

Reference values for intraocular pressure in collared scops owls (*Otus lettia*) measured using rebound tonometry

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Abstract

In this study, we aimed to establish species-specific reference values for intraocular pressure (IOP) in clinically healthy collared scops owls (*Otus lettia*) using rebound tonometry. Twelve free-living owls were included, and twenty-four eyes were examined. All owls were physically restrained in an upright position without sedation. Intraocular pressure was measured in both eyes using rebound tonometry (TONOVET; iCare Finland Oy, Vantaa, Finland) in d mode. No significant difference in IOP was observed between the right and left eyes. The mean IOP values were 10.42 ± 1.24 mmHg (median, 11 mmHg; range, 8–12 mmHg) in the right eye and 10.75 ± 1.42 mmHg (median, 11 mmHg; range, 8–13 mmHg) in the left eye. Data from both eyes were pooled. The mean pooled IOP was 10.58 ± 1.31 mmHg (median, 11 mmHg; range, 8–13 mmHg). These findings provide clinically relevant reference values for ophthalmic evaluations in avian medicine, particularly in wildlife rehabilitation settings. The establishment of species-specific IOP values may improve diagnostic accuracy and contribute to the development of baseline ophthalmological parameters for protected raptor species in Taiwan.

Keywords: avian ophthalmology, collared scops owl, intraocular pressure, rebound tonometry, wildlife rehabilitation

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Introduction

Vision plays a critical role in the survival of raptors in their natural environment, enabling them to hunt effectively, obtain essential environmental information, avoid predators and other threats, and reproduce successfully (O'Malley, 2005). Raptors possess disproportionately large ocular globes relative to their body size, a distinctive anatomical adaptation that enhances both visual sensitivity and acuity. Nevertheless, this specialization also increases their susceptibility to ocular injury (Pauli *et al.*, 2007; Seruca *et al.*, 2012). Consequently, comprehensive ophthalmic examinations are essential for accurately assessing ocular health and maintaining optimal visual function in these species (Labelle *et al.*, 2012; Ermutlu *et al.*, 2024).

Intraocular pressure (IOP) measurement is an essential component of ophthalmic examinations. It is commonly assessed using indirect tonometry, which estimates IOP by measuring corneal tension. This rapid, noninvasive, and well-tolerated technique provides valuable information for establishing the diagnosis, determining the prognosis, and guiding appropriate therapeutic interventions (Featherstone and Heinrich, 2021). As tonometry is routinely used to monitor disease progression, evaluate treatment response, and guide clinical management, the establishment of reliable reference values for normal IOP is essential for ophthalmic assessment in avian species (Yöñez *et al.*, 2022). Although limited reports have described ocular hypertension and glaucoma in owls (Rayment *et al.*, 1997; Jayson *et al.*, 2014), these findings underscore the clinical importance of accurate IOP assessment in this group.

Two principal methods are employed to measure IOP in avian species: applanation and rebound tonometry. Applanation tonometry requires the application of topical anesthesia and is suitable only for eyes with a corneal diameter exceeding 9 mm. By contrast, rebound tonometry does not have these limitations (Reuter *et al.*, 2011). Consequently, rebound tonometry has become the preferred method for measuring IOP in avian species in recent years (Moore and Montiani-Ferreira, 2022; Bayram *et al.*, 2023).

The collared scops owl (*Otus lettia*) is a small, nocturnal raptor commonly found in Taiwan, primarily inhabiting low-altitude hilly regions across the island. This species frequently lives near human settlements and is notable for its frequent interactions with humans (Chan *et al.*, 2012). Due to this close association, the collared scops owl is among the most commonly treated species in wildlife rescue and rehabilitation centers (Chiu *et al.*, 2025).

In this study, we established species-specific reference values for IOP in collared scops owls using rebound tonometry. The development of these reference values may enhance the accuracy of ophthalmic diagnosis in this species, enable timely and appropriate treatment, assist in prognostic evaluation, and serves as a baseline ophthalmic data for protected raptor species in Taiwan.

Materials and Methods

Ethical approval: This study was approved by the Institutional Animal Care and Use Committee of National Taiwan University (approval numbers: NTU-113-EL-00044 and NTU-114-EL-00071). No animals were captured, restrained, sedated, or anesthetized specifically for the purpose of this study.

Animals: Free-living collared scops owls (*Otus lettia*) admitted to a certified Wildlife Rescue Center between June 2024 and December 2025 were eligible for enrollment in this study. All owls were rescued due to various traumatic injuries, including head trauma, juvenile falls from nest, and limb fractures and were undergoing rehabilitation. The sex of the owls was unknown. Based on the plumage characteristics, all individuals were estimated to be adults. Body weights ranged from 150 to 180 g.

Each owl was housed individually in a stainless-steel enclosure (80 × 60 × 60 cm) equipped with padded perches and visual barriers to minimize stress. The enclosures were located in a quiet, dimly lit indoor room maintained at 22–28°C (71.6–82.4°F) under a 12:12-h light–dark cycle. Each bird was provided with one whole Japanese quail (*Coturnix japonica*) each evening and received oral multivitamin and calcium supplementation twice weekly.

Birds were excluded if they were suspected to have ophthalmic disease, were clinically unhealthy based on physical examination, or exhibited overt signs of stress. Stress-related behaviors—such as resistance to manual restraint, panting, and open-mouth breathing—were carefully assessed to minimize potential confounding effects on IOP measurements. Only individuals without clinical signs suggestive of systemic disease were included in the study.

Ophthalmic examination and IOP measurement: Twelve owls were included in this study, resulting in the examination of twenty-four eyes, all of which were included in the analysis. Comprehensive ophthalmic examinations were conducted prior to IOP measurement and included the assessment of palpebral and dazzle reflexes, fluorescein staining (Omni Fluro; Opto Hellas, Katerini, Greece), slit-lamp biomicroscopy (Kowa SL-17; Kowa, Nagoya, Japan), and indirect ophthalmoscopy using a 40-diopter condensing lens (Volk Optical Inc., Mentor, OH, USA). Only eyes without detectable abnormalities were included in this study.

All owls were physically restrained in an upright position by an experienced assistant, with the wings flexed in a neutral position and gently wrapped in a towel, while their respiratory status was closely monitored. Special care was taken to avoid applying pressure on the neck or eyes. No sedation or topical ocular anesthesia was administered during the procedure.

Rebound tonometry (TONOVET; iCare, Vantaa, Finland) was performed on both eyes of each bird using d mode. A disposable probe was used for each bird and not changed between the eyes. The probe was positioned 4–8 mm from the central corneal surface.

IOP measurements were consistently conducted initially in the right eye, followed by the left eye; all measurements were performed by the same operator, with assistance from the same handler, to ensure consistency. Measurements were conducted between 2:00 PM and 4:00 PM to minimize diurnal variation. For each eye, repeated measurements were obtained, and readings with a variation greater than 3 mmHg were excluded. Care was taken to obtain measurements when the corneal surface was adequately exposed, minimizing interference from the nictitating membrane. IOP was calculated using the built-in software of the TONOVET device, which determines the values based on its rebound-measuring principle. The software calculates IOP by analyzing the probe's deceleration and contact time, with the displayed value representing the average of six consecutive measurements. Following the examinations, the owls were returned to their original enclosures on the same day. Subsequent retinal morphological and functional assessments, including optical coherence tomography and electroretinography, are planned to confirm normal visual function prior to pre-release evaluation and rehabilitation training.

Statistical analysis: Data were analyzed using IBM SPSS Statistics (version 25.0; IBM Corp., Armonk, NY, USA). The normality of IOP values for the right and left eyes was assessed separately using the Shapiro-Wilk

test, with significance defined as a $P < 0.05$. IOP measurements between the right and left eyes were compared using a paired t-test. Subsequently, IOP values from both eyes were pooled to provide a more comprehensive representation of intraocular pressure in this species. Pooled IOP values were summarized using descriptive statistics, including mean, standard deviation, median, minimum, maximum, and 95% confidence intervals (CIs). All statistical tests were two-tailed.

Results

Complete ophthalmic examinations and IOP measurements were successfully performed in all owls. No abnormalities were detected during the ophthalmic examinations. IOP values for both eyes were normally distributed. No significant difference was observed in IOP values between the right and left eyes ($P > 0.05$). The mean IOP values were 10.42 ± 1.24 mmHg (median, 11 mmHg; range, 8–12 mmHg; 95% CI, 9.63–11.2) in the right eye and 10.75 ± 1.42 mmHg (median, 11 mmHg; range, 8–13 mmHg; 95% CI, 9.85–11.65) in the left eye. Given the absence of interocular differences, data from both eyes were pooled for further analysis. The mean pooled IOP was 10.58 ± 1.31 mmHg (median, 11 mmHg; range, 8–13 mmHg; 95% CI, 10.02–11.12). A detailed summary of the IOP measurements is provided in Table 1.

Table 1 Intraocular pressure (IOP) measurements in clinically healthy collared scops owls (*Otus lettia*) obtained using rebound tonometry (TONOVET, d mode).

	No. of eyes	Mean $\pm$ SD	Median	Min	Max	95% CIs
Right eye	12	10.42 ± 1.24	11	8	12	9.63–11.20
Left eye	12	10.75 ± 1.42	11	8	13	9.85–11.65
Both eyes	24	10.58 ± 1.31	11	8	13	10.02–11.12

Data are presented separately for the right and left eyes, as well as pooled values. Values are expressed as the mean $\pm$ standard deviation (SD), median, minimum (Min), maximum (Max), and 95% confidence intervals (CIs). All values are reported in millimeters of mercury (mmHg).

Discussion

Raptors comprise a wide range of species that exhibit marked interspecific differences in IOP (Barsotti *et al.*, 2013; Beckwith-Cohen *et al.*, 2015). Accordingly, characterizing ophthalmic physiological differences among raptor species and establishing reliable species-specific reference values for IOP are essential for accurate clinical assessment, informed therapeutic decision-making, and applications in wildlife conservation medicine (Ermutlu *et al.*, 2024).

Rebound tonometry (TONOVET) was selected in the present study as it does not require topical anesthesia, allows rapid acquisition of IOP measurements, and minimizes handling-related stress (Cho *et al.*, 2022). These advantages are particularly important when examining wild raptors, as prolonged restraint and additional manipulation may induce stress responses that could potentially influence IOP values (Yöñez *et al.*, 2022). In the present study, no stress-related clinical signs were observed in collared scops owls during IOP measurement. Therefore, rebound tonometry represents a practical and suitable

technique for ophthalmic assessment in free-living or rehabilitating raptor species.

When interpreting IOP values, measurements obtained using rebound tonometry may differ from those obtained using applanation tonometry (Harris *et al.*, 2008; Reuter *et al.*, 2011). Therefore, caution is warranted when comparing IOP values across studies or applying reference ranges derived from different measurement devices. For example, rebound tonometry has been reported to yield significantly higher IOP values compared with applanation tonometry (Jeong *et al.*, 2007; Hwang *et al.*, 2020).

The TONOVET tonometer provides three measurement settings: d, h, and p. The d mode is used for dogs and cats, whereas the h mode is designed for horses. The third setting, p mode, is intended for species without a predefined calibration. The default setting of the device is d mode, which was applied in the present study.

The d mode was selected for several reasons. First, a previous study involving 44 free-ranging birds of prey from eight species demonstrated a strong linear correlation between TONOVET measurements obtained in the d mode and direct manometric values

(Reuter *et al.*, 2010). In addition, another study evaluating IOP in domestic pigeons (*Columba livia domestica*) compared the d and p modes of the TONOVET with direct manometry and reported that the d mode provided greater accuracy in that species (Lim *et al.*, 2019). Finally, maintaining the default d mode without switching settings facilitated more rapid measurements and reduced handling time, thereby minimizing restraint-related stress. However, other studies have used the p mode (Yöñez *et al.*, 2022), and differences in IOP values have been reported when different modes are used in the same species (Harris *et al.*, 2008; Lim *et al.*, 2019). These findings suggest that the measurement mode may influence the recorded IOP values; therefore, caution is warranted when comparing results across studies employing different device settings. Furthermore, species-specific calibration for owls is currently unavailable, which may influence the absolute accuracy of the measured IOP values.

Interspecific variation in IOP among raptors appears to be more pronounced than that reported in domestic animals (Yöñez *et al.*, 2022). Previous studies have primarily evaluated IOP in three raptor families: Accipitridae, Falconidae, and Strigidae, with the collared scops owl belonging to the Strigidae family. Reported IOP values in members of the Accipitridae are generally higher than those recorded in Falconidae and Strigidae (Labelle *et al.*, 2012; Yöñez *et al.*, 2022). For example, the Egyptian vulture has a mean IOP of 27.2 ± 3.76 mmHg (Gomez *et al.*, 2025), which is markedly higher than that reported for the collared scops owl (10.58 ± 1.31 mmHg) and the peregrine falcon (14.50 ± 0.65 mmHg) (Yöñez *et al.*, 2022). One possible explanation for this interspecific difference is the variation in corneal thickness, which correlates positively with measured IOP values (Bayon *et al.*, 2006). However, comparative data on corneal thickness among different raptor species remain limited. Therefore, further investigation is warranted to clarify the potential contribution of corneal morphology to interspecific differences in IOP.

When comparisons are limited to species within the family Strigidae, previously reported mean IOP values generally range from approximately 10 to 14 mmHg (Jeong *et al.*, 2007; Harris *et al.*, 2008; Labelle *et al.*, 2012; Beckwith-Cohen *et al.*, 2022; Ermutlu *et al.*, 2024), with representative values such as 11.6 ± 1.8 mmHg reported for the Burrowing owl (Bennett *et al.*, 2022). The mean IOP observed in the present study (10.58 ± 1.31 mmHg) falls within this range and is comparable to values reported for strigid species.

In addition to interspecific variations, age influences the IOP. Juvenile birds tend to exhibit lower IOP compared with adults, a pattern documented in northern goshawks, common buzzards, and common kestrels (Reuter *et al.*, 2011). The age-related increase in IOP has been suggested to result from age-dependent changes in ocular rigidity (Pallikaris *et al.*, 2005). In the present study, all collared scops owls were classified as adults based primarily on plumage characteristics. However, precise age determination was not available, and age-related variability cannot be entirely excluded.

In addition, sex was not available for all individuals. Although previous studies in birds of prey have reported no significant association between sex and IOP values (Harris *et al.*, 2008), the lack of definitive sex determination and precise age assessment may still contribute to biological variability in IOP measurements in the present study.

Several technical and physiological factors can influence IOP measurements. Body position can affect measured values, with differences observed between dorsal recumbency and upright positioning (Reuter *et al.*, 2011). In addition, diurnal variation has been reported to influence IOP values in various animal species (Martín-Suárez *et al.*, 2014). Excessive restraint or inadvertent pressure applied to the globe or cervical region may artificially elevate IOP (Yöñez *et al.*, 2022). Examiner-related factors also represent a potential source of variability in IOP measurements. In the present study, all measurements were performed with the owls maintained in an upright position. Care was taken to avoid pressure on the globe and neck during manual restraint. In addition, all IOP measurements were performed by the same examiner with assistance from the same handler throughout the study to minimize procedural variability. Furthermore, to reduce the potential influence of diurnal variation, all measurements were obtained within a standardized time window between 2:00 PM and 4:00 PM.

In avian clinical practice, alterations in IOP may occur in association with intraocular inflammatory conditions, such as uveitis and ocular trauma. Ocular trauma is a commonly encountered in free-ranging raptors admitted for rehabilitation and can substantially influence IOP values (Carter and Lewin, 2021). Measurement of IOP is also important for the diagnosis and monitoring of glaucomatous conditions (Rayment *et al.*, 1997; Jayson *et al.*, 2014); however, compared with inflammatory ocular disease, persistently elevated IOP appears to be less frequently observed in avian species (Bennett *et al.*, 2022). Furthermore, postoperative monitoring of IOP following cataract surgery is warranted to detect secondary glaucoma (Sigmund *et al.*, 2019). In wildlife and rehabilitation settings, accurate IOP assessment may aid in evaluating visual prognosis and guiding treatment decisions. Therefore, the establishment of reliable species-specific reference values is essential for appropriate clinical interpretation (Labelle *et al.*, 2012).

Limitations of this study include its relatively small sample size ($n = 12$); therefore, the reported intraocular pressure (IOP) values should be considered preliminary reference values. Although IOP measurements were obtained from both eyes (24 eyes in total), these data are not entirely independent, as measurements from the same individual may be correlated. However, no significant difference was identified between right and left eyes, and the inclusion of both eyes was intended to provide a broader descriptive representation of IOP values in this species. Because the primary aim of this study was to establish preliminary reference values rather than evaluate treatment effects or population-level associations, pooled analysis of both eyes was

considered acceptable for this exploratory study design. In addition, all owls were admitted to wildlife rehabilitation center, and thus may not fully represent a normal, healthy wild population. Although individuals with clinical abnormalities were excluded, the potential influence of prior injury or rehabilitation status cannot be entirely ruled out. Several collared scops owls presented with concurrent medical conditions and were excluded, further limiting sample availability. Further studies involving larger and more representative populations are warranted to validate and expand upon these findings.

In conclusion, this study established preliminary reference values for IOP in clinically healthy collared scops owls using rebound tonometry. These findings provide a practical reference for clinical evaluation in avian medicine, particularly in wildlife rehabilitation settings, where accurate IOP assessment can aid in diagnosis, treatment planning, and prognostic evaluation. The establishment of species-specific IOP data contributes to improved ophthalmic care and supports the continued development of baseline ophthalmological parameters for protected raptor species in Taiwan.

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Declaration of artificial intelligence use: During the preparation of this work, the authors used ChatGPT solely for language editing. The authors take full responsibility for the integrity, accuracy, and originality of the work.

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