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Review Article

Ophthalmic Evaluation of Raptors Suffering From Ocular Trauma

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Abstract: Ocular problems are often associated with traumatic injury in raptors. A comprehensive evaluation, including a complete ophthalmic examination, is vital in determining the patient's overall health and suitability for release. Steps for conducting ocular examination and diagnostic testing in raptors is discussed. Additionally, common clinical findings after trauma, as well as the mechanisms by which ocular injury occurs, are outlined. An overview of medical treatments recommended for commonly diagnosed ocular diseases and the utility of ancillary diagnostic procedures is also presented.

Key words: ocular trauma, injuries, eye, ophthalmology, avian, raptors

INTRODUCTION

Trauma has been reported as the most common cause of ocular morbidity in raptors.[1,2] Ocular trauma is often the consequence of penetrating or blunt injury. Examples of penetrating trauma include gunshot wounds, claw injuries, or bite wounds, whereas blunt trauma may result from flight into an object (eg, automobile, window, building).[3] There is a significant increase in vision-threatening ocular disease in birds that present with head trauma.[4] The reported incidence of ocular lesions attributed to trauma on presentation varies but is reported to be as high as 90%.[1,2,5–7]

The severity and type of traumatic ocular injury is likely influenced by multiple factors, including body size, age, species, and time of peak activity.[8] Gunshot wounds and window strike were more common in larger, diurnal raptor species,[9] whereas nocturnal birds were involved more often in vehicle collisions that resulted in head trauma.[8,10] In some reports, serious injury was less common in juvenile compared with adult patients.[8] Moreover, in one study,[10] juvenile patients were more likely to be released compared with adults, which were 7.6 times more likely to be euthanized or die. One proposed theory for the difference in severity of injury between age groups is that juvenile birds were presented by well-meaning individuals after being found out of their nest.[2]

A separate report found that diurnal versus nocturnal activity played a significant role in age distribution and injury rates.[8] In this retrospective study, most young owls were admitted as healthy nestlings and fledglings. However, higher numbers of injured juvenile hawks were admitted compared with adults. This finding may be related to juvenile diurnal birds still learning the techniques of flying and hunting, resulting in self-injury.[8]

Unfortunately, ocular trauma has a negative influence on a successful release from rehabilitation. In one study evaluating tawny owls (*Strix aluco*) recovered from road accidents, the highest odds for successful release were found in birds only diagnosed with corneal injuries.[7] In one report, none of the birds with anterior segment pathology were released and only 36.4% of birds with posterior segment lesions were released.[7] Therefore, both age and the extent of ocular damage on presentation play a major role in determining suitability for future release.

Many features of the avian eye increase the risk for traumatic injury. The eyes have a frontal location and are larger relative to their body size than in other animal species. The globes fit narrowly within the orbit, having minimal periocular cushion.[11] Additionally, the equatorial diam-

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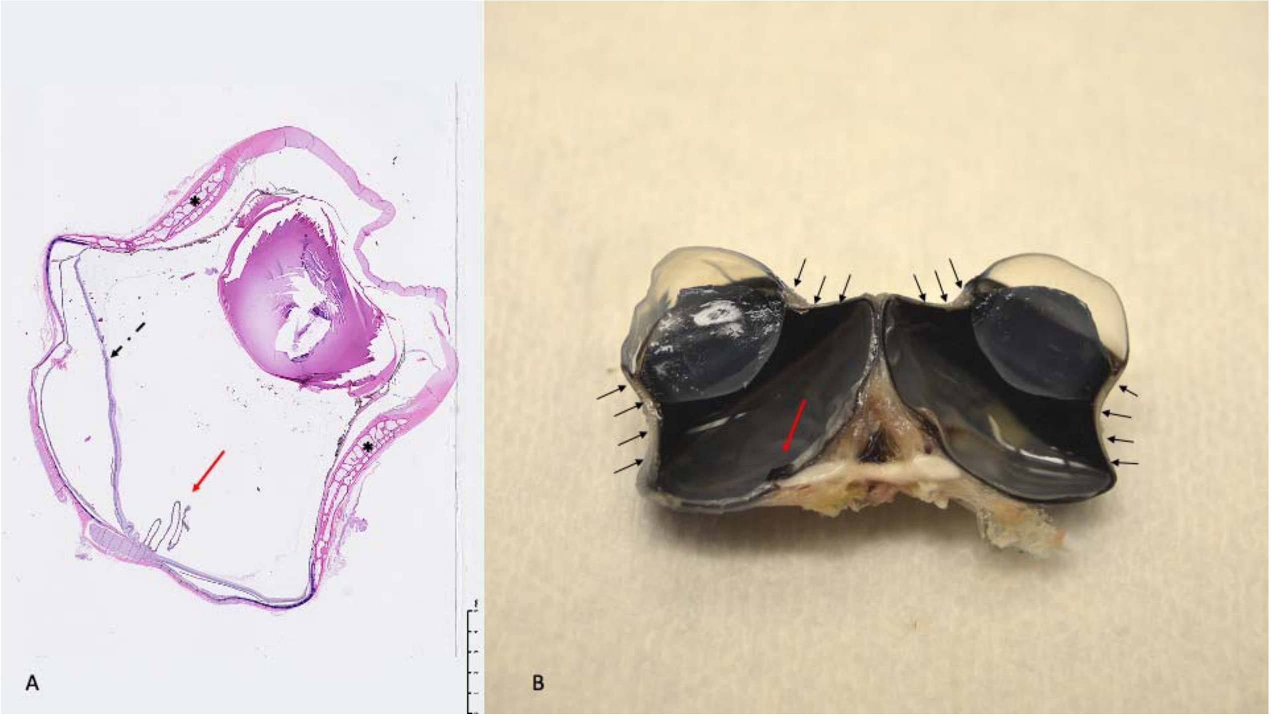

Figure 1. Histological section of a globe from the left eye of a barred owl stained with hematoxylin and eosin (A) and the same globe bisected (sagittal) for the gross image (B). Bony scleral ossicles affect the overall shape of the eye (tubular) and impart rigidity to the globe (A, black asterisks and arrows). The pecten projects into the vitreous and covers the optic nerve head (A, B, red arrow). The retina is artifactually detached from sectioning (A, dashed black arrow). Photos courtesy of Drs Emi Sasaki and Ingeborg Langohr.

eter of an avian globe often exceeds that of the anterior bony rim leaving the temporal and dorsal aspects of the globe unprotected by the bony orbit.[5] This anatomical conformation occurs to a greater degree in nocturnal birds such as owls compared with diurnal birds such as hawks.[12] The area of the eye that extends beyond the orbit is internally surrounded by bony scleral ossicles within the globe as an adaptive form of protection. These scleral ossicles affect the overall shape of the eye (eg, flat, globose, or tubular), impart rigidity to the globe, and provide a firm site of origin for striated ciliary muscles (Fig 1).[13,14]

A protective supraorbital ridge is present in diurnal raptors but is absent in nocturnal species, increasing their risk of blunt ocular trauma.[7] Overall, various anatomical factors such as the location, size, shape, and rigidity of the globe, as well as the proximity of the globes to each other, have been implicated in influencing the severity of lesions after blunt ocular trauma.[1,3,11,15]

Minimal extraocular muscle movement is present in birds because of the lack of significant extraocular muscle development and is most limited in patients with a tubular globe shape.[12] However, species differences exist in extraocular muscle development and function. The superior oblique muscle of a hawk acts with greater force and speed when compared with owls, allowing for movements of the eye of up to 8° in hawks compared with 2° in owls.[12] This adaptive difference is likely essential given the diurnal hunting behaviors of hawks. The extraocular muscles are not only important in the movement of the globe but have also been shown to provide critical mechanical support to the globe. In owls, the superior oblique muscle is important in providing tonic and stationary support of the globe because of the greater weight of the eye that extends beyond the orbit.[12]

OCULAR EXAMINATION

A complete ophthalmic examination includes a neuro-ophthalmic examination, obtaining baseline diagnostics (tear testing, measurement of intraocular pressure, fluorescein staining), an examination of the adnexa (the supportive structures of the eye, such as the eyelids and conjunctiva), and a full evaluation of the anterior and posterior segments of the globe. Ophthalmic examination in raptor species is similar to that of other small animal

Figure 2. Demonstration of proper restraint of a barred owl and injured screech owl for ocular examination. (A) The patient is often held upright or in dorsal recumbency with the wings and legs properly restrained. A towel can be used to assist with restraint of the wings if elected. (B) To stabilize the head and protect the examiner from injury, it is common for the handler to hold the head at the base of the skull.

(canine and feline) patients with a few key exceptions.

Before ophthalmic examination, it is vital to evaluate the overall condition of the patient to ensure that the bird can tolerate the additional stress of restraint and examination. To minimize patient stress, an efficient evaluation in a quiet environment is required. Additionally, examinations should take place in a room that can be sufficiently darkened. Most raptors can be examined with manual restraint and without sedation. The patient is often held upright or in dorsal recumbency with the wings and legs properly restrained (Fig 2A).[16] To stabilize the head and protect the examiner from injury, it is common for the handler to hold the head at the base of the skull (Fig 2B).[17] While restrained in an upright position, the person holding the bird can turn the patient to the side to allow the examiner to evaluate each eye in turn. Often, the examiner briefly has to "wait out" the third eyelid covering the eye, allowing the patient to retract the third eyelid slowly, allowing for a full evaluation.[3] The third eyelid is variably translucent depending on the species (especially pronounced in diurnal birds), whereas in some birds the normal vasculature of the third eyelid can be mistaken for keratitis.[18]

The primary pupillary sphincter is composed of striated circumferential muscle in avian species, allowing for rapid, voluntary control of the iris. The voluntary control of iridal diameter is likely an adaptive mechanism to assist with hunting during flight. As a result of this voluntary control, hippus (normal spontaneous pupil movements) is common in excited birds.[3] With a bright light source it should be possible to elicit a direct pupillary light reflex and dazzle reflex (involuntary blink in response to bright light) in a normal patient. The presence of significant anisocoria (unequal pupil size) or marked mydriasis (pupillary dilation) is suggestive of severe retinal dysfunction, a primary lesion of the iris, or oculomotor nerve dysfunction (Fig 3).[13] A slow direct pupillary light reflex may be indicative of profound cranial injury.[13]

Horner syndrome secondary to sympathetic nerve dysfunction has been reported in birds.[19,20] This condition will often result in ptosis (drooping upper eyelid), anisocoria (with the affected side being miotic),and erect ear-tuft feathers, also on the affected side.[19,20] Because of the striated muscle component to the iridal tissue, miosis (pupillary constriction) is typically not as severe as that observed in companion animal species. Additionally, the globe is less mobile in raptor species so

Figure 3. Prominent anisocoria (unequal pupils) in a great horned owl after head trauma. The pupil of the right eye was mydriatic secondary to a retinal detachment. Concurrently, the patient exhibited pain (blepharospasm) secondary to periocular injury and anterior uveitis.

enophthalmos of the globe and secondary protrusion of the third eyelid is not usually present in birds diagnosed with Horner syndrome.[19,20] Additionally, the musculature of the third eyelid contains a striated muscle component limiting the effect of sympathetic denervation. An improvement in ptosis associated with Horner syndrome has been reported by pharmacological testing with topical dilute 1% phenylephrine.[19,20]

Accurate assessment of vision is challenging in raptors. Evaluation of a menace response is of little clinical benefit in determining visual status, because the menace response is typically weak, even in birds with normal vision.[5] When demonstrated, a positive menace response is often manifested as movement of the third eyelid versus closure of the palpebrae.[3] Examiners must be aware that differences in the menace response exist among raptors. Depending on the raptor species being evaluated, a stoic or overstimulated menace behavior can be misinterpreted as a positive or negative response to visual stimuli.[13]

Additionally, many patients evaluated after trauma may have a coexisting systemic injury, a disease condition, or both. The presence of systemic disease, head trauma, or both has the potential to decrease visual responses. Typically, patients demonstrating a head tilt without other neurological signs have severe unilateral ocular disease.[13] When performing a neuro-ophthalmic examination in normal birds, the palpebral reflexes are often incomplete, whereas the third eyelid reflex is complete.[3,5] As previously discussed, because of limited extraocular muscle development, ocular motility in birds is reduced.

Many ocular lesions are associated with a traumatic brain injury because the orbit takes up a large proportion of the midline region of the skull. Traumatic brain injuries can affect vision, hearing, equilibrium, olfaction, and motor control.[21] Because of the lack of extraocular muscle development, nystagmus (involuntary eye movement) is often demonstrated by complete movement of the head.[21] Damage after blunt trauma is often extensive because of contrecoup injury. The presence of bilateral severe miosis is often indicative of severe central nervous system trauma and probable increased intracranial pressure.[21]

Baseline ophthalmic diagnostic testing should be performed as part of a complete ophthalmic examination before applying any medications or solutions to the eye. Unfortunately, significant differences in baseline diagnostic test values have been noted to exist between raptor species that may be influenced by the regional environment, time of activity (nocturnal versus diurnal), and body weight.[22–24] Therefore, it is important to use species-specific reference values when available to avoid misinterpretation of test results.[22,23]

Tear testing

Tear production in raptors can be evaluated by performing a Schirmer tear test (STT), modified Schirmer tear test (mSTT), or phenol red thread test (PRT). STT measures both basal and reflex tear production. With PRT testing, reflex tears are not measured, and only residual tear volume and basal tear production are assessed.

The most common form of tear testing is the STT-1 (without topical anesthesia), in which a 5-mm-wide paper strip with an impregnated dye column is inserted into the lower conjunctival fornix, and tear production is measured after 1 minute. Unfortunately, for some raptor species with a small palpebral fissure, the insertion of the paper strip can be challenging. For these species, one option for measuring tear production is by performing the mSTT. To perform a mSTT, commercial STT strips are cut vertically into 1–2-mm strips and placed as described above. Physically cutting the strips introduces the possibility of measuring error, and unfortunately there are limited reports of reference intervals with the use of this technique. Therefore, if one is performing a mSTT, this modality is recommended to be used only to compare the eyes of the same bird.[25]

To combat the issues of small palpebral fissure length, the PRT test can be a useful alternative. This form of tear testing uses a cotton thread impregnated with phenol red dye as an indicator. More consistent tear testing results were obtained in screech owls (*Megascops asio*), and the PRT was found to be better at detecting small differences in tear production.[25,26] To perform, the cotton thread is placed in the lower conjunctival fornix for 15 seconds. The examiner often must keep the eye closed after placement in the lower conjunctival fornix to prevent premature dislodging of the thread. Unfortunately, STT and PRT test results do not correlate well with each other, so specific reference intervals for each individual test should be consulted when performing either test on clinical patients (Table 1).[22–32]

A primary cause of reduced tear production in wild birds is neurologic injury.[22] Decreased tear test values can also be associated with keratitis and hypovitaminosis A secondary to metaplasia of epithelial and glandular tissue. Increased tear test values are often identified in patients with ocular pain or obstruction of the lacrimal drainage system.[25] Two glands, Harderian and lacrimal, are responsible for tear production in most raptors, although species variations do exist. The Harderian gland is located at the base of the third eyelid within the orbit. The lacrimal gland is present at the inferior-temporal aspect of the globe within the orbit and is considered the main source of tear production in birds.[5,22] Previous reports have documented lower tear test values in nocturnal raptors compared with diurnal species.[22] This finding is likely due to differences in the anatomy of the lacrimal tissues. In nocturnal species, the Harderian gland is less developed and may be absent.[33] Additionally, owls are reported to have vestigial or absent lacrimal glands.[6,34] It has been hypothesized that nocturnal birds may not need higher levels of lacrimation because of increased humidity levels at night.[22,27] Diurnal variation may play a role in the results obtained in these studies, and further investigation is warranted.

Age has been reported as a factor in determining tear test values. Hatchling griffon (*Gyps fulvus*) and Eurasian black vultures (*Aegypius monachus*) were noted to have higher STT values when compared with other age groups.[30] Lower tear test values in adult raptors may predispose these mature birds to exposure keratopathy (corneal damage from dryness) and corneal ulceration after trauma.[7]

Intraocular pressure

Reported methods for evaluating intraocular pressure (IOP) in raptors include the use of the applanation tonometer (Tonopen, Reichert Technologies, Depew, NY, USA) or the rebound tonometer (Tonovet, Icare Finland Oy, Helsinki, Finland). The anatomy of the avian patient should be considered when choosing a tonometry method. The Tonopen measures intraocular pressure by flattening a small region of cornea with a small footplate at the tip of the instrument. It is necessary to apply one drop of topical proparacaine (Akorn Pharmaceuticals, Lake Forest, IL, USA) to the eye before evaluating intraocular pressures with the Tonopen. Because of its construction, the Tonopen has been shown to require a minimum corneal diameter of 9 mm, which limits its usefulness in smaller raptor species.[35] Reproducibility with the Tonopen was found to be limited in patients with a corneal diameter of less than 5 mm.[35,36] This limitation is likely due to the high curvature of the cornea in patients with a small corneal diameter.[35] Therefore, the Tonovet is recommended for patients with a small corneal diameter.[37] When compared with manometry (direct measurement of pressure within the eye with a monometer), the Tonopen was found to have good correlation in avian species for IOP between 10 and 25 mm Hg. Once the values reduced to <10 mm Hg, Tonopen values were falsely increased; at values >25 mm Hg, Tonopen values were falsely decreased.[38]

Rebound tonometry (Tonovet) functions by brief contact with an electromagnetically charged probe on the corneal surface to estimate intraocular pressure. Because of its design, topical anesthetics (eg, proparacaine) are not required, and the device can be used for patients with a small corneal diameter because the probe's tip diameter is 1.4 mm. The instrument also has separate calibration settings for different species, including a "p" or other setting, for species in which the instrument does not have an internal calibration table. For avian species, most clinicians use the instrument in either "p" or "d" (canine) mode.

Similar to tear testing, numerous factors contribute to variation in the IOP values obtained. Some of the factors implicated include the type of instrument used, activity of the patient (diurnal versus nocturnal), time of day testing is completed, age of the patient (juvenile versus adult), and body positioning.[39–41] For example, the Tonovet has been found to overestimate IOP in diurnal species and underestimate IOP in nocturnal species.[39] The variability between species likely has to do not only with anatomical differences (eg, shape and size of the eye, corneal thickness, corneal curvature), but also normal physiologic variations in diurnal versus nocturnal species.[26,31,41,42] Because anatom-

Table 1. Tear test values reported for raptor species are summarized and organized by raptor family.

Common name	Species	STT-1, mm/min	PRT, mm/15 s	Reference
Family Strigidae (nocturnal)				
Scops owl	*Otus scops*	1.0 ± 0.5	11.8 ± 5	Beckwith-Cohen et al[24]
Barn owl	*Tyto alba*	3.6 ± 2.2	19.5 ± 7.2	Beckwith-Cohen et al[24]
Long-eared owl	*Asio otus*	1.25 ± 1.0	8.0 ± 2.8	Beckwith-Cohen et al[24]
Eurasian eagle owl	*Bubo bubo interpositus*	12.0 ± 7.0	28.5 ± 2.1	Beckwith-Cohen et al[24]
Pharaoh eagle owl	*Bubo bubo ascalaphus*	15.0 ± 0	21.0 ± 0	Beckwith-Cohen et al[24]
Eurasian tawny owl	*Strix aluco*	3.12 ± 1.92		Barsotti et al[22]
		7.2 (juvenile) 4.25 (adult)		Cosquer[7]
		3.2 ± 0.4[a]		Williams et al[14]
Little owl	*Athene noctua*	2.5 ± 0.7	22.0 ± 2.8	Beckwith-Cohen et al[24]
		3.5 ± 1.96		Barsotti et al[22]
Great grey owl	*Strix nebulosa*	9.8 ± 2.8		Wills et al[23]
Snowy owl	*Bubo scandiacus*	9.8 ± 2.4		Wills et al[23]
Eastern screech owl	*Megascops asio*	≤2[b]	15.0 ± 4.3	Harris et al[26]
Striped owl	*Asio clamator*	5.03 ± 3.29		Rodarte-Almeida et al[28]
Assorted members		<3 (2.70 ± 1.4)[a]		Korbel and Leitenstorfer[27]
Family Accipitridae (diurnal)				
Bald eagle	*Haliaeetus leucocephalus*	14.0 ± 2.0		Kuhn et al[29]
Short-toed snake eagle	*Circaetus gallicus*	7.5 ± 3.5	22.5 ± 7.7	Beckwith-Cohen et al[24]
Black kite	*Milvus migrans*	7.4 ± 5.7	12.6 ± 9	Beckwith-Cohen et al[24]
Western marsh harrier	*Circus aeruginosus*	12.0 ± 5.6	30.0 ± 0	Beckwith-Cohen et al[24]
Montagu's harrier	*Circus pygargus*	8.0 ± 2.8	27.0 ± 4.2	Beckwith-Cohen et al[24]
Common buzzard	*Buteo buteo*	13.7 ± 4.4	16.0 ± 7.7	Beckwith-Cohen et al[24]
		12.47 ± 2.66		Barsotti et al[22]
		11.5 ± 5.4		Korbel and Leitenstorfer[27]
Steppe buzzard	*Buteo buteo vulpinus*	3.0 ± 0	12.0 ± 0	Beckwith-Cohen et al[24]
European honey buzzard	*Pernis apivorus*	7.5 ± 2.2	25.6 ± 8.6	Beckwith-Cohen et al[24]
Long-legged buzzard	*Buteo rufinus*	12.5 ± 10.0	28.0 ± 2.0	Beckwith-Cohen et al[24]
Griffon vultures	*Gyps fulvus*	6.4–6.5 ± 1.8		Komnenou et al[30]
Assorted members		Range of 10.7–11.5		Korbel and Leitenstorfer[27]
Family Falconidae (diurnal)				
Barbary falcon	*Falco pelegrinoides*	3.0 ± 0	25.0 ± 0	Beckwith-Cohen et al[24]
Lesser kestrel	*Falco naumanni*	2.0 ± 0	24.0 ± 0	Beckwith-Cohen et al[24]
European (common) kestrel	*Falco tinnunculus*	6.20 ± 3.67		Barsotti et al[22]
		4.1 ± 2.7		Korbel and Leitenstorfer[27]
		7.4 ± 3.27		Kim et al[31]
		5.8 ± 4.0	29.6 ± 4.7	Beckwith-Cohen et al[24]
Southern crested caracara	*Caracara plancus*	7.84 ± 3.05		Baldotto[32]
Assorted members		30.6 ± 4.2		Smith et al[25,c]
Assorted members		4.1–14.4		Korbel and Leitenstorfer[27,c]
Family Cathartidae (diurnal)				
Eurasian black vultures	*Aegypius monachus*	10.9 ± 3.3 OD		Komnenou et al[30]

STT-1 indicates Schirmer tear test (without application of topical anesthesia) reported as $\bar{x}$ ± SD; PRT, phenol red thread test reported as $\bar{x}$ ± SD.

[a] Modified Schirmer tear test.

[b] Median value reported.

[c] Reference information provided as a range by family group.

Table 2. A summary of average intraocular pressure values obtained for adult raptors by either rebound tonometry (Tonovet) or applanation tonometry (Tonopen). Values are organized by raptor family.

Common name	Species	Rebound tonometry, mm Hg	Applanation tonometry, mm Hg	Reference
Family Strigidae (nocturnal)				
Scops owl	*Otus scops*		14.5 ± 3.9	Beckwith-Cohen et al[24]
Barn owl	*Tyto alba*	10.8 ± 3.8[a]		Reuter et al[40]
			18.0 ± 6.6	Beckwith-Cohen et al[24]
Long-eared owl	*Asio otus*	7.8 ± 3.2[a]		Reuter et al[40]
			9.8 ± 1.2	Beckwith-Cohen et al[24]
Eurasian eagle owl	*Bubo bubo interpositus*	10.45 ± 1.64[b]	9.35 ± 1.81	Jeong et al[42]
			15.4 ± 4.1	Beckwith-Cohen et al[24]
Pharaoh eagle owl	*Bubo bubo ascalaphus*		7.8 ± 3.5	Beckwith-Cohen et al[24]
Eurasian tawny owl	*Strix aluco*		11.21 ± 3.12	Barsotti et al[22]
		9.4 ± 4.1[a]		Reuter et al[40]
			15.6 ± 3.4	Williams et al[14]
Little owl	*Athene noctua*		9.83 ± 3.41	Barsotti et al[22]
			12.3 ± 2.5	Beckwith-Cohen et al[24]
Great grey owl	*Strix nebulosa*	9.6 ± 2.6[b]		Wills et al[23]
Snowy owl	*Bubo scandiacus*	9.1 ± 1.9[b]		Wills et al[23]
Eastern screech owl	*Megascops asio*	6.3 ± 1.3[b]	9.3 ± 2.6	Labelle et al[4]
		9.0 ± 1.8[b]	11.0 ± 1.9	Harris et al[26]
		14.0 ± 2.4[a]		Harris et al[26]
Great horned owl	*Bubo virginianus*	9.9 ± 2.2[b]	9.9 ± 2.4	Labelle et al[4]
			10.8 ± 3.6	Stiles et al[41]
Barred owl	*Strix varia*	8.3 ± 3.2[b]	11.7 ± 3.8	Labelle et al[4]
Striped owl	*Asio clamator*		13.81 ± 5.63	Rodarte-Almeida et al[28]
Family Accipitridae (diurnal)				
Bald eagle	*Haliaeetus leucocephalus*		21.5 ± 1.7	Kuhn et al[29]
			20.6 ± 2.0	Stiles et al[41]
White-tailed sea eagle	*Haliaeetus albicilla*	26.9 ± 5.8[a]		Reuter et al[40]
Golden eagle	*Aquila chrysaetos*		21.5 ± 3.0	Stiles et al[41]
Short-toed snake eagle	*Circaetus gallicus*		18.6 ± 2.2	Beckwith-Cohen et al[24]
Northern goshawk	*Accipiter gentilis*	18.3 ± 3.8[a]		Reuter et al[40]
Eurasian sparrowhawk	*Accipiter nisus*	15.5 ± 2.5[a]		Reuter et al[40]
Cooper's hawk	*Accipiter cooperii*	10.7 ± 1.4[b]	16.0 ± 1.8	Labelle et al[4]
Red-tailed hawk	*Buteo jamaicensis*	19.8 ± 4.9[b]	20.3 ± 2.8	Labelle et al[4]
			20.6 ± 3.4	Stiles et al[41]
Swainson's hawk	*Buteo swainsoni*		20.8 ± 2.3	Stiles et al[41]
Black kite	*Milvus migrans*		17.1 ± 7.2	Beckwith-Cohen et al[24]
Red kite	*Milvus milvus*	13.0 ± 5.5[a]		Reuter et al[40]
Western marsh harrier	*Circus aeruginosus*		13.6 ± 0.8	Beckwith-Cohen et al[24]
Montagu's harrier	*Circus pygargus*		13.4 ± 1.1	Beckwith-Cohen et al[24]
Common buzzard	*Buteo buteo*		17.2 ± 3.53	Barsotti et al[22]
		26.9 ± 7.0[a]		Reuter et al[40]
			19.4 ± 3.9	Beckwith-Cohen et al[24]
Steppe buzzard	*Buteo buteo vulpinus*		25.0 ± 1.6	Beckwith-Cohen et al[24]
European honey buzzard	*Pernis apivorus*		14.4 ± 2.8	Beckwith-Cohen et al[24]
Long-legged buzzard	*Buteo rufinus*		13.3 ± 4	Beckwith-Cohen et al[24]
Family Falconidae (diurnal)				
Barbary falcon	*Falco pelegrinoides*		9.2 ± 1.8	Beckwith-Cohen et al[24]
Peregrine falcon	*Falco peregrinus*	12.7 ± 5.8[a]		Reuter et al[40]
Lesser kestrel	*Falco naumanni*		13.7 ± 1.0	Beckwith-Cohen et al[24]
American kestrel	*Falco sparverius*	6.8 ± 1.7[b]	8.5 ± 4.4	Labelle et al[4]

Table 2. Continued.

Common name	Species	Rebound tonometry, mm Hg	Applanation tonometry, mm Hg	Reference
European (common) kestrel	*Falco tinnunculus*		8.53 ± 1.59	Barsotti et al[22]
		9.8 ± 2.5[a]		Reuter et al[40]
			11.9 ± 3.3	Beckwith-Cohen et al[24]
			10.5 ± 3.15	Kim et al[31]
Southern crested caracara	*Caracara plancus*		19.18 ± 3.06	Baldotto[32]
Family Cathartidae (diurnal)				
Turkey vulture	*Cathartes aura*	11.7 ± 1.0[b]	15.0 ± 2.1	Labelle et al[4]

[a] Measurement made with Tonovet "d" setting.
[b] Measurement made with Tonovet "p" setting.

ical and physiological differences exist, species-specific, as well as instrument-specific reference intervals, should be used when possible (Table 2).[a]

Changes in intraocular pressure are likely to occur secondary to ocular trauma. Although primary glaucoma is rarely diagnosed in raptors, secondary glaucoma can occur in patients with severe intraocular hemorrhage, chronic uveitis, or lens luxation. Low intraocular pressures are often detected in patients with anterior uveitis.

Generally one does not need to dilate the eyes of a raptor patient to perform a complete ophthalmic examination. The voluntary control of pupil size that raptors possess prevents the use of routine topical parasympatholytic dilating agents (eg, tropicamide, atropine) traditionally used in domestic animal species. Normally, because of patient stress, the pupils will sufficiently dilate to allow for full examination. This response is most prominent in nocturnal species. Thus, full fundic examinations are more challenging in diurnal species. Often this challenge can be reduced by examining the patient in a darkened room and by using smaller diameter, higher diopter (D) lenses when focusing through a small pupillary aperture (28D–60D).

Intracameral drugs such as cisatracurium and *d*-tubocurarine (neuromuscular blocking agents) are typically reserved for mydriasis of patients undergoing intraocular surgery because of the risk of systemic paralysis. To assess the risk of systemic side effects, topically applied neuromuscular blocking agents have been evaluated in raptors.[43–47]

Application of a 4 mg/mL solution of vecuronium bromide (2 drops topical eye application, q15min × 3; Norcuron, Organon Teknika, Fresnes, France) to one eye of a European kestrel (*Falco tinnunculus*) resulted in pupillary dilation with no adverse side effects reported.[43] Rocuronium bromide (Esmeron, Organon Italia SpA, Rome, Italy), a derivative of vecuronium, was evaluated in multiple raptor species.[46,47] Successful mydriasis was achieved by a single topical application to the eye without any adverse systemic side effects in European kestrels.[47] Pupillary light reflexes did not completely disappear in all birds receiving topical neuromuscular blockers, and this finding is believed to be associated with the variability in iridal melanin present that is capable of binding the drug.[44,45] However, despite this occurrence, pupillary dilation was sufficient to perform a complete fundic examination.[44,45]

After application of neuromuscular blocking agents, pupillary dilation reached peak effect within 40–90 minutes, with a prolonged duration of action (range 240–360 minutes) depending on the species.[43,44,46,47] The reported treatment protocol, dosage received, and species evaluated are reported in Table 3.[43,44,46,47]

TRAUMATIC OCULAR LESIONS

Penetrating trauma occurs when a foreign object enters the globe and directly injures the tissues with which it comes into contact. Most commonly, a penetrating injury causes unilateral disease. In contrast, widespread damage to multiple structures of the eye often occurs with blunt trauma.[13] Birds with blunt head trauma were significantly more likely to have vision-threatening ocular disease in one or both eyes compared with other groups.[4] In evaluated patients, bilateral lesions were more common, with 52.6% to 81.5% of birds affected.[1,4] The large, relatively close, forward-directed eyes found in raptor species is a possible explanation for the increased number of birds that were presented with bilateral ocular lesions from blunt trauma.[1,13] In one published report, 73% of avian ocular trauma cases had unilateral lesions; of these,

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[a] *References 4, 14, 22–24, 26, 28, 29, 31, 32, 40–42.*

Table 3. The use of topical neuromuscular blocking agents to achieve mydriasis in raptors. Treatment protocols and effect in evaluated raptor species are reported.

Agent tested	Common name	Species	Baseline pupil diameter, mm	Treatment protocol
Rocuronium bromide	Tawny owl	*Strix aluco*	4.0–4.5	One eye: 1 drop
				One eye: 2 drops
	Little owl	*Athene noctua*	4.5–6.5[a]	Both eyes: 1 drop
	Common buzzard	*Buteo buteo*	3.5–4.5[a]	Both eyes: 1 drop
	Kestrel	*Falco tinnunculus*	3.3 ± 0.71	Both eyes: 1 drop
Vecuronium bromide	Kestrel	*Falco tinnunculus*	4[a]	One eye: 1–2 drops

OD indicates right eye; OS, left eye.

[a] Estimate from chart in referenced article.

Table 3. Extended.

Agent tested	Dosage per eye, mg	Dosage per bird, mg	Posttreatment pupil diameter, mm	Time to maximum dilation, min	Reference
Rocuronium bromide	0.35	0.35	11.5 ± 0.3	80	Barsotti et al[44]
	0.70	0.70	11.0 ± 0.6	60	Barsotti et al[44]
	0.20	0.40	10.0 ± 0.75	40	Barsotti et al[46]
	0.40	0.80	OD: 8.1 ± 0.56 OS: 8.05 ± 0.59	110	Barsotti et al[46]
	0.12	0.24	OD: 6.3 ± 0.42 OS: 6.35 ± 0.41	90	Barsotti et al[47]
Vecuronium bromide	4 mg/mL solution every 15 minutes for 3 treatments		6.5[a]	65 ± 12	Mikaelian et al[43]

67% involved the anterior segment, 9% the posterior segment, and 27% both segments.[2] The disparity between published reports regarding the diagnosis of ocular trauma in raptors and blunt trauma is possibly due to the inclusion of cases with penetrating trauma.[1] Common clinical findings after ocular trauma include anterior uveitis, vitreal hemorrhage, and retinal detachment.[4]

Orbit

Many bones of the orbit are pneumatic and surrounded by the infraorbital sinus. Periorbital fractures may extend into the sinus and will lead to facial asymmetry, palpable fractures, and crepitus.[48] Forces transferred to the wall of the orbit during the traumatic event may result in "blow-out" fractures or gross displacement of the eye.[12] The clinician should carefully palpate the head and face of the patient or use diagnostic imaging for fractures, evaluate for asymmetry of the face and eyes, and perform imaging on the anatomic structures of concern. When initiating the ocular examination on a raptor, the lid margins should be opened to expose the cornea. If the globe feels soft and deformed it may be secondary to globe rupture and concurrent scleral ossicle fracture. Unfortunately, it is often difficult to diagnose fractures of the scleral ossicles by traditional radiographic imaging. Occasionally, air will be observed within the globe secondary to globe rupture (Fig 4). In 1 report of 3 screech owls with air in the anterior chamber after trauma, the air was suspected to be the result of scleral ossicle fracture and globe perforation.[49] In these cases, traditional radiographic imaging could not identify the fracture. All birds were eventually released after medical therapy and the air resorbed from the affected globe. In this series of cases, the scleral ossicles prevented collapse of the globe, maintaining the overall shape of the eye.[49]

Periocular tissues

The periocular tissues are collectively referred to as the adnexa and include the eyelids, conjunctiva, and lacrimal system. The periocular tissues are important in maintaining the overall health of the eye. Normal function of the eyelids, including the third eyelid, is required to maintain a healthy

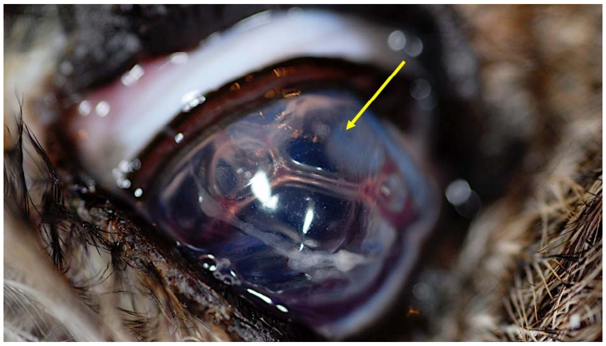

Figure 4. Great horned owl with orbital fracture and globe rupture. Free air evident as numerous coalescing air bubbles (yellow arrow) and blood (hyphema) can be seen within the anterior chamber of the ruptured globe. The corneal profile is also irregular secondary to the globe rupture.

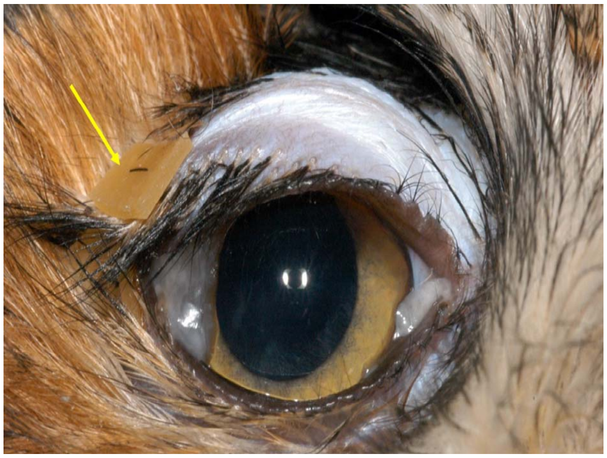

Figure 5. A great horned owl with a temporary tarsorrhaphy (eyelids partially sewn together to narrow the eyelid opening). The procedure is performed with 5-0 to 7-0 suture, with the initial suture placed at the lateral aspect of the palpebral fissure in a horizontal mattress pattern. The sutures are placed partial-thickness to avoid contact of suture material with the corneal surface. The use of a stent (yellow arrow, eg, cut piece of rubber band, IV tubing) is recommended to protect the underlying eyelid tissue. Moderate mucoid ocular discharge is present.

ocular surface. The veterinary clinician should evaluate the palpebral reflex of the patient so that the lid margins completely cover the globe. Motor innervation to the upper and lower eyelids is provided by the facial nerve. Facial nerve damage results in reduced palpebral reflexes and secondary exposure keratitis from lagophthalmos (incomplete coverage of the globe). The recommended treatments for lagophthalmos are topical lubricating ointments or placement of temporary tarsorrhaphy sutures to improve surface protection. A temporary tarsorrhaphy (eyelids partially sewn together to narrow the eyelid opening) is performed with 5-0 to 7-0 suture in most avian species. The authors prefer to use suture with a small reverse cutting needle in most instances. The initial suture should be placed at the lateral aspect of the palpebral fissure in a horizontal mattress pattern. Partial-thickness sutures are placed to avoid contact of suture material with the corneal surface. The use of a stent (eg, cut piece of rubber band, intravenous tubing) is recommended to protect the underlying eyelid tissue (Fig 5). Additional sutures may be placed in the lid margins until the desired amount of coverage of the globe is achieved. Typically, a small area located at the medial aspect of the palpebral fissure is left open to allow for the application of ocular medications. Third eyelid flaps are not recommended in raptor species and birds in general. The eyelid flaps limit the ability of the clinician to evaluate the ocular surface and risk permanent damage to the third eyelid.[48]

Nictitans dysfunction may also be diagnosed in birds that present with head injury. Two primary muscle groups are involved in the normal function of the nictitans in birds: the pyramidalis and quadratus muscles innervated by the abducens nerve. The pyramidalis muscle acts to extend the third eyelid ventronasally across the globe.[50] The tendon of the pyramidalis muscle passes through a sling formed by the quadratus muscle. This anatomical arrangement allows the latter to amplify the function of the pyramidalis muscle in closing the nictitating membrane.[37]

The size of the quadratus muscle has been noted to increase with increasing body weight of the bird.[12] In diurnal birds, the quadratus muscle is specialized for higher velocity contraction allowing for rapid movement of the third eyelid. Dysfunction of the third eyelid may be the result of direct injury to the pyramidalis or quadratus muscles or the abducens nerve.

The onset of palpebral inflammatory disorders in raptor patients is often associated with multifactorial causes. Blunt traumatic injuries often result in eyelid contusions, observed as bruising, swelling (blepharoedema), and abrasions (Fig 6). Frequently these adnexal lesions are bilateral, consistent with blunt trauma to the front of the face. Recommended treatment of raptor patients diagnosed traumatic ocular injuries is typically in the form of systemic nonsteroidal anti-inflammatory agents and topical broad-spectrum antibiotics.

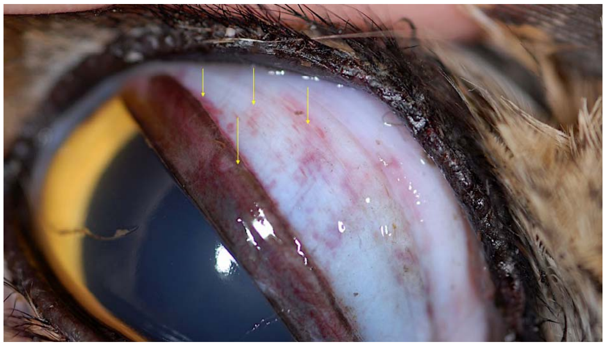

Figure 6. Great horned owl (*Bubo virginianus*) with multifocal, coalescing petechial hemorrhages of the third eyelid (yellow arrows) after blunt trauma.

Ectoparasites (eg, lice, mosquitoes, black flies, hippoboscid flies, keds) are commonly identified in raptors on presentation, resulting in periocular disease. *Knemidokoptes pilae* mites cause proliferative, hyperplastic, and scaly lesions in the periorbital area, around the beak, vent, and legs.[51] Significant blepharoconjunctivitis and hyperkeratosis of the lids and periocular area are often clinically identified in birds diagnosed with *K pilae* (Fig 7). Selective immunosuppression and genetic predisposition are believed to be the cause of the increased parasite presence and associated clinical disease. The observation of parasites from a skin scraping of affected tissue will confirm the diagnosis. Recommended treatment for *K pilae* is supportive care and ivermectin therapy (200 μg/kg SQ or PO with a second dose in 7 days).[51] Multisystemic mite parasitism is rare but has been reported for an ascarid mite in a bald eagle (*Haliaeetus leucocephalus*).[52] Both episcleral disease and intraocular disease were diagnosed in the bald eagle; the intraocular lesions characterized as serpiginous chorioretinal lesions (spreading tracks visible on ocular examination consistent with parasitic migration).[52] Bilateral blepharitis and dermatitis of the head has been reported in a falcon hybrid (*Falco peregrinus* × *Falco rusticolus*) secondary to *Aspergillus* species infection.[53] The falcon hybrid was successfully treated with systemic itraconazole (Sporonox, Janssen Pharmaceutical, Beerse, Belgium) and topical miconazole (Monostat, Ortho-McNeal Pharmaceutical Inc, Ratan, NJ, USA).[53]

The eyelids should be carefully evaluated for the presence of partial- or full-thickness lacerations. Acute full-thickness lacerations that involve the eyelid margin usually require surgical repair to maintain the smooth lid margin necessary for a healthy ocular surface. Minimal debridement of eyelid margin lacerations is recommended before closure with 5-0 to 7-0 absorbable suture material. The authors prefer to use suture with a small reverse cutting needle in most instances. It is important to remember to use incomplete penetration through the eyelid with the suture needle when closing the laceration to prevent suture material from contacting the corneal surface. When lacerations of the third eyelid are encountered, a single-layer, partial-thickness closure with 7-0 to 9-0 absorbable suture (reverse cutting or spatula needle) is required. After the surgical repair of eyelid lacerations, a broad-spectrum topical antibiotic is indicated 3 times a day until wound healing is complete. Often chronic defects of the eyelid margin do not require surgical repair if the third eyelid has normal function.[48]

Figure 7. Severe dermatologic disease with blepharoconjunctivitis and hyperkeratosis of the lids and periocular area secondary to *Knemidokoptes pilae* in a bald eagle with *Sarcocystis*. Selective immunosuppression and genetic predisposition are believed to be the cause of the increased parasite presence and associated clinical disease.

Periocular tissues of rehabilitated raptors are commonly reinjured in flight enclosures before release. Eyelid "notches" (healed full-thickness defects in the eyelid margin) and other periocular abnormalities have been reported to occur at a higher frequency in animals that sustain self-trauma in their flight enclosures.[26]

The conjunctiva should be thoroughly evaluated for the presence of foreign bodies (eg, plant material, soil). Thorough flushing of the conjunctival surface with eyewash or saline is sufficient in most cases to remove any foreign material present. Conjunctivitis, secondary to trauma, is generally responsive to topical or systemic nonsteroidal anti-inflammatory therapy. If infectious conjunctivitis is suspected, a cytology and culture of the affected conjunctival surface would be indicated to select the most appropriate topical therapy. The most common bacterial isolates cultured from the conjunctival surface of normal raptors included *Staphylococcus* species and *Corynebacterium* species; fungal isolates identified included *Aspergillus* species and *Cladosporium* species.[54,55]

Cornea

Focal corneal ulceration is commonly diagnosed in raptor species after traumatic injury. Surface damage to the eye was identified more often in adult birds, perhaps because of their larger globe size relative to juveniles.[7] Corneal lesions are readily identified after fluorescein staining and may be bilateral. Topical broad-spectrum antibiotics are prescribed to manage corneal ulceration by reducing the risk of secondary bacterial infection. Antibiotic drugs frequently used to treat corneal ulcers include second-generation fluoroquinolones (eg, ofloxacin, ciprofloxacin) or a triple antibiotic product (solution or ointment). For simple, noncomplex ulcers, antibiotic therapy is typically administered every 8 hours to the affected eye. Reexamination of corneal ulcers is recommended every 3–5 days until wound healing is complete.

Complex corneal ulcers are characterized by having 1 or more of the following characteristics: stromal loss (contour change to the corneal surface), melting (soft, grey appearance), or infiltrate (hallmark of infectious keratitis). These complex ulcers require additional diagnostic testing that may include corneal cytology and bacterial and fungal cultures. The diagnostic tests will provide more information to the clinician regarding the extent of the disease process and contribute toward developing an appropriate treatment plan. Additionally, more frequent medical therapy and reexaminations are necessary for raptor patients diagnosed with complex corneal ulcers. Unfortunately, frequent ocular treatment is often difficult because of the increased stress to the patient when repeatedly restrained. Broad-spectrum, bactericidal agents and, frequently, multiagent therapy is used pending culture results. Commercially available products or compounded products such as 33 mg/mL cefazolin and 1% amikacin in artificial tears are commonly employed to treat complex corneal ulcers.

Subconjunctival antibiotic injections may be performed to achieve local therapeutic drug concentrations quickly in severe corneal ulcer cases. Subconjunctival doses of 0.5–1.25 mg of amikacin have been reported as an adjunctive therapy for a captive whooping crane (*Grus americana*) with a corneal ulcer from which *Pseudomonas aeruginosa* was isolated.[55] Other classes of antibiotic agents may be subconjunctivally administered, but it is imperative that any product used in this manner be water soluble. When administering any drug into the subconjunctiva, the clinician should consider the risk of systemic side effects on the basis dose administered and body weight of the patient. The use of subconjunctival injections is not meant to replace the need for topical antimicrobial administration.

The topical antifungal agent miconazole was used to treat mycotic blepharitis in a falcon (*F peregrinus* × *F rusticolus*).[53] Diffuse yellow-white plaques on the cornea in a Campbell duck (*Anas platyrhynchos domesticus*) diagnosed with an *Aspergillus* species infection was successfully treated with oral voriconazole at 20 mg/kg PO q12h for 64 days (Mylan Pharmaceuticals, Morgantown, WV, USA) after 1 week of therapy with 1% voriconazole solution (1 drop OS q4–6h; Vfend, Roerig/Pfizer, New York, NY, USA) did not resolve the ocular disease.[56] To the authors' knowledge, the use of voriconazole and other antifungal agents for the treatment of fungal keratitis has not been reported in raptors. Silver sulfadiazine is an antimicrobial agent that has been used topically for skin disease in raptors.[57] Studies evaluating its antifungal effect demonstrated a good spectrum of activity against filamentous fungi in vitro.[58] On the basis of this and other reports, silver sulfadiazine has been used for treating ocular infectious disease in other species safely and may be a useful agent in raptors.

Corneal malacia (keratomalacia) is the result of collagenolysis and is best managed by the use of topical antiproteolytic agents. Products reported to reduce corneal melting include topical EDTA, acetylcysteine, tetracyclines, and blood products (eg, serum, plasma). The agents listed above are widely used in other animal species, but limited published reports are available in avian species. In one report, 5%–10% acetylcysteine in artificial tears and homologous serum were used in the treatment of captive cranes (*Grus leucogeranus, G americana*) with *P aeruginosa* corneal ulceration.[55] Because of the limitations for autologous and homologous serum treatment in birds, heterologous serum can be considered a viable treatment option. Anecdotally, heterologous serum has been used in clinical practice and appears to be a safe and effective treatment for keratomalacia as long as the sample is obtained from a healthy donor and properly stored. Topical serum may be applied frequently to the eye until melting of the corneal tissue is arrested (no longer soft in appearance with well-demarcated edges to the ulcer on fluorescein staining). It is important to keep serum refrigerated and replace the supply every 3–4 days to limit the risk of contamination.

In contrast to clinical reports, in a retrospective histopathological review of avian trauma cases, the cornea was found to be relatively free of disease.[11] The difference between clinical and histological reports is likely related to simple ulcers being managed medically and resolving, whereas more severely injured globes are enucleated. Acute perforation was found infrequently in raptors and is most often identified in wild-caught birds or those subjected to projectile injury.[59] If minimal intraocular damage is present, repair of corneal lacerations can be performed with a partial-thickness closure by 8-0 to 10-0 absorbable or nonabsorbable suture material. The authors prefer to use suture with a small reverse cutting needle in most instances. Although nonabsorbable material generally causes less suture reaction within the tissue, later suture removal is required, resulting in additional stress to the patient. Both systemic and topical antibiotic therapy is indicated when full-thickness lesions occur to reduce the risk of infectious endophthalmitis.

Recurrent corneal ulceration has been reported in raptors, possibly as a result of traumatic injury within an enclosure. Persistent corneal erosions were reported in 20% of birds in 1 resident facility and 6 scops owls (*Otus scops*) over a 1–3-month period.[1,14] Traumatic removal of the Bowman's layer of the cornea is believed to effect the rate of epithelialization directly.[1,14] Treatment of recurrent corneal ulcers by debridement, grid keratotomy, and diamond burr have been attempted, with little success observed clinically to decrease healing time. Corneal vascularization and pigmentation were not commonly diagnosed in the treated recurrent corneal ulcer cases.

Although trauma is thought to be a common etiology for recurrent corneal ulcers, a recent report identified a novel herpes virus associated with recurrent corneal ulceration in a great horned owl (*Bubo virginianus*). The patient developed proliferative conjunctival changes and a chronic superficial corneal ulcer characterized by epithelial lipping.[60] Progressive corneal vascularization and diffuse darkening of the iris secondary to reflex uveitis occurred over time.[60] The histopathology results from an excisional biopsy of the conjunctival lesion was consistent with a viral etiology, and PCR testing identified a novel alphaherpesvirus classified as a Strigid Herpesvirus 1.[60] The great horned owl in the report was treated with topical compounded interferon α2β, 1% cidofovir, antibiotics, and oral L-lysine.[60] Healing was prolonged but occurred after chronic topical antibiotics treatment, debridement, anterior stromal puncture, and diamond burr keratotomy.[60]

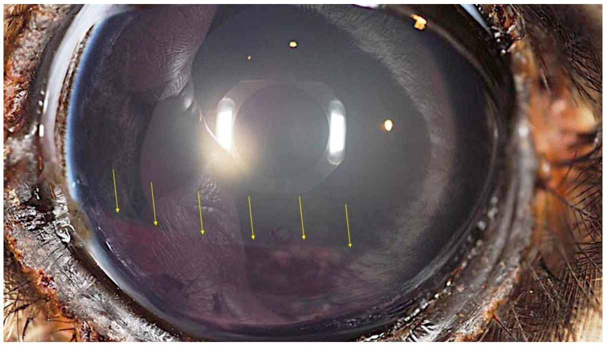

Figure 8. Hyphema and blood and fibrin clots in the ventral anterior chamber of an owl after blunt trauma (yellow arrows).

Chronic sequelae to previous corneal injury are the presence of corneal scars that will present as flat, well-demarcated, white to gray lesions. Corneal scars are not associated with clinical signs of ocular pain. Lipid degeneration has also been reported in chronically diseased avian eyes and aged falcons.[16,61] The clinical appearance of lipid degeneration of the cornea is characterized by bright white opacities with varying development of associated corneal vascularization. In falcons, the lesions associated with lipid degeneration begin adjacent to the temporal limbus and are progressive. The cause of lipid degeneration of the cornea in falcons is currently unknown, with multiple etiologies proposed.[61]

Anterior chamber and anterior uvea

The anterior segment of the eye is frequently injured in raptors suffering from blunt trauma.[2] Hyphema (blood in the anterior chamber) was the most commonly identified ocular lesion in multiple retrospective studies published on raptor trauma cases and is indicative of severe intraocular injury (Fig 8).[1,3] Eyes diagnosed with hyphema typically have concurrent severe intraocular abnormalities.[1,62] The incidence of hyphema was found to range between 8.1% and 9.3% in little owls (*Athene noctua*) and scops owls after blunt trauma.[1] Unfortunately, the presence of hyphema often precludes a complete ophthalmic examination, which often results in the need for additional diagnostic testing modalities (eg, ocular ultrasound) to fully evaluate the patient's affected eye.

Anterior uveitis is the presence of inflammation involving the iris, ciliary body, or both. Anterior uveitis, including hyphema, was diagnosed in 19% of cases of free-living raptors evaluated in one report.[4] A separate report identified anterior uveitis in 23.3%–27.8% of cases (independent of hyphema).[1,4] Numerous clinical signs are evident in patients with anterior uveitis, including iridal hyperemia, fibrin formation, pigment dispersion, aqueous flare, hyphema, hypopyon (inflammatory cells in the anterior chamber), miosis, and low intraocular pressure. Because of the viscous nature of the aqueous in raptors, it is common to see a nonuniform distribution of cells and protein in the anterior chamber. Raptor aqueous was significantly more viscous when compared with other animal species (canine, feline, equine).[63] The viscosity of barred owl aqueous was found to be 4.7 times that of canine aqueous humor.[63] Differences in viscosity may be due to the presence of an increase in the concentration of glycosaminoglycans (eg, hyaluronic acid).[63]

Fibrin, blood clots, and clumps of separated iridal tissue are often observed on slit-lamp biomicroscopy of the anterior chamber after traumatic injury in raptor eyes. The depth of the anterior chamber should be evaluated during the eye examination. The anterior chamber will be shallow in cases of anterior lens luxation, anterior synechiation (iris adhesions), or globe collapse. The chamber will be deeper in cases diagnosed with posterior lens luxation, hypermature (resorptive) cataracts, or iridodialysis.

Trauma resulting in tears of the iris may occur with blunt or sharp trauma. Often when a patient is subjected to blunt trauma, a tear separating the iris and or ciliary body from attachments to the sclera may occur (irido/cyclodialysis), clinically resulting in an alteration in the uniformity of the peripheral regions of the iris with direct illumination of the eye. The edges of the pectinate ligament fibers can be appreciated as being further away from the cornea (asymmetric distribution) when the iris root is torn from its attachments to the sclera, and the anterior chamber will often appear deeper. Iridodialysis has been reported in approximately 2% of raptors after sustaining blunt trauma.[1] In a histopathological study evaluating birds after blunt trauma to the eye, 77% of cases demonstrated evidence of irido/cyclodialysis.[11] The disparity between clinical and histopathological findings suggests that this lesion is not always appreciated on clinical examination. Although glaucoma is rarely reported in raptors, it has been reported in patients with chronic iridodialysis.[14] Posterior synechia, as a consequence of previous inflammation or penetrating trauma, has been reported to range between 2% and 9.3%. A higher incidence was noted in cases with suspected blunt trauma when compared with wild-caught birds.[1,59]

Treatment for anterior uveitis is typically topical nonsteroidal anti-inflammatory eye drops and systemic anti-inflammatory therapy. Caution is advised in patients with hyphema because nonsteroidal anti-inflammatory drugs can increase the bleeding activity within the anterior chamber. Although topical steroids such as 0.1% dexamethasone or 1% prednisolone acetate can be prescribed for anterior uveitis, there is a risk of systemic absorption, morbidity, and mortality associated with their use, especially in birds that are presented in a poor body condition.[48] Subconjunctival steroid administration with triamcinolone has also been reported for larger birds with anterior uveitis when the use of topical medication is not possible.[48]

Anterior chamber blood clots and fibrin will typically resolve with a combination of topical and systemic anti-inflammatory therapy. However, for patients with extensive injury to the anterior chamber, and no evidence of active or rebleeding events, intracameral injection of tissue plasminogen activator into the anterior chamber can be used to accelerate resolution and reduce secondary cataract and synechia development.[3,48] If elected, tissue plasminogen activator should be used within 5–7 days to be effective at a dose of 25 μg. Because of the differences in anterior uveal anatomy in birds, relative to mammalian species, topical atropine does not achieve pupillary dilation. Topical atropine is often prescribed in canine and feline patients diagnosed with uveitis to limit the development of posterior synechia formation.

Lens

The lens encompasses approximately one-third of the intraocular volume of the avian eye. Lens luxation rarely occurs in raptors because of the direct fusion of the ciliary processes to the equatorial region of the lens. When avian patients diagnosed with lens luxation were examined, both ocular and nonocular lesions were often observed.[2] The extent of the ocular injury associated with lens luxation is likely a reflection of the severe trauma required for this lesion to occur.[2] When present, a pigmented ring from the avulsed tips of the ciliary processes is often observed (Fig 9).[2] If diffuse

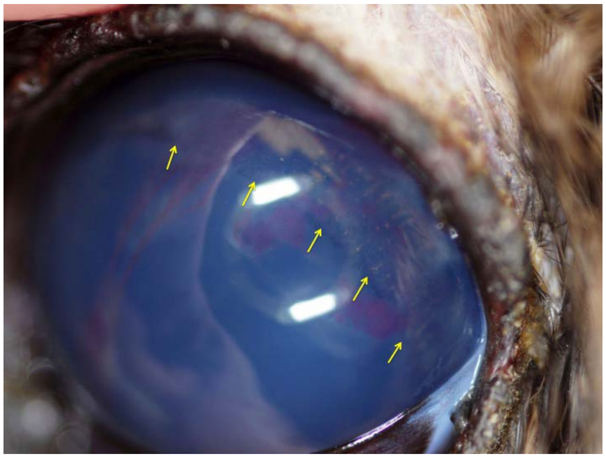

Figure 9. Anterior lens luxation in a great horned owl resulting in a shallow anterior chamber, hyphema, and corneal edema. A pigmented ring of tissue (yellow arrows) can be visualized at the equator of the lens representing avulsion of the lens from the ciliary body.

corneal edema or hyphema is present and limiting the ability of the clinician to evaluate for lens luxation, an ocular ultrasound is required for a more complete evaluation of the eye.

Anterior or posterior cortical cataracts may develop secondary to previous inflammation. In one study evaluating tawny owls injured by road traffic, the majority of opacities observed involved the posterior aspect of the lens.[14] Most lens opacities in raptors examined after a traumatic incident were considered contusional, primarily unilateral, and associated with other signs of ocular injury.[1] Bilateral subcapsular vacuolar cataracts have also been reported in a great horned owl that suffered an electrocution injury.[64] These cataracts slowly resolved, and the owl regained sight and was eventually released.[64] In diurnal birds, cataracts after trauma can rapidly progress to the hypermature (resorptive) stage leading to a wrinkled lens capsule, deep anterior chamber, and refractile clinical appearance (Fig 10).

Vitreous

The vitreal body (posterior segment) is significantly longer in diurnal raptor species.[24] Vitreal hemorrhage has a reported incidence ranging from 5.6% to 15.2%[1,4] and was the second most common ocular abnormality identified in raptors (with anterior uveitis being the most common abnormality). The presence of vitreal hemorrhage precluded direct examination of the posterior segment in a number of birds, necessitating ancillary examination techniques for complete evaluation.[4] Unfortunately, vitreal hemorrhage may take several weeks to months to fully resolve, necessitating repeated ocular examinations.[6] Given the vascular nature of the pecten, it is the likely source of hemorrhage in the posterior segment after a traumatic incident.[13] Because of the firm attachment of the vitreous to the apex of the pecten, contrecoup injury often leads to tearing, damage, and avulsion of the pecten.[13]

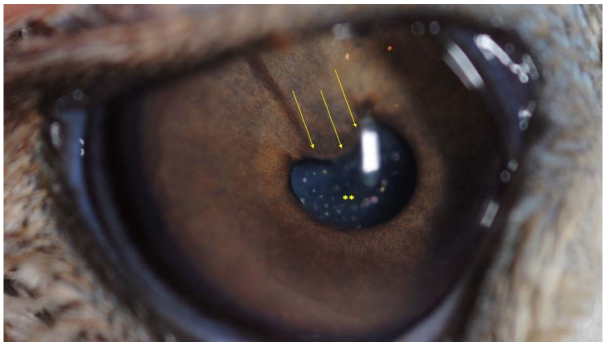

Figure 10. Focal posterior synechia (yellow arrows) and crystalline/refractile appearance to the lens (yellow asterisks) secondary to a hypermature cataract in a red-tailed hawk. In diurnal birds, cataracts after trauma may rapidly progress to the hypermature (resorptive) stage, leading to a wrinkled lens capsule, a deep anterior chamber, and a refractile clinical appearance.

Retina

The fundus can be visualized with a light source and handheld lens of 20D–60D depending on the size of the eye and the size of the pupil. The normal fundus examination evaluates the vitreous body, the retina (including the fovea), pecten, and choroid (Fig 11). The fundus examination is vital to evaluate the eye for lesions involving the fovea because abnormalities would significantly impair

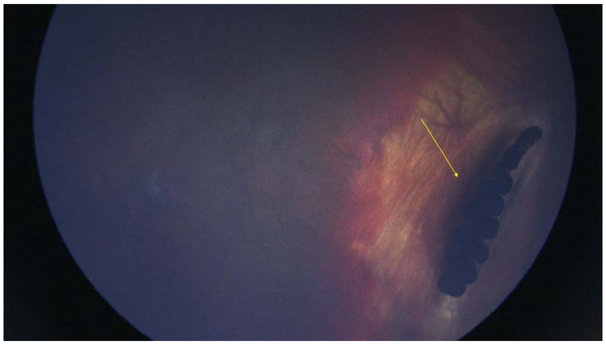

Figure 11. Fundic photo of a barred owl demonstrating normal pecten oculi (yellow arrow) and prominent choroidal vessels. Photo courtesy of Dr Filipe Espinheira.

Figure 12. Fundic photo of a barred owl demonstrating extensive, multifocal regions of retinal edema and subretinal exudate (yellow asterisks) resulting in multifocal retinal detachments and a focal retinal fold (yellow arrow) after blunt trauma. Photo courtesy of Dr Filipe Espinheira.

vision in the affected eye. Owls have a single fovea dorsal and temporal to the pecten. Diurnal raptors have 2 fovea temporal and dorsal/medial to the pecten. The retina is anangiotic (without the presence of intraretinal blood vessels) in birds, and nourishment is reliant on the highly vascularized pecten oculi and the underlying choriocapillaris. The choroidal vessels are typically difficult to appreciate in most diurnal raptors because of the pigmentation of the overlying retinal pigmented epithelium.[13] A dorsal vascular choroidal cascade is often visualized in more lightly pigmented birds. A choroidal tapetum is absent in avian species. The pecten oculi is located in the temporal and ventral aspect of the fundus obscuring the optic nerve head (Fig 1A and B). The pecten likely functions as a source of nutrients for the avascular retina, specifically the inner layers. Other described functions of the pecten include aqueous formation, maintenance of the intraocular acid-base balance, protection against solar ultraviolet radiation, and facilitation of intraocular thermoregulation.[13,65,66]

Acute lesions identified on fundic examination may include vitreal hemorrhage, avulsion of the pecten, chorioretinitis, retinal tears, retinal detachment, and chorioretinal or scleral rupture. Chorioretinitis can be unilateral or bilateral and can appear as focal, multifocal, or diffuse raised lesions (Fig 12).[1] The incidence of chorioretinitis has been reported as 42.6%–53.5% after blunt trauma and can appear as an exudative change on fundic examination (Fig 13).[1]

Retinal tears and detachment are a common occurrence because of contrecoup forces associated with trauma and are typically unilateral.[1] Retinal detachments may develop secondary to acute exudation or from the development of a tear in this ocular structure. Retinal tears and detachments were present in 71% of avian blunt trauma cases.[11] Acute blunt trauma has been shown to cause photoreceptor inner and outer segment fragmentation along with hemorrhage and a phagocytic response.[11]

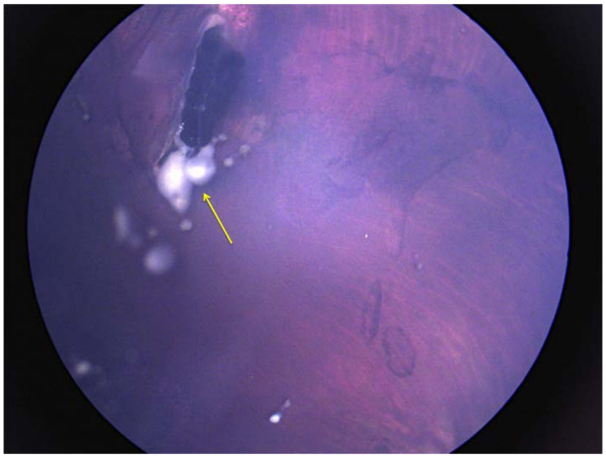

Figure 13. Fundic photo in a barred owl demonstrating exudate surrounding the pecten and within the vitreous (yellow arrow) after blunt trauma. A layer of inflammatory material can also be seen covering the pecten that appears irregular in shape.

Although the edge of a retinal tear is typically visible as a raised white line or edge, the lack of retinal vasculature in birds makes the identification of retinal detachments difficult to appreciate (Fig 14). Consequently ocular ultrasound is recommended with exudative detachments that are compounded by opacities of the ocular media.[67]

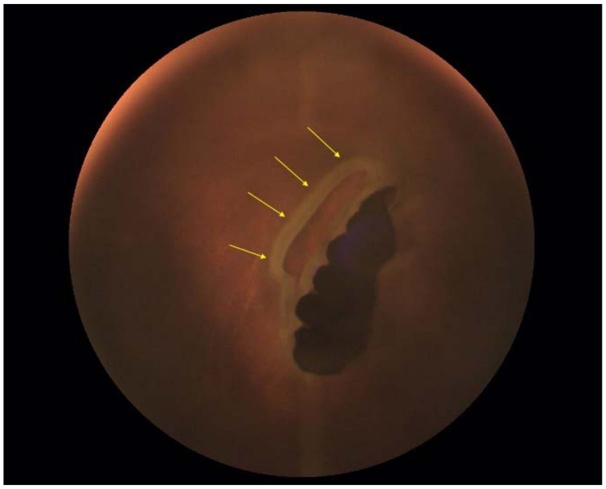

Figure 14. Focal retinal tear and detachment (yellow arrows) adjacent to the pecten in a screech owl secondary to blunt trauma. Courtesy of the Cornell University Comparative Ophthalmology Section Collection.

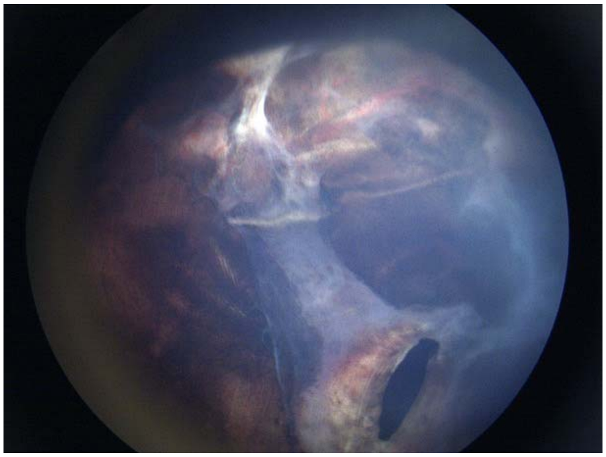

Figure 15. Severe, diffuse retinal atrophy with fibrosis. The pecten is atrophied and blunted in appearance in this blind eye. Photo courtesy of Dr Filipe Espinheira.

Exudative retinal detachments can reattach over a 2–4-week period. One should note that retinal reattachment is often followed by tissue degeneration because of a greater degree of hypoxia present with the avascular retina.[1]

The size, shape, and color of the pecten should be carefully evaluated on examination. There are 3 primary types of pecten: conical, vaned, or pleated. The pleated type is the most common pectin found in avian species.[65] The pecten tends to be small and simple in nocturnal birds and longer and highly complex in diurnal birds.[24,65] For example, red-tailed hawks (*Buteo jamaicensis*) have 17–18 pleats compared with 8–10 in the barred owl (*Strix varia*).[68,69] After trauma, the pecten may appear misshapen and surrounded by vitreal hemorrhage, and small pieces of the pecten tissue may be seen suspended within the vitreous. Inflammation of the pecten typically results in a gray discoloration. With significant damage to the pecten, progressive retinal degeneration and vision loss will often occur (in eyes that were initially sighted/tracking) (Fig 15).

Concurrent systemic disease conditions can result in abnormalities identified on fundic examination. In patients affected by West Nile virus, fundic lesions were characterized as linear or geographic areas of chorioretinal exudates.[70] Pectenitis was manifested as a fibrinous material completely or partially coating the pecten in 6 eyes in one report.[70] In a bald eagle with lead toxicosis, retinal tears and detachment occurred secondary to systemic vasculopathy.[71]

Pigmented retinal lesions found on examination signify chronicity and may be incidental unless severe change is noted ipsilateral to the acute lesion.[13] In cases diagnosed with chronic pigmented retinal lesions, the clinician should consider whether the areas of concern represent "blind spots" that contributed to acute trauma.[67] Systemic anti-inflammatory therapy is indicated for active posterior segment lesions. Serial ocular examinations are recommended to assess for progressive retinal changes or changes in visual status.

MECHANISMS FOR TRAUMATIC OCULAR LESIONS

Often the severity of the ocular disease is not evident on initial presentation after blunt force trauma. Injury to the posterior segment of the eye may be "out of proportion" with anterior segment findings and not reflected by the patient's systemic status or evident to the veterinarian examining the bird.[15] The likely explanation for the delay in development of ocular disease after blunt force trauma is the high degree of traumatic force applied to the eye for this type of injury in birds, coupled with the anatomy of the avian eye. Unlike sharp penetrating trauma that often results in very localized regions of tissue injury, blunt trauma has a broader effect on the health of the globe. Mechanisms for ocular injury in blunt trauma occur in 1 of 3 ways: direct ocular compression, coup, or contrecoup.[3]

Direct ocular compression

Blunt trauma results in anterior–posterior compression and horizontal displacement of the intraocular fluid.[3] High hydrostatic pressure in the anterior chamber during impact compression results in posterior lens displacement and zonular rupture in experimental studies evaluating ocular trauma.[72] Lens dislocation was observed over many impact velocities into the vitreous; however, at higher impact velocities, the lens would occasionally rebound into the anterior chamber.[72] Although rupture of the globe would be expected at the corneal-scleral junction from fluid expansion, this is less likely to occur in raptors because of the presence of the scleral ossicles.

Coup injury

Coup injury occurs when the eye is compromised at the point of impact. Decreased scleral compliance, because of scleral ossicles and cartilage, may increase the risk to uveal structures held in place by surface tension and intravitreal pressure.[11,15] Shock tube experiments show that motion of the vitreous relative to the ciliary body induces shearing at the junction of the ciliary body and the sclera.[72,73] This coup mechanism of injury results in shear injury at the iridocorneal angle secondary to the inertia of the lens and vitreous.[72] Severe angle recession was often accompanied by partial or complete detachment and separation of the iris and ciliary body,[72] which is likely the mechanism for angle recession and irido/cyclodialysis diagnosed in birds after blunt trauma.[11,73]

Contrecoup injury

Many of the injuries that occur within the eye are found opposite the point of impact. Typically this results in posterior segment lesions that are disproportionally worse than those identified in the anterior segment.[1,15] The avian anatomical arrangement of a tightly encased globe and little periocular cushion, combined with rigid ocular tissues (eg, scleral ossicles, cartilage), predisposes the raptor eye to contrecoup injury during blunt trauma.[3,11,15] Transfer of kinetic injury results in late-term dynamic pressure wave reflections off of the interior ocular surfaces that damage the posterior segment.[11,72,73] These energy waves disrupt the junction of the inner and outer photoreceptor segments, resulting in a separation of photoreceptors and destabilization at the uveoscleral interface. Separation of the retinal and choroidal tissue results in retinal detachment, subretinal hemorrhage, and subsequent retinal degeneration.[11] It has been theorized that the avascular avian retina is predisposed to damage because of the lack of intraretinal vascularization to support the delicate retinal tissue.[11] Pressure reflections off the posterior segment result in a localized negative pressure region that can cause retinal detachment and retinal and choroidal tears.[11,72] The vitreous body is well-attached around pecten and ora ciliaris that can result in retinal tear or avulsion in these regions after blunt force injury. This damage occurs from shear stress on these tissues as pressure reflections propagate through the vitreous after blunt trauma[3,11] and has been verified by commonly identifying detachment of the retina from the choroid, as well as tearing and segmentation of the retina on histopathology of the affected eyes.[11]

ADVANCED DIAGNOSTIC TECHNIQUES

Anterior segment lesions are often readily diagnosed, whereas posterior segment lesions may not be recognized without a thorough ophthalmic examination with advanced diagnostic techniques. The posterior segment lesions are often disproportionately more severe for the reasons discussed above.

Ocular ultrasound

Advanced imaging techniques are often used when opacification of the ocular media prevents a full diagnostic intraocular examination. Ultrasound is often used because it is inexpensive and typically requires only topical anesthetic and patient restraint to perform. The corneal contact method using a gel standoff has been shown to be sufficient to visualize the entire globe.[74] Bones of the scleral ossicles appear as hyperechoic stripes, causing a distal shadow effect.[74] This shadowing limits the ability of the ultrasound examination to evaluate the orbit, optic nerve, and fibrous tunics fully.[16,74]

Ultrasonography is useful in evaluating the size and integrity of the pecten and the homogeneity of the vitreous and to obtain evidence of retinal detachment (Fig 16A). Ultrasound measurements have been used to evaluate pecten size in multiple raptor species.[4,23] Establishing normal pecten size helps with determining the integrity of the pecten (Table 4).[4] The pecten normally shows a moderate echogenicity. Color flow doppler ultrasound can be used to evaluate blood flow patterns that would normally be disrupted in an avulsed or atrophied pecten (Fig 16B). It was not possible to visualize the pecten by computed tomography or magnetic resonance imaging in one study.[74] However by magnetic resonance imaging with a 3.0 Tesla unit and microscopy coils, the pecten could be evaluated in diurnal birds of prey.[76] Unfortunately, this technique and others, such as optical coherence tomography of the posterior segment, are not practicable for most raptor patients at this time. Therefore, evaluating pecten biometry and blood flow by Doppler ocular ultrasound (modalities readily obtainable and of low cost) can aid in determining the integrity of the pecten after blunt trauma and assist with determining a prognosis.[23]

With ocular ultrasound, eyes were found to be abnormal in 11.4% (9/79) of free-living raptors on presentation; 9 of these birds had abnormalities on ocular ultrasound.[4] Increased vitreal echogenicity was noted in 78% (7/9) of birds, and retinal detachment was identified in 56% (5/9) of birds (Fig 16).[4] Abnormalities identified on ocular ultrasound in these free-living raptors were small

Table 4. Comparative ocular biometry measurements reported in raptor species. Values for horizontal and vertical corneal diameter were obtained by caliper measurements. The remaining biometry values were obtained by ocular ultrasound. Results are organized by raptor family.

Name	Species	AGL, mm	ALT, mm	ACD, mm	VCL, mm
Family Strigidae (nocturnal)					
Scops owl	*Otus scops*	13.4 ± 1.1			6.3 ± 0.5
Barn owl	*Tyto alba*	15.4 ± 0.6			6.6 ± 0.3
		15.9 ± 0.57	6.3 ± 0.2	2.70 ± 0.23	6.5 ± 0.27
Long-eared owl	*Asio otus*	17.2 ± 0.2			7.6 ± 0.1
		17.3 ± 1	6.8 ± 0.18	2.4 ± 0.65	7.4 ± 0.23
Eurasian eagle owl	*Bubo bubo interpositus*	34.5 ± 0.7			18.7 ± 0.5
Pharaoh eagle owl	*Bubo bubo ascalaphus*	34.0 ± 1			17.1 ± 0
Eurasian tawny owl	*Strix aluco*	24.7 ± 0.82	8.6 ± 0.3	3.1 ± 0.59	12.5 ± 0.40
Little owl	*Athene noctua*	16.5 ± 1			8.4 ± 0.2
Great grey owl	*Strix nebulosa*	23.6 ± 0.9	7.0 ± 0.6	4.0 ± 0.6	12.5 ± 0.6
Snowy owl	*Bubo scandiacus*	32.6 ± 0.8	7.9 ± 0.7	5.7 ± 0.5	18.8 ± 0.7
Eastern screech owl	*Megascops asio*	19.4 ± 0.8	6.2 ± 0.8	3.9 ± 0.4	9.5 ± 0.3
		20.33 ± 0.6		4.03 ± 0.3	
Great Horned owl	*Bubo virginianus*	31.9 ± 1.7	9.3 ± 0.9	5.6 ± 1.3	17.3 ± 0.5
Barred owl	*Strix varia*	27.6 ± 3.4	9.8 ± 1.6	4.8 ± 1.6	12.5 ± 0.9
Striped owl	*Rhinoptynx clamator*	OS: 23.76 ± 0.92	7.79 ± 0.27	4.27 ± 0.47	11.36 ± 0.29
		OD: 24.25 ± 0.79	8.03 ± 0.40	4.56 ± 0.52	11.40 ± 0.25
Family Accipitridae (diurnal)					
Bald eagle	*Haliaeetus leucocephalus*	26.57 ± 0.45	5.49 ± 0.14	4.45 ± 0.18	
Short-toed snake eagle	*Circaetus gallicus*	29.5 ± 0.2			18.5 ± 0.2
Cooper's hawk	*Accipiter cooperii*	16.6 ± 0.5	4.2 ± 0.5	3.0 ± 0.5	9.4 ± 0.2
Red-tailed hawk	*Buteo jamaicensis*	24.3 ± 0.9	6.3 ± 1.9	4.1 ± 1.6	14.9 ± 1.9
Black kite	*Milvus migrans*	19.5 ± 1.2			12 ± 0.6
Western marsh harrier	*Circus aeruginosus*	18 ± 0.1			11.1 ± 0.2
Montagu's harrier	*Circus pygargus*	16.5 ± 0.1			9.3 ± 0.3
Common buzzard	*Buteo buteo*	22.2 ± 1			13.1 ± 0.6
		22.7 ± 0.5	5.50 ± 0.35	2.90 ± 0.1	13.0 ± 0.38
Steppe buzzard	*Buteo buteo vulpinus*	20.4 ± 0			11.7 ± 0.2
European honey buzzard	*Pernis apivorus*	20.7 ± 0.6			12.3 ± 0.5
Long-legged buzzard	*Buteo rufinus*	19.8 ± 7			11.7 ± 5
Family Falconidae (diurnal)					
Barbary falcon	*Falco pelegrinoides*	17.1 ± 0.1			9.5 ± 0.1
Lesser kestrel	*Falco naumanni*	12.1 ± 0.5			6.4 ± 0.5
American kestrel	*Falco sparverius*	12.0 ± 0.4	3.3 ± 0.1	3.0 ± 2.0	7.3 ± 0.2
European kestrel	*Falco tinnunculus*	14.3 ± 0.5			7.9 ± 0.3
		15.6 ± 0.24	4.3 ± 0.12	1.9 ± 0.14	8.2 ± 0.19
Family Cathartidae (diurnal)					
Turkey vulture	*Cathartes aura*	16.8 ± 1.1	3.5 ± 0.4	3.1 ± 0.5	10.4 ± 0.5
Cinereous vulture	*Aegypius monachus*	27.74 ± 0.77	5.41 ± 0.18	3.73 ± 0.62	18.60 ± 0.58

AGL indicates axial globe length; ALT, axial lens thickness; ACD, anterior chamber depth; VCL, vitreal chamber length; PH, pecten height; PL, pecten length; PW, pecten width; HCD, horizontal corneal diameter; VCD, vertical corneal diameter; OD, right eye; OS, left eye; SEM, scanning electron micrograph.

[a] The terms length and height were used interchangeably between papers when evaluating similar parameters for the pecten oculi and referred to the distance that the pecten projected into the vitreal cavity.

[b] Apex to base length of pecten oculi taken on subgross inspection.

[c] Formalin-fixed sample.

particles of echogenicity within the vitreous near the pecten which were thought to be pieces of torn pecten tissue.[4] Larger particles of echogenicity observed next to an irregularly shaped pecten in a common buzzard (*Buteo buteo*) represented hemorrhage and rupture of the pecten; these changes could not be seen on computed tomography.[74] Opacities of the anterior segment of the eye did not

Table 4. Extended.

Name	PH, mm[a]	PL, mm[b]	PW, mm	HCD, mm	VCD, mm	Reference	Probe, MHz
Family Strigidae (nocturnal)							
Scops owl	7.1 ± 0.7					Beckwith-Cohen et al[24]	12
Barn owl	8.7 ± 0.5					Beckwith-Cohen et al[24]	12
	3.9 ± 0.52					Gumpenberger and Kolm[74]	5–8
Long-eared owl						Beckwith-Cohen et al[24]	12
	4.3 ± 0.31					Gumpenberger and Kolm[74]	5–8
Eurasian eagle owl	6.9 ± 0.2					Beckwith-Cohen et al[24]	12
Pharaoh eagle owl						Beckwith-Cohen et al[24]	12
Eurasian tawny owl	5.7 ± 0.73					Gumpenberger and Kolm[74]	5–8
Little owl	4.1 ± 0.3					Beckwith-Cohen et al[24]	12
Great grey owl	5.5 ± 0.9		3.3 ± 0.7	20 ± 0.84		Wills et al[23]	8
Snowy owl	8.3 ± 1.1		5.2 ± 1.3	23.4 ± 1.0		Wills et al[23]	8
Eastern screech owl	4.2 ± 0.4		1.9 ± 0.3	14.8		Labelle et al[4]	12
				15.25 ± 0.5	14.5 ± 0.5	Harris et al[26]	15
Great Horned owl	7.3 ± 0.9		3.4 ± 1.5	23.5 ± 1.1		Labelle et a[4]	12
Barred owl	5.9 ± 0.4		2.2 ± 1.0	20.9 ± 5.1		Labelle et al[4]	12
Striped owl	5.69 ± 0.50					Squarzoni et al[16]	12
	5.68 ± 0.41					Squarzoni et al[16]	12
Family Accipitridae (diurnal)				15.7 ± 2.74		Rodarte-Almeida et al[28]	
Bald eagle						Kuhn et al[29]	8
Short-toed snake eagle	8.7 ± 0.3					Beckwith-Cohen et al[24]	12
Cooper's hawk	5.1 ± 1.0		2.9 ± 1.7	10.0 ± 0.8		Labelle et al[4]	12
Red-tailed hawk	7.6 ± 1.1		3.4 ± 0.6	14.5 ± 1.3		Labelle et al[4]	12
Black kite	5 ± 0.01					Beckwith-Cohen et al[24]	12
	3–5[c]	7.0[c]				Kiama et al[66]	SEM[c]
Western marsh harrier	4.9 ± 0					Beckwith-Cohen et al[24]	12
Montagu's harrier	5.9 ± 0.2					Beckwith-Cohen et al[24]	12
Common buzzard	5.4 ± 0.5					Gumpenberger and Kolm[74]	5–8
	7.8 ± 0.47					Gumpenberger and Kolm[74]	5–8
	OD: 5.26 ± 0.73	11.13 ± 0.97				Gultiken et al[65]	SEM[c]
	OS: 5.17 ± 0.52	10.9 ± 1.56				Gultiken et al[65]	SEM[c]
Steppe buzzard	6.6 ± 0					Beckwith-Cohen et al[24]	12
European honey buzzard	7.1 ± 0.2					Beckwith-Cohen et al[24]	12
Long-legged buzzard						Beckwith-Cohen et al[24]	12
Family Falconidae (diurnal)							
Barbary falcon						Beckwith-Cohen et al[24]	12
Lesser kestrel						Beckwith-Cohen et al[24]	12
American kestrel	4.0 ± 0.3		1.8 ± 0.5	7.5 ± 0.6		Labelle et al[4]	12
European kestrel	4.7 ± 0.1					Beckwith-Cohen et al[24]	12
	5.7 ± 0.34					Gumpenberger and Kolm[74]	5–8
				OD: 9.6 ± 0.8	9.8 ± 1.2	Kim et al[31]	
				OS: 10.0 ± 1.0	9.6 ± 1.1	Kim et al[31]	
Family Cathartidae (diurnal)							
Turkey vulture	7.4 ± 0.6		3.3 ± 0.6	9.7 ± 0.5		Labelle et al[4]	12
Cinereous vulture	10.21 ± 1.19					Apruzzese et al[75]	12.5

interfere with the quality and ability of the ocular ultrasound to evaluate structures of the posterior segment.[74] Disorders within the anterior chamber and vitreous are more obvious when evaluated by ocular ultrasound (Figure 17). On computed tomography, the vitreous appeared too homogeneous for lesion identification.[74] Ocular ultrasound can also be used to confirm lens subluxation; however, both sagittal and dorsal plane images are necessary to identify asymmetry.[74]

Electroretinogram

Referral for electroretinogram testing by a veterinary ophthalmologist may provide valuable complimentary information in assessing suitability for release. All birds with bilaterally normal to moderately decreased electroretinogram values had normal visual behavior (defined as function between 50% and 90% of the control group).[1] However, because of the panretinal response obtained, results might not actively predict the effect of lesions

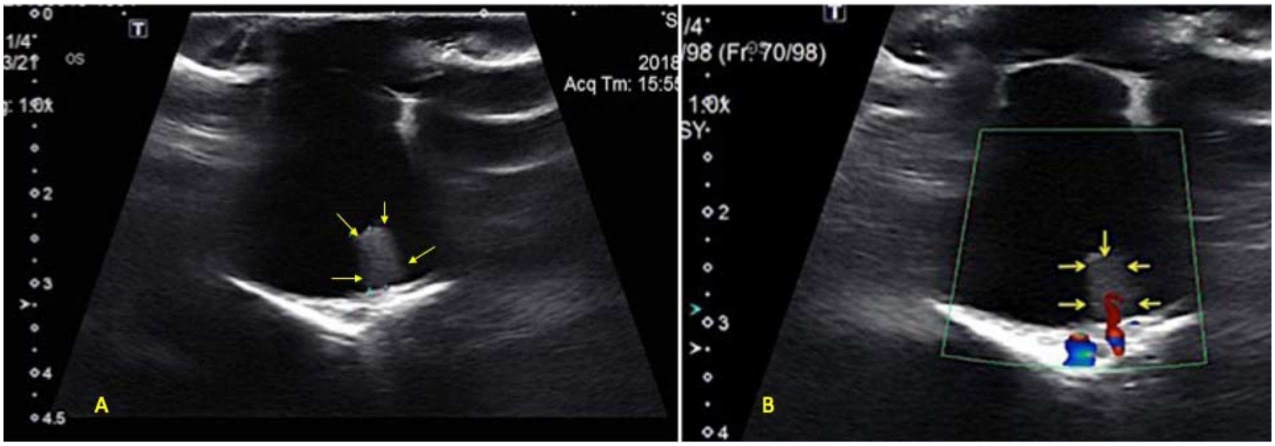

Figure 16. Ocular ultrasound performed with manual restraint and topical proparacaine in a great horned owl in a normal eye (A). Color flow doppler to evaluate blood flow and profile of the pecten oculi is also demonstrated (B). Yellow arrows indicate pecten oculi projecting into the vitreal cavity.

involving the fovea.[4] In scops owls, exudative retinal detachments reattached over a 2–4-week period in 50% (3/6) of birds; an electroretinogram confirmed the recovery of retinal function.[1]

COMORBIDITIES

The presence of comorbidities is important in determining the prognosis for successful rehabilitation of raptor patients that are diagnosed with ocular disease and is also important when determining a therapeutic recovery plan. Nonocular lesions were typically ipsilateral to the ocular lesion in 63% of raptors evaluated.[2,26] Often the severity of the ocular lesions did not correlate with the severity of concurrent systemic lesions. Depending on the disorder, multiple body systems may be

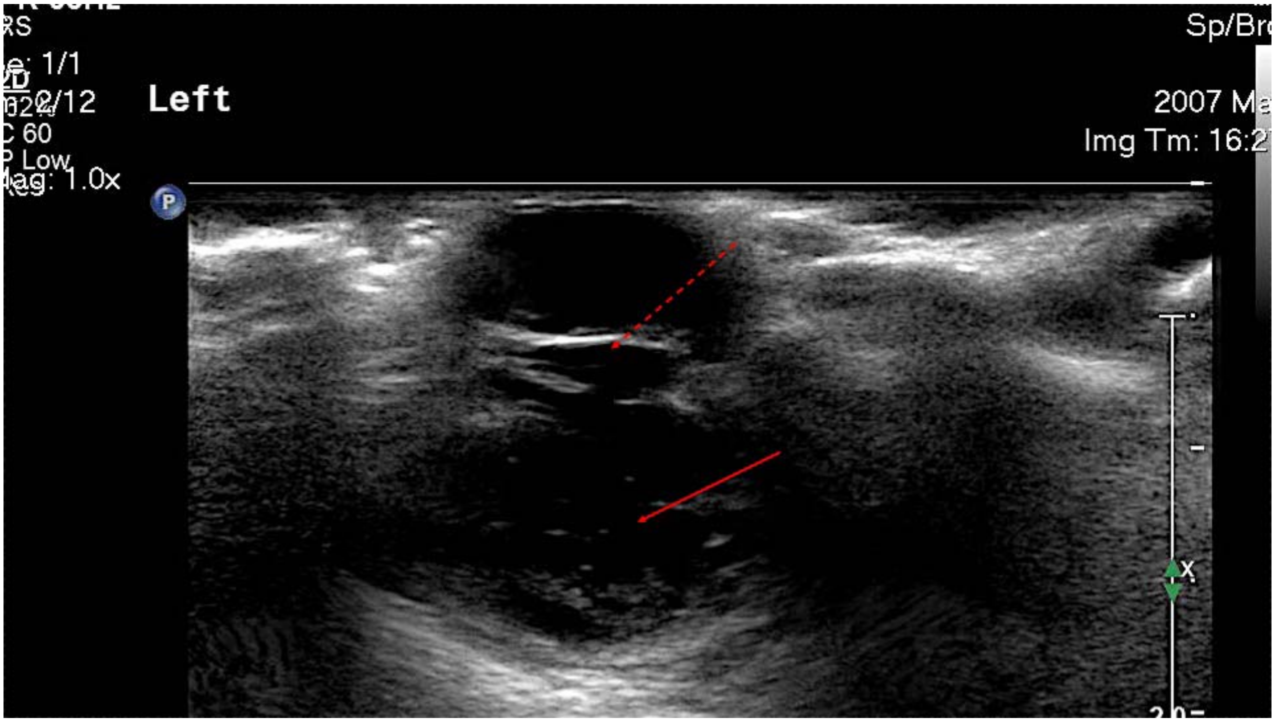

Figure 17. Ocular ultrasound demonstrating resorption of the lens, as evidenced by a reduced lens profile (dashed red arrow) in a screech owl with a hypermature cataract. Diffuse hyperechoic foci (solid red arrow) are present within the vitreous, consistent with vitreal degeneration.

Table 5. Template for the treatment of commonly encountered ophthalmic conditions in raptors with recommendations for drug selection, frequency, and monitoring.

Lesion	Treatment	Frequency	Monitoring
Eyelid abrasions, conjunctivitis, simple corneal ulceration	Broad-spectrum topical antibiotics: neomycin-polymyxin-bacitracin, neomycin-polymyxin-gramicidin, ofloxacin, ciprofloxacin, oxytetracycline/polymyxin B	q8h	Recheck in 3–5 days
	Systemic anti-inflammatory: meloxicam 0.5–2 mg/kg PO, IM; carprofen 1–2 mg/kg PO, IM	q12–24h × 7 days; dose and frequency dependent on severity of inflammation	
Complex corneal ulcer	Broad-spectrum topical antibiotics: neomycin-polymyxin-bacitracin, neomycin-polymyxin-gramicidin, ofloxacin, ciprofloxacin Compounded antibiotic agents may be used: 1% amikacin or gentamicin, 33 mg/mL cefazolin Compounded products are generally used in combination with other products to ensure adequate broad-spectrum coverage	q2–6h	Depending on severity, recheck daily or every other day
	Homologous or heterologous serum for keratomalacia	q2–6h depending on severity	
	Topical antifungal therapy: 2% miconazole, 1% voriconazole, natamycin, SSD	q4–6h	
	Systemic anti-inflammatory for secondary uveitis: meloxicam 0.5–2 mg/kg PO, IM; carprofen 1–2 mg/kg PO, IM	q12–24h × 7 days; dose and frequency dependent on severity of inflammation	
Anterior uveitis	Topical nonsteroidal anti-inflammatory: diclofenac 0.1%; ketorolac 0.5%; flurbiprofen 0.03%	q6–12h depending on severity: • Diclofenac: caution in *Gyps* vultures, risk of toxicosis • Topical nonsteroidals may increase risk of bleeding in patients with active anterior chamber hemorrhage	Recheck every 5–7 days depending on severity
	Topical steroids: prednisolone acetate 1%; dexamethasone 0.1%	q8–12h • Caution advised as may increase risk of immunosuppression, especially in smaller raptors • Not for use in patients with corneal ulceration	
	Subconjunctival triamcinolone: 0.1–0.25 mL	Once • For larger raptors only because of risk of systemic immunosuppression. For cases in which repeated handling is not possible. • Not for use in patients with corneal ulceration.	
	Tissue plasminogen activator: 25 µg intracameral injection	Once • To treat persistent fibrin in the anterior chamber • Contraindicated in cases of active bleeding	
Posterior segment inflammation	Systemic nonsteroidal anti-inflammatory: meloxicam 0.5–2 mg/kg PO, IM; carprofen 1–2 mg/kg PO, IM	q12–24h × 7 days Dose and frequency dependent on severity of inflammation. Preferred over systemic steroids because of risk of immunosuppression/infection	
	Systemic broad-spectrum antibiotic recommended in cases of globe rupture	10–14 days	

SSD indicates silver sulfadiazine.

involved, including the respiratory system and central nervous system.

In addition to traumatic brain injury, contusions, lacerations, and fractures that commonly occur in patients with ocular trauma, patients may have had preexisting conditions that increased their risk for injury. These patients can be in poor body condition, parasitized, anemic, subjected to toxin exposure, immunosuppressed, or suffer from a combination of conditions, complicating the recovery effort.

TREATMENT

Initial stabilization of a traumatized raptor for debilitation, shock, or respiratory compromise is extremely important. A complete ophthalmic examination should only be performed once the patient is stable enough to withstand the stress of handling. A list of common ophthalmic conditions and a template for treatment planning is listed in Table 5.[3,13,48,53,55,77] The frequency of medical therapy and reexaminations is based on the clinician's judgment as to the severity of clinical disease, as well as the ability of the patient to tolerate the stress associated with the frequency of proposed medical therapy. In situations where the ability to handle the patient safely is limited, adjunctive subconjunctival injections should be considered.

In choosing a route for anti-inflammatory therapy, it is important to remember that topical agents will only be effective for the anterior segment of the eye. If the posterior segment of the eye is inflamed, a systemic anti-inflammatory agent will be indicated. Slowly tapering topical anti-inflammatory therapy, if possible, is important to minimize the incidence of anterior uveitis.

CONSIDERATIONS FOR RELEASE

Wildlife rehabilitators must consider numerous factors when evaluating raptor patients for potential release. Raptor patients are not considered releasable when significant vision-threatening, bilateral ocular lesions are present. Additionally, patients with lesions that involve the fovea are expected to have a greater reduction of vision because of the effect this change has on stereopsis (depth perception as a result of binocular vision).[13,67] Changes that are centrally located compared with peripheral lesions also have a more significant effect on vision. The predatory characteristics of the patient should also be considered when unilateral vision loss is present. Nocturnal species often use other special senses (eg, hearing) when hunting compared with diurnal hunters that require stereopsis.[67]

The presence of significant comorbidities such as a systemic illness or other physical injuries must also be considered when determining the ability to rehabilitate and release a patient. Chronic lesions should be evaluated relative to the patient's body condition. If a raptor patient is found to be in good body condition with a chronic ophthalmic lesion, that bird has possibly learned to compensate for that lesion. Young and inexperienced raptors are expected to have a more difficult time accommodating partial vision loss for hunting than older more experienced birds.[13]

Flight and food testing of the raptor patient that presents with ocular injury should be performed before release. Wildlife rehabilitators should monitor the bird for signs of visual disability that include a failure to find food left in the flight cage, a reluctance to fly, the development of exaggerated defensive reactions, or repeated reinjury in flight enclosures.[13] For further discussion on considerations for release, the reader is referred to an excellent review article by Pauli et al 2007.[67]

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