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Influence on clinical biochemistry values of black-tufted marmosets (*Callithrix penicillata*) anesthetized with isoflurane or sevoflurane

Influência sobre valores de bioquímica clínica de saguis-de-tufo-preto (Callithrix penicillata) *anestesiados com isoflurano ou sevoflurano*

A. *Costa*, D.R. *Soares*, C.O. *Borella*, W. *Dietze*, A.S. *Uliana*, A.N. *Moraes*, M.E. *Saito*

Universidade do Estado de Santa Catarina, Centro de Ciências Agroveterinária, Hospital de Clínica Veterinária, Lages, SC, Brasil

ABSTRACT

The objective of this study was to evaluate the clinical biochemistry behavior of Black-Tufted Marmosets (*Callithrix penicillatta*) submitted to blood collection without sedation and after general anesthesia with anesthetics isoflurane or sevoflurane. Blood collections were performed on (M1) day before anesthesia by physical restraint, and (M2) after anesthesia. There were four groups: Isoflurane (GI) and Sevoflurane (GS) using an anesthetic box. GIM: isoflurane induction with mask for a shorter period. Control group (GP): physical restraint in both moments. Plasma was separated and frozen to measure clinic biochemistry values. Urea was higher at M2 in groups GI and GP. AST was higher in M2 in GI, GS, and GP and only GI showed an increase in CK in M2. Glucose was higher in M1 in the GI, GS, and GP groups and fructosamine was higher in M2 in the GI. Stress caused by physical restraint can cause biochemical changes and these must be considered when interpreting the exams. Both the inhalational anesthetic isoflurane and sevoflurane did not cause clinically significant changes in clinical biochemistry results.

Keywords: primates, inhalation anesthesia, biochemistry, physical and chemical restraint

RESUMO

O objetivo desse estudo foi avaliar o comportamento da bioquímica clínica de saguis-do-tufo-preto (Callithrix penicillatta) *submetidos à coleta sanguínea sem sedação e após anestesia geral, com os anestésicos isoflurano ou sevoflurano. As coletas de sangue foram realizadas: (M1) dia antes da anestesia por contenção física e (M2) após anestesia. Foram definidos quatro grupos: isoflurano (GI) e sevoflurano (GS), utilizando caixa anestésica; GIM: indução com isoflurano com máscara por um período menor; grupo controle (GCF): contenção física em ambos os momentos. O plasma com EDTA foi separado e congelado para realizar dosagem da bioquímica clínica. A ureia foi maior no M2 nos grupos GI e GCF. A AST foi maior no M2 nos GI, GS e GCF e somente o GI apresentou aumento de CK no M2. A glicose foi maior no M1 nos grupos GI, GS e GCF, e a frutosamina foi maior no M2 no GI. O estresse causado pela contenção física pode causar alterações bioquímicas e essas devem ser levadas em consideração na interpretação dos exames. Tanto o anestésico inalatório isoflurano quanto o sevoflurano não causaram alterações clinicamente significantes nos resultados da bioquímica clínica.*

Palavras-chave: primatas, anestesia inalatória, bioquímica, contenção física e química

INTRODUCTION

Biomarkers or biological markers can be defined as elements related to cellular, biochemical, or molecular changes, measurable in biological components, such as tissues, cells, or fluids. More recently, the definition has been expanded to include biological characteristics that can be objectively measured and evaluated as an indicator of normal biological processes, pathogens, or pharmacological responses to

Corresponding author: adsoncostavet@gmail.com
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therapeutic interventions. In practice, biomarkers include tools and technologies that can aid in understanding the prediction, cause, diagnosis, progression, regression, or outcome of treatment of a disease (Eckersall and Bell, 2010).

Callitrichidae's renal function is evaluated from the measurement of urea and creatinine. Azotemia is indicative of renal disease and, as in other species, extensive renal injury must occur for elevations in urea and creatinine values to be observed (Aulbach and Patrick, 2019).

According to Heatley and Russell (2020), alanine aminotransferase (ALT) is an indicator of hepatocellular injury with high sensitivity, but low specificity because in marmosets there is ALT activity in the heart muscle and kidneys. Aspartate aminotransferase (AST) has the highest activity in the heart muscle followed by the liver and can also be used to detect hepatocellular injury. Hepatobiliary damage can be verified by the measurement of alkaline phosphatase (FA), total bilirubin and/or gamma glutamyltransferase (GGT). In monkeys of the Macaca genus, GGT has been described as a more sensitive and specific marker for biliary diseases than FA (Aulbach and Patrick, 2019). Bilirubin metabolism in marmosets is similar to that of humans. Therefore, hepatobiliary and hemolytic diseases cause the elevation of total bilirubin values (Heatley and Russel, 2020).

Glucose values can be influenced by numerous factors. Stress can cause hyperglycemia and the opposite can occur in cases of prolonged fasting. Therefore, small primates should be continuously evaluated for serum or plasma glucose levels during anesthesia (Vilani, 2009; Heatley and Russel, 2020).

Variations due to age, sex, species, geographic origin, duration in captivity and estrus status have been identified in non-human primates (NHP). Substantial variations in lymphocyte counts, total protein, globulin, and C-Reactive Protein (PCR) levels are often found among wild-caught NHPs because of their varied history and environmental exposure to naturally occurring antigens and diseases (Hall and Everds, 2003).

MATERIAL AND METHODS

An authorization issued by the Brazilian Institute for the Environment and Renewable Resources (IBAMA) was granted for the execution of the project through the scientific activity authorization SISBIO nº 72968-1. Also approved by the Ethics Committee on the Use of Animals (CEUA) under protocol nº 6387021219. A partnership was carried out between the 5th Platoon of the Garrison Environmental Military Police of Santa Catarina and the Veterinary Clinic Hospital of the University of Santa Catarina State, with the objective of performing the anesthetic experiment and later the ligation or vasectomy procedure for population control of the animals involved.

Thirty-two black-tufted marmosets were used, of both sexes, originating from an illegal captivity charged by the 5th Garrison Platoon of the Environmental Military Police. Currently, the animals are in the same operated location, with a temporary designated trustee and awaiting transfer to the Wild Animal Screening Center (CETAS) at Rio Vermelho State Park, Florianópolis-SC. The animals were captured manually with the help of leather gloves and transferred in transport boxes with packaging divided into families to the Veterinary Clinic Hospital - HCV, located at CAV-UDESC in Lages/SC, with a journey of approximately ten minutes. The average weight of the animals was 0.409 kg, with a minimum of 0.193kg and a maximum of 0.506kg, with 17 males and 15 females.

The study was carried out on the premises of the Veterinary Clinic Hospital (HCV), at the Agroveterinarian Sciences Center (CAV), at the University of Santa Catarina State (UDESC), in Lages/SC. It also counted with the collaboration of the Veterinary Clinical Laboratory Services and Veterinary Anesthesiology at the institution.

To transport the animals between captivity and the HCV, an air-conditioned car with a large transport box was used, capable of transporting a family of primates without separating the families to avoid the stress of separation. The natural environment marmosets live in family social units, and social isolation is a stressor that can lead to the emergence of behavioral disorders and physiological changes and, in the

long term, induce the emergence of pathologies (Cinini *et al*., 2014). The moving of animals was carried out 48 hours before the experiment, one family per phase, and allocated in a 2m3 cage for acclimatization.

The animals were fed every 12 hours with extruded food for small primates (Megazoo®) and various fruits. Water was kept ad libitum and always fresh throughout the study period. All animals were fasted for four hours before the anesthetic and surgical procedure. At times, when apathy and altered state of consciousness of the animals were noticed, the patient's blood glucose was measured with an Accu Chek Performa® portable glucometer. 50% glucose (0.5ml/kg) was administered orally or injected in hypoglycemic animals (less than 60mg/dL).

The surgical procedure of choice was the Parkland technique of bilateral partial salpingectomy in females and the double ligation technique was used for vasectomy in males. All animals used in the study were returned to the trustee after 48 hours of observation.

Blood collections were performed at two times. Moment 1 (M1) corresponds to blood collection 24 hours before the anesthetic and surgical procedure. In M1, the animals were manually restrained with the help of a leather glove and then antisepsis was performed with 70% alcohol to collect blood by puncturing the femoral vein at the femoral trigone level. At moment 2 (M2) the animals were under inhalation anesthesia, except for the control group, and the collection was performed before the surgical procedure. In both moments, 1.0 mL of blood was collected by venipuncture with a 26G needle and a 1 mL syringe. Blood was stored in 2 mL polypropylene microtubes containing 20µL of 10% disodium EDTA anticoagulant, resulting in a final concentration of 2mg/mL of whole blood.

The animals were divided into four groups. Isoflurane (GI) was used in the first group and sevoflurane (GS) was used in the second group. The animals were induced using an anesthetic box (capacity for 16.6 L), anesthetic concentration of 5 V% for the isoflurane group and 5 V% for the sevoflurane group, with 100% O2 (4 L/min). As they reached recumbency, they were intubated with a Pean Murph endotracheal tube suitable for their size, supplemented with 100% volume of O2 at a flow of 2L/min, in an open circuit without rebreathing gases, and maintained with spontaneous ventilation. In these first two groups, post-anesthesia blood collection was performed on average 40 minutes after anesthetic induction. And a physical restraint group (GP), which served as a control group, in which the blood samples of the two moments were performed only with physical restraint. To complete the number of different groups, some animals were submitted to the study more than once, with an interval of 2 to 3 months between their implementations. Thus, the number of animals per group was GI (n=12), GS (n=13), GIM (n=8) and GP (n=9).

Pre-anesthetic induction with injectable drugs was not performed, as the black-tufted marmosets are small primates, weighing around 300 g. To avoid excessive stress or the animals' escape, the capture was performed manually, with the aid of leather glove, and immediate packaging in anesthetic boxes, in which they were induced with the tested inhalational anesthetics. The use of pre-anesthetic medication with injectable drugs is recommended only in primates weighing more than 8kg (Longley, 2008).

Blood samples with EDTA were centrifuged at 2000*g*. The plasma was separated, placed in micro tubes and frozen at -20ºC. The volume of plasma samples averaged 0.5mL. Plasma measurements of the following analytes and respective methods were performed: urea (UV Enzyme), creatinine (Alkali Picrate Colorimetric - Jaffé), alanine aminotransferase (UV-IFCC Kinetics), aspartate aminotransferase (UV-IFCC Kinetics), gamma glutamyltransferase (modified Szasz), triglycerides (Colorimetric Glycerolperoxidase), glucose (GOD - Trinder), fructosamine (NBT Reduction) and creatine kinase (UV-IFCC Kinetics). All measurements were performed using colorimetric tests with commercial kits (Labtest, Lagoa Santa-MG) in an automatic analyzer (Labmax Plenno, Labtest, Lagoa Santa-MG).

The results were initially analyzed for normality using the Shapiro-Wilk test. Differences were considered statistically significant when $p<0.05$. Parametric data were analyzed using the paired t-test and values were expressed as average ± standard deviation. Nonparametric data by the

Mann-Whitney test and values were expressed as median. The ANOVA test of variance between groups GI, GS and GIM was also performed. The analyses were performed with the aid of Sigma Stat 3.1 computer software.

RESULTS AND DISCUSSION

To better interpret the results presented, Table 1 shows two studies, one carried out by Cardoso, *et al*. (2021) with 14 black-tufted marmosets (*Callithrix penicillata*) and one performed by Kuehnel, *et al*. (2012) in 54 white-tufted marmosets (*Callithrix jacchus*), showing values of healthy animals. For the value of fructosamine, the closest species found was the cotton-headed marmoset (*Saguinus oedipus*) in a study conducted by Shukan, *et al*. (2012). The average ± standard deviation for males was 255.79±53.62µmol/L and for females 255.58±47.62 µmol/L.

Table 1. Values (Mean ± standard deviation) from a study conducted by Cardoso *et al*. (2021) clinical biochemistry of samples obtained from 14 black-tufted marmosets (*Callithrix penicillata*) and values (Median and percentile range) from a study conducted by Kuehnel, *et al*. (2012) in 54 white-tufted marmosets (*Callithrix jacchus*)

	Callithrix penicillata		*Callithrix jacchus*	
	Male	Female	Median	Range (3º–97º percentile)
Urea (mg/dL)	11.10±5.20	14.50±5.92	50.46	20.24–112.15
Creatinine (mg/dL)	0.39±0.07	0.35±0.06	0.32	0.16–0.55
ALT (UI/L)	-	-	2.95	0.24–13.50
AST (UI/L)	128.90±123.96	87.50±31.98	155.7	51.24–316.21
GGT (UI/L)	-	3.5±7.0	2.8	0.24–13.50
Triglycerides (mg/dL)	123.80±58.96	79.00±77.05	95.38	49.0–230.13
Glucose (mg/dL)	123.80±38.31	113.75±8.96	124.3	72.24–214.21
CK (UI/L)	-	-	281	76.90–1801.84

ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; GGT: Gamma glutamyltransferase; CK: Creatine kinase.

The values (Average±standard deviation, median and minimum – maximum) of the dosages of the clinical biochemistry analytes of the different groups are shown in Table 2 separated by the different groups of work. The statistical difference of the parametric data was mentioned in the average ± standard deviation column while the non-parametric data in the median column.

Urea values were statistically higher at M2 in groups GI and GC. Cortisol causes an increase in protein catabolism, leading to an increase in urinary nitrogen. There is an increase in serum amino acids with greater degradation of them, raising the plasma urea concentration. Protein anabolism is inhibited, with growth depression. Low levels of cortisol in the liver have an effect of increasing protein synthesis and reducing lysis, with an increase in the concentration of plasma proteins (González and Silva, 2003).

Another cause of interference, but less likely, would be the lack of adaptation regarding water intake, which may have been the cause, resulting in subclinical dehydration. Which could also justify that, in GI, the creatinine value was also statistically higher in M2. However, there was no increase above the reference values for the species to the point of characterizing pre-renal azotemia. According to Scott and Stockham (2002), pre-renal azotemia develops when there are situations that lead to decreased blood flow to the kidneys, such as dehydration, blood loss and congestive heart failure, resulting in a decrease in glomerular filtration rate. Hypovolemia causes increased reabsorption of sodium, water, and, passively, urea in the proximal convoluted tubule, as the slower flow allows more time for reabsorption.

Table 2. Values [Mean ± Standard Deviation or Median (Range)] of plasma biochemistry of samples obtained from black-tufted marmosets (*Callithrix penicillata*) physically contained (M1) and chemically contained (M2) with isoflurane (GI), sevoflurane (GS), isoflurane with mask for a shorter time (GIM) and only with physical containment (GP)

	GI		GS		GIM		GP	
	M1	M2	M1	M2	M1	M2	M1	M2
Urea (mg/dL)	35.4± 20.3[a]	57.8± 19.9[b]	57.2± 24.1	58.7± 13.8	47.6± 19.7	49± 16.1	28.4± 11.5[a]	59.7± 16.8[b]
Creatinine (mg/dL)	0,.46± 0.27[a]	0.63± 0.2[b]	0.71± 0.3	0.73± 0.2	0.56± 0.18	0.74± 0.33	0.57± 0.24	0.63± 0.19
ALT (UI/L)	4(1–25)	1(1–10)	2(1–8)	1(1–20)	2.4±2.4	3.8±3.9	6.5±7.9	6±11.4
AST (UI/L)	93.5± 60.6[a]	163.8± 91.6[b]	129[a] (73-210)	195[b] (115-2293)	122.2±27.6	138.6± 65.9	134.4± 36.7[a]	193.4± 65.2[b]
GGT (UI/L)	15± 14.6	13.9± 10.3	17.1± 11.3	14.8± 10.4	31.3± 46.9	27.6± 31	19.5± 15.8	20.6± 12.9
Triglycerides (mg/dL)	170 (76–342)	151 (84–206)	134 (108-630)	120 (83-638)	212.2± 55	168.6± 72.6	329.6± 245.6	239.9± 75.4
Glucose (mg/dL)	255.3± 92.6[a]	130.2± 24.5[b]	205.9± 79.2[a]	79.7± 37.9[b]	186.7± 37.4	212.1± 70	205.4± 64.9[a]	143.5± 657[b]
Fructosamine (µmol/L)	329.4± 23.3[a]	359.9± 16.2[b]	345.3± 22.4[a]	387.8± 15.6[b]	347 (296–377)	348 (301–366)	347 (290-390)	354 (330–381)
CK (UI/L)	522[a] (165-6076)	1241[b] (559-16862)	1128 (422-6049)	1243 (441-35098)	359 (140-1241)	275 (210-1018)	972 (161-1988)	1185 (532-2866)

[ab]Different lowercase letters on the same line mean statistical difference between moments.
ALT: Alanine aminotransferase, AST: aspartate aminotransferase, GGT: gamma glutamyltransferase, CK: Creatine kinase.

As for AST, it was higher in M2 in GI, GS, and GP. A muscle injury resulting from capture at M1 may have led to muscle damage (capture myopathy) after restraint and consequent increase in the enzyme at M2. It is believed that the sensation of fear triggers, through the activation of the sympathetic autonomic nervous system (SANS) and the release of catecholamines, the "sympathetic response to stress". It is a phenomenon characterized by several organic reactions, including hyperglycemia and increases in cellular metabolism, muscle glycogenolysis and vascular tone, with consequent blood deviation to the skeletal striated musculature (Black-Décima *et al*., 2010). When an animal is captured, there is a sudden interruption of skeletal muscle activity, thus blocking a physiological process known as the "muscle pump". The phenomenon is characterized by the mechanical action of muscle contracture on the vascular plexus with consequent expulsion of blood from the venocapillary beds. The heat generated by muscle activity is dissipated and the by-products of glycogenolysis, particularly lactic acid, are removed from the muscle microenvironment. The sudden interruption of the "muscle pump" causes accumulation of lactic acid in the musculature and hypoxia resulting from venous blood stasis. These components, associated with the absence of efficient heat dissipation mechanisms, can lead to cell death (Catão-Dias and Camargo, 2010).

According to Black-Décima, *et al*. (2010), in cases of capture myopathy there is a marked to slight increase in serum enzymes AST, CK and lactic dehydrogenase (LDH). In this study, only the GI showed a significant increase in CK in M2. The increase in AST and absence of increase in CK in the other groups is due to the kinetics of these two enzymes. After muscle injury, the increase in serum CK activity occurs rapidly (peaking at 6 to 12 h), but also decreases rapidly (1 or 2 days), as CK has a short half-life of around 2 h. After muscle injury, serum AST activity rises more slowly than that of CK. The peak of action occurs approximately 24 to 36 h after acute muscle injury, decreasing more slowly than CK after the injury has ceased. The

half-life of AST in blood has been estimated to be 4 to 12 h in dogs, 77 min in cats, and 7 to 8 days in horses (Allison, 2015).

The glucose value was statistically higher in M1 compared to M2 in groups GI, GS and GP. This was due to the sympathetic response by catecholamines previously mentioned. According to Tasker and Herman (2011), the SANS are the main neural component activated during the stress response of the reflex component, through stimulation of the locus coeruleus (LC), with the use of the neurotransmitter noradrenaline (NE) and activation of the adrenal medulla that produces and releases the catecholaminergic hormones noradrenaline and adrenaline (McEwen and Wingfield, 2003). These chemical messengers are responsible for dilating pupils, increasing constriction of the body's blood vessels and cardiac activity, inhibiting the functioning of the gastrointestinal tract, among others. Adrenaline also has a strong role in increasing the metabolic rate, as it increases gluconeogenesis in the liver and skeletal muscles, releasing glucose into the blood (Guyton and Hall, 2012).

There was also a statistically significant difference in the GP, with the glucose value being higher in M1. It can be clearly observed in the second harvest (M2) that the animals visually presented a lower degree of stress, suggesting that the longer adaptation time in the new location and having already passed through the restraint reduced the stress during the second physical restraint. This may have caused less action of catecholamines in relation to the first physical restraint.

As for fructosamine, there was a statistical difference in GI where the value was higher in M2. Fructosamine is formed by the glycosylation of serum proteins, mainly albumin and with serum concentration directly related to blood glucose concentration (Greco, 2001). Some factors with hypoproteinemia and hypoalbuminemia can decrease the values obtained, while others, such as the storage of samples at room temperature, can increase the values of fructosamine (Feldman and Nelson, 2004). Fructosamine is a glycated protein, consisting mainly of albumin, which reflects glycemic control in the previous 1 to 2 weeks, since the half-life of albumin is 14 to 20 days (Tests…, 2001, Camargo *et al.*, 1994), and the glycemic peak occurring in M1, caused by adrenaline, may increase the value of fructosamine in M2.

CONCLUSION

Based on the results obtained with the adopted methodology, it can be concluded that for the species *Callithrix penicillata*, stress caused by physical restraint can cause biochemical changes and these must be considered when interpreting the exams. Both the inhalational anesthetic isoflurane and sevoflurane did not cause clinically significant changes in clinical biochemistry results.

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REFERENCES

ALLISON, R.W. Detecção laboratorial das lesões musculares. In: THRALL, M.A.; WEISER, G.; ALLISON, R.W.; CAMPBELL, T.W. *Hematologia e bioquímica clínica veterinária*. 2.ed. São Paulo: Roca, 2015. p.1011-1014.

AULBACH, A.D.; PATRICK, D.J. Nonhuman primates in preclinical research. In: GUPTA, R.C. (Ed.). *Biomarkers in toxicology*. [California]: Academic Press, 2019. p.91-101.

BLACK-DÉCIMA, P.; ROSSI, R.V.; VOGLIOTTI, A. *et al*. Brown brocket deer *Mazama gouazoubira* (Fischer 1814). In: DUARTE, J.M.B.; GONZALEZ, S. (Eds.). *Neotropical cervidology*: biology and medicine of latin american deer. Jaboticabal: Funep/IUCN, 2010. cap.22, p.190-201.

CAMARGO, J.L.; PINHO, C.; FILLMANN, L. *et al*. Efeito do sexo e da gestação sobre os níveis séricos de frutosamina de indivíduos normais. *Rev. AMRIGS*, v.38, p.13-17, 1994.

CARDOSO, D.L.; COSTA, S.M.; ESPINHEIRO, R.F.; CASTRO, P.H.G.; DIAS, H.L.T. Perfil hematológico e bioquímico de primatas não humanos (*Callithrix penicillata*) cativos no Centro Nacional de Primatas no Estado do Pará. *Biotemas*, v.34, p.1-9, 2021.

CATÃO-DIAS, J.L.; CAMARGO, C.M.S. Capture myopathy. In: DUARTE, J.M.B.; GONZALEZ, S. (Eds.). *Neotropical cervidology*: biology and medicine

CININI, S. M; BARNABE, G. F; GALVÃO-COELHO, N; MEDEIROS, M. A. DE, PEREZ-MENDES, P; SOUSA, M. B. C; COVOLAN, L; MELLO, L. E. Social isolation disrupts hippocampal neurogenesis in young non-human primates. *Frontiers in Neuroscience*, v.8, n.45, 2014.

ECKERSALL, P.D.; BELL, R. Acute phase proteins: Biomarkers of infection and inflammation in veterinary medicine. *Vet. J*., v.185, p.23-27, 2010.

FELDMAN, E.C.; NELSON, R.W. Feline diabetes mellitus. In: FELDMAN, E.C.; NELSON, R.W. (Eds.). *Canine and feline endocrinology and reproduction*. St. Louis: Saunders, 2004. p.539-579.

GONZÁLEZ, F.H.D.; SILVA, S.C. *Introdução à bioquímica clínica veterinária*. Porto Alegre: UFRGS, 2003. 198p.

GRECO, D.S. Diagnosis of diabetes mellitus in cats and dogs. *Vet. Clin. North Am. Small Anim. Pract*., v.31, p.845-853, 2001.

GUYTON, A.C.; HALL, J.E. *Tratado de fisiologia médica*. 12.ed. Rio de Janeiro: Elsevier, 2012. 728p.

HALL, R.L.; EVERDS, N.E. Factors affecting the interpretation of canine and nonhuman primate clinical pathology. *Toxicol. Pathol*., v.31, p.6-10, 2003.

HEATLEY, J.J.; RUSSELL, K.E. *Exotic animal laboratory diagnosis*. New Jersey: Wiley-Blackwell, 2020. 648p.

KUEHNEL, F.; GROHMANN, J.; BUCHWALD, U. *et al*. Parameters of haematology, clinical chemistry and lipid metabolism in the common marmoset and alterations under stress conditions. *J. Med. Primatol*., v.41, p.241-250, 2012.

LONGLEY, L. *Anaesthesia of exotic pets*. Edinburgh: Elsevier Saunders, 2008.

McEWEN, B.S.; WINGFIELD, J.C. The concept of allostasis in biology and biomedicine. *Horm. Behav*., v.43, p.2-15, 2003.

of latin american deer. Jaboticabal: Funep/IUCN, 2010. cap.35, p.324-329.

SCOTT, M.A.; STOCKHAM, S.L. Urinary system. In: _____. *Fundamentals of veterinary clinical pathology*. Iowoa: Iowoa State Press, 2002. p.277-336.

SHUKAN, E.T.; BOE, C.Y.; HASENFUS, A.V. *et al*. Normal hematologic and serum biochemical values of cotton-top tamarins (*Saguinus oedipus*). *J. Am. Assoc. Lab. Anim. Sci*., v.51, p.150-154, 2012.

TASKER J.G.; HERMAN J.P. Mechanisms of rapid glucocorticoid feedback inhibition of the hypothalamic-pituitary-adrenal axis. *Stress*, v.14, p.398-406, 2011.

TESTS of glycemia in diabetes. *Diabetes Care*, v.24, suppl.1, p.S80-S82, 2001.

VILANI, R.G.O.C. Contenção química e anestesia em primatas não humanos. In: KINDLOVITS, A.; KINDLOVTS, L.M. *Clínica e terapêutica em primatas neoptropicais*. Rio de Janeiro: UFJF, 2009. p.297-310.