

Intra-ocular Pressure in the Sonoran Desert Tortoise (*Gopherus morafkai*) Using Rebound Tonometry

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Abstract

A complete ophthalmic examination includes the measurement of intra-ocular pressure (IOP). IOP has been recorded in several species of reptiles, and differences between species have been recognized. This study measured IOP in *Gopherus morafkai* (Sonoran Desert tortoise) presented to a veterinary hospital. The IOP observed in this study (right eye 15.8 mm Hg \pm 2.66 and left eye 16.8 mm Hg \pm 2.75) was higher than those reported in aquatic chelonians. This study demonstrates the reliability of rebound tonometry for measuring IOP in Sonoran Desert tortoises, providing a robust method for future research. It is not recommended that IOP values be extrapolated between species and collection methods.

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

Introduction

Mexico is a significant habitat for three species of desert tortoises of the genus *Gopherus*: *Gopherus 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. A debate is also occurring 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; Edwards *et al.*, 2016).

Mexican tortoises are protected. The Mapimi tortoise is the only species classified as endangered in Mexico (NORMA Oficial Mexicana NOM-059-SEMARNAT-2010, 2010). Previously, the Mojave Desert tortoise was considered under special protection, but because 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, 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 effects 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; Mayer *et al.*, 2010; Reyes-Olivares *et al.*, 2016; Agostinho *et al.*, 2023; Fumero-Hernandez *et al.*, 2023). Examination of intra-ocular pressure (IOP) is essential because 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*),

Table 1. Mean intra-ocular pressure (IOP) values in Sonoran Desert tortoises (*Gopherus morafkai*). SD values are shown in parentheses.

	Male		Female		Sex		Eye	
	OD	OS	OD	OS	Male	Female	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)

SD, standard deviation; OD, right eye; OS, left eye.

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 (Selmi *et al.*, 2002; Selmi *et al.*, 2003; Selleri *et al.*, 2012; Wojick *et al.*, 2013; Delgado *et al.*, 2014; Espinheira *et al.*, 2015; Rajaei *et al.*, 2015; Schuster *et al.*, 2015; Gornik *et al.*, 2016; Cordeiro de Araujo *et al.*, 2017; Petritz *et al.*, 2019; Martín de Bustamante *et al.*, 2020; Rowatt *et al.*, 2020; Lama-gna *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 performed 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 (5.74 lb; standard deviation [SD] = 1.9) for the females and 2.443 kg (5.39 lb; SD = 1.6) for the males. The exact ages of the tortoises were difficult to obtain because 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 yr. 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.

The 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 because this has been used previously in other *Gopherus* species (Rowatt *et al.*, 2020). The IOP data were analyzed using a linear model, including the effects of eye (right and left), sex (male and female), eye × 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. The IOPs were obtained without excessive delay and with consistency. It is worthy 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 $\pm 10\%$ (>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 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

Table 2. Average intra-ocular 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						
<i>Lepidochelys kempii</i>	25/20	6.5 ± 1.0 (h setting) 3.8 ± 1.1 (no definida)	None	Rebound	Tonovet	Gornik <i>et al.</i> (2016)
<i>Caretta caretta</i>	11	5 (range 4 to 9)	Manual	Rebound	Tonovet	Petriz <i>et al.</i> (2019)
Terrapine						
<i>Trachemys scripta elegans</i>	17	11.32 ± 1.57	None	Rebound	Tonovet	Delgado <i>et al.</i> (2014)
<i>Trachemys scripta elegans</i>	17	10.2 ± 0.66	None	Rebound	Tonolab	Delgado <i>et al.</i> (2014)
<i>Trachemys scripta elegans</i>	17	6.31 ± 5.59	Manual At neck	Rebound	Tonolab	Delgado <i>et al.</i> (2014)
<i>Trachemys scripta elegans</i>	17	6.75 ± 6.01	Manual At head (rostral)	Rebound	Tonolab	Delgado <i>et al.</i> (2014)
<i>Trachemys scripta elegans</i>	11	-1.79 ± 1.17	Chemical	Rebound	Tonolab	Delgado <i>et al.</i> (2014)
<i>Trachemys scripta elegans</i>	13	-1 ± 0.76	Chemical	Rebound	Tonolab	Delgado <i>et al.</i> (2014)
<i>Emys orbicularis</i>	22	5.42 ± 0.96	None	Rebound	Tonovet	Rajaei <i>et al.</i> (2015)
Semi-aquatic/terrestrial						
<i>Terrapene spp.</i>	103	—	Manual	Rebound	Tonovet	Espinheira <i>et al.</i> (2015)
<i>Terrapene carolina major</i>	69	6.7 ± 1.4	Manual	Rebound	Tonovet	Espinheira <i>et al.</i> (2015)
<i>Terrapene carolina triunguis</i>	24	8.3 ± 1.5	Manual	Rebound	Tonovet	Espinheira <i>et al.</i> (2015)
Terrestrial						
<i>Geochelone carbonaria</i>	25	15.3 ± 8.81	Manual	Applanation	Tonopen	Selmi <i>et al.</i> (2002)
<i>Geochelone denticulata</i>	15	14.2 ± 1.2	Manual	Applanation	Tonopen	Selmi <i>et al.</i> (2003)
<i>Testudo hermanni</i>	26	15.74 ± 0.20	Manual	Rebound	Tonovet	Selleri <i>et al.</i> (2012)
<i>Chelonoidis chathamensis</i>	39	13.38 ± 3.81	Manual	Rebound	Tonovet	Masterson <i>et al.</i> (2022)
<i>Gopherus berlandieri</i>	61	13.8 ± 2.4	Manual At head (rostral)	Rebound	Tonovet	Rowatt <i>et al.</i> (2020)
<i>Gopherus morafkai</i>	20	16.3 ± 2.7	None	Rebound	Tonovet	This study

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 marine species such as Kemp's ridley sea turtles and loggerhead sea turtles for which the lowest values documented in chelonians have been obtained (Delgado *et al.*, 2014; Rajaei *et al.*, 2015; Petriz *et al.*, 2019; Fumero-Hernández *et al.*, 2023). The IOP measured in box turtles 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 the chelonian species seems unrelated to IOP, based on the IOPs 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 papillaris* [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 intra-ocular 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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