Effect of head position on intraocular pressure in horses

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Objective—To evaluate the effect of head position on intraocular pressure (IOP) in horses.

Animals—30 horses.

Procedures—Horses were sedated with detomidine HCl (0.01 mg/kg, IV). Auriculopalpebral nerve blocks were applied bilaterally with 2% lidocaine HCl. The corneas of both eyes were anesthetized with ophthalmic 0.5% proparacaine solution. Intraocular pressures were measured with an applanation tonometer with the head positioned below and above heart level. The mean of 3 readings was taken for each eye at each position for data analysis. The effect of head position on IOP was assessed and generalized estimating equations were used to adjust for the correlation from repeated measures of the same eye and intereye correlation from the same horse.

Results—Of the 60 eyes, 52 (87%) had increased IOP when measured below the heart level. A significant difference (mean ± SE, 8.20 ± 1.01 mm Hg) was seen in the mean IOP when the head was above (17.5 ± 0.8 mm Hg) or below (25.7 ± 1.2 mm Hg) heart level. No significant effect of sex, age, or neck length on IOP change was found.

Conclusions and Clinical Relevance—Head position has a significant effect on the IOP of horses. Failure to maintain a consistent head position between IOP measurements could potentially prevent the meaningful interpretation of perceived aberrations or changes in IOP. (*Am J Vet Res* 2006;67:1232–1235)

ABBREVIATION	
IOP	Intraocular pressure

Several factors influence IOP readings such as the time of day or sedation. Physiologic circadian IOP variations have been reported for several species, including humans,[8] rhesus monkeys,[9] rabbits,[10] and dogs.[11] No significant diurnal IOP variations have been detected in horses.[12-14] The pressure-lowering effect of sedation in horses has been observed for xylazine,[3,15,16] ketamine,[16] and acepromazine.[15] Eyelid tension may not have a substantial effect on IOP in horses as pressure measurements with or without auriculopalpebral nerve block have been comparable.[1,3]

The effect of head position on IOP has been well documented for humans. Intraocular pressures are increased by 2 to 4 mm Hg in the supine versus the sitting or standing positions.[17] Studies have even been performed to measure IOP in the inverted position (ie, with humans suspended by their legs with their heads positioned below heart level). Intraocular pressures increased from reference range values of 13 to 17 mm Hg to 33 to 39 mm Hg in the inverted position.[18,19] These high values of IOP were clearly greater than a safe target pressure.[20] Mechanisms that contribute to such increases in pressure are an increase in episcleral venous pressure, compressive forces on the globe by congested orbital content, and an increase in ocular blood volume with congestion of the uveal tract.[19]

In contrast to people, horses frequently have their heads positioned below heart level, especially during grazing and feeding off the ground. Eyes can also be positioned below heart level in a deeply sedated horse as it lowers its head. This may happen if a horse has to be sedated for an ophthalmic examination. Information about the positional effect on IOP in horses is scarce. Anecdotally, anesthetized horses with their hind limbs suspended for laparoscopic surgery (Trendelenburg position) can have an IOP of > 70 mm Hg.[21] The purpose of the study reported here was to determine the effect of head position on the IOP in sedated horses.

Materials and Methods

Animals—Thirty horses were recruited for this study. Horses consisted of privately owned horses (n = 17) as well as teaching and research horses belonging to the University of Pennsylvania (n = 13). The normal status of the eyes was verified by slitlamp examination and indirect ophthalmoscopy. These examinations were done without the use of pharmacologic mydriasis because this could have potentially affected the IOP.[22] This study was conducted in accordance

The IOP measurement or tonometry is part of the routine eye examination in horses and has become more widely used in recent years. A high IOP indicates the presence of glaucoma, whereas a low IOP is suggestive of anterior uveitis. Numerous studies have been published about tonometry in horses, and it is generally agreed that the reference range values of IOP are between 15 and 30 mm Hg.[1-6] In general, an IOP of ≥ 30 to 35 mm Hg has been considered diagnostic for glaucoma.[7]

with the Association for Research in Vision and Ophthalmology Statement for the Use of Animals in Ophthalmic and Vision Research and the University of Pennsylvania Institutional Animal Care and Use and Privately-Owned Animal Protocol Committees.

Tonometry—Bilateral auriculopalpebral nerve blocks were applied with 2 mL of 2% lidocaine HCl. The corneal surface was anesthetized with 0.5% proparacaine ophthalmic solution. Horses were then sedated by IV injection of detomidine HCl (0.01 mg/kg). Intraocular pressures were measured by use of an applanation tonometer.[a] In each position, 5 readings were taken/eye with an SE of 5%. Of these 5 readings, the 2 outliers were discarded, and the remaining 3 measurements were used for analysis.

Study design—A repeated-measures design was used. The measurements on the sedated horse started with the head-down position. A coin toss decided the order of right and left eye on the first horse. On subsequent horses, the eye to be examined first was alternated so that an equal number of left and right eyes was examined first. After measuring the IOP of the first eye in the head-down position, the head was elevated and held above heart level by positioning the mandible on the shoulder of one of the investigators. Two minutes after elevation of the head, the IOP was measured again in the first eye in the head-up position, followed by the measurement of the IOP in the contralateral (second) eye in the head-up position. Subsequently, the head was lowered, and 2 minutes later, the IOP was measured again in the second eye in the head-down position. Under this design, with the same horse, IOP from 1 eye was measured first in the head-down position, whereas in the contralateral eye, IOP was first measured in the head-up position.

Several anatomic measurements were taken. The height of the cranial division of the greater tubercle of the humerus (point of the shoulder) was measured as an estimation of the right atrial position.[23] Eye height measurements were taken in the head-up and head-down positions. The difference between the eye height and the point of shoulder was a measure for the position of the eye relative to the heart. Finally, the neck length was measured ventrally from the thoracic inlet to the angular process of the mandible and dorsally from the spinous process of the second thoracic vertebra (withers) to the occipital protuberance.

Data analysis—The mean of 3 IOP readings was used for data analysis. The descriptive analysis for IOP by head position and difference in IOP between head positions was performed. The formal evaluation for effect of head position on the IOP was performed by an ANOVA with repeated measurement. The correlation from repeated measures of the same eye and intereye correlation in IOP from the same horse was adjusted by the generalized estimating equations.[24] The position of the eyes was analyzed as a categoric factor (eye above vs below heart level) and a continuous parameter (centimeters relative to heart level). The data analysis was performed by use of a software program.[b]

Results

Horses—Horses enrolled in this study consisted of 9 Thoroughbreds, 4 Morgans, 3 warmbloods, 3 Standardbreds, 2 Quarter Horses, 2 Arabians, 2 ponies, 1 Haflinger, and 4 crossbreds. There were 12 mares, 17 geldings, and 1 stallion. The median age was 10.5 years with a range of 2 to 34 years (mean ± SD, 12.6 ± 8.3 years).

IOP—A significant ($P < 0.001$) difference was found in IOP between the head-up and head-down position, with a higher IOP in the head-down position. Mean ± SE

values of IOP below heart level were 25.7 ± 1.2 mm Hg and above heart level were 17.5 ± 0.8 mm Hg (**Figure 1**). Of the 60 eyes from 30 horses, 52 (87%) eyes had an increase in IOP in the head-down position, compared with the head-up position. The difference in IOP
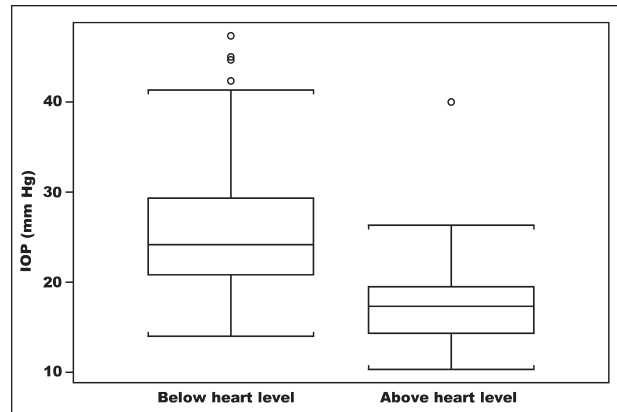

Figure 1—Boxplots of IOP when head position was above heart level and below heart level for 30 horses (60 eyes). For each box plot, notice the upper extreme (whisker, excluding outliers [circles outside box]), upper quartile (upper portion of box), median (horizontal line in box), lower quartile (lower portion of box), and lower extreme (whisker). A significant ($P < 0.001$) difference was found in IOP between head position above heart level versus below heart level.
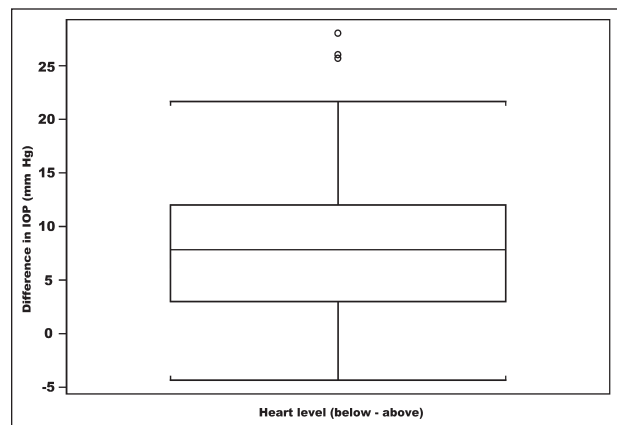

Figure 2—Boxplot of the differences in IOP between the head-down and the head-up positions for 30 horses (60 eyes). Notice the upper extreme (whisker, excluding outliers [circles outside box]), upper quartile (upper portion of box), median (horizontal line in box), lower quartile (lower portion of box), and lower extreme (whisker).

Table 1—Mean ± SE values of IOP as a function of eye height for 30 horses (60 eyes).

Head position*	Categories of eye height†	No. of eyes	IOP (mm Hg)
Head down (cm)			
	−52.1 to −26.6	34	26.1 ± 1.42
	−26.5 to −8.9	26	25.2 ± 2.19
Head up (cm)			
	49.5 to 65.6	30	17.3 ± 1.40
	65.7 to 72.4	30	17.6 ± 0.75

*Eyes were either located below heart level (head down; negative numbers) or above heart level (head up; positive numbers). †Significant ($P < 0.001$) differences were found in IOP between categories of eye heights.

between the head-down and head-up positions ranged from −4.3 to 28.0 mm Hg (median, 7.8 mm Hg), with a mean ± SE difference of 8.20 ± 1.01 mm Hg (95% confidence interval, 6.23 to 10.2 mm Hg; **Figure 2**).

When head position was analyzed on the basis of centimeter intervals relative to heart level, significant differences ($P < 0.001$) were found in IOP (**Table 1**). Changes in IOP by eye position were not significantly affected by sex ($P = 0.95$), age ($P = 0.40$), dorsal ($P = 0.69$) and ventral neck length ($P = 0.93$), left versus right eye ($P = 0.79$), or the first versus second eye ($P = 0.77$; data not shown).

Discussion

The effect of head position on the IOP has been well documented for humans.[17-19] This effect occurs mostly through a change in episcleral venous pressure.[18,19,25] As eyes move from above heart level (sitting or standing position) to heart level (supine position) or even below heart level (inverted position), the episcleral venous pressure increases.[25] Upon inversion, blood appeared in Schlemm's canal in some of the eyes studied with gonioscopy as a result of reflux from an increase in episcleral venous pressure.[25] As the downstream recipient of conventional aqueous outflow, the physiologic function of the orbital venous system (including the episcleral veins) is intertwined with aqueous dynamics and ocular hemodynamics.[26] The episcleral venous pressure is the pressure head that must be overcome for aqueous passage through the trabecular pathway, and so it is the key determinant of steady state IOP.[27] In addition, the congested orbital tissues and uveal tract contribute to an increase in IOP, especially in the inverted position.[18,19]

To our knowledge, our report is the first detailed documentation of a positional effect on IOP in horses. We found that IOP is significantly increased with the head below heart level, compared with IOP in the head-up position. Our results suggest that tonometry should be performed in the head-up position in horses.

We found considerable variability between individual horses. Although the IOP hardly changed in some horses, it almost tripled in others, reaching pressure levels in the head-down position that are generally considered hazardous. We were unable to identify specific factors that may have contributed to this variability. Nevertheless, we think that the IOP should always be measured in the same head position, especially if the pressures are monitored in an individual horse over time.

The findings from our study have implications on the design of studies for IOP fluctuations over time or clinical trials with IOP as an outcome. The significant effect of head position on IOP suggests that in longitudinal studies, IOP should be measured consistently in the same head position. The large magnitude of change in IOP with different head position (mean, 8.20 mm Hg) can possibly confound the IOP fluctuations or treatment effect on IOP if head position varies across time or across horses. It remains to be shown whether reductions in the neurophysiologic function of the retina and the visual cortex occur in horses in the head-down position, as described in humans.[19]

Even though we used a repeated-measures design, we still have to consider that detomidine, an α_2-adrenergic agonist, may have influenced our results. Other α_2-adrenergic agonists, such as apraclonidine and brimonidine, are powerful ocular hypotensive agents when applied topically and are believed to lower IOP primarily by decreasing aqueous humor formation.[28,29] Detomidine may have affected the episcleral vasculature and therefore led to more substantial pressure changes than would have occurred in unsedated horses.

Although our study design allows us to draw conclusions about the positional changes in IOP in sedated horses, we can only speculate about these positional pressure variations in unsedated horses. Without special training of horses or the use of telemetric tonometry devices, it would be impossible to study physiologic variations in IOP. Nevertheless, it is likely that IOP undergoes similar changes in the unsedated horse to those that we are reporting here. As horses have their heads in the head-down position during grazing, the IOP is probably increased to some degree. It is possible that after an extended period of time in the head-down position (longer than the 2 minutes studied in our report), the IOP may slowly normalize. Such normalization has not been observed in humans during complete inversion for over 30 minutes.[25] However, long-term compensatory mechanisms have been described in humans over several days in a head-down tilt.[30] Abrupt episcleral venous pressure and IOP changes do probably still occur in grazing horses whenever they raise their heads to look for potential dangers in the surrounding environment. In humans, immediately upon inversion into the head-down vertical position, IOP increases rapidly; within 10 seconds, 70% of the increase has occurred, and within 1 minute, a constant value is reached.[31]

From a clinical point of view, it is widely accepted that the equine eye can withstand an increase in IOP much better that other animals, as glaucomatous equine eyes retain sight for much longer than, for example, a canine eye with similar pressures. One can speculate that the equine eye is designed to withstand constant considerable pressure changes much better than would be the case in a human or canine eye because it is required for the success of a grazing prey.

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