How to Diagnose and Manage Horses With Glaucoma

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1. Introduction
Glaucoma is a painful ocular disease that often results in vision loss and can be frustrating to treat.1–4 Equine glaucoma is most often secondary to chronic, recurrent episodes of intraocular inflammation as occur with equine recurrent uveitis (ERU).1–8 Diagnosis of glaucoma requires tonometry, or measurement of the intraocular pressure (IOP). Many types of portable, affordable tonometers are available to the veterinary practitioner, and tonometry is becoming more widely used in equine practice. Once a diagnosis of glaucoma has been established, therapy options range from topical and oral medications to advanced surgical procedures. Referral to a veterinary ophthalmologist is appropriate for all cases of equine glaucoma. Determining the cause of the glaucoma and deciding on an appropriate treatment plan is crucial to obtain the ultimate goal of maintaining a comfortable and visual eye. When vision has been lost and IOP is uncontrolled, surgical procedures to ensure long-term comfort, including enucleation, should be considered.

2. Anatomy and Pathophysiology of Glaucoma
Knowledge of normal ocular anatomy allows the practitioner to recognize abnormalities in the equine eye and pathologic changes associated with glaucoma. Immediately posterior to the iris is the ciliary body, which is hidden from view by the iris face even when the pupil is fully dilated. The ciliary body processes produce aqueous humor, the clear intraocular fluid that provides metabolic support to the posterior cornea and the internal structures of the eye. Aqueous humor flows from the posterior chamber, through the pupil, into the anterior chamber, and drains from the eye through the uveoscleral or iridocorneal outflow pathways (Fig. 1).9 The iridocorneal angle is visible as an intraocular meshwork at the temporal and nasal limbus, with pectinate ligaments extending from the iris root to the corneoscleral junction (Fig. 2).10,11 Horses are unique in that up to 50% of their aqueous humor drainage is through the uveoscleral (also called “unconventional”) outflow pathway.12,13

Intraocular pressure is a balance of aqueous humor production and aqueous humor outflow. Glaucoma is a series of intraocular pathologic events culminating in IOP elevation, optic nerve damage, and vision loss. Elevated IOP results in decreased blood flow and optic nerve axoplasmic flow, ultimately resulting in retinal cell death, compression of
the optic nerve, and blindness.\textsuperscript{14} In humans, forms of glaucoma are recognized that result in optic nerve degeneration, retinal degeneration, and vision loss without elevation in IOP. Similar forms of glaucoma have not been documented in the horse; elevation in IOP is thought to be the most important risk factor for glaucomatous optic nerve damage in equine patients.\textsuperscript{14,15} Intraocular pressure elevation typically results from obstruction of the aqueous humor outflow pathway. Aqueous humor overproduction has not been reported in any domestic animal species and is not considered to be a cause of glaucoma in the horse.

Glaucoma in the horse is often divided into three categories: primary, secondary, and congenital. Congenital glaucoma is present at birth and is unlikely to respond to therapy.\textsuperscript{7,8,16} Primary glaucoma in small-animal species is a heritable, bilateral condition that results from abnormal functioning of the aqueous humor outflow system. Primary glaucoma is infrequently reported in the horse. Glaucoma in horses is most often secondary to a concurrent ocular disease such as ERU, intraocular neoplasia, corneal perforation, or lens luxation.\textsuperscript{2–4,17} Although ERU is widely regarded as the most common cause of glaucoma in horses, the mechanism by which ERU leads to secondary glaucoma is poorly understood.\textsuperscript{4}

3. Examination Techniques

The minimum equipment necessary for any equine ophthalmic examination includes a Finhoff transilluminator, magnification head loupe, fluorescein stain, a tonometer, tropicamide,\textsuperscript{a} and a retinoscope (such as a direct ophthalmoscope or hand lens). If possible, the horse should be observed navigating in its environment before sedation. An obstacle course can be created with the use of large objects in the barn (such as trash cans and poles on the ground) to allow the practitioner to more critically assess vision. Menace responses and dazzle reflexes should also be observed before sedation. Ophthalmic examination should be performed in a dimly lit location to maximize detection of subtle lesions. Sedation with detomidine hydrochloride\textsuperscript{b} or xylazine hydrochloride\textsuperscript{c} and an auriculopalpebral block are important for completion of a complete examination. Butorphanol tartrate\textsuperscript{d} is not recommended because it tends to result in jerky, spontaneous head movements.

Tonometry is recommended for all horses with clinical signs of ophthalmic disease. Whereas sedation with \(\alpha\)-2 agonists can decrease IOP readings, an auriculopalpebral block has no effect on IOP.\textsuperscript{18,19} Head position does have a critical effect on IOP; lowering the head below the heart causes significant elevations in IOP.\textsuperscript{20} It is important to maintain a head position level with or above the heart while performing tonometry. Consistency is recommended when performing serial IOP measurements, with the use of the same sedation, nerve block, tonometer, and examiner each time to achieve maximal comparability between measurements. Careful attention to technique is also important. Any excessive pressure on the globe may artificially increase IOP.

Two types of tonometers are commercially available for use in the horse: rebound and applanation.\textsuperscript{21–23} The rebound tonometer\textsuperscript{e} (Fig. 3) uses a magnetic probe that is projected at the cornea. The rebound tonometer is handheld, battery-operated, and does not require daily calibration. The noise emitted from the machine while taking the required six readings is very quiet and not likely to disturb the horse, even if not sedated. The readings are averaged within the machine and displayed...
in an easily viewed window opposite the probe. Topical anesthesia is not required. The mean intraocular pressure with the use of a TonoVet is $22.1 \pm 5.9$ mm Hg, with a range from 10 to 34 mm Hg.23

Multiple applanation tonometers are commercially availablef,g (Fig. 4). Applanation tonometers differ from the rebound tonometer in that they measure the force required to flatten the corneal surface. All of the devices are handheld and portable. Applanation tonometers require a latex cover to protect the tip of the device. Both of the listed applanation tonometers require use of topical anesthesia to obtain accurate readings. One advantage of an applanation tonometer is that it can be used with the patient in any position, unlike the rebound tonometer, which must remain perpendicular to the patient with the magnetic probe parallel to the ground. The mean intraocular pressure with the use of a Tono-Pen is $21.0 \pm 5.9$ mm Hg, with a range from 9 to 33 mm Hg.23

4. Clinical Signs of Glaucoma

The clinical signs of glaucoma vary.1–3,7,8,17,24 Many horses with glaucoma do not exhibit the classic signs of ocular pain, including blepharospasm and epiphora. Acute signs often differ from chronic signs (Table 1).

<table>
<thead>
<tr>
<th>Acute signs</th>
<th>Chronic signs</th>
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<tbody>
<tr>
<td>Vision loss</td>
<td>Vision loss</td>
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<tr>
<td>Epiphora</td>
<td>Epiphora</td>
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<tr>
<td>Blepharospasm</td>
<td>Blepharospasm</td>
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<tr>
<td>Corneal edema</td>
<td>Buphthalmos</td>
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<tr>
<td>Conjunctival hyperemia</td>
<td>Corneal ulcers</td>
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<tr>
<td>Mydriasis</td>
<td>Lens luxation</td>
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<tr>
<td>Changes in the appearance of drainage angle (collapse, fibrosis)</td>
<td>Mydriasis</td>
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<tr>
<td>Retinal degeneration</td>
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<tr>
<td>Optic nerve cupping</td>
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Glaucomatous horses exhibit variable pupillary light reflex deficits. Glaucoma generally results in a mydriatic pupil caused by effects on the optic nerve and iris sphincter muscle, but horses with concurrent intraocular inflammation may have miotic pupils instead. Dyscoria, an abnormally shaped pupil, may result from posterior synechiae (adhesions between the iris and the lens capsule) (Fig. 5). Posterior synechiae may result in pupil size being discordant with concurrent ocular disease (ie, a miotic pupil in an end-stage glaucoma eye).

Table 1. Clinical Signs of Equine Glaucoma
Conjunctival hyperemia and episcleral injection is common in glaucomatous horses. Mild to severe diffuse corneal edema is observed frequently. Corneal edema may be focal or begin as a vertical stripe across the cornea, then progress to diffuse edema (Fig. 6). Edema results from dysfunction of the endothelium and physical distortion of corneal stromal fibers. Descemet’s striae (also termed “corneal striae” or “Haab’s striae”) are areas of discontinuity in Descemet’s membrane and may later appear at these sites of linear edema traversing the cornea (Fig. 7). Severe corneal edema may be associated with fluid-filled subepithelial blisters or bullae. Bullae may rupture and result in corneal ulceration.

Corneal vascularization may be superficial, perilimbal, and extend several millimeters from the limbus toward the axial cornea. Keratic precipitates (pinpoint conglomerates of fibrin and inflammatory cells) may be present on the corneal endothelium. Keratic precipitates are often difficult to visualize without magnification.

The diffuse corneal edema, frequently present in horses with glaucoma, makes intraocular examination challenging. Performing the exam in a dark area and directing a light source across the anterior chamber from limbus to limbus facilitates visualization of intraocular structures. Common intraocular exam findings may include clinical signs seen with ERU, including iridal hyperpigmentation, atrophy of the corpora nigra, posterior synechiae, dyscoria, aqueous flare, and cataract. The iridocorneal angle is most visible laterally, in which the opening of the trabecular meshwork is visible just axial to the limbus. Pectinate ligaments are visible as a meshwork traversing the opening of the iridocorneal angle. Abnormal iridocorneal angles may be sclerotic, with a band of white fibrous tissue replacing the normal pectinate ligaments, or narrowed (Fig. 8).

Appearance of the iridocorneal angle has not been correlated with the onset of glaucoma or prognosis in horses. Lens subluxation or luxation is usually a result of chronic expansion of the glaucomatous globe (termed “buphthalmos”) and subsequent zonular stretching and degeneration (Fig. 9).

In the early stages of glaucoma, the appearance of the retina may be normal. With time, the optic nerve may become atrophic, pale, and “cupped” in appearance, as if the center of the optic nerve was...
available. 

... can be closely monitored. Should only be used in cases of glaucoma when IOP elevations in IOP may lead to expansion in the size of the globe, termed buphthalmos.

5. Treatment of Glaucoma

The goal of glaucoma treatment is maintaining IOP in a range that prevents continuing optic nerve and retinal damage. The “ideal” IOP is unknown, but most clinicians agree that <25 mm Hg would be acceptable. Because IOP is a balance of aqueous humor production and drainage, all glaucoma treatments are aimed at one of two targets: reducing aqueous humor production or increasing IOP drainage. Glaucoma treatment can be divided into medical and surgical therapies; medical therapy is typically the first-line treatment. The underlying causes of glaucoma, such as ERU, may also require concurrent treatment. In addition to topical antiglaucoma medications, such cases may also need topical and systemic anti-inflammatories. The use of atropine in cases of concurrent ERU and glaucoma is controversial because atropine may be associated with elevations in IOP. Atropine should only be used in cases of glaucoma when IOP can be closely monitored.

Medical therapy is generally the first line of treatment for glaucoma. Drug classes that reduce aqueous humor production include β-adrenergic antagonists and carbonic anhydrase inhibitors (CAIs). β-Adrenergic antagonists, also called β-blockers, inhibit cAMP activity in the ciliary body. Timolol maleate 0.5% is the most commonly used drug in this class. It has been shown to reduce IOP in clinically normal horses. Other commercially available β-adrenergic agonists include betaxolol, levobunolol, and metipranolol. These drugs are widely used and have not been evaluated in horses. β-Adrenergic agents should be applied every 8 to 12 hours.

Carbonic anhydrase inhibitors inhibit carbonic anhydrase, an enzyme in the ciliary body epithelium that is required for aqueous humor production. Commercially available CAIs include brinzolamide 1% and dorzolamide 2%. Both have been demonstrated to reduce IOP in clinically normal horses, although brinzolamide results in slightly greater reduction. Generic dorzolamide is affordable and widely available, which has made it more popular for the treatment of equine glaucoma in the United States. Dorzolamide 2% and timolol 0.5% solution is also available as a combination drug. The efficacy of a dorzolamide/timolol combination versus dorzolamide alone versus brinzolamide alone has not been evaluated in horses with glaucoma. Topical CAIs should be administered every 8 to 12 hours. Acetazolamide, an oral CAI, is frequently used as a potassium-wasting diuretic in horses with hyperkalemic periodic paralysis at doses of 2 to 3 mg/kg PO every 12 hours. The efficacy of this drug in decreasing IOP is unknown; however, it is available as an oral formulation. This makes it advantageous for use in patients in which topical administration of a solution is not possible.

Few drugs are available for increasing IOP outflow. Prostaglandin analogues include lantanoprost 0.005% and travaprost 0.004%. This drug class results in miosis and increased IOP outflow in other species but is not consistently effective in the horse. Complications are reported with use of prostaglandin analogues, including increased ocular pain and intraocular inflammation. A high rate of complications, including increased ocular pain, is reported. This drug class should be used with great caution in horses with glaucoma associated with ERU.

Surgical therapy for glaucoma can either increase aqueous outflow or decrease production. The most common surgical procedure is cyclophotocoagulation (laser ablation of the ciliary body epithelium), which results in decreased aqueous humor production. The procedure can be performed transsclerally or endoscopically with the use of a diode laser that preferentially targets pigmented tissue such as the ciliary body epithelium. Complications of cyclophotocoagulation include corneal ulceration, uveitis, hyphema, cataract formation, and retinal detachment. Continued topical medications are often necessary despite surgical intervention.

Surgical therapies for glaucoma were previously limited to those decreasing aqueous humor outflow. Recent evidence supports the use of drainage implants that direct aqueous humor subconjunctivally. Ahmed valved shunts have been placed experimentally with good success. Clinical trials are underway evaluating the use of this type of drainage implant in clinical glaucoma patients.

When glaucoma therapy fails, the patient is left with a painful, blind globe, and eliminating ocular pain is essential for the welfare of the horse. Enucleation is one therapy to eliminate glaucoma pain in a blind eye. Surgical alternatives to enucleation include placement of a cosmetic intraocular or in-
Chemical ciliary body ablation can be used to decrease aqueous humor production and induce shrinkage of the globe (phthisis bulbii). Intravitreal injection of 50 to 75 mg of gentamicin sulfate results in necrosis of the ciliary body with long-term reduction of IOP. Intravitreal injection can be performed in the sedated horse with the use of topical anesthesia; a retrobulbar block may be necessary. After the application of topical anesthesia, a 22- to 25-g needle should be positioned 10 to 12 mm posterior to the dorsolateral limbus and aimed toward the optic nerve (Fig. 10). Ensuring the appropriate angle of the needle is essential to avoid lacerating the posterior lens capsule during intravitreal injection, because intractable uveitis probably will result. If IOP is elevated at the time of injection, aqueous paracentesis should be performed first to lower IOP into a normal range and prevent further IOP elevation. Tonometry should be performed after injection, and, if the IOP is still elevated, the aqueous paracentesis should be repeated.

References and Footnotes


*Mydriacyl, Alcon Laboratories, Fort Worth, TX 76134.

*bDormosedan, Orion Corporation, Espoo, Finland.

*cRompun, Bayer Animal Health Division, Shawnee, KS 66216.

*dTorbugesic, Fort Dodge Animal Health, Fort Dodge, IA 50501.

*eTonoVet, Icare Finland Oy, Helsinki, Finland.

*fTono-Pen XL, Reichert, Depew, NY 14043.

*gTono-Pen AVIA, Reichert, Depew, NY 14043.

*hTimolol maleate, Bausch & Lomb Pharmaceuticals Inc, Tampa, FL 33637.

*iAzopt, Alcon Laboratories, Fort Worth, TX 76134.

+jTrusopt, Merck, West Point, PA 19454.

+kTravatan, Alcon, Irvine, CA 92618.

+lXalatan, Pfizer, New York, NY 10017.