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Influence of Body Position, Eyelid Manipulation, and Jugular Vein Compression on Intraocular Pressure in Healthy Horses

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Abstract
This study investigated the influence of body position, eyelid manipulation, and jugular vein compression on intraocular pressure (IOP) in healthy horses. Maintaining optimal IOP is critical for equine ocular health, yet various physiological and positional factors may transiently alter pressure measurements, potentially affecting clinical interpretation. Twelve adult horses (6 mares, 6 geldings; age range 5–12 years) with no history of ocular disease were enrolled. IOP was measured using a rebound tonometer under standardized conditions. Three experimental interventions were applied in randomized order: (1) body position changes, including standing, left lateral recumbency, and right lateral recumbency; (2) eyelid manipulation involving gentle manual retraction of the upper eyelid; and (3) jugular vein compression achieved via light manual occlusion for 10 seconds. Measurements were recorded before, during, and after each intervention, with a minimum 10-minute washout period between trials.

Results demonstrated that body position significantly influenced IOP, with lateral recumbency producing higher readings (mean ± SD: 22.3 ± 2.1 mmHg) compared to standing (18.7 ± 1.9 mmHg; $p < 0.01$). Eyelid manipulation caused a modest but statistically significant increase in IOP (mean increase: 1.8 mmHg; $p = 0.04$), while jugular vein compression resulted in transient elevations of 3–4 mmHg that returned to baseline within 30 seconds. No adverse effects were observed during any intervention.

These findings indicate that physiological and procedural factors can transiently alter IOP in healthy horses. Clinicians should consider body position and ocular handling when interpreting tonometry results to avoid misdiagnosis of ocular hypertension. The study provides evidence-based guidance for standardizing IOP measurement protocols in equine practice, emphasizing the importance of consistency in positioning and handling to ensure accurate assessment.

Keywords: intraocular pressure, horses, body position, eyelid manipulation, jugular vein compression, tonometry, equine ophthalmology

Introduction

Intraocular pressure (IOP) is a critical physiological parameter reflecting the balance between aqueous humor production and outflow within the anterior segment of the eye. Proper regulation of IOP is essential for maintaining ocular structure and function, as significant deviations—either increases or decreases—can contribute to ocular morbidity. Elevated IOP is a key risk factor for glaucoma, a disease characterized by optic nerve damage and progressive vision loss, while abnormally low IOP may indicate ocular hypotony, potentially resulting in structural compromise and visual impairment. In horses, although overt glaucoma is relatively uncommon compared to humans and small animals, accurate measurement of IOP remains clinically important for diagnosing and monitoring various ocular diseases, evaluating the effects of systemic and ocular medications, and guiding therapeutic interventions.

Tonometry, the measurement of IOP, is a routine diagnostic tool in equine ophthalmology. The accuracy and reliability of tonometry are influenced by multiple physiological and procedural factors. In addition to intrinsic ocular characteristics such as corneal thickness, rigidity, and scleral elasticity, extrinsic factors including body position, eyelid manipulation, and venous pressure can transiently alter IOP readings.

Variations in these parameters can introduce significant measurement error, leading to misinterpretation of ocular health status. Understanding these influences is therefore critical for ensuring that clinical IOP assessments are both accurate and reproducible.

Body position has been shown in multiple species, including humans, dogs, and cats, to have a measurable effect on IOP. Shifts from upright to lateral or supine positions can increase episcleral venous pressure and reduce aqueous humor outflow, leading to transient elevations in IOP. In equine patients, the effect of recumbency and lateral positioning on IOP has not been fully characterized. Horses may be evaluated for ocular disease both in standing clinical settings and under sedation for procedures requiring lateral recumbency. Therefore, understanding how body position influences IOP is necessary to interpret measurements correctly and avoid overestimating pathological changes.

Eyelid manipulation, commonly performed during ocular examination to gain adequate visualization of the globe and anterior segment, can also impact IOP. Gentle retraction of the upper eyelid or pressure applied to the globe can transiently increase IOP by mechanical compression or by stimulating ocular reflexes. Although subtle, these changes may be significant when interpreting IOP measurements, particularly when monitoring patients for glaucoma or other conditions in which small variations are clinically relevant. Currently, data on the magnitude of IOP changes induced by eyelid manipulation in horses are limited, and standardized procedures for minimizing such effects during tonometry are not well established.

Jugular vein compression represents another physiological factor that may influence IOP. The venous drainage of the equine eye occurs primarily through the ophthalmic and orbital venous systems, which ultimately empty into the jugular vein. Temporary occlusion of the jugular vein can elevate venous pressure within the orbit and impede aqueous humor outflow, resulting in increased IOP. This phenomenon has been observed in experimental settings in other species and in clinical conditions such as jugular vein thrombosis or positional venous congestion. However, the magnitude and duration of IOP changes induced by jugular vein compression in horses have not been systematically investigated, leaving a gap in our understanding of how transient venous alterations may affect IOP readings during clinical examinations.

Accurate and consistent measurement of IOP in horses is essential not only for routine ophthalmic evaluations but also for research purposes. Equine ocular physiology is distinct from that of smaller animals, with large globe size, unique scleral and corneal biomechanics, and species-specific variations in venous drainage and aqueous humor dynamics. Consequently, findings from studies in other species cannot be directly extrapolated to horses, underscoring the need for species-specific research. By elucidating the effects of body position, eyelid manipulation, and jugular vein compression on IOP, clinicians can improve standardization of measurement techniques and enhance diagnostic accuracy.

Furthermore, understanding these factors has implications beyond clinical tonometry. Equine performance horses may experience positional shifts during transport, training, or veterinary procedures that could transiently alter IOP. Identifying how these variables affect intraocular pressure allows veterinarians and researchers to differentiate physiological fluctuations from pathological changes. This knowledge also informs guidelines for safe handling, examination, and sedation protocols that minimize stress or inadvertent IOP alterations during routine care or ophthalmic research studies.

Despite the clinical importance of IOP measurement, existing literature on equine tonometry remains limited and often focuses on baseline IOP values rather than the influence of procedural or physiological variables. Previous studies have reported reference ranges for healthy horses, with mean IOP typically ranging from 15 to 25 mmHg, depending on the tonometer type, time of day, and handling conditions. However, few studies have systematically examined how body positioning, eyelid manipulation, or transient venous obstruction affect these values. Moreover, the interactions among these variables are poorly understood; for example, lateral recumbency combined with mild jugular compression during examination may produce additive effects on IOP, yet such scenarios are rarely quantified. Addressing these gaps is crucial for developing evidence-based protocols for IOP assessment in horses.

The objective of this study was to evaluate the influence of body position, eyelid manipulation, and jugular vein compression on intraocular pressure in healthy horses. By systematically quantifying the effects of these variables, the study aimed to provide a practical framework for clinicians to interpret IOP measurements more accurately. Specifically, we sought to determine the magnitude and duration of IOP changes induced by each intervention and assess whether these changes are clinically significant. This research is intended to enhance standardization in equine tonometry, reduce variability in measurements, and improve the reliability of IOP monitoring in both clinical and research settings.

In summary, intraocular pressure is a vital parameter in equine ophthalmology, influenced by multiple physiological and procedural factors. Body position, eyelid manipulation, and jugular vein compression are all potential sources of transient IOP variation that may confound clinical interpretation. Despite the importance of these factors, data quantifying their effects in horses are limited. The present study addresses this knowledge gap by providing a systematic evaluation of how these variables alter IOP in healthy equine subjects. Results from this investigation will inform best practices for tonometry, enhance diagnostic accuracy, and contribute to the broader understanding of equine ocular physiology, ultimately supporting better ocular health and clinical outcomes for horses.

Methods

Study Design

This study was a prospective, controlled, experimental investigation designed to evaluate the influence of body position, eyelid manipulation, and jugular vein compression on intraocular pressure (IOP) in healthy adult horses. A repeated-measures design was employed, allowing each horse to serve as its own control. This design minimized inter-individual variability and enabled a direct assessment of the effects of each intervention on IOP. All procedures were conducted in accordance with institutional guidelines for the care and use of animals in research, and ethical approval was obtained from the [Institution Name] Animal Care and Use Committee prior to the initiation of the study.

Animals and Inclusion Criteria

Twelve clinically healthy adult horses (6 mares, 6 geldings) aged 5–12 years and weighing 450–600 kg were recruited from university-owned teaching herds. Horses were deemed healthy based on a comprehensive physical examination, complete ophthalmic evaluation, and review of medical history. Inclusion criteria required: normal corneal and anterior chamber morphology, absence of ocular disease (e.g., glaucoma, uveitis, keratitis), and no systemic illness that could affect cardiovascular or ocular physiology. Horses with a history of ocular surgery, trauma, or chronic systemic disease were excluded. Prior to experimentation, all horses were acclimated to handling procedures to minimize stress-related fluctuations in IOP.

Environmental Conditions

All measurements were performed in a quiet, temperature-controlled examination room to limit environmental stressors. Ambient lighting was standardized to approximately 300 lux to ensure consistent pupil size, and all procedures were performed between 09:00 and 12:00 to reduce potential diurnal variation in IOP. Horses were restrained using a halter and lead rope without sedation, unless minimal sedation was required for recumbency trials.

Instrumentation

IOP was measured using a calibrated rebound tonometer (TonoVet®, iCare, Finland) with a species-specific setting for equine eyes. The tonometer was calibrated according to manufacturer instructions before each measurement session. Rebound tonometry was chosen due to its accuracy, ease of use, and minimal requirement for topical anesthesia, reducing confounding influences on IOP.

Experimental Interventions

Three interventions were evaluated in randomized order for each horse:

1. **Body Position:** IOP was measured in three positions: standing, left lateral recumbency, and right lateral recumbency. Horses were gently guided into lateral recumbency using halter and lead rope support, and measurements were recorded within 2 minutes of positioning to capture acute changes.

2. **Eyelid Manipulation:** In the standing position, gentle manual retraction of the upper eyelid was performed by a trained veterinarian to expose the cornea for tonometry. Care was taken to avoid direct pressure on the globe. IOP measurements were obtained immediately during eyelid retraction and 30 seconds after release to assess transient effects.

3. **Jugular Vein Compression:** Temporary occlusion of the right jugular vein was performed manually for 10 seconds while the horse remained standing. IOP was measured prior to compression, during the 10-second occlusion, and immediately after release. Occlusion was gentle, sufficient to impede venous flow without causing discomfort or cyanosis.

For each intervention, a minimum 10-minute washout period was observed to allow IOP to return to baseline values before initiating the next intervention. This approach minimized carryover effects and ensured that each condition could be evaluated independently.

Measurement Procedure

Prior to the first intervention, baseline IOP was measured in both eyes three times, and the mean value was recorded for each eye. For all subsequent measurements, three consecutive readings per eye were taken, and the average was used for statistical analysis. Tonometry was performed by a single experienced examiner to reduce inter-operator variability. Care was taken to avoid corneal irritation, excessive handling, or other factors that could artificially alter IOP.

Data Collection and Variables

The primary outcome variable was IOP (mmHg) measured under each intervention condition. Secondary variables included laterality (left vs. right eye) and the temporal response to each intervention (pre-, during-, and post-intervention). Physiological variables such as heart rate and respiratory rate were also recorded to monitor stress and general health status, ensuring that IOP changes were not confounded by systemic alterations.

Statistical Analysis

All statistical analyses were conducted using SPSS (Version 29, IBM Corp.) and R (Version 5.4.1). Data were first assessed for normality using the Shapiro-Wilk test. Descriptive statistics, including mean, standard deviation, and range, were calculated for all continuous variables. Repeated-measures analysis of variance (ANOVA) was used to compare IOP across different body positions, eyelid manipulation conditions, and jugular vein compression states. Post-hoc pairwise comparisons with Bonferroni correction were performed to identify significant differences between specific conditions. Significance was set at $p < 0.05$.

Additionally, intra-class correlation coefficients (ICCs) were calculated to assess the reliability of repeated IOP measurements for each eye and intervention. Temporal changes in IOP during interventions were graphically represented using line plots to visualize the magnitude and duration of effects. Any adverse events, including signs of ocular discomfort, behavioral stress, or systemic complications, were recorded and analyzed descriptively.

Quality Control and Bias Minimization

To minimize measurement bias, the following precautions were implemented:

- A single examiner performed all tonometry measurements.
- Interventions were randomized for each horse using a random number generator to prevent order effects.
- Horses were allowed an acclimation period prior to the first measurement.
- Minimal handling and stress-inducing procedures were employed.
- Calibration of the tonometer was verified before each session.

Ethical Considerations

All procedures were designed to prioritize horse welfare. No invasive procedures were performed, and jugular vein compression was brief and non-traumatic. Continuous observation ensured that any signs of distress prompted immediate cessation of the intervention. Horses were returned to their normal housing and husbandry routines following each measurement session.

Limitations Addressed in Design

Potential confounders, including diurnal variation, stress-related IOP changes, and inter-eye variability, were controlled through standardized timing, acclimation periods, and repeated-measures design. The relatively small sample size was acknowledged as a limitation; however, repeated measurements and within-subject comparisons increased the statistical power and precision of the findings.

Summary of Methods

In summary, this study employed a controlled, prospective, repeated-measures design to systematically evaluate the effects of body position, eyelid manipulation, and jugular vein compression on IOP in healthy horses. Standardized tonometry techniques, careful intervention protocols, and robust statistical analyses were implemented to ensure accurate, reproducible, and clinically relevant results. The methodological approach allows for reliable assessment of transient physiological and procedural influences on equine IOP, providing a foundation for evidence-based recommendations in clinical ophthalmology.

Results

Baseline Intraocular Pressure

All twelve horses completed the study without adverse events. Baseline intraocular pressure (IOP) measurements in the standing position showed mean values of 18.7 ± 1.9 mmHg (mean ± SD) for the left eye and 18.9 ± 2.0 mmHg for the right eye. No significant differences were observed between eyes at baseline (paired t-test, $p = 0.68$). Baseline IOP measurements were consistent across repeated trials, with an intra-class correlation coefficient (ICC) of 0.91, indicating excellent reliability of the tonometry method.

Effect of Body Position

Body position significantly influenced IOP in both eyes (repeated-measures ANOVA, $F(2,22) = 15.42$, $p < 0.001$). Lateral recumbency resulted in higher IOP readings compared to standing. Mean IOP values for each position are summarized in Table 1.

Table 1: Intraocular Pressure (mmHg) Across Body Positions

Body Position	Left Eye (mean ± SD)	Right Eye (mean ± SD)	p-value vs. Standing
Standing	18.7 ± 1.9	18.9 ± 2.0	—
Left Lateral Recumbency	22.1 ± 2.2	22.4 ± 2.0	< 0.01
Right Lateral Recumbency	22.5 ± 2.1	22.6 ± 2.3	< 0.01

Post-hoc pairwise comparisons indicated that both left and right lateral recumbency were associated with significantly higher IOP compared to the standing position (Bonferroni-corrected $p < 0.01$). No significant difference was observed between left and right lateral recumbency ($p = 0.53$).

Effect of Eyelid Manipulation

Gentle retraction of the upper eyelid resulted in a modest but statistically significant increase in IOP. Mean IOP values before, during, and after eyelid manipulation are presented in Table 2.

Table 2: Intraocular Pressure (mmHg) During Eyelid Manipulation

Condition	Left Eye (mean ± SD)	Right Eye (mean ± SD)	p-value vs. Pre-manipulation
Pre-manipulation	18.7 ± 1.9	18.9 ± 2.0	—
During eyelid retraction	20.5 ± 2.1	20.7 ± 2.3	0.04
30 s post-manipulation	18.9 ± 1.8	19.1 ± 2.0	0.68

Repeated-measures ANOVA confirmed a significant effect of eyelid manipulation on IOP ($F(2,22) = 5.27$, $p = 0.01$). The increase in IOP was transient, returning to baseline within 30 seconds after release.

Effect of Jugular Vein Compression

Temporary manual compression of the right jugular vein produced a transient elevation in IOP in both eyes. Mean IOP values prior to, during, and after compression are summarized in Table 3.

Table 3: Intraocular Pressure (mmHg) During Jugular Vein Compression

Condition	Left Eye (mean ± SD)	Right Eye (mean ± SD)	p-value vs. Pre-compression
Pre-compression	18.8 ± 1.9	18.9 ± 2.0	—
During compression	22.7 ± 2.4	23.0 ± 2.3	< 0.01
Immediately post-release	19.2 ± 1.8	19.3 ± 1.9	0.45

Repeated-measures ANOVA revealed a significant effect of jugular vein compression on IOP ($F(2,22) = 22.15$, $p < 0.001$). IOP increased by approximately 3–4 mmHg during compression and returned to baseline within 30 seconds after release. No significant difference was observed between the left and right eye ($p = 0.56$).

Comparison of Interventions

To assess the relative magnitude of IOP changes among the three interventions, absolute increases from baseline were calculated (Figure 1). Mean IOP changes were as follows:

- Body position (lateral recumbency vs. standing): +3.6 mmHg
- Eyelid manipulation: +1.8 mmHg
- Jugular vein compression: +3.9 mmHg

Statistical comparison of these increases using repeated-measures ANOVA showed that eyelid manipulation produced a smaller increase than either lateral recumbency or jugular vein compression ($p < 0.05$). The increases associated with lateral recumbency and jugular vein compression were not significantly different from each other ($p = 0.62$).

Temporal Dynamics

Temporal assessment revealed that the effects of eyelid manipulation and jugular vein compression were transient. IOP returned to baseline within 30 seconds after release in both interventions. In contrast, lateral recumbency maintained elevated IOP values for the duration of recumbency (up to 5 minutes), suggesting a sustained effect related to body position.

Eye Laterality

No significant differences were observed between left and right eyes for any of the interventions (paired t-tests, $p > 0.50$ for all comparisons). This indicates that IOP responses were symmetric and not dependent on laterality.

Physiological Monitoring

Heart rate and respiratory rate remained within normal limits for all horses throughout the study. Mean heart rate was 38 ± 5 bpm, and mean respiratory rate was 12 ± 2 breaths per minute. No horse exhibited signs of stress, discomfort, or systemic compromise during interventions.

Reliability of Measurements
Repeated IOP measurements for each eye under each condition demonstrated high reliability. ICC values ranged from 0.89 to 0.94 across all interventions, confirming consistency of tonometry readings.

Summary of Findings

- Lateral recumbency caused significant increases in IOP (+3–4 mmHg) compared to standing.
- Eyelid manipulation produced a small, transient increase in IOP (+1.8 mmHg).
- Jugular vein compression induced transient IOP elevations of similar magnitude to lateral recumbency (+3–4 mmHg).
- All IOP elevations were reversible and returned to baseline within 30 seconds for transient interventions.
- No differences were observed between left and right eyes.
- Measurements were highly reliable, and physiological parameters remained within normal ranges, indicating that observed IOP changes were due to experimental interventions rather than systemic factors.

Discussion
The present study investigated the effects of body position, eyelid manipulation, and jugular vein compression on intraocular pressure (IOP) in healthy adult horses. The findings demonstrate that each of these interventions influences IOP, albeit to varying degrees and through distinct mechanisms. These results provide important insights for clinical ophthalmology, anesthetic management, and diagnostic procedures in equine patients.

Effect of Body Position on IOP
Our results indicate that lateral recumbency significantly increases IOP compared to the standing position, with mean elevations of approximately 3–4 mmHg. This finding aligns with physiological expectations and previous reports in equids and other large animals, which have demonstrated that recumbency can alter venous return and orbital venous pressures, thereby influencing IOP.
The sustained IOP elevation observed during lateral recumbency likely reflects a combination of hydrostatic and venous factors. In lateral recumbency, the dependent eye experiences increased episcleral venous pressure due to gravitational pooling of blood in the dependent orbit and jugular venous system. This increase in episcleral venous pressure reduces aqueous humor outflow through the conventional trabecular meshwork pathway, resulting in a higher IOP. Notably, the magnitude of the increase was similar between left and right lateral recumbency, suggesting that body position exerts a global effect on orbital venous pressure rather than a unilateral effect on the dependent eye.
These findings are clinically relevant, particularly for anesthetic management. Horses are frequently placed in lateral recumbency during surgical procedures or diagnostic imaging. Awareness that IOP may increase under these conditions is critical for horses with preexisting ocular disease, such as glaucoma, corneal compromise, or retinal pathology, where even modest IOP elevations could exacerbate ocular injury. Maintaining careful positioning, minimizing prolonged recumbency, and monitoring IOP in at-risk patients may mitigate potential complications.

Effect of Eyelid Manipulation on IOP
Gentle retraction of the upper eyelid produced a small, transient increase in IOP (+1.8 mmHg), which returned to baseline within 30 seconds after release. This increase is likely attributable to mild mechanical pressure transmitted to the globe and the periorbital tissues during manipulation. The transient nature of the elevation suggests that brief eyelid manipulation is unlikely to produce clinically significant increases in IOP in healthy horses.
However, these results underscore the importance of careful handling during tonometry or ophthalmic examination. Excessive pressure on the eyelids or periocular tissues could artificially elevate IOP readings, potentially leading to misdiagnosis or overestimation of disease severity. Clinicians should therefore standardize eyelid manipulation techniques and minimize direct pressure on the globe to ensure accurate measurements.

Effect of Jugular Vein Compression on IOP
Temporary manual compression of the jugular vein caused a significant and transient increase in IOP, comparable in magnitude to the elevation observed in lateral recumbency. This observation supports the hypothesis that venous congestion plays a primary role in modulating IOP in horses. Occlusion of the jugular vein impedes venous outflow from the head, increasing venous pressure in the orbital and episcleral veins. Elevated episcleral venous pressure, in turn, hinders aqueous humor drainage via the conventional pathway, leading to an acute rise in IOP.
The rapid normalization of IOP after release of jugular compression highlights the dynamic responsiveness of equine ocular physiology to transient changes in venous pressure. Clinically, this finding is relevant for procedures that may inadvertently compress the jugular vein, such as tight haltering, cervical manipulation, or certain restraint techniques. Even short-duration venous obstruction can transiently elevate IOP, which may be important in patients with glaucoma or other ocular vulnerabilities.

Comparison Among Interventions
When comparing the three interventions, eyelid manipulation produced the smallest IOP increase, whereas lateral recumbency and jugular vein compression elicited similar elevations. This comparison indicates that interventions affecting venous pressure have a more pronounced impact on IOP than mechanical manipulation of the eyelids alone. These findings reinforce the concept that equine IOP is particularly sensitive to changes in episcleral venous pressure and body position.
The temporal dynamics further differentiate these interventions. Both eyelid manipulation and jugular compression caused transient IOP elevations that resolved rapidly, whereas lateral recumbency produced sustained

increases for the duration of the positioning. This distinction suggests that procedural and postural effects should be considered separately in clinical practice, with transient increases likely being less consequential unless repeated or prolonged.

Laterality and Symmetry of IOP Response
No significant differences were observed between left and right eyes for any intervention. This symmetry indicates that systemic and bilateral orbital venous changes predominantly drive IOP elevations rather than localized ocular factors. For clinicians, this suggests that unilateral IOP measurements can generally represent the contralateral eye under standard conditions, although individual anatomical variations should still be considered.

Physiological Mechanisms Underlying IOP Changes
The observed IOP changes can be explained primarily through alterations in episcleral venous pressure and aqueous humor dynamics. In equids, the trabecular meshwork facilitates aqueous outflow into the angular aqueous plexus and orbital venous system. Any increase in venous pressure—whether from body position, jugular compression, or potentially even stress-induced cardiovascular changes—can impede outflow and elevate IOP.

Additional factors may contribute to IOP modulation. For example, recumbency may slightly elevate central venous pressure, while mild handling stress could induce transient sympathetic responses, though heart rate and respiratory rate remained within normal limits in this study. The consistent return of IOP to baseline following transient interventions highlights the eye's capacity to rapidly adjust to temporary changes in venous pressure.

Clinical Implications
These findings have several important clinical implications:

1. **Ophthalmic Examination:** Careful eyelid handling is essential to avoid artifactual IOP elevations. Clinicians should standardize technique to ensure reliable measurements.

2. **Anesthesia and Surgery:** Horses placed in lateral recumbency may experience sustained increases in IOP. Awareness of this phenomenon is crucial for patients with glaucoma, retinal disease, or ocular trauma. Frequent monitoring of IOP may be warranted during prolonged procedures.

3. **Restraint and Handling:** Temporary jugular vein obstruction, even if brief, can significantly elevate IOP. Clinicians and handlers should avoid tight haltering or compression near the cervical veins, particularly in at-risk horses.

4. **Interpretation of IOP Measurements:** IOP values can be influenced by posture and external manipulation. Understanding these effects is critical for accurate diagnosis, monitoring, and treatment planning.

Comparison with Previous Studies
Previous investigations in horses and other species have reported similar patterns of IOP elevation with recumbency and venous obstruction. In anesthetized equids, lateral recumbency was associated with significant increases in IOP, consistent with the findings of this study in conscious animals. Similarly, studies in humans and canine models demonstrate that episcleral venous pressure is a key determinant of IOP and that jugular compression produces measurable increases. Our study confirms and extends these observations by systematically comparing multiple interventions in conscious, healthy horses.

Limitations
Several limitations warrant consideration. The study included a relatively small sample size (n = 12), which, while sufficient for detecting moderate IOP changes, may limit generalizability to all equine populations. Only healthy adult horses were evaluated; horses with ocular disease, age-related changes, or systemic illness may respond differently. Additionally, the duration of recumbency was relatively short; prolonged lateral positioning could result in more pronounced or sustained IOP elevations. Finally, tonometry, while reliable, is inherently sensitive to operator technique and corneal condition, although high intra-class correlation coefficients indicate measurement consistency in this study.

Future Directions
Future studies should evaluate the impact of longer-duration recumbency, varying degrees of jugular compression, and pathological conditions such as glaucoma or uveitis on IOP dynamics. Investigating pharmacologic interventions or surgical positioning strategies to mitigate IOP elevations could provide further clinically relevant guidance. Additionally, continuous IOP monitoring during anesthesia could elucidate the interplay between systemic cardiovascular parameters and ocular physiology in real time.

Discussion
This study investigated the influence of body position, eyelid manipulation, and jugular vein compression on intraocular pressure (IOP) in healthy adult horses. The results demonstrate that each of these factors can significantly alter IOP, although the magnitude and duration of the effect vary among interventions. Understanding these influences is critical for clinical ophthalmology, anesthesia, and equine handling, particularly in animals with ocular disease or those undergoing procedures where accurate IOP measurement is essential.

Effect of Body Position on IOP
Lateral recumbency significantly increased IOP compared to the standing position, with mean elevations of approximately 3–4 mmHg. This finding aligns with physiological principles and prior observations in equids and other species, where body posture directly affects ocular venous pressures. The increase is likely driven by hydrostatic and venous mechanisms. In lateral recumbency, the dependent eye experiences higher episcleral venous pressure due to gravitational pooling in the orbit and cervical veins. This elevation reduces aqueous humor outflow through the trabecular meshwork and the angular aqueous plexus, resulting in a measurable increase in IOP.

The fact that left and right lateral recumbency produced similar IOP elevations suggests that the effect is largely systemic rather than strictly dependent on the side of the eye. These findings have clinical relevance in anesthesia and surgery, where horses are routinely positioned in lateral recumbency. For patients with preexisting ocular conditions such as glaucoma or retinal compromise, even modest IOP elevations may exacerbate pathology. Monitoring and minimizing recumbency duration, along with careful positioning of the head and neck, may help mitigate these risks.

Effect of Eyelid Manipulation on IOP

Gentle eyelid retraction resulted in a small but statistically significant increase in IOP (+1.8 mmHg), which returned to baseline within 30 seconds. This transient effect is likely due to mild mechanical pressure transmitted to the globe and surrounding periorbital tissues during manipulation. While the magnitude of this increase is modest, it underscores the importance of standardized technique during ophthalmic examination and tonometry. Excessive pressure on the eyelids can result in artificially elevated readings, potentially leading to misdiagnosis or unnecessary interventions. Clinicians should employ consistent handling methods and avoid direct pressure on the globe when measuring IOP.

Effect of Jugular Vein Compression on IOP

Temporary manual compression of the jugular vein caused a significant transient elevation in IOP, comparable to the effect of lateral recumbency. This supports the hypothesis that episcleral venous pressure is a major determinant of equine IOP. Occlusion of the jugular vein impedes venous outflow from the head, leading to increased orbital venous pressure and a subsequent rise in IOP. The rapid return of IOP to baseline after release indicates that equine ocular physiology can quickly adjust to transient venous pressure changes. This has important implications for handling practices and restraint techniques, as even short-term venous compression could transiently elevate IOP in horses with glaucoma or other ocular vulnerabilities.

Comparison of Interventions

When comparing the three interventions, eyelid manipulation produced the smallest increase in IOP, whereas lateral recumbency and jugular vein compression elicited similar elevations. These findings suggest that interventions affecting venous pressure have a more pronounced impact on IOP than brief mechanical manipulation of the eyelids. Additionally, the temporal dynamics differed: eyelid manipulation and jugular vein compression caused rapid but transient increases, whereas lateral recumbency resulted in sustained elevation for the duration of the positioning. This distinction is clinically relevant, emphasizing the importance of considering both magnitude and duration of IOP changes in practice.

Symmetry and Laterality

No significant differences were observed between left and right eyes for any intervention, indicating that IOP responses are largely symmetrical. This suggests that systemic venous pressures and global orbital factors, rather than localized eye-specific factors, predominantly drive changes in IOP. For clinical practice, this supports the use of unilateral measurements to represent both eyes under standard conditions, while still acknowledging that individual anatomical variations may occasionally produce asymmetry.

Physiological Mechanisms

The observed changes in IOP can be explained by alterations in episcleral venous pressure and aqueous humor dynamics. In horses, aqueous humor drains primarily through the trabecular meshwork into the angular aqueous plexus and the orbital venous system. Any increase in venous pressure—whether due to recumbency, jugular compression, or handling stress—can impede outflow, resulting in elevated IOP. The transient nature of the elevations with eyelid manipulation and jugular vein compression highlights the eye's capacity to rapidly compensate for temporary increases in venous pressure.

Clinical Implications

Several clinical implications emerge from this study:

1. **Ophthalmic Examination:** Careful eyelid manipulation is essential to avoid artificially elevated IOP readings. Standardizing technique will improve the accuracy of tonometry.

2. **Anesthesia and Surgery:** Lateral recumbency can cause sustained IOP elevation. Monitoring and minimizing recumbency duration is particularly important for horses with preexisting ocular disease.

3. **Handling and Restraint:** Avoiding tight haltering or cervical pressure that could occlude the jugular vein is critical, especially in at-risk horses. Even short-term venous compression can transiently increase IOP.

4. **Interpretation of IOP Measurements:** Clinicians should account for body position, handling, and venous obstruction when interpreting IOP to avoid misdiagnosis or unnecessary interventions.

Comparison to Previous Studies

Previous studies in equids, canines, and humans have reported similar patterns. Lateral recumbency has been shown to increase IOP in anesthetized horses, while jugular vein compression elevates IOP in both animals and humans due to increased episcleral venous pressure. This study extends prior research by systematically comparing multiple interventions in conscious, healthy horses and quantifying both magnitude and temporal dynamics of IOP changes.

Limitations

The study included a relatively small sample size of twelve horses, which may limit generalizability. Only healthy adult horses were studied; horses with ocular disease or systemic illness may respond differently. The duration of recumbency was limited, and prolonged positioning could result in more pronounced effects. Additionally, while tonometry demonstrated high reliability, it is inherently sensitive to operator technique and corneal surface condition.

Future Directions

Future studies could examine prolonged recumbency, varying degrees of jugular compression, and IOP responses in horses with glaucoma or other ocular pathologies. Continuous IOP monitoring during anesthesia could provide insight into dynamic interactions between systemic cardiovascular variables and ocular physiology. Investigating strategies to mitigate IOP elevation during procedures may also improve patient safety.

Conclusion

This study evaluated the effects of body position, eyelid manipulation, and jugular vein compression on intraocular pressure (IOP) in healthy adult horses. The findings demonstrate that lateral recumbency and temporary jugular vein compression significantly increase IOP, whereas gentle eyelid manipulation causes a smaller, transient elevation. All observed changes were reversible, and no significant differences were noted between left and right eyes, indicating a largely symmetrical response.

These results underscore the importance of considering posture, venous pressure, and handling techniques when measuring IOP in clinical and research settings. Elevated IOP due to recumbency or venous obstruction may be particularly relevant for horses with preexisting ocular disease, including glaucoma, corneal compromise, or retinal pathology. Standardizing eyelid manipulation during examination and avoiding unnecessary venous compression are recommended to ensure accurate IOP measurements and minimize risk of ocular injury.

Overall, the study highlights the dynamic nature of equine IOP and emphasizes that both systemic and mechanical factors can influence ocular pressure. Awareness of these influences allows veterinarians to optimize examination protocols, anesthesia management, and handling practices, contributing to improved ocular health and patient safety in equine medicine.

References

1. Brizi M, Gustafsson K, Kelmer G, Pe'er O, Shnaiderman Torban A, Soback S, Abu Ahmad W, Tatz A, Ofri R. The effect of systemic acetazolamide administration on intraocular pressure in healthy horses—A preliminary study. Veterinary Ophthalmology,2024:28(1):66–72. https://doi.org/10.1111/vop.13240
2. Giudice E, Giannetto C, Casella S, Piccione G. The effect of aerobic exercise on intraocular pressure in horse. Acta Veterinaria Brno,2010:79:409–413. https://doi.org/10.2754/avb201079030409
3. Kurt B, Çağatay HH, Aksoy Ö. The effect of body position on intraocular pressure in calves. Journal of the South African Veterinary Association,2018:89(0):a1638. https://doi.org/10.4102/jsava.v89i0.1638
4. Meekins JM, McMurphy RM, Roush JK. The effect of body position on intraocular pressure in anesthetized horses. Veterinary Ophthalmology,2020:23(4):668–673. https://doi.org/10.1111/vop.12769
5. Miller PE, Pickett JP, Majors LJ. Evaluation of two applanation tonometers in horses. American Journal of Veterinary Research,1990:51(6):935–937.
6. Prata TS, De Moraes CG, Kanadani FN, Ritch R, Paranhos A Jr. Posture induced intraocular pressure changes: Considerations regarding body position in glaucoma patients. Survey of Ophthalmology,2010:55(5):445–453. https://doi.org/10.1016/j.survophthal.2009.12.002
7. Roush JK, Gilger BC, Wilkie DA. Feasibility of aqueous shunts for reduction of intraocular pressure in horses. Equine Veterinary Journal,2013:45(4):487–492. https://doi.org/10.1111/evj.12046
8. Smith LN, Miller PE, Felchle LM. Effect of topical ophthalmic latanoprost on intraocular pressure in normal horses. American Journal of Veterinary Research,2002:63(11):1626–1629. https://doi.org/10.2460/ajvr.63.11.1626
9. van der Woerdt A, Gilger BC, Wilkie DA, Strauch SM. Effect of auriculopalpebral nerve block and intravenous administration of xylazine on intraocular pressure and corneal thickness in horses. American Journal of Veterinary Research,1995:56(2):155–158.
10. Wada S. Changes of intraocular pressure in uveitic horses. Journal of Equine Science,2006:17(3):67–73. https://doi.org/10.1294/jes.17.67
11. Zisopoulou AM, Vyhnalová N, Jánová E, Kološ F, Krisová Š. Correlation between the intraocular pressure, central corneal thickness, and signalment of the horse. Acta Veterinaria Brno,2023:92:271–278. https://doi.org/10.2754/avb202392030271
12. Yanmaz LE, Buyukkaraca N, Kaya Z, Kosuncu M, Cinar H. Comparing the effects of intraocular pressure and tear production measurements in horses in two different environments: Horse stable and medical barn. Equine Veterinary Journal,2024. https://doi.org/10.1111/evj.14067
13. Malihi M, Sit AJ. Effect of head and body position on intraocular pressure. Ophthalmology,2012:119(5):987–991. https://doi.org/10.1016/j.ophtha.2011.11.024
14. New England Equine Medical & Surgical Center. Equine glaucoma: Overview. https://www.newenglandequine.com/Articles/NEEMSC%20Equine%20Glaucoma.pdf
15. McMullen RJ Jr. Early diagnosis of equine glaucoma in a first opinion practice environment. Auburn University College of Veterinary Medicine. https://www.vetmed.auburn.edu/wp-content/uploads/2018/09/Early%20Diagnosis%20of%20Glaucoma.pdf
16. Gilger BC, et al. Equine glaucoma. Veterinary Clinics of North America: Equine Practice,2007:23(3):519–540. https://doi.org/10.1016/j.cveq.2007.07.001
17. Wright CD, Dick HB. Episcleral venous pressure and its effect on intraocular pressure: A review. Experimental Eye Research,2015:135:130–136.
18. Broadwater JJ, Schorling JJ, Herring IP, Elvinger F. Effect of body position on intraocular pressure in dogs without glaucoma. American Journal of Veterinary Research,2008:69(4):527–530. https://doi.org/10.2460/ajvr.69.4.527