Ophthalmic examination findings in healthy white storks (*Ciconia Ciconia*)

Oftalmologisch onderzoek bij gezonde witte ooievaars (Ciconia ciconia)

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ABSTRACT

In birds, vision plays an essential role in vital functions such as feeding and reproduction. In this study, it was aimed to determine the ophthalmic examination findings in healthy storks. A total of eleven healthy white storks were included in the study. Schirmer tear test 1 (STT-I), intraocular pressure (IOP) and ocular biometry were performed on both eyes of each stork. The mean STT-I values were 12±3.4 (right eye) and 11.9±3.14 mm/min (left eye), and the IOP values were 19±0.97 (right eye) and 18.85±0.73 mmHg (left eye). The mean ocular biometric values were as follows: anterior chamber depth, 2.30±0.18 and 2.29±0.13 mm, lens thickness 5.18±0.1 and 5.19±0.13 mm, vitreous body 11.72±0.25 and 11.82±0.34 mm, and pecten 7.94±0.34 and 7.9±0.37 mm of the right and left eyes, respectively. Knowledge of the normal value ranges in healthy white storks is necessary for the diagnosis of ocular diseases in this species. To the authors' knowledge, this is the first study in which normal ophthalmic value ranges in healthy storks are described.

SAMENVATTING

Bij vogels is een goed zicht van essentieel belang voor vitale functies zoals voeden en voortplanting. In het voorliggende onderzoek werden de normale oogheelkundige parameters bepaald bij gezonde, in het wildlevende ooievaars. In totaal werden er elf gezonde ooievaars in het onderzoek opgenomen. Schirmer-teartest 1 (STT-I), oogdruk (IOP) en oculaire biometrie werden voor de beide ogen van elke ooievaar geëvalueerd. De gemiddelde STT-I-waarden waren 12±3,4 mm/min (rechteroog) en 11,9±3,14 mm/min (linkeroog), de IOP-waarden waren 19±0,97 mmHg (rechteroog) en 18,85±0,73 mmHg (linkeroog). De oculaire biometrische gemiddelde waarden waren als volgt: diepte van de voorste kamer 2,30 ± 0,18 mm en 2,29 ± 0,13 mm, lensdikte: 5,18 ± 0,1 mm en 5,19 ± 0,13 mm, corpus vitreum 11,72 ± 0,25 mm en 11,82 ± 0,34 mm en pecten: 7,94 ± 0,34 mm en 7,9 ± 0,37 mm, bij respectievelijk het rechter- en linkeroog. De kennis van de normale parameters bij gezonde ooievaars is van essentieel belang voor de diagnosestelling van oogziekten bij deze diersoort. Volgens de auteurs is dit de eerste studie waarin de bevindingen van oftalmologisch onderzoek bij gezonde ooievaars beschreven worden.

INTRODUCTION

Trauma is one of the major reasons for presenting wild birds to clinics (Kayikci et al., 2019; Aslan et al., 2009; Wendell et al., 2002; Deem et al., 1998). Ocular lesions are common findings in birds with head trauma (Williams et al., 2006). The main reason for the rehabilitation of wild birds is to bring them back to normal health conditions, so they can survive in their natural habitats (Reuter et al., 2011). The standard procedure includes ophthalmic examination as a major component (Williams et al., 2006; Han et al., 2019).

In all animal species, procedures such as the Schirmer tear test I (STT-I), intraocular pressure measurement (IOP) and anatomical structure evaluation of the eyes are essential in the standard ophthalmic examination (Akgül et al., 2022; Çakır et al., 2014; Pearce and Moore, 2013; Alkan et al., 2004).

The tear production is important for a healthy corneal epithelium. Many methods are used to determine the amount of tear secretion; STT-I is a frequently preferred measuring method and should be routinely performed (Kulualp et al., 2019; Akgül et al., 2017; Vashisht and Singh, 2011; Werner et al., 2008; Xiong et al., 2008; Alkan et al., 2004).

Ocular hypertension is considered one of the greatest risk factors for the development of glaucoma, and IOP measurement is the most consistent predictor of glaucoma in animals and humans (Maggio, 2015; Gelatt and MacKay, 2004). Increased IOP causes optic nerve head degeneration and retina, resulting in glaucoma that can cause irreversible blindness in humans and animals (Tham et al., 2014; Gelatt and MacKay, 2004).

Ocular ultrasonography is an important imaging method that allows for safe and noninvasive evaluation of intraocular structures without the requirement of sedation or anesthesia (Mirshahi et al., 2014). Furthermore, ocular ultrasonography is required for the evaluation of intraocular structures in cases where the transparent structures of the eye become opaque, such as corneal edema and cataracts (Maggs et al., 2008).

Reproductive biology, feeding behavior, migration routes and infectious and parasitic diseases in storks have been described (Bentrad and Chalabi-Belhadj, 2018; Girisgin et al., 2017; Shephard et al., 2015; Ivande et al., 2012; Olias et al., 2010). Although ophthalmology in wild birds has been described (Shivaprasad et al. 2022), to the authors' knowledge, there are no ophthalmologic studies in living storks available in the literature. Therefore, in this study, it was aimed to examine and present ocular parameters, such as STT-I, IOP and ultrasonographic findings in healthy storks without ophthalmological conditions.

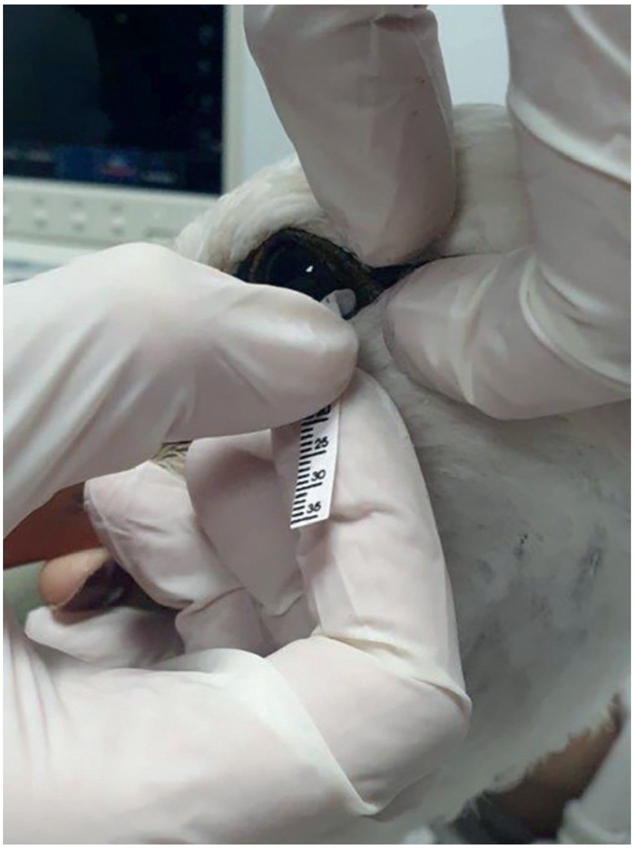

Figure 1. STT-I measurement using a 5-mm strip.

MATERIALS AND METHODS

This study was approved by the Ministry of Forestry and Water Affairs (January, 23, 2023, # E-21264211-288.04-8588213).

Wild animals seized for various reasons, i.e. disease, injury or illegal capture, within the borders of the province of Aydın (Turkey) are brought to the Veterinary Faculty Animal Hospital of Aydın Adnan Menderes University for physical examination and treatment. Animals that have recovered and that are diagnosed to be healthy, are released back into the wild.

Only healthy white storks (n=11) were included in this study. They were captured by General Directorate of Nature Conservation and National Parks officials and brought to the Aydın Adnan Menderes University Faculty of Veterinary Medicine.

Physical examination was performed prior to the ocular examination; the findings of these examinations constitute the material of this study.

Ophthalmologic examination

The storks were examined under restraint without requiring sedation or anesthesia. During the examination, ophthalmic reflexes were examined and evaluated in detail.

The storks were restrained by hand for ophthalmologic examination, and the results of hand-held slit-lamp biomicroscopy (Kowa SL-15, Japan) showed that both eyes of all birds were clinically normal. Palpebral, corneal and direct pupillary light reflexes were evaluated, and STT-I was performed using test strips (ERC, Turkey), which have a printed mm scale. The STT-I strips were positioned laterally in the lower conjunctival fornix of both eyes (Figure 1). A Tonovet rebound tonometer (TonoVet®, ICARE, USA) was used for all IOP measurements (Figure 2). The recorded measurements were automatically generated as an average of five readings. Standard transcorneal ocular ultrasonography was performed. Symmetry was pursued when placing the probe on the cornea. The optimal position of the probe was achieved by imaging the echogenic pecten (anteroposterior view). Ecobiometric measurements were made on optimal images , where the cornea, the front and back surfaces of the lens, the back wall and the pecten were determined along the optical axis. Analysis of B-mode ultrasound images and the ocular biometry of the storks were recorded (Figure 3).

Data obtained from this study were analyzed statistically using SPSS in. 22.0 software (SPSS Inc, USA). Descriptive analyses were used to summarize data and check if the assumptions were met. The results were evaluated using the Shapiro-Wilk Test for normality and the Levene test for homogeneity of variances. Differences in the IOP, STT-I, and echobiometric globe measurements between the right and left eyes were assessed with the paired samples t-test. A p-value of <0.05 was considered statistically significant for all analyses.

RESULTS

The eleven storks included in this study underwent routine ocular examination; STT-I, IOP and echobiometric tests were well tolerated by the storks.

The results of the STT-I and intraocular pressure tests were as follows: 12±3.4 mm/min (right), 11.9±3.14 mm/min (left) and 19±2.14 mmHg (right), 19.09±1.57 mmHg (left), respectively (Table 1).

Along the optic axis, four hyperechoic principal landmarks were observed, i. e. the cornea, the anterior and posterior lens capsules and the posterior wall of the eye. The anterior chamber between the cornea and the anterior capsule of the lens was anechoic. The lens appeared as an ovoid structure with a hyperechogenic anterior and a posterior capsule. The vitreous chamber, which was located between the posterior capsule and the posterior wall of the eye, was identified as anechoic. The pecten, starting from the retina, was observed as an echogenic tubular structure. The choroid, sclera and retina were visible as a hyperechoic line on the posterior wall of the globe and could hence not be distinguished. The mean values of the anterior chamber depth were 2.30±0.18 mm (right) and 2.29±0.13 mm (left), lens thickness 5.18±0.1 mm (right) and 5.19±0.13 mm (left), vitreous body 11.72±0.25 mm (right) and 11.82±0.34 mm (left), and pecten 7.94±0.34 mm (right) and (left) 7.9±0.37 mm (Table 2).

Table 1. Mean STT-I and IOP values of the eleven storks (Mean±SD).

	STT-I mm/min	IOP mmHg
Right	12±3.4	19±2.14
Left	11.9±3.14	19.09±1.57

Figure 2. IOP measurement using rebound tonometry.

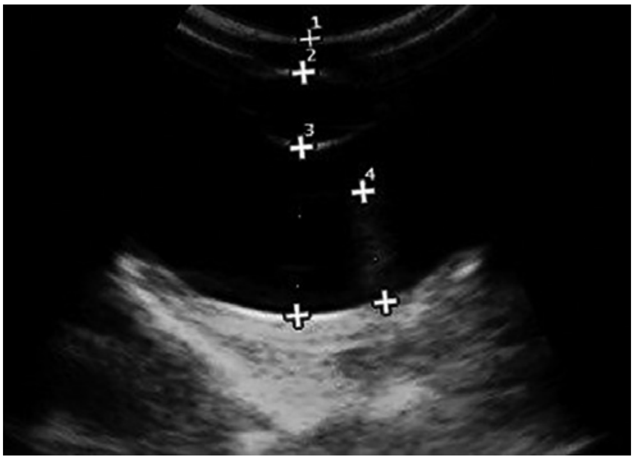

Figure 3. Echobiometric measurements of globe via ultrasonography. 1. Distance between the cornea and anterior lens capsule. 2. Distance between the anterior and posterior capsule of the lens. 3. Distance between the posterior lens capsule and the optic papilla. 4. Longitudinal distance of the pecten.

Table 2. Mean ocular ultrasound measurement values (mm) for both eyes of seven storks (Mean±SD).

	D1	D2	D3	D4
Right	2.30±0.18	5.18±0.1	11.72±0.25	7.94±0.34
Left	2.29±0.13	5.19±0.13	11.82±0.34	7.9±0.37

B-scan of the following structure, D1 = distance between the cornea and anterior lens capsule. D2 = distance between the anterior and posterior capsule of the lens. D3 = distance between the posterior lens capsule and the optic papilla. D4 = longitudinal distance of the pecten.

DISCUSSION

Detecting normal examination findings in healthy birds is crucial for diagnosing ocular diseases. Normal ranges for STT-I and IOP values and ultrasonographic ocular biometry in healthy eyes of white storks are provided in this study. The analysis of the B-mode ultrasound images and normal ocular biometry of the storks could serve as a basis for the ultrasound examination of patients which may have ocular diseases affecting measurements or sizes. In ophthalmologic studies conducted on avian species, significant differences in intraocular pressure, tear production and biometric measurements have been shown, even among different species and breeds (Ansari Mood et al., 2017; Meekins et al., 2015; Barsotti et al., 2013; Mercado et al. 2010).

Generally, birds are anesthetized during ophthalmic examination to diagnose ocular disease (Kamiloğlu, 2017; Topal, 2001; Ünsaldı, 2000); however, physical and ophthalmic examinations can be easily completed during manual restraint. In this study, the tonometry probe (TonoVet®, ICARE, USA) did not cause a corneal reflex and was well tolerated by the storks as is the case in other avian species (Ansari Mood et al., 2017; Meekins et al., 2015; Mercado et al., 2010). The study results indicate that the IOP in the storks is higher than reported in captive American flamingos (*Phoenicopterus ruber ruber*), i. e. mean±SD, 9.5±1.7 mm Hg) (Meekins et al., 2015).

Although 2-4 mm cuts from 5-mm strips for small bird species have been used in several avian studies, in the present study, a 5-mm strip was used (Ansari Mood et al., 2017; Barsotti et al., 2013; Harris et al., 2008). In a study by Meekins et al. (2015) in Caribbean flamingos, the mean tear production was 12.3±4.5 mm/min for modified STT. In a study by Ansari Mood et al. (2017) in which STT-I readings were obtained with 5-mm strips in ducks, the STT-I reading range was found to be 5.5-6.7 mm/min. In a study by O'Connell et al. (2017), the mean STT in normal brown pelicans was 5.45±1.88 mm/min. In the present study, the STT-I values measured in the storks were found to be 12±3.4 for the right eye and 11.9±3.14 for the left eye. To the best of the authors' knowledge, there is currently no other study showing the STT-I value of healthy storks. However, the data obtained from this study show that the mean STT-I in storks is quite high compared to other water birds.

The use of ultrasonography as a noninvasive method to measure ocular biometry in birds is especially relevant for clinical and research purposes, because it allows accurate and repeatable measurements of different ocular structures. To evaluate the eyeball with B-mode ultrasonography, a medium frequency (7.5-10 MHz) sector, a microconvex or a linear probe with high resolution and a small contact area (1-4 cm) should be used (Lehmkuhl et al., 2010; Von Eicken et al., 2006). In the present study, a 7.5 MHz microconvex probe was used and the pecten could be detected in all cases.

Normal ultrasonographic structures are almost identical for all avian species. The following structures are consistently visible in all living animals: curved hyperechoic cornea, anechoic anterior chamber, anechoic lens, prominent anterior and posterior lens capsule, anechoic vitreous chamber and hyperechoic globe posterior wall (sclera, retina and choroidea). In avian species, the pecten extends from the retina to the vitreous chamber.

In a study by Ince et al. (2017), the ocular bulbus diameter in seagulls was measured to be 22.07±1.18 mm. The pecten oculi has been described as a structure originating from n. opticus. The length of the pecten oculi (6.4 ± 0.62 mm) was 1/3 of the diameter of the bulbus oculi (Ince et al., 2017). In a study by Onuk et al. (2013), the pecten of storks was found to be 5.53±1.11 mm, and the diameter of the bulbus oculi 25.37±2.58 mm. Under these conditions, the length of the pecten oculi was to 2/5 of the diameter of the bulbus oculi (Onuk et al., 2013). Similarly, in the current study, the ratio of pecten to bulbus oculi was 2/5. The pecten has been reported to be 4 mm in ducks (Corona et al. 2004) and 5 mm in geese (Korkmaz et al. 2022). The pecten oculi originates from the nervus opticus, resulting in an opticus and accordion-shaped formation (Girisgin et al., 2017; Onuk et al., 2013). On ultrasonography, the pecten oculi of the storks in the present study had a similar location and structure. Although different sphere sizes have been reported, pecten sizes in waterfowl are very similar to each other (Korkmaz et al., 2022; Meekins et al., 2015; Onuk et al., 2013; Corona et al., 2004). In this study however, the size of the pecten of the storks differed from the pecten size in other studies, i. e. 7.94±0.34 mm (right) and 7.9±0.37 mm (left).

In a study by Meekins et al. (2015), the mean ultrasonographic globe measurements of American flamingos were as follows: anterior chamber depth 1.75± 0.05, lens thickness 4.6±0.06, vitreous body 6.95± 0.10, and pecten length 5.1±0.38. Meekins et al. (2015) found that the anterior and vitreal chambers of white storks are almost twice the size of the anterior and vitreal chambers of American flamingos, and the pecten length and lens thickness of the white storks were higher than in American flamingos (Meekins et al. 2015). In the present study, the echobiometric globe measurements were highly similar to the measurements found in brown pelicans. In a study by O'Connell et al. (2017), echobiometric measurements in brown pelicans showed a mean anterior chamber depth of 3.38±0.19 mm, a mean axial lens diameter of 5.19±0.23 mm, a mean vitreal chamber length of 12.15±0.53 mm and a mean pecten 7.2 mm. Although the mean ultrasonographic globe measurements in the brown pelicans were similar to those in the white storks, the mean STT and IOP values in white storks were higher than the values found in the brown pelicans (5.45±1.88 mm/min and 10.86±1.61 mm Hg) (O'Connell et al. 2017). In a study by Ansari Mood et al. (2017), the mean STT and IOP values in ducks and geese varied between 5-6.7mm/min and 9.1-10.3 mm/Hg, respectively, and were quite low compared to values reported in white storks.

The differences in ocular measurements between avian species reflect the adaptations of the different species to different visual environments and habitats in general. Consistent with reported findings in other animal species, no significant differences were observed between the axial length and intraocular structure dimensions of the left and right eyes (Squarzoni et al., 2010).

Overall, comparative analysis of ocular biometry highlights the diversity of ocular characteristics among avian species and the importance of considering species-specific ocular parameters in clinical and research settings.

Considering that the storks included in this study were free-living storks brought to the Veterinary Faculty Animal Hospital of Aydın Adnan Menderes University by government officials for clinical examination, and considering the prevalence of storks is much less than the prevalence of domestic birds, the number of animals included in the study was limited.

The anatomical structures of the eye, tear quantity and normal IOP values vary greatly between different species (Ansari Mood et al. 2017; Meekins et al. 2015; Barsotti et al. 2013; Harris et al. 2008). Therefore, normal STT-I and IOP values and the normal ultrasonographic anatomy of the eye for each species should be established in order to evaluate the physiological and pathological states of wild birds. The normal anatomical structures of the eye and the normal STT-I and IOP values obtained in this study could be useful in future studies and in the interpretation of ophthalmic examination in clinical cases.

ETHICS STATEMENT

This study was approved by the Turkish Ministry of Forestry and Water Affairs (January, 23, 2023, # E-21264211-288.04-8588213) (ADU HADYEK - 6458 3101/2022/130).

Aydın Adnan Menderes University Faculty of Veterinary Medicine and Aydın Provincial Directorate affiliated with the General Directorate of Nature Conservation and National Parks enforced a protocol by the relevant provisions of the Protocol, CITES Convention, Land Hunting Law No. 4915, and Animal Protection Law No. 5199.

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