Effect of body position on intraocular pressure in dogs without glaucoma

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Objective—To determine the effects of body position on intraocular pressure (IOP) in dogs without glaucoma.

Animals—24 healthy dogs with no evidence of glaucoma.

Procedures—Dogs underwent ophthalmic examinations to ensure that no IOP-affecting ocular diseases were present. Each dog was sequentially placed in dorsal recumbency, sternal recumbency, and sitting position. For each of the 3 positions, IOP in the right eye was measured by use of an applanation tonometer immediately after positioning (0 minutes) and after 3 and 5 minutes had elapsed. The initial body position was randomly assigned; each position followed the other positions an equal number of times, and IOP measurements were initiated immediately after moving from one body position to the next. Proparacaine hydrochloride (0.5%) was applied to the right eye immediately prior to IOP measurements.

Results—Intraocular pressure was affected by body position. During the 5-minute examination, IOP decreased significantly in dogs that were dorsally recumbent or sitting but did not change significantly in dogs that were sternally recumbent. For the 3 positions, overall mean IOP differed significantly at each time point (0, 3, and 5 minutes). Mean IOP in dorsal recumbency was significantly higher than that in sternal recumbency at 0 and at 3 minutes; although the former was also higher than that in sitting position at 3 minutes, that difference was not significant.

Conclusions and Clinical Relevance—Body position affects IOP in dogs. When IOP is measured in dogs, body position should be recorded and consistent among repeat evaluations. (*Am J Vet Res* 2008;69:527–530)

Measurement of IOP in dogs is commonly performed in routine ophthalmic examinations because IOP values are an important indicator of ocular health and disease states. Changes in IOP are also the most frequently measured response in studies evaluating the efficacy of glaucoma treatments. Intraocular pressure is determined by aqueous humor volume, choroidal blood volume, vitreous humor volume, scleral rigidity and compliance, extraocular muscle tone, and external pressure applied to the globe.[1] Intraocular fluid volume is determined by aqueous humor formation and outflow.[1] Aqueous humor is formed at the ciliary process via active secretion and by passive processes such as diffusion and ultrafiltration of the plasma.[2] The fluid flows from the posterior chamber through the pupil into the anterior chamber, and finally to the iridocorneal angle to exit the eye.[2,3] In dogs, aqueous humor exiting the conventional outflow system flows through the corneoscleral trabecular meshwork into a network of veins called the angular aqueous plexus and then enters the episcleral venous system.[2,3] An alternate pathway of aqueous drainage, referred to as uveoscleral outflow, allows aqueous humor to exit the eye via percolation through the suprachoroidal space and sclera.[2,3] Mean ± SD IOP in dogs is reported to be 16.7 ± 4.0 mm Hg (range, 7 to 28 mm Hg[4]). Factors that influence or disrupt the aforementioned processes may lead to clinically important alterations in IOP. One such factor bearing consideration is body position.

Abbreviation

IOP	Intraocular pressure

In humans, it is established that alterations in body position have an effect on IOP,[5,6] and results of studies[7,8] in mice and horses have identified similar effects. Investigations have compared IOP measurements obtained from humans in typical sitting or standing positions to those obtained from humans in a range of altered positions including dorsal recumbency (supine),[9–11] sternal recumbency (prone),[12] sitting with head retroflexed,[13] and positions at various angles of head-down tilt.[5,6,10] Patients have also been evaluated in the supine position during anesthesia.[12] Each of these positions results in significantly higher IOPs, compared with values in humans in normal standing or sitting position.[6–13] A recent study[8] revealed a relationship between head position and IOP in standing horses, and it was concluded that

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IOP increases as the head position is lowered. Results of a study[7] in mice indicated that both episcleral venous pressure and IOP values increased in accordance with the degree of the head-down body position.

To facilitate IOP measurement, dogs are often manually restrained in sitting position or sternal recumbency and a topical ophthalmic anesthetic agent is used. Although it is generally recognized that increased restraint effort and pressure around the neck may affect IOP,[14] to the authors' knowledge, no studies have been performed in dogs to evaluate the effects of body position on IOP. If body position affects IOP in this species, the fact must be taken into account in investigative research and clinical settings. Therefore, the purpose of the study of this report was to determine the effect of 3 body positions (sitting, sternal recumbency, and dorsal recumbency) on IOP in dogs without glaucoma.

Materials and Methods

Twenty-four dogs (15 spayed females and 9 neutered males) were included in the study. The dogs' weight ranged from 4.3 to 40.9 kg (mean, 20.8 kg), and age ranged from 2 to 12 years (mean, 5.4 years). Each dog underwent a complete ophthalmic examination, which included diffuse and focal transillumination, slit-lamp biomicroscopy, indirect ophthalmoscopy, and tonometry. A dog was excluded if the IOP value was not within reference range (7 to 28 mm Hg), there was evidence of ocular disease that might affect IOP, or its temperament precluded completion of the study protocol. All dogs were evaluated in the same environment between the hours of 11 AM and 5 PM; for all dogs, the same investigator (JJS) performed all IOP measurements and 1 investigator (JJB) provided restraint. A drop of proparacaine hydrochloride (0.5%)[a] was placed in the right eye of each dog immediately prior to the procedures, with repeated doses applied as needed depending on the response to corneal contact. An applanation tonometer[b] was used to obtain IOP measurements; the first tonometric measurement obtained with < 5% error was recorded as the IOP. The instrument was calibrated daily to ensure consistent function throughout the study. Intraocular pressure measurements were obtained from the right eye of each dog in the dorsally recumbent, sternally recumbent, and sitting positions. These positions were chosen because dogs are commonly placed in a sitting position or sternal recumbency for assessment of IOP, and dorsal recumbency is frequently used during ophthalmic surgical procedures. While in a sitting position or in sternal recumbency, the dog's head was allowed to remain in a natural position (above the level of the heart); in dorsal recumbency, the dog's nose was directed toward the ceiling. Intraocular pressure was measured immediately after the dog was placed in each of the 3 positions (0 minutes), then again after 3 and 5 minutes of positional acclimatization. The positional order in which each dog was placed was randomly designated, and each position followed the other positions an equal number of times.

Statistical analysis—The study was laid out in 4-fold repeated balanced double 3 × 3 Latin squares in the main plot and repeated measures in time in the subplot of a split plot in time design. Dogs were randomly and equally assigned to 1 of 6 possible treatment sequences, such that each position was the initial position an equal number of times and each position followed the other 2 positions an equal number of times. After verification of normality and equalities of variances by use of a univariate procedure,[c] data were analyzed via ANOVA with a general linear models procedure[c] so that Latin square, dog identification number, period, position, and interactions in the main plot were tested by period × position × dog identification number within square residual; time was tested by the time × dog identification number within square residual; and interactions of time with other variables were tested by the overall error term. Main effects of position and time least squares means were further compared by use of the slice option with the Bonferroni adjustment, and pairwise comparisons of all means of the position × time interaction were assessed by use of the Bonferroni adjustment. A value of $P < 0.05$ was considered significant. Data are presented as mean ± SD.

Results

Of the 24 dogs in the study, ophthalmic examination revealed abnormalities in 6 eyes of 4 individuals. Multifocal mild retinal dysplasia was detected in both eyes of 1 dog and incipient anterior cortical cataracts were observed in both eyes of another dog. One dog had a < 1-mm focal anterior stromal corneal lipid accumulation in its right eye, and a fourth dog had an obstructed right nasolacrimal duct. The IOP results from these dogs were included in the data analyses because the ophthalmic abnormalities were considered unlikely to affect IOP.

Differences in IOP in association with body position were detected. Intraocular pressure decreased ($P < 0.001$) over time in each position; the overall mean IOP for the 3 body positions at 0 minutes was different from the value at 3 minutes ($P = 0.005$) and at 5 minutes ($P < 0.001$). In dorsal recumbency, sternal recumbency, and sitting position, mean ± SD IOP at 0 minutes was 13.4 ± 3.5 mm Hg, 11.7 ± 3.2 mm Hg, and 12.5 ± 3.3 mm Hg, respectively ($P = 0.004$); at 3 minutes, the value was 12.8 ± 3.9 mm Hg, 11.1 ± 3.5 mm Hg, and 11.2 ± 3.8 mm Hg, respectively ($P = 0.001$); and at 5 minutes, the value was 12.2 ± 3.2 mm Hg, 11.4 ± 3.0 mm Hg, and 11.0 ± 3.3 mm Hg ($P = 0.047$), respectively. Mean IOP differed over time in dorsal recumbency ($P = 0.044$) and in sitting position ($P = 0.006$) but not in sternal recumbency ($P = 0.453$). At 0 minutes, mean IOP was higher ($P = 0.035$) in dogs positioned in dorsal recumbency than it was in dogs positioned in sternal recumbency. At 3 minutes, mean IOP was higher ($P = 0.045$) in dogs positioned in dorsal recumbency than it was in dogs positioned in sternal recumbency; although the former value was higher than it was in dogs in sitting position, the difference was not significant ($P = 0.058$). At 5 minutes, mean IOP for dogs in different positions did not differ.

Discussion

In the present study, body position and the period for which that position was maintained affected IOP in dogs. Measured IOP values decreased during the 5-minute study period in dogs that were in sitting or dorsally recumbent positions, but did not change in dogs that were in a sternally recumbent position.

Studies[7–12] in other species have consistently revealed IOP alterations in relation to changes in head position. In humans, IOPs significantly increase when patients are placed in a horizontal prone[12] or supine[9–11] position, compared with values recorded when patients are sitting or standing. In a study[7] in mice, placement at 30° and 60° of head-down body tilt increased IOP, compared with values recorded in the horizontal position. Similarly, a study[8] comparing IOPs in horses standing normally with their heads elevated and standing with their heads lowered to the ground revealed significant increases in IOP associated with the head-down position. Similar to results in human studies, IOP values were significantly increased when the horses and mice were placed in the altered positions.[7,8]

The exact mechanisms affecting IOP in response to the alterations in body position are still under debate; however, several different ideas have been proposed. One common assumption is that the increase in IOP induced during movement from a sitting position to a supine position is attributable to decreased gravitational effect on blood flow to and from the head when lying down.[5,15,16] On the basis of findings of various studies,[5,7,15] it has been suggested that increased ophthalmic arterial pressure and a sudden increase in choroidal blood volume may cause the initial increase in IOP, whereas sustained increases in IOP may be a result of increased aqueous humor formation or increased outflow resistance associated with increased episcleral venous pressure. The precise mechanism for the positional increases in IOPs detected in humans, mice, and horses is most likely not driven by a single factor but rather by a combination of the aforementioned factors.[16]

Similar to the findings in humans, mice, and horses, the results of the present study in dogs indicated an effect of body position on IOP. However, unlike the studies performed in other species, a relative head-down position (ie, dorsal recumbency) in our study did not cause an increase in IOP over time. Differences in the anatomic orientations of the eyes in relation to the heart may play an important role in species-specific positional alterations of ocular blood flow and, hence, alterations of IOP. Under normal standing or sitting conditions, the eyes are located directly dorsal to the heart in humans. In comparison, because dogs are quadrupeds, their eyes are typically located much nearer the horizontal plane of the heart during standing or lying in sternal recumbency. In dogs, movement among body positions may result in less of a gravitational adjustment with respect to the heart-eye positioning, compared with humans. Thus, changes in gravitational resistance to blood flow, which is thought to be an important factor for positional effects on human IOP, may be less important in dogs. It is also possible that various factors in ocular physiology, including blood flow, volume, and pressure; aqueous humor production; and outflow resistance, are less affected by positional changes in dogs than they are in humans. The increases in IOP in mice and horses were achieved as the head was lowered relative to the heart, supporting the concept that position of the eye relative to the horizontal plane of the heart may have an important influence on IOP. Even though the dogs in the present study underwent 3 positional changes (sitting and sternal and dorsal recumbency), the eyes were not substantially lower than the heart in any of these positions. Evaluation of a position in which the dogs' eyes would be lower than their hearts was intentionally not pursued in our study because such a position would not be clinically relevant in this species. However, this may partly explain the fact that although IOP was affected by body position, the changes did not parallel the results obtained over time in the human, mouse, and horse studies.

Another possible explanation for our findings is that the study dogs may not have been maintained in the various body positions for adequate periods of time to allow the full effects of the physiologic response to positioning to develop. In human studies,[5,6,10] persons were placed in an altered position (prone, supine, or head-down tilt) for periods ranging from 6 to as long as 48 hours. It was believed that this length of time was not of clinical relevance in dogs and additionally, without extensive training, conscious unsedated dogs would not likely tolerate such unnatural body positions for several hours. Results of a study[17] in humans performed by Friberg and Weinreb indicated that a maximum increase in IOP following gravity inversion occurred within 30 to 45 seconds. For the remainder of that study (5 minutes), IOPs remained at the same value as the maximum measurement obtained after 30 to 45 seconds, indicating that the positional effects on IOP related to extreme changes in eye-heart positioning in humans are rapid and persistent.[17] Those results suggested that 5 minutes of acclimatization should be adequate to detect IOP changes in relation to body position. However, the relatively smaller magnitude of changes in eye-heart positioning achieved in the dogs of this report might not allow direct comparison of these studies.

The temporal decreases in IOP detected while dogs were maintained in dorsal recumbency, sternal recumbency, and a sitting position may be attributable to the initial excitement experienced by each dog as its position was altered. It is possible that the IOP estimates at 0 minutes were artifactually high because of stress associated with positioning; as the dogs adjusted to the sitting and dorsally recumbent positions, acclimatization may have resulted in decreasing IOP over time. Because IOP did not change significantly over time in dogs placed in sternal recumbency, it is possible that this position induced less excitement. After 5 minutes, the IOP in each dog in the 3 positions approached similar values, suggesting that excitement likely played a role in these findings. Whether excitement-related changes in IOP are related to transient increases in arterial pressure, orbital or extraocular muscle tone, eyelid tone, or other factors is unknown.

Physiologic variables that may alter IOP measurements, including changes in extraocular muscle tone and eyelid contraction, are difficult to measure but may have influenced our findings. However, signs of increased extraocular muscle tone or blepharospasm requiring excessive eyelid traction were not detected by the examiners in any of the study dogs. Additionally, care was taken not to place any digital pressure on the globe during IOP measurements. Evaluations in the present study were performed between the hours of 11 AM and 5 PM; diurnal IOP variation is unlikely to have affected the results because, although all dogs were not evaluated at the same time of day, each dog was placed in each of the 3 body positions in such a way that there was an even distribution of body positions throughout the study period.

Although instances were not specifically recorded, it was occasionally necessary to repeat IOP measurements to obtain a reading with < 5% error. It is possible that a tonographic effect from these repeated measurements may have resulted in decreasing IOP; however, previous studies[4,18,19] involving the same type of applanation tonometer as that used in the present study have not revealed evidence of a substantial tonographic effect from its use.

Although the position-related IOP differences detected in dogs in our study are unlikely to result in clinical misjudgment, the differences are of relevance to investigative IOP research. Results of research to evaluate the effect of drugs on IOP in dogs may indicate significant changes of only 2 to 3 mm Hg.[20–22] Given that our study revealed a significant effect of body position on IOP measurements, small changes of only 2 to 3 mm Hg could be attributed to or influenced by the variation in body position rather than by a drug or intervention that is under investigation. The results of the present study support the need to record the position of dogs during IOP measurement and to consistently use that positioning for subsequent measurements in research investigations, to negate potential effects of body position on the results. Researchers should note that in the present study, there was no significant change in IOP over time for dogs maintained in sternal recumbency, suggesting that this position may allow for the most consistent and repeatable IOP measurements. Additionally, dogs should be maintained in the selected body position for a consistent period to allow acclimatization prior to each IOP measurement.

a. Ophthetic, Allergan Inc, Irvine, Calif.
b. Tono-Pen XL, Mentor Ophthalmics Inc, Norwell, Mass.
c. SAS, version 9.1.3, SAS Institute Inc, Cary, NC.

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