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Intraocular Pressure in the Sonoran Desert Tortoise (*Gopherus morafkai*) Using Rebound Tonometry

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Abstract

A complete ophthalmic examination includes the measurement of intraocular pressure (IOP). IOP has been recorded in several species of reptiles, and differences between species have been recognized. This study measured IOP in Sonoran Desert tortoises (*Gopherus morafkai*) presented to a veterinary hospital. The IOP observed in this study (right eye 15.8 mm Hg ±2.66 and left eye 16.8 mm Hg ±2.75) was higher than those reported in aquatic chelonians. This study demonstrates the reliability of rebound tonometry (i Care® Tonovet Plus) for measuring IOP in Sonoran Desert tortoises, providing a robust method for future

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Keywords*:* Intra-ocular pressure, ophthalmology, Sonoran, tonometry, tortoise

Introduction

Mexico is a significant habitat for three species of desert tortoises of the genus *Gopherus*: *G. berlandieri* (Texas tortoise), *G. flavomarginatus* (Mapimi tortoise), and *G. morafkai* (Sonoran Desert tortoise). The Sonoran Desert tortoise was previously included in the species *G. agassizii*, which is now the Mojave Desert tortoise. There is also a debate over the existence of a fourth species within the genus and with a natural range within Mexico, *G. evgoodei* (Southern Sonora-Northern Sinaloa) (Edwards *et al.*, 2015, 2016).

Mexican tortoises are protected. The Mapimi tortoise is the only species classified as "endangered" in Mexico (NORMA Oficial Mexicana NOM-059-SEMARNAT-2010). Previously, the Mojave Desert tortoise was considered under "special protection," but since the Sonoran Desert tortoise was recognized as a separate species, the protection classification for this species within Mexico has not yet been reconsidered by the authorities (NORMA Oficial Mexicana NOM-059-SEMARNAT-2010); however, ownership of this species is illegal within Mexico. The Sonoran Desert tortoise population (including Arizona´s) is listed as vulnerable by the IUCN (Averill-Murray *et al.,* 2023).

Tortoises have greatly suffered from the impacts of human activities on their habitat, including habitat destruction, *e.g.*, through livestock farming and road construction. Additionally, droughts, vehicular trauma, and capture for pet ownership or zoological collection have negatively affected the population. Tortoises are regularly kept in human care in the cities of Baja California despite being a non-native species in this state (Edwards *et al.*, 2015).

Ocular diseases are common and widely reported in reptiles (Williams, 2012). These diseases can manifest as systemic or ophthalmic, and it is essential to differentiate and diagnose them accurately (Allgoewer *et al*., 2002; Reyes-Olivares *et al*., 2016; Mayer *et al*., 2010; Agostinho *et al*., 2023; Fumero-Hernandez *et al*., 2023). Examination of intraocular pressure (IOP) is essential as it provides crucial information for identifying conditions such as glaucoma and uveitis (Williams, 2012). IOP has already been reported in various species of reptiles such as the green iguana (*Iguana iguana*), Andros Island iguana (*Cyclura cychlura cychlura*), central bearded dragon (*Pogona vitticeps*), red-eared slider (*Trachemys scripta elegans*), loggerhead sea turtle (*Caretta caretta*), Kemp´s ridley sea turtle (*Lepidochelys kempii*), box turtle (*Terrapene* spp.*),* Hermann's tortoise (*Testudo hermanni*), red-footed tortoise (*Chelonoidis carbonarius*), yellow-foot tortoise (*Chelonoidis denticulatus*), San Cristóbal giant tortoise (*Chelonoidis niger chathamensis*), European pond turtle (*Emys orbicularis*) and Texas tortoise (*Gopherus berlandieri*) (Selmi *et al.*, 2002; Selmi *et al.*, 2003; Selleri *et al.*, 2012; Wojick *et al.*, 2013; Delgado *et al.*, 2014; Espinheira *et al.*, 2015; Schuster *et al.*, 2015; Rajaei *et al.*, 2015; Gornik *et al.*, 2016; Cordeiro de Araujo *et al.*, 2017; Petritz *et al.*, 2019; Martin de Bustamante *et al.*, 2020; Rowatt *et al.*, 2020; Lamagna *et al.,* 2021; Masterson *et al.*, 2022).

Differences in IOP have been documented between species and between collection methods, whether applanation tonometry or rebound tonometry. Rebound tonometry is more efficient in small eyes and allows data to be collected quickly in shy species, such as chelonians. This work reports IOP values obtained in Sonoran Desert tortoises in human care in Mexicali, Baja California, Mexico.

Methods

This study was carried out through a voluntary request to owners who wanted to know the health status of their Sonoran Desert tortoises in Mexicali, Baja California. This species is protected, and ownership as pets is forbidden (Averill-Murray *et al.,* 2023). However, they are commonly seen as patients in private practice. Twenty tortoises born in captivity were evaluated. Thirteen females and seven males were included in the study. The animals had a mean weight of 2.604 kg (SD = 1.9) for the females and 2.443 kg (SD = 1.6) for the males. The exact ages of the tortoises were difficult to obtain since some people had not owned the tortoise since its birth, and age was considered subjectively based on the time of ownership that could be documented, varying from 3 to 24 years. Other variables, such as carapace length and body condition (subjective), were obtained but were not considered as part of the analysis. At the time of the evaluation, no changes to the eyes or adjacent structures were reported or observed directly using an ophthalmoscope. The tortoises were evaluated in June 2023. According to the medical history, all tortoises were healthy during the examination. Tortoises were placed on top of a circular container above the surface of the examination table to prevent contact of their limbs with the table surface and therefore movement. This restraint method allowed the tortoises to relax and stick their heads out, out of curiosity.

IOP was measured using a rebound tonometer (i Care® Tonovet Plus, Icare Finland Oy, Vantaa, Finland) placing it perpendicular to the cornea of the tortoise, approximately 3-5 mm from the cornea. Six IOP readings (mm/Hg) were taken from each eye (right and left) using the "dog" configuration, as this has been used previously in other *Gopherus* species (Rowatt *et al.*, 2020). IOP data were analyzed using a linear model, including the effects of eye (right and left), sex (male and female), eye x sex interaction, and residual error. Assumptions of normality and common variance for residual error were evaluated using the Shapiro-Wilk and Levene's tests, respectively. The means were separated using the honestly significant difference test (Tukey's procedure). Effects were considered significant when the value of $P \leq 0.05$. The analysis was performed using the SAS/STAT® GLM procedure (SAS/STAT®, 2023).

Results

Manifestations of pain or discomfort were not observed, but there was a response of surprise when seeing or feeling the blunt-tipped needle of the tonometer in the cornea; the tortoises closed their eyes or hid their heads momentarily but allowed us to continue obtaining the measurements. IOPs were obtained without excessive delay and with consistency. It is important to note that local anesthetics are not required for this type of tonometry. No tortoises had to struggle or be forced during IOP collection. No eye problems were reported after IOP collection in any tortoise sampled. The i-Care Tonovet Plus offers a measurement range of 10 - 60 mmHg, with a precision of ± 2.5 mmHg (10-30 mmHg) and ± 10% (> 30-60 mmHg), and with a repeatability (coefficient of variation) of < 8%. The effects included in the linear model on IOP values are shown in Table 1.

No significant differences ($P > 0.05$) were observed for interaction and main effects of eye (right and left) and sex (male and female). Table 2 reports the IOP results obtained in this study and those of other chelonian species, including the type of instrument used for greater comparative ease for the clinician.

Discussion

This work establishes the average IOP values in Sonoran Desert tortoises obtained in healthy animals with the i Care® Tonovet Plus. IOP differences are recognized between reptile species. Slight differences have been found depending on the between species, restraint method (physical or chemical), and instrument used. Differences in IOPs as measured by applanation have been documented between red- and yellow-footed tortoises, both in the genus *Chelonoidis* (Selmi *et al.*, 2002; Selmi *et al.*, 2003).

It would seem likely that the IOP would be higher in aquatic-diving species to counteract the effects of water pressure; however, in aquatic species such as the European pond turtle and the red-eared slider, the IOP is lower than that found in our study. The same is true for the marine species such Kemp's ridley sea turtles and loggerhead sea turtles for which lowest values documented in chelonians have been obtained (Delgado *et al.*, 2014; Rajaei *et al.*, 2015; Petritz *et al.*, 2019; Fumero-Hernandez *et al.*, 2023). IOP measured in box turtles (*Terrapene* spp.) has also been found to be lower than in other terrestrial chelonians and slightly higher than or equal to aquatic chelonians (Espinheira *et al.*, 2015).

The IOP measured in the Sonoran Desert tortoises was slightly higher than those of other terrestrial species, such as the San Cristóbal giant tortoise and the Texas tortoise, where rebound tonometry was also used (Rowatt *et al.,* 2020; Masterson *et al*., 2022).

The body size of chelonian species seems unrelated to IOP, based on the IOP reported in species of different sizes. This has also been observed in other vertebrate species with no significant correlation between body size and IOP (Zouache *et al*., 2016). The most crucial difference observed is between terrestrial and aquatic animal species. Anatomical differences between terrestrial and aquatic reptile species could explain such differences, *e.g.*, the presence or total or partial absence of the *conus papilaris* (homologous to the pecten oculi of birds) could be a key structure for these differences. This structure is found in the retina and participates in retinal nutritional processes and regulation of intraocular fluid (Ringvold, 2022). However, further study of ocular anatomy of various species is needed to understand factors influencing physiological IOP.

Rebound tonometry is a reliable method for obtaining IOP measurements in Sonoran Desert tortoises. Extrapolating IOP results between species or methods is not recommended, and the clinician should consider such differences when interpreting results from species where IOP has not been reported yet.

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Table 1. Mean intraocular pressure (IOP) values in Sonoran Desert tortoises (*Gopherus morafkai*). SD values are shown in parentheses. OD = right eye, OS = left eye, M = male, F = female.

	Male		**Female**		**Sex**		**Eye**	
	OD	**OS**	**OD**	**OS**	**M**	**F**	**OD**	**OS**
IOP	15.42 (2.63)	16.28 (2.75)	16 (2.76)	17.07 (2.95)	15.85 (2.62)	16.53 (2.85)	15.8 (2.66)	16.8 (2.75)

Table 2. Average intraocular pressure (IOP) reported in different species of chelonians, including the type of restraint, measurement method, and equipment used.

Species	n	IOP (mm Hg)	Restraint	Type of Tonometry	Equipment	Reference
Marine						
Lepidochelys kempii	25/20	6.5±1.0(h setting) 3.8±1.1(no definida)	None	rebound	Tonovet	Gornik, et al. 2016
Caretta caretta	11	5 (range 4 to 9)	Manual	rebound	Tonovet	Petritz, et al. 2019
Terrapine				rebound		
Trachemys scripta elegans	17	11.32±1.57	None	rebound	Tonovet	Delgado, et al. 2014
Trachemys scripta elegans	17	10.2±0.66	None	rebound	Tonolab	Delgado, et al. 2014
Trachemys scripta elegans	17	6.31±5.59	Manual At neck	rebound	Tonolab	Delgado, et al. 2014
Trachemys scripta elegans	17	6.75±6.01	Manual at head (rostral)	rebound	Tonolab	Delgado, et al. 2014
Trachemys scripta elegans	11	-1.79±1.17	Chemical	rebound	Tonolab	Delgado, et al. 2014
Trachemys scripta elegans	13	-1±0.76	Chemical	rebound	Tonolab	Delgado, et al. 2014
Emys orbicularis	22	5.42±0.96	None	rebound	Tonovet	Rajaei, et al. 2015
Semi-aquatic/terrestrial				rebound		
Terrapene spp.	103	-	Manual	rebound	Tonovet	Espinehira, et al, 2015
Terrapene carolina major	69	6.7±1.4	Manual	rebound	Tonovet	Espinehira, et al, 2015
Terrapene carolina triunguis	24	8.3±1.5	Manual	rebound	Tonovet	Espinehira, et al, 2015
Terrestrial						
Geochelone carbonaria	25	15.3±8.81	Manual	applanation	Tonopen	Selmi, et al. 2002
Geochelone denticulata	15	14.2±1.2	Manual	applanation	Tonopen	Selmi, et al. 2003
Testudo hermanni	26	15.74±0.20	Manual	rebound	Tonovet	Selleri, et al. 2012
Chelonoidis chathamensis	39	13.38±3.81	Manual	rebound	Tonovet	Masterson, et al. 2022
Gopherus berlandieri	61	13.8±2.4	Manual At head (rostral)	rebound	Tonovet	Rowatt, et al. 2020
Gopherus morafkai	20	16.3±2.7	None	rebound	Tonovet	This study