Control values of intraocular pressure in different species: a review of literature

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It is generally accepted that intraocular pressure (IOP) depends on the rate of aqueous humor production, system outflow resistance, and episcleral venous pressure. Therefore, control IOP values are expected to be within the strict and predictable limits in specific animal species, and there should be no vast differences between species. However, in the literature the control IOP values significantly vary (from potentially "hypotensive" to "hypertensive") within the same species, and especially between species depending on the measurement technique, head position in relation to the rest of the body, circadian rhythm, age, and topical and systemic drugs (anesthetics) applied. These variations make it difficult to compare different therapeutic approaches for intraocular hypertension, investigate the correlation between IOP and intracranial pressure, and determine target IOP values in glaucoma research. We recommend that different IOP physiology and pathophysiology studies take into account all the mentioned factors when describing IOP measurement methodology.

It is generally considered that aqueous humor pressure depends on the amount of its production and absorption (1). Thus, aqueous humor is believed to be actively produced by secretion through the epithelial cells of the ciliary body (which stems from the same neuroectodermal origin as the brain choroidal plexus), then flows from the posterior to the anterior chamber of the eye to be absorbed through the trabecular meshwork and Schlemm canal (conventional outflow) or through the uveal tissues (unconventional outflow) (2-4). Its formation has a hydrostatic and a secretory component. The hydrostatic component results from passive leakage of fluid from the blood, and the secretory component results from the active transport of sodium and other ions by the ciliary epithelium. Fluid volume in the aqueous system of the human eye is around 250 μL, with the formation rate of 2.5 μL/min and the turnover rate of 1.0%-1.5% per min (3).

IOP depends on the venous pressure, the rate of secretion, and resistance to fluid drainage, which can be expressed with the formula: $IOP = ([F - Fu]/Ctot) + Pv$ (where F is aqueous humor formation rate, Fu is uveoscleral outflow rate, Ctot is total outflow facility, or total outflow conductance, and Pv is episcleral venous pressure) (5). This formula is known as the Goldmann equation, with various modifications.

The mean IOP in the human adult population is estimated at 15-16 mm Hg, with a standard deviation of nearly 3.0 mm Hg, ie, two standard deviations above the mean (6). These reference ranges date back to 1958, as reported in the study by Leydhecker et al (7). The Beijing Eye Study from 2011 (8) found normal IOP to be 14.5 ± 2.7 mm Hg with ±2 standard deviations (SD). This finding is consistent with the normal IOP range for the white population reported by other researchers. The researchers also listed systemic and ophthalmic factors that should be taken into account when determining IOP reference range: blood pressure, pulse rate, age, refractive error, central corneal thickness, and corneal curvature, among others (8-10). Conversely, there are still no exact reference intervals defined for commonly used experimental animals, despite numerous studies reporting control IOP values.

IOP can be measured invasively and non-invasively. An invasive method, used only in experimental animals, is the cannulation of the anterior chamber. The most frequently used non-invasive methods are Tono-Pen, TonoVet, Goldmann applanation tonometry, Schiotz indentation tonometry, and pneumotonometry. Newer tonometers, such as TonoLab and iCare TonoVet, are specially designed for IOP measurement in animals, while some older tonometers require modification of IOP using conversion tables (11).

A preliminary analysis of IOP control values in human and veterinary ophthalmology textbooks and review papers suggested that control values varied in individual species as a mean value ±2 SD. However, despite the use of appro-
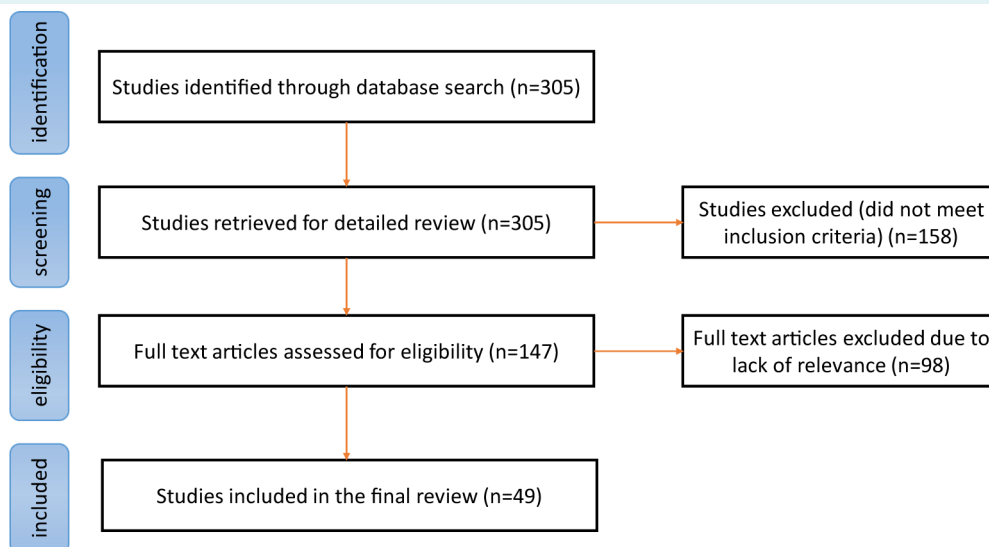

FIGURE 1. The PRISMA flowchart of the study selection process.

priate techniques within the same animal species, in some papers there was a large dispersion of the results. Namely, the values ranged from potentially hypotensive to hypertensive. Therefore, in this study, we more systematically reviewed the current literature covering IOP measurement in control settings. Additionally, we investigated the contributing and confounding factors that should be addressed when comparing the results. We also highlighted some clinical entities (correlation between intracranial pressure and IOP, spaceflight-associated neuro-ocular syndrome, normotensive glaucoma) whose research requires defined reference points in order to compare the interrelationship of pressures.

METHODS

The current review involved the available literature published up to December 1, 2023, with no date restrictions. PubMed, Embase, and Web of Science were searched by using the MeSH keywords: "intraocular pressure" and selected animal species (″cat,″ ″rabbit,″ ″monkey,″ ″mouse,″ ″rat,″ ″dog,″ ″donkey,″ ″horse″) or "humans." Inclusion criteria were IOP measurements in naive and untreated contralateral eyes, as in many studies the contralateral eye was considered an untreated internal control.

Publications were not included if they met any of the following criteria: treatment to the examined eye (vehicle or intravitreally treated eyes or sham controls) and genetically modified animals with genetically elevated intraocular pressure (ie, knockout animal strains, animals with congenital glaucoma) (Figure 1). We considered 305 articles, but due to a large number of publications, we included only those with an adequate number of examined eyes ("n") for a specific species (for large experimental animals minimally n ≥4 eyes, for small animals minimally n ≥8 eyes). Studies in which data were shown graphically were excluded. Quantitative data were presented as mean ± standard deviation (SD), unless stated otherwise.

RESULTS

Table 1 presents control IOP values in nine animal species (cat, rabbit, monkey, mouse, rat, dog, miniature donkey, horse), in which IOP was measured with various techniques (cannulation of the anterior chamber, Goldmann applanation tonometry, Tono-Pen, pneumotonometry, and TonoVet). Reference IOP values reported for the same animal species highly varied depending on the measurement method.

Control IOP in cats varied from 12.3 ± 4.0 mm Hg measured with Tono-Pen (12) to 25.0 ± 3.01 mm Hg measured with the cannulation of the anterior chamber (13), which represents a range from potentially hypotensive to potentially hypertensive values (14). Very wide ranges were also observed in other animal species. In the rabbit, the values ranged from 5.8 ± 0.6 with Tono-Pen (15) to 20.5 ± 0.2 mm Hg with a pneumotonometer (16). In the monkey, they ranged from 10.8 ± 1.7 mm Hg (17) with TonoPen (18) to 19.2 ± 4.2 mm Hg with the cannulation of the anterior chamber. In the rat, the range was from 8.6 ± 1.3 mm Hg with a pneumotonometer (19) to 29 ± 2 mm Hg with TonoPen (20).

Furthermore, control values varied significantly even when they were measured with the same method within the same species (Table 1). For example, control values of IOP in cats obtained with Tono-Pen differed from 12.3 ± 4.0 mm Hg (12) to 19.7 ± 5.6 mm Hg (21). In rats, the interval was even wider, ranging from 9.9 ± 1.2 mm Hg (22) to 29.0 ± 2.0 mm Hg (20). When measured with anterior chamber cannulation, considered one of the most precise methods, in rabbits the values spanned from 13.1 ± 1.3 mm Hg (23) to 18.1 ± 3.3 mm Hg (24), while in mice the range was even wider – from 7.7 ± 0.5 (25) to 18.9 ± 2.0 mm Hg (26).

In healthy humans, control IOP values varied less when non-invasive techniques such as the Goldmann applanation tonometer and Tono-Pen were used in a sitting position (Table 2). This observation can be attributed to technical improvements of newer portable tonometers or a lack of confounding factors often found in research on laboratory animals, which will be further discussed in the text.

DISCUSSION

This review showed that IOP in experimental animals depended on the measurement technique (Table 1). Control results widely varied with different methods but also when the same method was used (Table 1). The reported reference values also varied between and within species, which would not be expected according to anatomical characteristics and physiology within the same species.

This clearly suggests that IOP control values are influenced by various factors, such as applied anesthetics, circadian rhythm, body and head position, fixation, age, animal species and strains, as well as the measurement method. In humans, additional factors have been identified: exercise, respiration, fluid intake, heart rate, blood flow, and topical and systemic medications (8,10). Even though the fac-

tors that influence IOP values are discussed in the literature (27,28), all of these factors are usually not reported in detail when the methodology and conditions for IOP measurement are described.

These factors could lead to significant variations in the measured values, and their influence could plausibly explain the observed high variability of control IOP values within the same species measured with the same method (Table 1).

Anesthetics

In mice, anesthesia had an IOP-lowering effect that varied between strains, and also had a stronger effect on mice

TABLE 1. Control values of intraocular pressure (IOP) for different animal species (cat, rabbit, monkey, mouse, rat, dog, pig, miniature donkey, horse) obtained by different measurement methods (cannulation of anterior chamber, Goldmann applanation tonometry, Tono-Pen, pneumotonometry, TonoVet). The results are shown as mean value±standard deviation of intraocular pressure in mmHg, unless stated otherwise; n=number of eyes

Animal species	Cat	Rabbit	Monkey	Mouse	Rat	Dog	Pig	Miniature donkey	Horse
Cannulation of anterior chamber	23.4±2.8 (n=5)[65]¶ 25.0±3.0 (n=10)[13]*	13.1±1.3 (n=6)[23]† 14.1±0.5 (n=43)[70]† 15.0±6.3 (n=8)[71] 15.2±0.8 (n=14)[72]† 18.5±1.0 (n=12)[72]† 16.4±1.1 (n=25)[73]* 18.1±3.3 (n=6)[24]	19.2±0.9 (n=11)[79]‡	7.7±0.5 (n=8)[25]† 9.4±0.5 (n=11)[25]† 12.3±0.5 (n=10)[25]† 13.7±0.8 (n=9)[25]† 14.8±2.2 (n=173)[85] 17.4±0.6 (n=60)[86]† 17.8±0.4 (n=73)[87]† 18.9±2.0 (n=8)[26]	10.6±0.4 (n=11)[89]† 15.9±0.4 (n=20)[90]†		14.1±2.2 (n=7)[96]		
Goldmann		18.1±1.7 (n=4)[74]*	16.5±2.8 (n=5)[80] 16.8±0.5 (n=14)[81]†	15.2±0.6 (n=22)[88]†					
Tono-Pen	12.3±4.0 (n=1068)[12] 16.8±3.6 (n=50)[66] 19.7±5.6 (n=37)[21]	5.8±0.6 (n=14)[15] 9.7±1.8 (n=47)[75] 11.5±4.6 (n=50)[76] 11.8±3.7 (n=24)[107]	10.8±1.7 (n=41)[17] 15.9±2.8 (n=20)[82] 19.2±4.2 (n=24)[18]		9.9±1.2 (n=20)[22] 12.8±2.7 (n=120)[91] 20.8±0.2 (n=10)[92]† 29±2 (n=16)[20]	12.8±2.9 (n=50)[94] 14.0±3.1 (n=116)[95]	15.2±1.8 (n=5)[97]	20.7±5.1 (n=114)[99]	19.2±4.7 (n=72)[100]
Pneumo-tonometer	12.7±1.1 (n=12)[67]† 17.9±0.0 (n=24)[68]† 22.2±1.2 (n=12)[67]†	15.1±2.3 (n=15)[77] 18.7±0.4 (n=31)[78]† 20.5±0.2 (n=60)[16]†	14.9±2.1 (n=102)[83]§ 18.4±0.6 (n=12)[84]†		8.6±1.3 (n=61)[19] 11.5±0.7 (n=105)[93]		12.6±2.1 (n=6)[98]		
TonoVet	20.6±2.5 (n=40)[68] 18.9±3.9 (n=40)[106]	17.7±3.1 (n=50)[76] 11.4±3.9 (n=24)[107]				15.0±3.2 (n=50)[94] 15.3±2.7 (n=40)[106]		25.8±5.7 (n=114)[99]	25.7±5.8 (n=72)[100] 22.2±3.7 (n=40)[106]

*mean±standard error (SE).
†mean±standard error of the mean (SEM).
‡IOP value expressed in mmH_2O.
§mean IOP of the two eyes of each animal, one mean IOP value per animal
¶the superscript refers to the reference number.

with higher baseline IOP (29). Some types of general anesthesia increased IOP in mice; however, it stabilized 10-15 minutes after induction (30). IOP in laboratory mice was 2 mm Hg lower with intraperitoneal than with gas anesthesia (31). Similarly, in laboratory rabbits intravenous and intramuscular anesthetics decreased IOP (32). In children, a recent systematic review showed that most anesthetic agents significantly decreased IOP over time after the induction phase of general anesthesia (33).

Circadian rhythm

In rats, the baseline awake light and dark IOPs were 20.2 ± 2.1 and 30.4 ± 2.7 mm Hg, respectively (34). IOP varies to some extent due to pulsatility and circadian rhythm. The production of aqueous humor, for example, is higher during daytime and lower at night, possibly due to the diurnal activity of the sympathetic system (35,36). Aqueous humor flow rate and outflow facility are both reduced at night (36). Outflow facility is reduced at night, so that the mean IOP is usually 3 to 5 mm Hg higher at night than during the day (37). These results suggest that drainage reduction is more significant for IOP regulation than the rate of aqueous humor production. However, nocturnal changes in episcleral venous pressure and uveoscleral outflow probably contribute to lowering of IOP at night and maintaining its stability (38,39).

Newer research suggests that IOP follows a circadian rhythm synchronized with the suprachiasmatic nucleus, thought to be the circadian pacemaker. The suprachiasmatic nucleus resets peripheral clocks through sympathetic nerves or adrenal glucocorticoids. This suggests that IOP's circadian rhythm is governed by circadian time signals, sympathetic noradrenaline, and glucocorticoids, rather than the local clock (40).

Body and head position

It is theoretically possible that the results related to circadian rhythm are simultaneously related to the body position, especially in humans, who sleep at night (horizontal plane) and are active during the day (head-up position). When the head is in an upright position, IOP is lower, and when it is in a supine position, it tends to rise. In humans, IOP is higher by 3-4 mm Hg in a supine than in an upright position due to increased episcleral venous pressure, regardless of the time of day (3).

In a rabbit model, IOP increased by 2.3 ± 0.4 mm Hg from a supine position to head-down tilt (41). In cats, body position change from horizontal to upright decreased IOP from 18.5 ± 0.6 to 14.3 ± 0.1 cmH_2O (28). In mice, head-down position increased both IOP and episcleral venous pressure (42).

Higher IOP values in a supine position can be explained with higher episcleral venous pressure and slower venous outflow from the head and the eye, a Valsalva-like phenomenon (37). They can also be explained with a postural oscillation of cerebrospinal fluid pressure (Figure 2). Higher cerebrospinal fluid pressure increases resistance to venous drainage from the eye (28,43).

Measurement method

There are numerous studies that compare measurement techniques with the purpose of assessing the possibilities and usefulness of each. A suggestion is to set reference values of normal IOP for specific animal for each tonometer.

Goldmann applanation tonometer. Goldmann applanation tonometry (GAT) is considered to be a gold standard for IOP measurements in humans (44). However, the measurements are affected by the central corneal thickness, excessive or insufficient fluorescein in the tear film, high astigmatism, irregular or scarred cornea, squeezing of eyelids, wide pulse pressure, breath holding or other Valsalva maneuvers, pressure on the globe, excessive force applied to the restricted globe, vertical gaze, tight collars, repeated readings over a short period, and incorrect calibration.

TABLE 2. Reference values of intraocular pressure in humans obtained with Goldmann applanation tonometer and Tono-Pen. Results are shown as mean value ± standard deviation of intraocular pressure in mmHg

Goldmann applanation tonometer	Tono-Pen	Number of eyes	Study
12.22 ± 3.19	16.87 ± 4.42	259	Okudo et al (101)
16.10 ± 3.07	16.71 ± 3.09	255	Dervisogullari et al (102)
14.0 ± 2.7	17.3 ± 3.8	92	Osman et al (103)
15.8 ± 4.3	17.7 ± 1.5	274	Magela-Vieira et al (104)
15.5 ± 2.2	16.1 ± 3.0	200	Yilmaz et al (105)

In dogs, cats, and rabbits, the required diameter of the area of corneal applanation is 4 mm. In rats, the diameter is 2 mm, achieved with a tonometer tip with biprism angles of 48°, and the applied weight of 25 mg per Goldmann scale division (2 g full scale). In mice, the area of applanation is 1.5 mm in diameter, obtained with 36° biprism angles with the same applied weight as in rats (45-47).

Perkins tonometer. The Perkins tonometer can be used in either an upright or supine position and during anesthesia. Its disadvantages are low accuracy and the need for a more experienced examiner. In rats, the Perkins tonometer was calibrated against direct manometry, and normal values of IOP were detected (48), while in rabbits it underestimated IOP and had lower accuracy and higher variability (49).

Tono-Pen. Tono-Pen is a handheld electronic contact tonometer with the advantages of portability and reasonable accuracy in the eyes with distorted or edematous corneas. In monkeys, it provides reproducible measurements compared with the cannulation of the anterior chamber, and its measurement accuracy depends on the generation of an appropriate calibration curve (50). Tono-Pen was for a long time the preferred method in rats (51), but it is not much used anymore in rodents. It can be used to rapidly measure IOP in normal rabbit eyes, but it often underestimates pressures. However, a 95% confidence interval could be achieved with correction (52).

IOP values obtained by the Tono-Pen XL and Perkins tonometers in dogs and cats strongly correlated with those obtained by direct ocular manometry. No significant difference was found between the mean IOPs obtained with both tonometers in conscious animals, but the minimum and maximum values were on average 5-6 mm Hg higher with Tono-Pen XL. This justified the use of a table with normal values differentiated for each tonometer (53).

Pneumotonometer. A pneumotonometer´s accuracy is improved if an average of at least three readings is taken. Its advantage is measuring IOP on irregular corneal surfaces. In rabbits, it slightly overestimated IOP values (49).

Rebound tonometers. Rebound tonometry (eg, iCare, TonoVet, TonoLab) is commonly used in experiments on animals. In rabbits, TonoVet and Tono-Pen had excellent intrasession repeatability and inter-operator reproducibility but good intersession reproducibility. Both correlated well
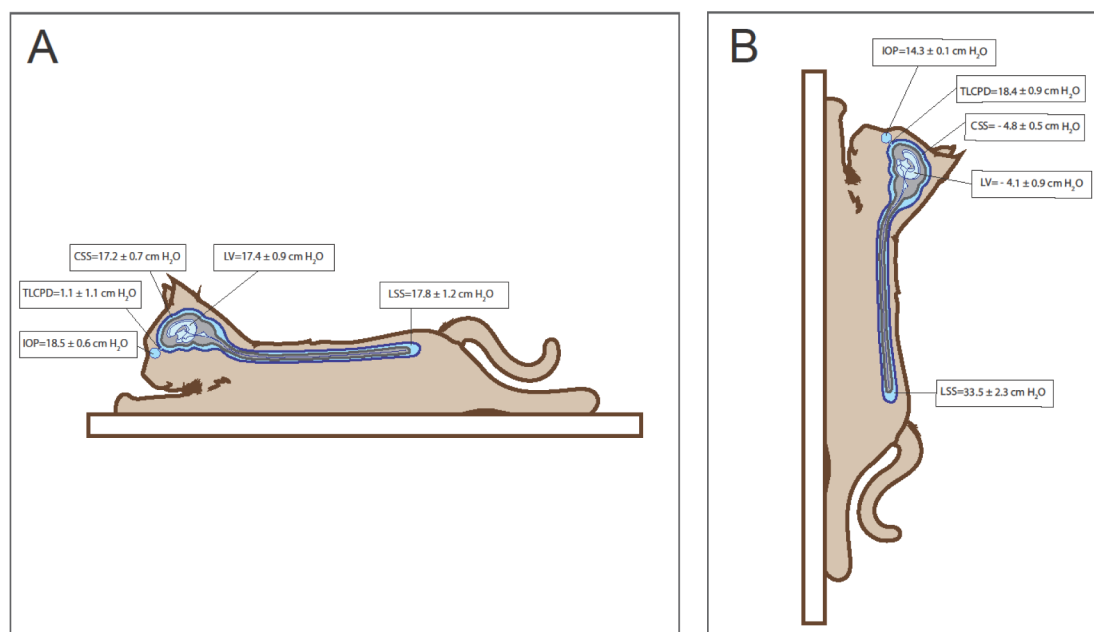

FIGURE 2. Intraocular pressure (IOP; cm H_2O) and cerebrospinal fluid pressure (cm H_2O) values in the cortical subarachnoid space (CSS), lateral ventricle (LV), and lumbar subarachnoid space (LSS) of the cat in the horizontal (**A**) and head-up position (**B**). Translamina cribrosa pressure difference (TLCPD) was also calculated. Pressure values are shown as mean ± standard error of the mean (data from 28).

with manometry, but also underestimated the manometric IOP (54). Tonovet is well tolerated and thus a valuable alternative to conventional tonometers for clinical use in dogs and cats. Compared with the Tonopen Vet applanation tonometer, the use of TonoVet resulted in slightly elevated IOP readings if the tonometer was directed onto the peripheral cornea (approximately 1.5 mm from the limbus) and if the measuring distance was reduced to <4 mm. IOP was substantially underestimated with an angular deviation of the measuring axis (55).

Additionally, IOP values obtained with TonoPen need to be calibrated for use in rodents as its raw readings are only accurate in humans (56). These potential sources of error should be considered to avoid false IOP values.

TonoLab is now being widely used in IOP measurements in laboratory mice and rats. Millar et al provided a good review offering additional information on noninvasive measurement of IOP in laboratory animals with possible future directions (57).

IOP measurements with different tonometers in humans show conflicting results. This could be a consequence of additional uncontrolled factors, such as ocular hypertension, age, central corneal thickness, and IOP level (58). A recent meta-analysis including 22 primary studies from 15 countries published from 2011-2021 showed that IOP values in healthy adult population were marginally higher when measured with Tono-Pen compared with GAT, but no significant difference was observed (59).

Invasive methods. Anterior chamber cannulation is one of the most precise methods for IOP measurement. A cannula is inserted into the anterior chamber and connected to a pressure transducer. Many of experimental measurements in mice, rats, rabbits, cats, dogs, pigs, and monkeys were obtained with this method. Although considered the most accurate, the method has high intra- and inter-animal variability. Furthermore, measuring IOP invasively is not practical, and comparison with non-invasive techniques is required. A reliable and reproducible method for measuring mouse IOP is the servo-null micropipette system (60).

Implications for research and clinical work

In our research, we encountered the problem of comparing IOP with intracranial pressure and other physiological parameters (28,43). To resolve methodologi-

cal issues arising from this problem, these measurements need to be done in the same hydrostatic and biophysical position.

Determining reference values can be of interest in research of spaceflight-associated neuro-ocular syndrome (61-63), intracranial hypertension or hypotension, and normal tension glaucoma with trans–lamina cribrosa pressure difference evaluation (64). Additionally, this raises the question regarding the referent IOP that should represent a target value for therapeutic measures.

Conclusion

IOP reference values in experimental animals are important for scientific research but remain incompletely documented and show wide variability. Since many factors may influence the reference values of IOP, in order to efficiently compare studies, researchers should thoroughly describe conditions under which IOP was measured (body and head position, fixation of the animal and the head with possible impact of fixator on orbital pressure, age, animal species and strains, circadian rhythm, respiration, fluid intake, heart rate, blood flow, anesthetics, topical and systemic medications, and method for IOP recording). This is important not only for better comparison of published work on IOP and glaucoma, but also in multidisciplinary research such as ocular and cerebrospinal fluid physiology and pathophysiology.

References

1   Janssen SF, Gorgels TG, Ten Brink JB, Jansonius NM, Bergen AA.
    Gene expression-based comparison of the human secretory

neuroepithelia of the brain choroid plexus and the ocular ciliary body: potential implications for glaucoma. Fluids Barriers CNS. 2014;11:2. Medline:24472183 doi:10.1186/2045-8118-11-2

2 Johnson M, McLaren JW, Overby DR. Unconventional aqueous humor outflow: A review. Exp Eye Res. 2017;158:94-111. Medline:26850315 doi:10.1016/j.exer.2016.01.017

3 Zhang LF, Hargens AR. Spaceflight-induced intracranial hypertension and visual impairment: pathophysiology and countermeasures. Physiol Rev. 2018;98:59-87. Medline:29167331 doi:10.1152/physrev.00017.2016

4 Da Silva F, Lira M. Intraocular pressure measurement: A review. Surv Ophthalmol. 2022;67:1319-31. Medline:35248558 doi:10.1016/j.survophthal.2022.03.001

5 Sherwood JM, Reina-Torres E, Bertrand JA, Rowe B, Overby DR. Measurement of Outflow Facility Using iPerfusion. PLoS One. 2016;11:e0150694. Medline:26949939 doi:10.1371/journal.pone.0150694

6 European Glaucoma Society Terminology and Guidelines for Glaucoma. 5th Edition. Br J Ophthalmol. 2021;105:1-169.

7 Leydhecker W, Akiyama K, Neumann HG. Der intraokulare Druck gesunder menschlicher Augen. Klin Monbl Augenheilkd Augenarztl Fortbild. 1958;133:662-70. Medline:13621563

8 Wang YX, Xu L, Wei WB, Jonas JB. Intraocular pressure and its normal range adjusted for ocular and systemic parameters. The Beijing Eye Study 2011. PLoS One. 2018;13:e0196926. Medline:29771944 doi:10.1371/journal.pone.0196926

9 Klein BE, Klein R, Linton KL. Intraocular pressure in an American community. The Beaver Dam Study. Invest Ophthalmol Vis Sci. 1992;33:2224-8. Medline:1607232

10 Chan MP, Grossi CM, Khawaja AP, Yip JL, Khaw KT, Patel PJ, et al. Associations with intraocular pressure in a large cohort: results from the UK Biobank. Ophthalmology. 2016;123:771-82. Medline:26795295 doi:10.1016/j.ophtha.2015.11.031

11 Passaglia CL, Guo X, Chen J, Troy JB. TonoPen XL calibration curves for cats, cows and sheep. Vet Ophthalmol. 2004;7:261-4. Medline:15200622 doi:10.1111/j.1463-5224.2004.04038.x

12 Kroll MM, Miller PE, Rodan I. Intraocular pressure measurements obtained as part of a comprehensive geriatric health examination from cats seven years of age or older. J Am Vet Med Assoc. 2001;219:1406-10. Medline:11724179 doi:10.2460/javma.2001.219.1406

13 Naito A, Izumi H, Karita K, Tamai M. Effects of a beta-adrenergic blocking agent timolol on intra ocular pressure responses induced by stimulation of cervical sympathetic nerve in the cat. Tohoku J Exp Med. 2001;195:219-25. Medline:11908823 doi:10.1620/tjem.195.219

14 McLellan GJ, Miller PE. Feline glaucoma–a comprehensive review. Vet Ophthalmol. 2011;1:15-29. Medline:21923820 doi:10.1111/j.1463-5224.2011.00912.x

15 Kobayashi A1. Yoshita T, Shirao Y. Accuracy of intraocular pressure

by Tono-Pen XL over amniotic membrane patching in rabbits. Am J Ophthalmol. 2003;135:536-7. Medline:12654373 doi:10.1016/S0002-9394(02)02051-2

16 Langham ME, Edwards N. A new procedure for the measurement of the outflow facility in conscious rabbits. Exp Eye Res. 1987;45:665-72. Medline:3428392 doi:10.1016/S0014-4835(87)80115-X

17 Fortune B, Burgoyne CF, Cull G, Reynaud J, Wang L. Onset and progression of peripapillary retinal nerve fiber layer (rnfl) retardance changes occur earlier than RNFL thickness changes in experimental glaucoma. Invest Ophthalmol Vis Sci. 2013;54:5653-61. Medline:23847322 doi:10.1167/iovs.13-12219

18 Oriá AP, Pinna MH, Almeida DS, da Silva RM, Pinheiro AC, Santana FO, et al. Conjunctival flora, Schirmer's tear test, intraocular pressure, and conjunctival cytology in neotropical primates from Salvador, Brazil. J Med Primatol. 2013;42:287-92. Medline:23879249 doi:10.1111/jmp.12059

19 Lam TT, Kwong JM, Tso MO. Early glial responses after acute elevated intraocular pressure in rats. Invest Ophthalmol Vis Sci. 2003;44:638-45. Medline:12556393 doi:10.1167/iovs.02-0255

20 Morrison JC, Nylander KB, Lauer AK, Cepurna WO, Johnson E. Glaucoma drops control intraocular pressure and protect optic nerves in a rat model of glaucoma. Invest Ophthalmol Vis Sci. 1998;39:526-31. Medline:9501862

21 Miller PE, Pickett JP, Majors LJ, Kurzman ID. Evaluation of two applanation tonometers in cats. Am J Vet Res. 1991;52:1917-21. Medline:1785739 doi:10.2460/ajvr.1991.52.11.1917

22 Yao B, Zhao Q, Yan H, Chen F, Liu L. Correlation between the reduced circulating endothelial progenitor cell counts and elevated intraocular pressure-induced retinal ganglion cell apoptosis. Curr Eye Res. 2015;40:516-25. Medline:25025752 doi:10.3109/02713683.2014.935442

23 Kawai SA. Measurement of intraocular pressure by both invasive and noninvasive techniques in rabbits exposed to head-down tilt. Jpn J Physiol. 1998;48:25-31. Medline:9538286 doi:10.2170/jjphysiol.48.25

24 Okuno T, Oku H, Sugiyama T, Yang Y, Ikeda T. Evidence that nitric oxide is involved in autoregulation in optic nerve head of rabbits. Invest Ophthalmol Vis Sci. 2002;43:784-9. Medline:11867599

25 John SW, Hagaman JR, MacTaggart TE, Peng L, Smithes O. Intraocular pressure in inbred mouse strains. Invest Ophthalmol Vis Sci. 1997;38:249-53. Medline:9008647

26 Aihara M, Lindsey JD, Weinreb RN. Ocular hypertension in mice with a targeted type I collagen mutation. Invest Ophthalmol Vis Sci. 2003;44:1581-5. Medline:12657595 doi:10.1167/iovs.02-0759

27 Nicou CM, Pillai A, Passaglia CL. Effects of acute stress, general anesthetics, tonometry, and temperature on intraocular pressure in rats. Exp Eye Res. 2021;210:108727. Medline:34390732 doi:10.1016/j.exer.2021.108727

28 Kuzman T, Jurjević I, Mandac I, Radoš M, Orešković D, Jednačak H,

et al. The effect of body position on intraocular and CSF pressures in the lateral ventricle, and in cortical and lumbar subarachnoid spaces in cats. Acta Neurochir Suppl (Wien). 2012;114:357-61. Medline:22327723 doi:10.1007/978-3-7091-0956-4_69

29 Boussommier-Calleja A, Overby DR. The influence of genetic background on conventional outflow facility in mice. Invest Ophthalmol Vis Sci. 2013;54:8251-8. Medline:24235015 doi:10.1167/iovs.13-13025

30 Qiu Y, Yang H, Lei B. Effects of three commonly used anesthetics on intraocular pressure in mouse. Curr Eye Res. 2014;39:365-9. Medline:24215504 doi:10.3109/02713683.2013.845224

31 Cone FE, Steinhart MR, Oglesby EN, Kalesnykas G, Pease ME, Quigley HA. The effects of anesthesia, mouse strain and age on intraocular pressure and an improved murine model of experimental glaucoma. Exp Eye Res. 2012;99:27-35. Medline:22554836 doi:10.1016/j.exer.2012.04.006

32 Holve DL, Gum GG, Pritt SL. Effect of sedation with xylazine and ketamine on intraocular pressure in New Zealand white rabbits. J Am Assoc Lab Anim Sci. 2013;52:488-90. Medline:23849448

33 Thanapaisal S, Oatts J, Zhao J, Perez CI, Yang Y, Porco TC, et al. Effect of general anaesthesia on intraocular pressure in paediatric patients: a systematic review. Eye (Lond). 2021;35:1205-12. Medline:32690926 doi:10.1038/s41433-020-1093-8

34 Kwong JM, Vo N, Quan A, Nam M, Kyung H, Yu F, et al. The dark phase intraocular pressure elevation and retinal ganglion cell degeneration in a rat model of experimental glaucoma. Exp Eye Res. 2013;112:21-8. Medline:23603611 doi:10.1016/j.exer.2013.04.008

35 Fan S, Hejkal JJ, Gulati V, Galata S, Camras CB, Toris CB. Aqueous humor dynamics during the day and night in volunteers with ocular hypertension. Arch Ophthalmol. 2011;129:1162-6. Medline:21911663 doi:10.1001/archophthalmol.2011.226

36 Liu H, Fan S, Gulati V, Camras LJ, Zhan G, Ghate D, et al. Aqueous humor dynamics during the day and night in healthy mature volunteers. Arch Ophthalmol. 2011;129:269-75. Medline:21402980 doi:10.1001/archophthalmol.2011.4

37 Kim YW, Park KH. Exogenous influences on intraocular pressure. Br J Ophthalmol. 2019;103:1209-16. Medline:30910873 doi:10.1136/bjophthalmol-2018-313381

38 Sit AJ, Nau CB, McLaren JW, Johnson DH, Hodge D. Circadian variation of aqueous dynamics in young healthy adults. Invest Ophthalmol Vis Sci. 2008;49:1473-9. Medline:18385065 doi:10.1167/iovs.07-1139

39 Nau CB, Malihi M, McLaren JW, Hodge DO, Sit AJ. Circadian variation of aqueous humor dynamics in older healthy adults. Invest Ophthalmol Vis Sci. 2013;54:7623-9. Medline:24243986

40 Ikegami K. Circadian rhythm of intraocular pressure. J Physiol Sci. 2024;74:14. Medline:38431563 doi:10.1186/s12576-024-00905-8

41 Lavery WJ, Kiel JW. Effects of head down tilt on episcleral venous pressure in a rabbit model. Exp Eye Res. 2013;111:88-94.

Medline:23567205 doi:10.1016/j.exer.2013.03.020

42 Aihara M, Lindsey JD, Weinreb RN. Episcleral venous pressure of mouse eye and effect of body position. Curr Eye Res. 2003;27:355-62. Medline:14704919 doi:10.1076/ceyr.27.6.355.18194

43 Klarica M, Kuzman T, Jurjević I, Radoš M, Tvrdeić A, Orešković D. The effect of body position on intraocular and intracranial pressure in rabbits. Acta Neurochir Suppl (Wien). 2016;122:279-82. Medline:27165921 doi:10.1007/978-3-319-22533-3_55

44 Bowling B. Kanski's Clinical Ophthalmology, A systemic approach. 8th edition. Sydney: Elsevier; 2016.

45 Wessels IF, Oh Y. Tonometer utilization, accuracy, and calibration under field conditions. Arch Ophthalmol. 1990;108:1709-12. Medline:2256841 doi:10.1001/archopht.1990.01070140063030

46 Cohan BE, Bohr DF. Measurement of intraocular pressure in awake mice. Invest Ophthalmol Vis Sci. 2001;42:2560-2. Medline:11581198

47 Cohan BE, Bohr DF. Goldmann applanation tonometry in the conscious rat. Invest Ophthalmol Vis Sci. 2001;42:340-2. Medline:11157864

48 Kurata K, Nishida E, Tsukuda R, Suzuki T, Sato S. Evaluation of Perkin's applanation tonometer and the normal range of intraocular pressure in anesthetized rats. J Toxicol Sci. 1996;21:249-52. Medline:8959649 doi:10.2131/jts.21.4_249

49 Abrams LS, Vitale S, Jampel HD. Comparison of three tonometers for measuring intraocular pressure in rabbits. Invest Ophthalmol Vis Sci. 1996;37:940-4. Medline:8603880

50 Peterson JA, Kiland JA, Croft MA, Kaufman PL. Intraocular pressure measurement in cynomolgus monkeys. Tono-Pen versus manometry. Invest Ophthalmol Vis Sci. 1996;37:1197-9. Medline:8631634

51 Mermoud A, Baerveldt G, Minckler DS, Lee MB, Rao NA. Intraocular pressure in Lewis rats. Invest Ophthalmol Vis Sci. 1994;35:2455-60. Medline:8163335

52 Mermoud A, Baerveldt G, Minckler DS, Lee MB, Rao NA. Measurement of rabbit intraocular pressure with the Tono-Pen. Ophthalmologica. 1995;209:275-7. Medline:8570152 doi:10.1159/000310630

53 Andrade SF, Palozzi RJ, Giuffrida R, de Campos RJ, Santos Gde C, Fukui RM. Comparison of intraocular pressure measurements between the Tono-Pen XL® and Perkins® applanation tonometers in dogs and cats. Vet Ophthalmol. 2012;15:14-20. Medline:22050624 doi:10.1111/j.1463-5224.2011.00926.x

54 Ma D, Chen CB, Liang J, Lu Z, Chen H, Zhang M. Repeatability, reproducibility and agreement of intraocular pressure measurement in rabbits by the TonoVet and Tono-Pen. Sci Rep. 2016;6:35187. Medline:27731381 doi:10.1038/srep35187

55 von Spiessen L, Karck J, Rohn K, Meyer-Lindenberg A. Clinical evaluation of the Tonovet® reboundtonometer in dogs and cats considering potential errors in handling. Tierarztl Prax Ausg K Kleintiere Heimtiere. 2013;41:213-20. Medline:23958704

56 Pang IH, Wang WH, Millar JC, Clark AF. Measurement of mouse

intraocular pressure with the Tono-Pen. Exp Eye Res. 2005;81:359-60. Medline:15979071 doi:10.1016/j.exer.2005.04.015

57 Millar JC, Pang IH. Non-continuous measurement of intraocular pressure in laboratory animals. Exp Eye Res. 2015;141:74-90. Medline:25933714 doi:10.1016/j.exer.2015.04.018

58 Kim NR, Kim CY, Kim H, Seong GJ, Lee ES. Comparison of goldmann applanation tonometer, noncontact tonometer, and TonoPen XL for intraocular pressure measurement in different types of glaucomatous, ocular hypertensive, and normal eyes. Curr Eye Res. 2011;36:295-300. Medline:21284505 doi:10.3109/02713683.2010.542865

59 Keller WJ. International comparisons of intraocular pressures, as measured by Tono-Pen and Goldmann applanation tonometry, in healthy adults: A meta-analysis. Medicine (Baltimore). 2023;102:e33078. Medline:36897721 doi:10.1097/MD.0000000000033078

60 Avila MY, Carré DA, Stone RA, Civan MM. Reliable measurement of mouse intraocular pressure by a servo-null micropipette system. Invest Ophthalmol Vis Sci. 2001;42:1841-6. Medline:11431452

61 Laurie SS, Lee SMC, Macias BR, Patel N, Stern C, Young M, et al. Optic disc edema and choroidal engorgement in astronauts during spaceflight and individuals exposed to bed rest. JAMA Ophthalmol. 2020;138:165-72. Medline:31876939 doi:10.1001/jamaophthalmol.2019.5261

62 Scott RA, Tarver WJ, Brunstetter TJ, Urquieta E. Optic nerve tortuosity on earth and in space. Aerosp Med Hum Perform. 2020;91:91-7. Medline:31980047 doi:10.3357/AMHP.5406.2020

63 Orešković D, Radoš M, Klarica M. A contribution to the understanding of ocular and cerebrospinal fluid dynamics in astronauts during long-lasting spaceflight. Croat Med J. 2021;62:420-1. Medline:34472745 doi:10.3325/cmj.2021.62.420

64 Lindén C, Qvarlander S, Jóhannesson G, Johansson E, Östlund F, Malm J, et al. Normal-tension glaucoma has normal intracranial pressure: a prospective study of intracranial pressure and intraocular pressure in different body positions. Ophthalmology. 2018;125:361-8. Medline:29096996 doi:10.1016/j.ophtha.2017.09.022

65 Zhao Q, Qian X, Li L, Sun W, Huang S, Liu Z. Effect of elevated intraocular pressure on the thickness changes of cat laminar and prelaminar tissue using optical coherence tomography. Biomed Mater Eng. 2014;24:2349-60. Medline:25226935 doi:10.3233/BME-141048

66 Andrade SF, Palozzi RJ, Giuffrida R, de Campos RJ, Santos Gde C, Fukui RM. Comparison of intraocular pressure measurements between the Tono-Pen XL® and Perkins® applanation tonometers in dogs and cats. Vet Ophthalmol. 2012;15:14-20. Medline:22050624 doi:10.1111/j.1463-5224.2011.00926.x

67 Wang YL, Toris CB, Zhan G, Yablonski ME. Effects of topical epinephrine on aqueous humor dynamics in the cat. Exp Eye Res. 1999;68:439-45. Medline:10192801 doi:10.1006/exer.1998.0623

68 Bhattacherjee P, Paterson CA, Spellman JM, Graff G, Yanni JM. Pharmacological validation of a feline model of steroid-induced ocular hypertension. Arch Ophthalmol. 1999;117:361-4. Medline:10088814 doi:10.1001/archopht.117.3.361

69 Faghihi H, Rajaei SM, Ostadhasan H, Alagha HE. Effect of topical 0.5% tetracaine hydrochloride on intraocular pressure in ophthalmologically normal cats. J Feline Med Surg. 2022;24:185-8. Medline:33908304 doi:10.1177/1098612X211005901

70 Lavery WJ, Kiel JW. Effects of head down tilt on episcleral venous pressure in a rabbit model. Exp Eye Res. 2013;111:88-94. Medline:23567205 doi:10.1016/j.exer.2013.03.020

71 Artru AA. Trabecular outflow facility and formation rate of aqueous humor during intravenous cocaine or lidocaine in rabbits. Anesth Analg. 1994;78:889-96. Medline:8160986 doi:10.1213/00000539-199405000-00010

72 Bogner B, Runge C, Strohmaier C, Trost A, Tockner B, Kiel JW, et al. The effect of vasopressin on ciliary blood flow and aqueous flow. Invest Ophthalmol Vis Sci. 2014;55:396-403. Medline:24327617 doi:10.1167/iovs.13-13286

73 Reitsamer HA, Kiel JW. A rabbit model to study orbital venous pressure, intraocular pressure, and ocular hemodynamics simultaneously. Invest Ophthalmol Vis Sci. 2002;43:3728-34. Medline:12454044

74 Jin J, Xu G, Yuan Z. Influence of the hypothalamic arcuate nucleus on intraocular pressure and the role of opioid peptides. PLoS One. 2014;9:e82315. Medline:24691128 doi:10.1371/journal.pone.0082315

75 Hazra S, Guha R, Jongkey G, Palui H, Mishra A, Vemuganti GK, et al. Modulation of matrix metalloproteinase activity by EDTA prevents posterior capsular opacification. Mol Vis. 2012;18:1701-11. Medline:22815623

76 Oliveira IV, Oliveira LVSX, Santos VMB, Souza JLT, Costa MLL, Borges PF, et al. Determination of intraocular pressure and Schirmer tear test and the comparison between the applanation tonometer (Tono-Pen AVIA®) and the rebound tonometer (TonoVet Plus®) in mini lionhead rabbits. Vet Ophthalmol. 2024;27:53-60. Medline:37747053 doi:10.1111/vop.13150

77 Lu DW, Chen YH, Chang CJ, Chiang CH, Yao HY. Nitric oxide levels in the aqueous humor vary in different ocular hypertension experimental models. Kaohsiung J Med Sci. 2014;30:593-8. Medline:25476096 doi:10.1016/j.kjms.2014.09.004

78 Impagnatiello F, Toris CB, Batugo M, Prasanna G, Borghi V, Bastia E, et al. Intraocular pressure–lowering activity of ncx 470, a novel nitric oxide–donating bimatoprost in preclinical models. Invest Ophthalmol Vis Sci. 2015;56:6558-64. Medline:26457541 doi:10.1167/iovs.15-17190

79 Mäepea O, Bill A. The pressures in the episcleral veins, Schlemm's canal and the trabecular meshwork in monkeys: effects of changes in intraocular pressure. Exp Eye Res. 1989;49:645-63. Medline:2806429 doi:10.1016/S0014-4835(89)80060-0

80   Yücel YH, Zhang Q, Weinreb RN, Kaufman PL, Gupta N. Atrophy of relay neurons in magno- and parvocellular layers in the lateral geniculate nucleus in experimental glaucoma. Invest Ophthalmol Vis Sci. 2001;42:3216-22. Medline:11726625

81   Lu W, Hu H, Sévigny J, Gabelt BT, Kaufman PL, Johnson EC, et al. Rat, mouse, and primate models of chronic glaucoma show sustained elevation of extracellular ATP and altered purinergic signaling in the posterior eye. Invest Ophthalmol Vis Sci. 2015;56:3075-83. Medline:26024091 doi:10.1167/iovs.14-15891

82   Kim J, Sapp HL Jr, Plummer CE, Brooks DE, Kim D, Kim MS. IOP change undergoing anesthesia in rhesus macaques (Macaca mulatta) with laser-induced ocular hypertension. J Vet Med Sci. 2012;74:1359-61. Medline:22673087 doi:10.1292/jvms.12-0059

83   Bito LZ, Merritt SQ, DeRousseau CJ. Intraocular pressure of rhesus monkey (Macaca mulatta). I. An initial survey of two free-breeding colonies. Invest Ophthalmol Vis Sci. 1979;18:785-93. Medline:110720

84   Akaishi T, Shimazaki A, Tonouchi A, Ueda K, Miyawaki N, Kawazu K. Benefits of tafluprost and timolol fixed-dose combination for the treatment of glaucoma are confirmed by studies on experimental animal models. J Ocul Pharmacol Ther. 2015;31:518-24. Medline:26325164 doi:10.1089/jop.2015.0031

85   Aihara M, Lindsey JD, Weinreb RN. Reduction of intraocular pressure in mouse eyes treated with latanoprost. Invest Ophthalmol Vis Sci. 2002;43:146-50. Medline:11773025

86   Avila MY, Stone RA, Civan MM. Knockout of A3 adenosine receptors reduces mouse intraocular pressure. Invest Ophthalmol Vis Sci. 2002;43:3021-6. Medline:12202525

87   Avila MY, Carré DA, Stone RA, Civan MM. Reliable measurement of mouse intraocular pressure by a servo-null micropipette system. Invest Ophthalmol Vis Sci. 2001;42:1841-6. Medline:11431452

88   Grozdanic S, Betts DM, Sakaguchi DS, Allbaugh RA, Kwon YH, Kardon RH. Laser-induced mouse model of chronic ocular hypertension. Invest Ophthalmol Vis Sci. 2003;44:4337-46. Medline:14507878 doi:10.1167/iovs.03-0015

89   Strohmaier CA, Reitsamer HA, Kiel JW. Episcleral venous pressure and iop responses to central electrical stimulation in the rat. Invest Ophthalmol Vis Sci. 2013;54:6860-6. Medline:24065806 doi:10.1167/iovs.13-12781

90   Funk R, Rohen JW, Skolasinska K. Intraocular pressure and systemic blood pressure after administration of vasoactive substances in hypertensive and normal rats. Graefes Arch Clin Exp Ophthalmol. 1985;223:145-9. Medline:3849458 doi:10.1007/BF02148890

91   Gui D, Li Y, Chen X, Gao D, Yang Y, Li X. HIF1 signaling pathway involving iNOS, COX2 and caspase 9 mediates the neuroprotection provided by erythropoietin in the retina of chronic ocular hypertension rats. Mol Med Rep. 2015;11:1490-6. Medline:25370745 doi:10.3892/mmr.2014.2859

92   Manuguerra-Gagné R, Boulos PR, Ammar A, Leblond FA, Krosl G, Pichette V, et al. Transplantation of mesenchymal stem cells promotes tissue regeneration in a glaucoma model through laser-induced paracrine factor secretion and progenitor cell recruitment. Stem Cells. 2013;31:1136-48. Medline:23495088 doi:10.1002/stem.1364

93   Shareef S, Sawada A, Neufeld AH. Isoforms of nitric oxide synthase in the optic nerves of rat eyes with chronic moderately elevated intraocular pressure. Invest Ophthalmol Vis Sci. 1999;40:2884-91. Medline:10549648

94   Ben-Shlomo G, Muirhead SF. Estimation of intraocular pressure in normal canine eyes utilizing the newly introduced TonoVet Plus and TonoPen Avia, and their comparison to the established TonoVet. Vet Ophthalmol. 2021;24:171-4. Medline:32154987 doi:10.1111/vop.12747

95   Diehl KA, Hofmeister EH, Keys DA, Kennedy CR. Single instead of triplicate intraocular pressure measurements in dogs do not substantially lower accuracy and precision but do slightly reduce statistical power. Am J Vet Res. 2022;83:349-55. Medline:35092667 doi:10.2460/ajvr.21.08.0114

96   Castejon H, Chiquet C, Savy O, Baguet JP, Khayi H, Tamisier R, et al. Effect of acute increase in blood pressure on intraocular pressure in pigs and humans. Invest Ophthalmol Vis Sci. 2010;51:1599-605. Medline:19850831 doi:10.1167/iovs.09-4215

97   Ruiz-Ederra J, García M, Hernández M, Urcola H, Hernández-Barbáchano E, Araiz J, et al. The pig eye as a novel model of glaucoma. Exp Eye Res. 2005;81:561-9. Medline:15949799 doi:10.1016/j.exer.2005.03.014

98   Ghate D, Kedar S, Havens S, Fan S, Thorell W, Nelson C, et al. The effects of acute intracranial pressure changes on the episcleral venous pressure, retinal vein diameter and intraocular pressure in a pig model. Curr Eye Res. 2021;46:524-31. Medline:32806985 doi:10.1080/02713683.2020.1805769

99   Hibbs CD, Barrett PM, Dees DD. Intraocular pressure reference intervals in eyes of clinically normal miniature donkeys (Equus africanus asinus). Vet Ophthalmol. 2019;22:24-30. Medline:29517162 doi:10.1111/vop.12561

100 Angeluci GC, Ricci CL, Passareli JVGC, Estanho GJG, Oliveira AS, Santos SGA, et al. Comparison of four tonometers in the measurement of intraocular pressure in healthy horses. Equine Vet J. 2023;55:1104-11. Medline:36537844 doi:10.1111/evj.13911

101 Okudo C, Babalola O, Abbiyesuku J. A comparative analysis of Goldmann applanation and Tonopen tonometers in adults attending a private eye clinic in Abuja, Nigeria. J Den Med Sci. 2021;20:32-6.

102 Dervisogullari M, Akarsu C, Ergin A. Comparison of the intraocular pressure measurements with the Tono-Pen and the Goldmann applanation tonometer and the effect of central corneal thickness on measurements. Ann Clin Anal Med. 2019;10:479-84.

103 Osman EA, Gikandi PW, Al-Jasser AA, Alotaibi M, Mousa A. Comparison of Goldmann Applanation, Noncontact Air Puff, and Tono-Pen XL Tonometry in normal controls versus glaucoma

patients at a University Hospital in Riyadh, Saudi Arabia. Middle East Afr J Ophthalmol. 2018;25:8-13. Medline:29899644 doi:10.4103/meajo.MEAJO_291_16

104 Magela-Vieira G, Carvalho-Sousa H, Pinto-Silva L. Comparison between rebound tonometer and Tono-Pen in relation to Goldmann applanation tonometry and the influence of central corneal thickness on these three methods. Rev Mex de Oftalmol. 2018;92:286-91.

105 Yilmaz I, Altan C, Aygit ED, Alagoz C, Baz O, Ahmet S, et al. Comparison of three methods of tonometry in normal subjects: Goldmann applanation tonometer, non-contact airpuff tonometer, and Tono-Pen XL. Clin Ophthalmol. 2014;8:1069-74. Medline:24944507 doi:10.2147/OPTH.S63915

106 Kovalcuka L, Mālniece A, Vanaga J. Comparison of Tonovet® and Tonovet plus® tonometers for measuring intraocular pressure in dogs, cats, horses, cattle, and sheep. Vet World. 2024;17:384-8. Medline:38595645 doi:10.14202/vetworld.2024.384-388

107 Bertens CJF, van Mechelen RJS, Berendschot TTJM, Gijs M, Wolters JEJ, Gorgels TGMF, et al. Repeatability, reproducibility, and agreement of three tonometers for measuring intraocular pressure in rabbits. Sci Rep. 2021;11:19217. Medline:34584185 doi:10.1038/s41598-021-98762-7