Journal of Avian Medicine and Surgery 24(2):138–141, 2010

Research Brief

Intraocular Pressure in Captive Black-footed Penguins (*Spheniscus demersus*) Measured by Rebound Tonometry

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Abstract: Intraocular pressure (IOP) measurement is a common procedure during eye examinations in birds. Differences in the IOP between avian species have been reported, which suggests the need to establish species-specific reference ranges. To determine IOP values of captive black-footed penguins (*Spheniscus demersus*), we obtained IOP readings with the use of a rebound tonometer by using two established calibration settings (dog and horse). No difference was seen in the IOP between the left and right eye when the horse setting was used; however, a difference was present when using the dog setting. No significant difference between the IOP of male and female penguins was seen in both eyes when the dog or horse setting was used. Rebound tonometry appears to be a safe and repeatable method to obtain IOP values in black-footed penguins.

Key words: intraocular pressure, ophthalmology, rebound tonometry, avian, black-footed penguin, *Spheniscus demersus*

Introduction

Avian ocular diseases have been extensively reported in companion and wild avian species.[1–3] Measurement of intraocular pressure (IOP) is a common procedure during eye examinations in avian patients.[1] Because avian eyes are generally smaller than those of mammals, limitations existed with the use of the Schiötz tonometer.[3] The use of the Tono-Pen XL applanation system (Reichert, Inc, Depew, NY, USA) has enabled measuring the IOP in birds and has been described for turkeys, raptors, and psittacine bird species.[1,4] This system is limited to certain avian cornea sizes and gives a reliable reading in birds with corneas between 5 and 9 mm in diameter.[3]

The Tono-Vet system (Icare Finland Oy, Espoo, Finland) uses rebound tonometry, a method that has been designed for animals with small eyes, for example, laboratory rats. Its useful application in other mammalian species led to the development of normal calibration settings for dogs, cats, and horses.[5] The use of rebound tonometry has been reported in diurnal and nocturnal raptor species and domestic chickens.[1,6,7] Because differences in the IOP between avian species are considerable, extrapolation of values from one species to another should be made with caution, and establishing species-specific reference ranges has been suggested.[4] In this report we describe the IOP values measured by rebound tonometry of captive black-footed penguins (*Spheniscus demersus*).

Materials and Methods

Seventeen black-footed penguins were presented to the animal clinic at the Audubon Aquarium of the Americas for their annual physical examination. The group consisted of 8 male and 9 female black-footed penguins (n = 17), between the ages of 2.3 and 26.9 years (mean, 16.4 years). All the birds were considered healthy at the time of examination, and only 2 birds had a history of eye disease. One black-footed penguin had a

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cataract in the left eye that had been detected 2 months before examination and another had undergone enucleation caused by trauma. Penguins were housed in an indoor enclosure with controlled temperature (air 68°F), ventilation, controlled light, and access to sunlight through a skylight. The enclosure was composed of rock-shaped walls and floor, a dry area made of concrete, and a pool (59°F) for swimming. A glass wall separated the penguins from visitors. The penguins were fed twice daily, and individual feed intake amounts were recorded.

The birds were restrained manually for examination and were weighed inside a plastic tub. Heart rates and respiratory rates were obtained, and direct ophthalmoscopy was performed. A subjective body condition score was assessed for each bird. Blood samples were obtained from the jugular vein or the dorsal metatarsal vein of the foot for complete blood cell count, plasma biochemical analysis, and plasma protein electrophoresis. During the examination, the bird's beaks were held firmly to prevent biting of the handler and the examiner, and the bird's head was kept in an extended position for ease of data collection. The tonometer was directed laterally and in a perpendicular angle to the corneal surface. During data collection, care was taken to ensure that the probe came in contact with the cornea only when the third eyelid (nictitating membrane) had been contracted to avoid readings that included this membrane and resultant false results.

Intraocular pressure readings were obtained with the use of a rebound tonometer (Tono-Vet) by using the dog (D) calibration setting installed in the tonometer by the manufacturer. The tonometer digitally displayed the IOP value on a screen each time the cornea was touched. After the fifth touch, an average of the previous 5 readings is generated automatically. In some birds, 5 readings could not be generated because of excessive movement during restraint, and the average reading was not generated; hence, only data in animals from which the 5 readings were successfully recorded are used for analysis. During a second session, performed a week later, a second IOP reading was obtained during light manual restraint by using the horse (H) calibration setting. The number of intraocular pressures per eye obtained with each one of the settings was the following: right eye (OD)-D (85), left eye (OS)-D (80), OD-H (80), and OS-H (85) for a total of 330 readings for the black-footed penguins.

Table 1. Descriptive statistics and differences of intraocular pressure (mm Hg) measured by digital rebound tonometer by using dog (D) and horse (H) settings in black-footed penguins.

Side/setting	Median[a]	Range	Mean	SD
OD-D	31.00 ^{A}	21.00–43.00	30.41	4.27
OS-D	27.00 ^{B}	15.00–47.00	28.13	6.84
OD-H	25.00 ^{C}	15.00–34.00	25.06	4.35
OS-H	25.00 ^{C}	12.00–40.00	25.05	5.56

Abbreviations: OD indicates right eye; OS, left eye.
[a] Values with different superscripts are significantly different ($P < .05$).

Statistical analyses

Readings of IOP were taken on the left and right eyes with dog and horse settings, and means were compared by 1-way analysis of variance. When data were not normally distributed, the Kruskal-Wallis 1-way analysis of variance was used for analysis. The effect of sex on the IOP for each eye and the tonometer setting of each species were compared by using the t test or the nonparametric Mann-Whitney rank sum test. Differences were considered significant when $P < .05$. Descriptive statistics was also used to present data. The analyses were performed with SigmaStat computer software (SigmaStat version 3.11, Systat Software Inc, San Jose, CA, USA).

Results

All the birds were considered healthy based on physical examination findings and results of blood tests, which were within reference ranges reported for the species.[8] No ocular problems were observed in these birds since data collection. Descriptive statistics and differences in intraocular pressures with the dog and horse settings are presented in Table 1. The mean IOP varied between 31 (OD-D) to 27 (OS-D) and 25 (OD-H and OS-H). There was no difference in the IOP of either eye with the horse setting; however, the right eye reading obtained by using the dog setting was significantly higher than that of the left eye. There was no significant difference between the IOP of males and females in either eye when using the dog or horse setting (Table 2).

Discussion

The results of this study showed that rebound tonometry appears to be a safe, well-tolerated, and repeatable method to obtain IOP values in penguins. Because the values were similar for the left and right eyes, we recommend the use of the

Table 2. Intraocular pressure (IOP) (mean ± SD or median) by sex in black-footed penguins measured by digital rebound tonometer by using dog (D) and horse (H) settings.

		IOP (mm Hg)[a]			
Sex	N	OD-D	OS-D	OD-H	OS-H
Female	45	30.4 ± 4.7	26.9 ± 6.2	24.0	24.0
Male	40	30.4 ± 3.9	29.7 ± 7.3	25.5	25.0

Abbreviations: OD indicates right eye; OS, left eye.
[a] Values in the same column did not differ significantly ($P \geq .05$).

horse setting in penguins and emphasize the importance of developing reference ranges for different avian species.

Although there are reports of IOP measurements in birds, to our knowledge, this is the first report of IOP measurement in a penguin species. Because statistical differences have been observed between applanation tonometry and rebound tonometry, the results of one method cannot be applied to another; also, the different interspecific anatomic characteristics seen in vertebrates led to questions about the extrapolation of IOP data collected in different species.[1,6]

The eye and visual adaptations of different penguin species have been described, and specific adjustments exist for water and air vision.[9–12] However, the microscopic structure of the penguin's cornea is considered similar to that of other vertebrates.[13] One important anatomic difference is that penguins have a cornea that is relatively flat. The largest corneal surface is seen in king penguins (*Aptenodytes patagonicus*), with a diameter of 32.9 mm.[9,10,14] This anatomic characteristic seems to facilitate the use of tonometry for collection of intraocular pressure in these species.

We cannot explain the differences in the right and left eye of the penguin when the dog setting was used. The rebound tonometer has been proven to maintain excellent linearity and robustness to variation in the probe-to-cornea distance in nonanesthetized chickens.[7] Small alignment errors that are expected when taking measurements in nonanesthetized animals are unlikely to affect accuracy.[7] However, such differences were not seen with the use of the horse setting, and the difference is probably of no clinical significance.

The IOP in black-footed penguins was higher than that reported in screech owls (*Megascops asio*) (mean ± SD, 9.0 ± 1.8 mm Hg), Eurasian eagle owls (*Bubo bubo*) (mean ± SD, 14.0 ± 2.4 mm Hg), and chickens (mean ± SD, 17.5 ± 0.1 mm Hg) with the use of the rebound tonometry.[6,7,15] The IOPs reported here were also higher than those reported for dogs and horses, which are 10.8 ± 3.1 mm Hg and 22.1 ± 5.9 mm Hg, respectively.[5]

Although neither primary nor secondary glaucoma is commonly seen in birds, glaucoma has been reported in poultry, raptor species, and in a canary (*Serinus canaria*).[2] In a case of glaucoma in a great horned owl (*Bubo virginianus*), IOPs of 37.2–50.6 mm Hg in the left eye (mean ± SD, 42.2 ± 5.6 mm Hg) and 23.1–27.2 mm Hg in the right eye (mean ± SD, 26.4 ± 1.8 mm Hg) were reported; however, these data were obtained with the use of a Schiötz tonometer.[16]

In general, eyes from raptor species with intraocular inflammatory lesions have significantly lower intraocular pressure (mean ± SD, 7.4 ± 4.6 mm Hg) than normal eyes (mean ± SD, 15.6 ± 3.4 mm Hg), and eyes with iridodialysis or cyclodialysis have higher intraocular pressure (mean ± SD, 35.4 ± 12.2 mm Hg).[17]

The data presented in this study will help clinicians to differentiate between the normal high IOP seen in black-footed penguins and the high IOP of birds of other species with ocular pathology. Perhaps the high normal IOP value in penguins is another adaptation for higher atmospheric pressure during diving, but this theory requires further study.

Acknowledgment: We thank the Animal Husbandry Department of the Audubon Nature Institute Aquarium of the Americas, specifically the Aviculture Department, for the valuable help and assistance during this study.

References

1. Bayon A, Almela RM, Talavera J. Avian ophthalmology. *Eur J Comp Anim Med*. 2007;17:253–265.
2. Willis AM, Wilkie D. Avian ophthalmology, part 2: review of ophthalmic diseases. *J Avian Med Surg*. 1999;13:245–251.
3. Williams D. Ophthalmology. In: Ritchie BW, Harrison GJ, Harrison LR, eds. *Avian Medicine: Principles and Application*. Lake Worth, FL: Wingers Publishing; 1994:673–677.
4. Stiles J, Buyukmichi NC, Farver TB. Tonometry of normal eyes in raptors. *Am J Vet Res*. 1994;55:477–479.
5. Knollinger AM, La Croix NC, Barrett PM, Miller PE. Evaluation of a rebound tonometer for measuring intraocular pressure in dogs and horses. *J Am Vet Med Assoc*. 2005;227:244–248.
6. Jeong M-B, Kim YJ, Yi NY, et al. Comparison of the rebound tonometer (Tonovet®) with the applanation tonometer (TonoPen XL®) in normal Eurasian eagle owls (*Bubo bubo*). *Vet Ophthalmol*. 2007;10:376–379.

7. Prashar A, Guggenheim JA, Erichsen JT, et al. Measurement of intraocular pressure (IOP) in chickens using a rebound tonometer: quantitative evaluation of variance due to position inaccuracies. *Exp Eye Res*. 2007;85:563–571.
8. International Species Information System (ISIS) Web site. http://www.isis.org. Accessed December 2008.
9. Martin GR, Young SR. *The Eye of the Humboldt Penguin,* Spheniscus humboldti: *Visual Fields and Schematic Optics*. London, United Kingdom: The Royal Society; 1984.
10. Sivak J, Howland HC, McGill-Harelstad P. *Vision of the Humboldt Penguin* (Spheniscus humboldti) *in Air and Water*. London, United Kingdom: The Royal Society; 1987.
11. Suburo AM, Scolaro JA. The eye of the magellanic penguin (*Spheniscus magellanicus*): structure of the anterior segment. *Am J Anat*. 1990;189:245–252.
12. Waas JR. An analysis of communication during the aggressive interactions of little blue penguins (*Eudyptula minor*). In: Davis LS, Darby JT, eds. *Penguin Biology*. San Diego, CA: Academic Press; 1990:352.
13. Pigatto JA, Laus JL, Santos JM, et al. Corneal endothelium of the magellanic penguin (*Spheniscus magellanicus*) by scanning electron microscopy. *J Zoo Wildl Med*. 2005;36:702–705.
14. Martin GR. Eye structure and foraging in king penguins *Aptenodytes patagonicus*. *Ibis*. 1999;141: 444–450.
15. Harris MC, Schorling JJ, Herring IP, et al. Ophthalmic examination findings in a colony of screech owls (*Megascops asio*). *Vet Ophthalmol*. 2008;11:186–192.
16. Rayment LJ, Williams D. Glaucoma in a captive-bred great horned owl (*Bubo virginianus virginianus*). *Vet Rec*. 1997;140:481–483.
17. Williams DL, Gonzalez Villavincencio CM, Wilson S. Chronic ocular lesions in tawny owls (*Strix aluco*) injured by road traffic. *Vet Rec*. 2006;159: 148–153.