

**Intraocular pressure and its correlation with blood gas parameters in crested caracaras (*Caracara plancus*) anesthetized with isoflurane and sevoflurane**

[Pressão intra-ocular e sua correlação com parâmetros hemogasométricos em caracaras (*Caracara plancus*) anestesiados com isofluorano e sevofluorano]

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**ABSTRACT**

The intraocular pressure (IOP) and its correlations with arterial carbon dioxide partial pressure (PaCO<sub>2</sub>) and arterial pH were studied in five crested caracaras (*Caracara plancus*) anesthetized with isoflurane (ISO) and sevoflurane (SEV). Baseline IOP values were measured in both eyes (M0). Brachial artery was previously catheterized to obtain blood gas and cardiorespiratory analysis. Anesthesia was induced with 5% ISO and maintained with 2.5% for 40 minutes. IOP measurements and blood samples were evaluated in different moments until the end of the procedure. After recovering, a second anesthesia was induced with 6% SEV and maintained with 3.5%. Parameters were evaluated at the same time points of the previous procedure. IOP reduced significantly (P= 0.012) from M0 at all time points and no significative changes were observed between ISO and SEV anesthetics. Correlation between IOP and PaCO<sub>2</sub> and between PIO and blood pH were found only for SEV. IOP and blood pH decreased in parallel with IOP, whereas values of PaCO<sub>2</sub> increased in caracaras anesthetized with isoflurane and sevoflurane.

Keywords: crested caracara, *Caracara plancus*, isoflurane, sevoflurane, intraocular pressure, blood gas

**RESUMO**

Avaliou-se a pressão intra-ocular (PIO) e estimaram-se as correlações entre PIO e pressão de dióxido de carbono (PaCO<sub>2</sub>) e pH arterial de cinco caracaras (*Caracara plancus*), anestesiados com isofluorano (ISO) ou sevofluorano (SEV). Valores basais da PIO foram aferidos em ambos os olhos (M0). Cateterizou-se previamente a artéria braquial para obtenção de parâmetros hemogasométricos e cardiorespiratórios. Anestesia foi induzida com ISO a 5V% e mantida por 40 minutos com 2,5V%. PIO e amostras de sangue foram avaliadas em diferentes momentos até o final do procedimento. Após recuperação, uma segunda anestesia foi realizada com SEV a 6% e mantida com 3,5%. Os parâmetros foram aferidos nos mesmos momentos estabelecidos previamente. A PIO decresceu significativamente (P=0,012) de M0 em todos os momentos e não houve diferença estatística entre ISO e SEV. Correlações significativas entre PIO e PaCO<sub>2</sub> e entre PIO e pH sanguíneo foram observadas apenas para a anestesia com SEV. O pH sanguíneo decresceu paralelamente a PIO, enquanto a PaCO<sub>2</sub> aumentou, em caracaras anestesiados com isofluorano e sevofluorano.

Palavras-chave: carcará, *Caracara plancus*, isofluorano, sevofluorano, pressão intra-ocular, hemogasometria

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Recebido em 26 de março de 2008

Aceito em 10 de novembro de 2008

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## INTRODUCTION

Intraocular pressure (IOP) is defined as the pressure exerted by the components of the eye against the fibrous tunics, and such parameter must remain stable in ophthalmic surgeries (Artru and Yoshiriro, 1999; Gelatt and Gelatt, 2001). An exacerbated increase in IOP may lead to serious interurrences in patients with glaucoma and in those with penetrating ocular injury (Sator et al., 1998). Thus, sustain of IOP reduces the risks of vitreous expansion and lens extrusion during cataract surgery (Gelatt and Gelatt, 2001). These authors informed that some anesthetic drugs are able to produce ocular hypertension, notably those that produce marked increases in the central venous pressure and in the episcleral venous pressure. Drugs that directly cause ocular hypotension can also produce ocular hypertension secondary to respiratory depression and acidosis that sometimes occurs with prolonged general anesthesia (Gelatt and Gelatt, 2001). The intraocular vascular tonus is influenced by the partial arterial pressure of carbon dioxide, which may influence the choroidal and retrobulbar blood volumes (Murphy, 1985).

Drugs with sympathetic or parasympathetic actions (such as inhaled anesthetics) can alter the IOP via effects on aqueous humor formation, intraocular blood volume and vascular resistance, extraocular muscle tone, and on the diencephalon. Thus, knowledge of the effects of anesthetic gases on IOP is important (Almeida et al., 2004).

Corneal and lens affections, such as cataract, are commonly found in birds of prey and in others of wild living, forcing them to undergo ophthalmic procedures in cases in which vision is intended (Brooks et al., 1983; Kern et al., 1986; Wilson and Pettifer, 2004; Allgoewer et al., 2006).

The crested caracara (*Caracara plancus*) is a bird of prey and belongs to the Falconiform order. Its geographic distribution extends from the south of Patagonia to the south of the United States of America. It is considered a long neck and feather falcon, and weights 1kg, in average (Sick, 1997).

This study evaluated the IOP in crested caracaras (*Caracara plancus*) before and after isoflurane and sevoflurane anesthesia, and correlated its results with partial arterial pressure of carbon dioxide and blood pH.

## MATERIAL E METHODS

Five crested caracaras were selected and their use was authorized by the *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* (IBAMA). The study was approved by the Ethics Committee on Animal Experimentation of the Faculdade de Ciências Agrárias e Veterinárias (FCAV) at the Universidade Estadual Paulista (UNESP), Jaboticabal, São Paulo, and followed the ethical norms of the Association for Research in Vision and Ophthalmology (ARVO; National Institutes of Health, Publications no. 85-23, revised 1985).

All birds, adapted to captivity, were maintained in the wild animal section of the FCAV - UNESP, in an appropriate environment, and fed once daily received with water *ad libitum*.

IOP from left (LE) and right eyes (RE) were measured by means of applanation tonometry<sup>1</sup>, after ophthalmic instillation of proximetacaine<sup>2</sup>. Baseline values were evaluated at a first moment (M0), and only measurements achieving less than 5% standard deviation by the tonometer were considered.

Anesthetic induction was achieved with 5% isoflurane<sup>3</sup> (ISO), being delivered by a facial mask. For maintenance, the ISO concentration was reduced to 2.5%. Arterial dissection and catheterization of the brachial artery were proceeded in order to obtain blood pressure and blood gas analysis<sup>4</sup>.

It was admitted that birds were recovered based on of the normalization of the cardiac and respiratory parameters, as well as normalization of temperature, vocalization, resistance to physical restraint, and state of awakesness. Once recovered, arterial blood sample was collected and evaluated for baseline values of arterial

<sup>1</sup>Tono-Pen<sup>®</sup>, Mentor O&O - Norwell, MA, USA.

<sup>2</sup>Anestalcon<sup>®</sup>, Alcon - São Paulo, Brazil.

<sup>3</sup>Cristália<sup>®</sup>, Itapira - São Paulo, Brazil.

<sup>4</sup>Hemogasômetro ABL 330<sup>®</sup>, Radiometer - Copenhagen, Holland.

carbon dioxide partial pressure (PaCO<sub>2</sub>) and arterial pH (M0). Induction of anesthesia was carried out as previously described, birds were endotracheally intubated and maintained for 40 minutes with 2,5% ISO diluted in 100% oxygen (1l/min), using an Ayre's T-piece nonrebreathing circuit and monitored throughout the procedure. Birds were maintained in dorsal recumbency, with their heads in lateral recumbency.

IOP was measured five minutes after the ISO anesthetic induction (M5), and at three different time points (M15, M25, M35), at every 10 minutes, with the last IOP measurement occurring five minutes after the end of the anesthesia (M45). Arterial blood samples were collected at four different time points (M0 to M40) in order to analyze PaCO<sub>2</sub> and blood pH. A second anesthetic procedure, with 6% sevoflurane<sup>5</sup> (SEV) for induction and 3.5% for maintenance, was accomplished. IOP and blood gas parameters were measured at the same time points adopted before.

Collected data were analysed<sup>6</sup> by one way repeated measures ANOVA and Tuckey as a post-hoc test, aiming to compare means obtained at different moments. Paired Student *t* test was used to compare the overall mean between ISO and SEV anesthetics. Statistical significance was set at  $P < 0.05$ . Person's test was used to access a possible correlation between IOP and PaCO<sub>2</sub> or IOP and blood pH.

## RESULTS

Overall mean and standard error of mean ( $\pm$ SEM) for IOP at M0 before ISO anesthesia was  $13.19 \pm 1.04$  mmHg, being  $15.1 \pm 1.12$  mmHg the highest value and  $9.16 \pm 1.42$  mmHg the lowest value. Before SEV anesthesia (M0), mean  $\pm$  SEM of IOP was  $14.15 \pm 1.08$  mmHg ( $16.08 \pm 1.11$  mmHg, the highest and  $11.03 \pm 1.02$  mmHg, the lowest values). Significant changes between LE and RE were not seen at M0 ( $P = 0.823$ ). Significant decrease ( $P = 0.012$ ) was observed when values at M0 were compared with the other moments, being the lowest mean  $\pm$  SEM for ISO observed at M1 ( $7.04 \pm 1.08$  mmHg) and the highest at M35

( $8.19 \pm 0.97$  mmHg). In the SEV anesthesia, the lowest mean  $\pm$  SEM was seen at M25 ( $6.82 \pm 0.55$  mmHg) and the highest at M15 ( $7.92 \pm 1.60$  mmHg).

During both anesthetic procedures, IOP values between LE and RE did not change significantly at any time points ( $P = 0.727$ ). In addition, IOP did not vary significantly between ISO ( $7.04 \pm 1.08$  mmHg) and SEV ( $8.85 \pm 1.31$  mmHg) anesthesia, at any of the moments (M5 to M35). Although not significant, IOP tended to reach 1.80 mmHg at M45, during SEV anesthesia. The condition could not be seen when the birds were submitted to ISO anesthesia. Fig. 1 summarizes the results of IOP from M0 to M45.

Table 1 summarizes the results of the evaluated blood gas parameters. Significant increase in values of PaCO<sub>2</sub> were seen during both ISO and SEV anesthetics ( $P = 0.0022$ ). During ISO anesthesia, mean  $\pm$  SEM at M0 was  $24.32 \pm 2.05$  mmHg, with the highest value observed at M25 ( $46.28 \pm 1.4$  mmHg). In SEV anesthesia, mean  $\pm$  SEM at M0 was  $27.56 \pm 2.26$  mmHg, being the highest result seen at M25 ( $43.95 \pm 1.26$  mmHg). Results did not change significantly when both anesthetic procedures were compared ( $P = 0.086$ ).

Values of blood pH significantly decreased during ISO and SEV anesthetics ( $P = 0.0034$ ). For ISO, mean  $\pm$  SEM at M0 was  $7.53 \pm 0.02$ , being the highest value observed at M40 ( $7.33 \pm 0.01$ ). During SEV anesthesia, mean  $\pm$  SEM in M0 was  $7.49 \pm 0.01$ , being the highest one observed at M40 ( $7.35 \pm 0.01$ ). Results did not change significantly when both anesthetic procedures were compared ( $P = 0.089$ ).

Negative correlation between IOP and PaCO<sub>2</sub> was observed during sevoflurane anesthesia ( $r^2 = 0.9826$ ;  $P = 0.0087$ ). Although a high value of root squared was reached for isoflurane, a significant negative correlation between IOP and PaCO<sub>2</sub> could not be observed ( $r^2 = 0.8767$ ;  $P = 0.0637$ ) (Fig. 2). Similarly, positive correlation was only seen for sevoflurane, when blood pH and IOP were compared ( $r^2 = 0.9917$ ;  $P = 0.0042$ ). For isoflurane, although a high value of root squared was reached, a significant positive correlation could not be observed ( $r^2 = 0.8891$ ;  $P = 0.0571$ ) (Fig. 3).

<sup>5</sup>Abbott® Laboratórios - São Paulo, Brazil.

<sup>6</sup>SigmaStat® version 3.0 for Windows - San Jose, CA, USA.

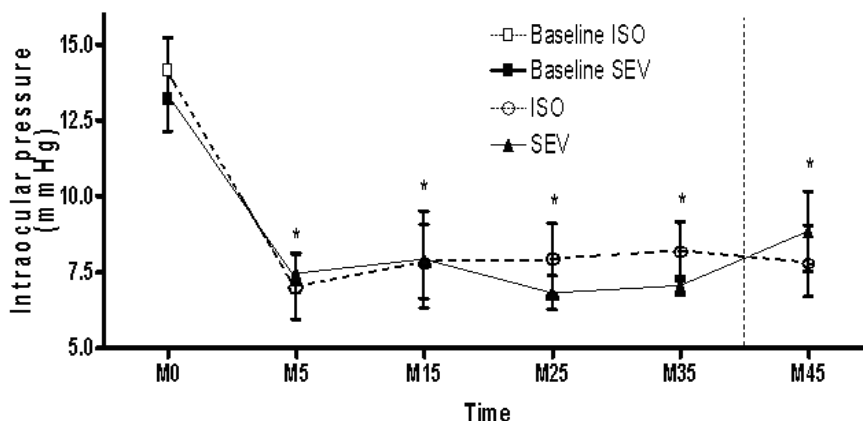


Figure 1. Mean and standard error of mean of intraocular pressure (IOP), at different moments (M0 to M45), from baseline (full and opened squares) throughout 40 minutes of anesthesia (vertical dotted line) in crested caracaras (*Caracara plancus*) anesthetized with isoflurane (ISO) (opened circle and dotted line) or sevoflurane (SEV) (full pyramid and line). \*Differ significantly from M0 by Tukey's test.

Table 1. Mean and standard error of mean ( $\pm$ SEM) of arterial carbon dioxide partial pressure (PaCO<sub>2</sub>) and arterial pH in five crested caracaras (*Caracara plancus*) anesthetized with isoflurane and sevoflurane at different moments

Anesthetic agent and moment (M)	PaCO <sub>2</sub> (mmHg) (mean $\pm$ SEM)	Blood pH (mean $\pm$ SEM)
Isoflurane M0	24.322 $\pm$ 2.057	7.532 $\pm$ 0.0261
Isoflurane M10	40.900 $\pm$ 1.795*	7.381 $\pm$ 0.0151*
Isoflurane M25	43.438 $\pm$ 2.021*	7.360 $\pm$ 0.0156*
Isoflurane M40	46.288 $\pm$ 2.113*	7.337 $\pm$ 0.0154*
Sevoflurane M0	27.563 $\pm$ 2.263	7.494 $\pm$ 0.0168
Sevoflurane M10	41.263 $\pm$ 2.170*	7.379 $\pm$ 0.0121*
Sevoflurane M25	42.513 $\pm$ 1.323*	7.378 $\pm$ 0.0135*
Sevoflurane M40	43.950 $\pm$ 1.260*	7.352 $\pm$ 0.0193*

\*Differ significantly (P $\leq$ 0.05) from M0 by Tukey's test.

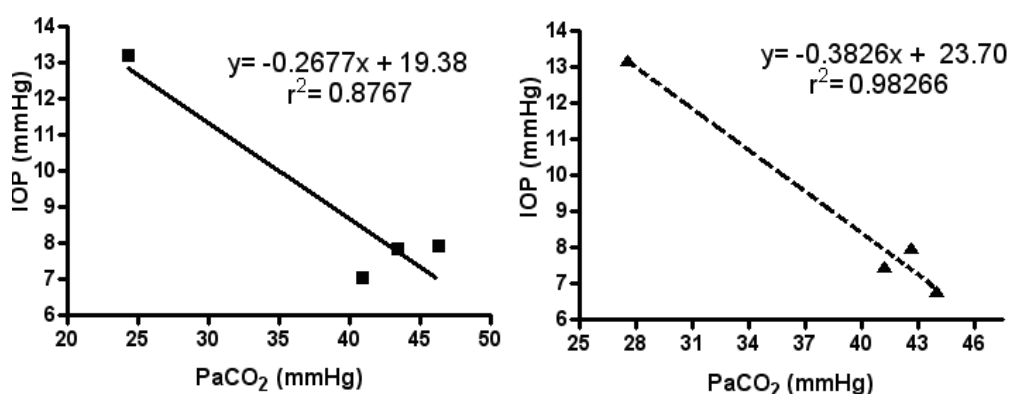


Figure 2. Linear regression curves indicating the regression of intraocular pressure (IOP) values on arterial carbon dioxide partial pressure (PaCO<sub>2</sub>) values in crested caracaras (*Caracara plancus*) anesthetized with isoflurane (squares) and sevoflurane (pyramids). Dotted line represents the calculated regression in which the negative correlation between measured IOP values and measured PaCO<sub>2</sub> values was significant (P=0.0087). For isoflurane anesthesia (solid line), a correlation was not found (P=0.0637).

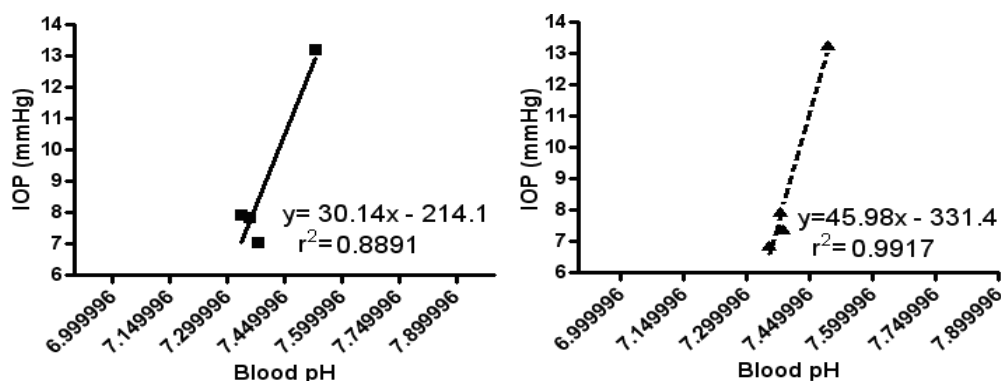


Figure 3. Linear regression curves indicating the regression of intraocular pressure (IOP) values on arterial pH values in crested caracaras (*Caracara plancus*) anesthetized with isoflurane (squares) and sevoflurane (pyramids). The dotted line represents the calculated regression in which the positive correlation between measured IOP values and measured blood pH values was significant ( $P=0.0042$ ). For isoflurane anesthesia, (solid line) a correlation was not found ( $P=0.0571$ ).

### DISCUSSION

This study showed that both isoflurane and sevoflurane anesthetics decreased IOP values in crested caracaras, in accordance with previous publications on dogs and human beings (Sator et al., 1998). During isoflurane anesthesia, IOP decreased 46% from baseline values, whereas with sevoflurane, this decrease was 33%. However, no significant difference was observed between the anesthetics agents ( $P=0.727$ ). In the course of anesthesia, the reduction in IOP values may be attributed to mechanisms that involve a diminishing in the aqueous humor production in the ciliary body and the enhancement of its outflow by the iridocorneal angle (Artru and Yoshiriro, 1999). External eye compression and hydrostatic events due to recumbency may interfere with IOP measurements (Murphy, 1985; Cunningham and Barry, 1986). However, in these study, neither statistically ( $P=0.727$ ) nor clinically significant differences occurred between left and right eyes due to lateral head recumbency in both anesthetic procedures. The limitations of this study may be attributed to the restricted number of subjects used; what can be justified when wild species are employed in researching.

Primary glaucoma is a disease of rare occurrence in birds (Kern, 2003). Even so, the secondary form has already been reported (Kern, 2003; Bras et al., 2005). IOP elevation occurs during intubation and extubation in anesthetic procedures in dogs (Hofmeister et al., 2006).

Although measurement of IOP after extubation has not been done herein, it is reasonable to admit that such intercurrent may have happened. The increase of 1.80mmHg that occurred five minutes after the end of sevoflurane anesthesia may be attributed to the faster recovering of the birds, once this agent possesses a lower blood/gas partition coefficient in comparison to isoflurane (Nunes et al., 2003).

Even though the present study did not established the behavior of IOP in a daily curve, such parameter featured lower values based in comparison to previously reported values in eagles (Stiles et al., 1994). Birds of prey commonly undergo ophthalmic surgeries (Brooks et al., 1983; Kern et al., 1986; Wilson and Pettifer, 2004; Allgoewer et al., 2006). Knowledge of changes in IOP values during anesthetic procedures add assistance or even determine for the decision by the use of viscoelastic agents in intraocular surgeries. Resistance of the fibrous tunics plays an important role in the maintenance of IOP. Domestic animals, in general, possess lower ocular rigidity than man (Gelatt and Gelatt, 2001). In contrast, the ocular bulbus of birds is formed and maintained by the hyaline cartilage enclosed into the sclera of the posterior segment, and by 10-18 scleral ossicles scattered into the sclera of the intermediary segment (Kern, 2003). Brooks et al. (1983) reported that, in owls, scleral ossicles are capable of maintaining IOP in accepted levels for intraocular surgeries. This

observation do not corroborates to the findings of the present study.

Factors that influence the inflow and outflow of blood to the eye can change IOP. Variations of intraocular blood flow originate from the intraocular vascular tonus. The intraocular vascular tonus is influenced by the arterial carbon dioxide partial pressure (PaCO<sub>2</sub>), which may influence the choroidal and retrobulbar blood volumes (Murphy, 1985) and by the diencephalon, which could mediate a neurogenic control of extraocular muscle tone (Murphy, 1985).

Gelatt and Gelatt (2001) informed that some anesthetic drugs that are to produce ocular hypotension can also produce ocular hypertension, secondary to respiratory depression and acidosis that sometimes occurs with prolonged general anesthesia. Hypoventilation contributes to the increase in venous blood pressure, with choroidal vasodilatation, causing an elevation in IOP (Duncalf and Weitzner, 1963; Hvidberg et al., 1981). In respiratory alkalosis, diminution of IOP occurs as a consequence of the reduction in the choroidal blood volume, diminution of blood flow to the ciliary body, inhibition of carbonic anhydrase enzyme, and decrease of filtration of the aqueous humor (Smith et al., 1981; Cunningham and Barry, 1986). Nevertheless, the respiratory acidosis that took place in the birds of the present study, did not elicit increase values of IOP.

It was decided to correlate IOP changes with both PaCO<sub>2</sub> and arterial pH because changes in arterial pressure may have a limited effect on IOP (Macri, 1961). As a matter of fact, a significative correlation between IOP and PaCO<sub>2</sub> (P=0.0087) and between IOP and blood pH (P=0.0042) was found only for sevoflurane. During isoflurane anesthesia, although the P values were not significant, the behavior of such parameters can be compared to those found to sevoflurane, and right indexes of root square were achieved ( $r^2=0.8767$  for IOP - PaCO<sub>2</sub>;  $r^2=0.8891$  for IOP-blood pH).

Almeida et al. (2004) studied normocapneic dogs, anesthetized with sevoflurane and desflurane, and observed that a significant change in IOP values did not occurre in the

course of both procedures, differently from what was noted in human beings anesthetized and maintained under controlled ventilation (Sator et al., 1998). Even though, it is feasible to control respiration during anesthesia in birds (Naganobu et al., 2000), there is no way to predict if such procedure would interfere on the IOP values, once it was not employed in the present study.

In summary, it is reasonable to admit that both isoflurane and sevoflurane anesthetics increase PaCO<sub>2</sub> values and decrease IOP and blood pH values in crested caracaras. In addition, the decline in IOP values seen in this study points to the existence of a positive correlation between IOP and blood pH, but negative between IOP and PaCO<sub>2</sub>.

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