{a}\pm9.0$	$40^{b}\pm22.0$	$86^{a}\pm13.0$	$82^{a}\pm21.0$	$86^{a}\pm12.0$

Different lowercase letters in the same column mean significant difference between times ($P<0.05$).

Biochemical analyses of AST and GGT activity, and urea and creatinine concentrations (data not shown) were performed to assess the influence of blood loss on the kidneys and liver of the animals, since severe blood loss may cause pre-renal azotemia and alterations in liver enzymes, due to tissue hypoxia (SOUSA et al., 2012). However, these variables remained within the reference values for the species, indicating that the induced blood loss did not cause damage to these organs.

The acute loss of 30% of total blood volume in goats caused changes in clinical, blood gas, biochemical, and cardiovascular parameters that were compensated for within the first six hours, while hematological changes were more persistent, with basal values restored only after 24 days.

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