Objectives:
1) To provide an overview of the theoretical basis and history of tonometry
2) To evaluate and discuss the practical clinical application of tonometry in comparative ophthalmology

I. Introduction: Measurement of Intraocular Pressure
- In veterinary patients, the single most consistent feature of all glaucomas characterized to date is elevation in intraocular pressure (IOP).
- Intraocular pressures > 25mmHg in dogs and > 31mmHg in cats, or differences of more than a few mmHg between eyes should be considered suspicious.
- However, many factors can influence IOP measurements, including breed, age and gender, method of restraint, time of day, the technique of the “tonometrist” and the tonometer itself. Hence, it is very difficult to provide a precise “cut-off” point for determining normal versus abnormal IOP. For this reason, one should always interpret tonometry readings in light of other clinical findings. “High” IOP is a measurement (or rather an estimate), not a diagnosis.

- Direct measurement – manometry
  - The most accurate way to measure IOP
  - Invasive, thus not practical in a clinical setting
  - Restricted to a research setting
  - Used in the validation of accuracy and precision of indirect tonometry methods
- Indirect Measurement – tonometry
  - Two main forms that both represent contact tonometry:
    - Indentation tonometry
    - Applanation tonometry
  - Non-contact (air puff) tonometry

A detailed review of the history of tonometry is out-with the scope of this lecture and the list of references provided is neither intended to be exhaustive, nor exhausting. For a detailed review of the history of tonometry in humans see Kniestedt, et al.\textsuperscript{[1]} Chihara,\textsuperscript{[2]} considers theoretical challenges to accurate determination of IOP in humans.

All methods of tonometry are subject to the same basic tenets. Extraneous factors that influence IOP should be avoided / taken into consideration:
- Pressure exerted by the fingers of the examiner on the globe or eyelids will artificially raise IOP.\textsuperscript{[3]}
- Squeezing of the eyelids, eye movements and accommodation can falsely alter IOP
- Corneal / ocular pathology can affect IOP readings \textsuperscript{[4]}
- Firm restraint, particularly where pressure is exerted on the neck (jugular occlusion) and tight collars increase episcleral venous pressure and elevate IOP.\textsuperscript{[3, 5]}
- Posture / head position can influence IOP.\textsuperscript{[6, 7]}
- Drugs administered, including sedation, may affect IOP.\textsuperscript{[8, 9]} \textsuperscript{[10]}
- Repeated measurements over time (particularly where a weight is applied to the eye) will lower IOP by influencing pressure dependent aqueous outflow facility.
- Time of day influences IOP. \textsuperscript{[11]}
- All tonometers will show inter-operator variability to a greater or lesser extent.
- Different tonometers differ in their accuracy and precision. Use a consistent tonometer and specify what you’re using! \textsuperscript{[12]}
• Age has an effect on IOP that is species dependent; often immature animals have a lower IOP which then shows an increase with maturity.\textsuperscript{[13]} A decline in IOP is often noted in older dogs and cats.\textsuperscript{[14, 15]}
• IOP fluctuates with activity.\textsuperscript{[16]}
• When evaluating studies that claim to validate a tonometric method in a given species:
  o Consider whether values obtained are compared to manometry (the gold standard) or just another inherently inaccurate device…
  o Consider accuracy (which is reflected by the slope of the regression line, this should be as close to one as possible)
  o Consider reproducibility / consistency / variability (which is at least partly represented by the $r^2$ value, which should also be close to 1).
  o Any relative under- or over-estimation of IOP should preferably be linear and consistent over the range of IOPs that might be expected in clinical patients.
  o Are all of the data points presented, to give the reader a better sense of the performance of the instrument?
  o What is the magnitude of any departure from true IOP? 2mmHg may be of little clinical importance when distinguishing between a normal and glaucomatous subject, but may be of greater importance if the tonometer is to be used to detect a small change in IOP in a pharmacologic study. Read papers critically: there is a difference between clinical and statistical significance!\textsuperscript{[17]}

II. Contact tonometers
• **Indentation tonometers**
  o Digital or glass rod tonometry
    o the clinician determines the resistance by pushing on the eye alternately with their index fingers, or assesses the degree of indentation in response to pressure on the eye from a glass rod
    o doesn’t provide a numeric measurement
    o imprecise and highly subjective
  o Variable force tonometers
    o Determines the weight required to produce a given indentation
    o Less common type
  o Variable indentation tonometers
    o Measures the depth of indentation made by a given force
    o **Schiotz** tonometer\textsuperscript{[18-20]}
      i. introduced in 1905 and still in use today
      ii. most widely used of the many indentation tonometers developed
      iii. Theory: Based loosely on Maklakoff and Fick’s law:
      \[ W = P \times A \]
      Where $W$ = weight of plunger/lever/gram weight assembly, $A$ = area of indentation in mm$^2$, and $P$ = pressure.
      In effect, the lower the IOP, the deeper the indentation, and the higher the scale reading. Correction is made for corneal elasticity/ sclera rigidity based on assumptions of average sclera rigidity in the “Friedenwald Nomogram” conversion table for Schiotz scale readings.
      iv. Gravity provides a known force on a weighted metal plunger. The plunger moves freely within a a metal cylinder attached to a footplate that approximates the human corneal curvature. The top of the plunger pushes against a curved lever that is attached to a pointer that in turn indicates a reading on a curved scale. Each scale unit is equivalent to 0.05mm of indentation. The relationship between indentation and IOP is logarithmic, not linear, so that the low end of the scale (higher IOP values) is compressed.
      v. Practical use:
        i. a solid, steel test block is provided and should be used to zero the instrument prior to obtaining readings.
ii. Topical anesthesia is necessary
iii. The patient is positioned so that the corneal plane is horizontal. (This precludes its use in large animal species)
iv. The footplate assembly is placed on the cornea with the pointer/scale assembly directed vertically, perpendicular to the corneal assembly. The weight of the plunger assembly is 5.5g; addition of a further 2g (“7.5g” weight), 4.5g (10g weight) or 9.5g (15g weight) may be necessary if scale reading is below 5 (higher IOP). Scale readings below 3 do not provide valid IOP measurements.
v. Typically 2 or 3 consistent readings are obtained. If scale readings are inconsistent, further readings may be obtained using different weights and compared. However, prolonged contact and protracted, repeated measurements should be avoided
vi. A consistent conversion table must be used and specified. In general, the human conversion table that accompanies the instrument (Friedenwald 1955 table) is most widely used in veterinary medicine, despite the fact that there are several species-specific tables published in the veterinary literature.
vii. The plunger assembly should be disassembled, thoroughly cleaned (alcohol then distilled water rinse) and allowed to dry after use. Debris leading to friction on the assembly will result in highly inaccurate readings.
viii. Corneal drying should be avoided as it leads to errors in IOP measurement

vi. Corneal and sclera rigidity impact IOP measurement using the Schiötz tonometer
   i. Increased ocular rigidity will lead to falsely high IOP (less indentation)
   ii. Eyes with low rigidity (e.g. young eyes) will lead to falsely low IOP (greater indentation)
   iii. Ocular rigidity varies by species: macaque>human>pig>cat>dog. Rabbit ocular rigidity is highly variable.
   iv. Edematous cornea is less flexible (leading to lower scale readings, i.e. overestimation of IOP)
   v. Steeper corneal curvature (lower radius of curvature) can lead to falsely high IOP readings.
   vi. Vertical placement of the plunger on the eye is critical!

- **Applanation tonometers**
  - Either measure the area of the cornea flattened by a known weight or measure the force required to flatten a fixed area of the cornea.
  - **Variable Area Tonometers**
    - **Maklakov type**
      - First introduced in 1885 in Russia.
      - A dumb-bell shaped plunger of a known weight is coated with a dye suspension and allowed to rest against the eye with the patient in a supine position. The tonometer end is then pressed onto special paper and a circle of dye produced, the diameter of which corresponds to the intraocular pressure. A scale, based on the plunger weight divided by the area of contact, is placed over the ring converting it into an IOP value. Tonometers of various weights allow an estimate of ocular rigidity and revised
calibration tables have been produced to account for the influence of ocular rigidity.

- The **Tonomat** is a mid-20th century derivative of the Maklakov Tonometer. The cornea is applanated using a standard weighted probe that has a disposable plastic end plate. An impression is made from the ring which is then measured with a built in scale.
- This type of tonometer was not widely adopted for use in veterinary patients and few have been evaluated.

- **Variable force, fixed area tonometers**
  - **Theory:** These devices are based on the **Imbert-Fick law**:
    \[ F = PA \]
    Where \( F \) is the force required to flatten a circular area \( A \) of the surface of a spherical container which has a relative internal pressure \( P \).
    Assumptions - object is spherical, dry, perfectly flexible, infinitely thin and the container wall contributes nothing to the force equation. Clearly, modifications to this law are necessary as the eye is neither perfectly spherical, dry, perfectly spherical nor infinitely thin.\[21\]
  - Fortunately, the tear film surface tension augments the force applied by the tonometer to the cornea, balancing the resistance to deformation of the cornea, which has some thickness.

- **Goldmann** (table mounted) and **Perkins** (portable hand-held) tonometers
  - **The Goldmann tonometer** remains the “Gold standard” for physician ophthalmologists but underestimates IOP in dogs and cats.
  - The **Perkins tonometer** is less accurate but has the advantage of portability and can be used in the supine position.
  - Both provide an optical means of determining corneal applanation, using a plastic probe with a doubling prism that creates two offset hemi-circles that are viewed through oculars and brought into alignment by the operator.
  - **Practical use:**
    - **i.** Topical anesthetic is applied in conjunction with fluorescein staining of the tear film.
    - **ii.** A cobalt blue filter is used to produce a blue light, and the tonometer prism is advanced until close to the cornea, then observed through the ocular(s).
    - **iii.** When the inner edges of the two hemi-circles are aligned (by turning the force knob) and in contact with each other, a circle of cornea 3.06mm in diameter is flattened (displacing ~0.5µl of aqueous humor), and each 1gm of force corresponds to 10mmHg IOP, assuming an average corneal thickness.
    - **iv.** A thicker cornea requires more force, a thinner cornea requires less force, to flatten the cornea, yielding, respectively, artificially high or low estimates of IOP. However, each increase in corneal thickness of 10µm leads to about 0.2mmHg increase in IOP with the Goldmann tonometer in normal human eyes. Various correction formulas try to adjust for that, but it is clear that other biomechanical properties of the cornea affect IOP measurement (as discussed later).
    - **v.** Corneas that are scarred or have epithelial edema may actually lead to underestimation of IOP.\[22\] Increase in corneal stiffness leads to increase in Goldmann (and Tono-Pen) readings in dogs.\[23\] Finding the end-point in subjects with irregular corneas is very difficult.
While the Goldmann tonometer has not been widely used or validated in domestic animals due to the constraints of using table-mounted equipment, the Perkins tonometer has been validated in a number of animal species. While less accurate than some other means of measuring IOP, the relatively low cost and portability of the Perkins tonometer, has made it a valid option in some settings including evaluation of ruminant experimental glaucoma models. However, reliance on a clear, regular cornea and its maximal scale reading of 5 (equating to a maximal IOP measurement of about 50mmHg) limit its utility in clinical veterinary practice.

Mackay-Marg & Tono-Pen (Reichert) 
- These electronic, variable force applanation tonometers work on the same basic premise as other applanation tonometers – determining the force required to flatten a given area of the cornea. However, the applanation “end-point” is detected electromechanically, rather than optically.
- Theory: In both tonometers, a small central plunger (1-1.5mm in diameter) protrudes very slightly beyond a flat, circular footplate. In both instances displacement of the central plunger is detected by a transducer, which converts the displacement into an electrical signal. The Mackay-Marg Tonometer records this on a paper chart, from which the operator calculates IOP (see below). In contrast, a microprocessor within the Tono-Pen automatically calculates an average IOP and provides a digital readout on an LCD display. For several decades, this tonometer type has been the most widely used in veterinary ophthalmology. The Mackay-Marg has now been largely superceded by the Tono-Pen Vet / Tono-Pen XL / Tono-Pen Vet.
- Not all pen type applanation tonometers are created equal! The central plunger of the Mackay-Marg probe tip is 1.5mm in diameter as is that of the original Tono-Pen. The probe tip of the Tono-Pen XL, Tono-Pen Vet and Tono-Pen Avia has been reduced to 1.02mm in diameter, which may have contributed to reduced accuracy of the latter versions relative to the original Tono-Pen and Mackay-Marg tonometers. The AccuPen (Accutome) has not yet been calibrated in veterinary species and it appears that it is not interchangeable with the Tono-Pen.

Practical use:
- i. Prior to first use of the day, both tonometers require calibration by means of gravity (pointing the probe tip down and then up). Unfortunately, for the Tono-Pen there is no easy way to verify that the internal calibration process is correct (this needs to be done by the manufacturers).
- ii. Topical anesthetic is applied prior to use of these tonometers (IOP measurements are generally about 2mmHg higher if no anesthetic is applied).
- iii. A disposable, sanitized latex tip cover is placed over the probe.
- iv. The tonometer tip is gently touched against the cornea, with the probe directed perpendicular to the corneal surface.
- v. For the Mackay-Marg tonometer, stages of applanation are reflected in the shape of the tracing.
1. As the central plunger contacts the cornea, IOP and corneal elasticity push it back. During this phase, a steeply rising trace is recorded.

2. When the plunger no longer protrudes (i.e. the surrounding footplate contacts and applanates the cornea) the force is taken off the plunger, resulting in a slight “dip” in the trace.

3. As the plunger and footplate continue to be pressed farther into the cornea, slight indentation occurs, resulting in IOP elevation. A further rise in the trace is then observed. Note that there is no alteration of IOP until this after this “shoulder” is reached – IOP is calculated from baseline to the “dip”.

4. The “dip” tends to be more of a plateau than a distinct trough in eyes with lower ocular rigidity (e.g. dog and cat, vs horse and human)

vi. For the Tono-Pen, Each measurement requires several applanations.

1. An audible “click” is heard whenever an acceptable applanation is achieved.

2. The internal microprocessor monitors the data and automatically calculates an average IOP from several (3-6) acceptable readings and provides a digital readout on an LCD display, alerting the user with an audible “beep”. The device also provides an estimate of the variability between readings, with standard deviations indicated ranging from 5-20%. A standard deviation of ≤5% is preferred and only readings with ≤10% deviation should be considered acceptable.

vii. The IOP measurement range for all Tono-Pens is 5-80mmHg, with the exception of the Tono-Pen Avia (for which the measurement range is listed as 5-55mmHg). The Tono-Pen Avia, which has not been validated in animal subjects, is therefore less well suited to detect the wide range of IOPs encountered in veterinary patients. The AccuPen (another recently introduced applanation tonometer) has a measurement range of 5-60mmHg.

- The Mackay-Marg is highly accurate in dogs and cats, only slightly underestimating IOP.
- Tono-Pen is accurate over the normal physiologic range of IOP in dogs but is less accurate at high IOP (where it significantly underestimates the actual value) and at low IOP (where it tends to overestimate the actual value).[45] It can be difficult to obtain consistent readings in very soft eyes, and it is of limited use when IOPs are below 5mmHg. There is a very significant, systematic underestimation of IOP by the Tono-Pen XL in cats.[33, 34, 46]
- Measurement of IOP through a therapeutic soft contact lens using applanation tonometry (Mackay-Marg or Tono-Pen) had little effect on IOP readings in dogs,[47, 48] and accuracy of these electronic tonometers appears to be less affected by corneal disease, including irregularity and scarring, than other tonometer types.[49]
• Unlike indentation tonometry, underestimation of IOP is considered unlikely. Thus, it is suggested that the lowest reliable reading is recorded.
• Viscosity of the tear film, particularly after application of methylcellulose e.g. for gonioscopy, can have a significant impact on IOP measurement, increasing IOP readings by more than 25%, with this technique. This issue can be overcome by thorough rinsing.
• Off-center application has not been shown to significantly affect IOP measurement by Tono-Pen in humans, allowing focal corneal lesions to be avoided.

  o **Pneumotonometers**
    • The same basic principle is applied as for Mackay-Marg and Tono-Pen tonometers, except that a column of air replaces the central plunger as the central sensing device.
    • Contact with the eye is achieved by a silastic membrane (this should not be confused with an air-puff tonometer that doesn’t make contact with the ocular surface).
    • These tonometers have not found favor in veterinary medicine, particularly as some require prolonged contact with the eye (e.g. 5 secs)

• **Rebound tonometers**[^50]
  o Also known as induction-impact tonometers
  o A disposable light-weight, magnetized metal probe with a plastic covered tip is propelled towards the cornea
  o The pin must be directed horizontally (<25° from the horizontal axis) from 4-8mm away from the axial cornea.
  o The solenoid detects the rebound velocity (deceleration) following brief contact with the cornea
  o The probe motion characteristics relate to globe “hardness” (as the probe will rebound from a soft eye less quickly than from a hard eye) and these characteristics have been calibrated to allow species-specific IOP measurements.
  o The **TonoVet tonometer** has been calibrated to measure IOP in cats and dogs (=‘d’); in horses (=“h”) and may be utilized in other species including rabbits[^51]—typically on the ‘d’ setting (note that setting “other =p” is actually NOT the setting that should be used for ‘all other species’!).[^5, 46, 52, 53]
  o The **TonoLab tonometer** utilizes the same principles to measure IOP in laboratory rodents.[^54-56]
  o The **I-Care tonometer** is calibrated for use in humans (as is the recently introduced “RTONE” designed for self-tonometry in human patients)
  o 6 consecutive readings are obtained and the average displayed. The display also indicates the species calibration used e.g. “d”, and indicates the degree of variance between readings by either a steady display or blinking display with a bar at the bottom (acceptable) or blinking display with a bar in the middle or at the top (unacceptable variance).
  o The handle position can be rotated without impacting readings, so long as the probe direction remains horizontal and distance to cornea is consistent[^13]
  o The device will detect problems with probe movement (e.g. if bent or dirty) or misalignment and discard these individual measurements.
  o Up to 10 of the previous averaged IOP measurements are automatically stored and can be reviewed.
  o Although the device has been shown to have good accuracy and precision in a range of species, there is greater variability than with most applanation tonometers
  o Measurement accuracy is impacted by viscosity of the tear film, and is likely impacted by corneal thickness in edematous corneas.[^22] Conversely, readings could
be reduced in thinner corneas. Values show increase in variability when measurements are obtained through a contact lens with this tonometer type.

II. Non-Contact tonometry-
- The air puff tonometer is still widely used as a screening tool in human optometry patients, as it does not require technical expertise to perform.
  - Essentially, the technique is a form of applanation tonometry that utilizes a puff of air to “touch” and applanate the cornea, resulting in increased reflection of light from the flattened area.
  - It is less accurate than the Goldmann applanation tonometer (discussed previously) and is reliable only within the normal range of IOP.
  - Considerable patient co-operation and fixation is required to avoid fluctuations in IOP that might significantly affect the validity of IOP estimates.
  - These devices are typically large and expensive and require frequent calibration and have not been widely adopted in comparative ophthalmology.

III. Other forms of tonometry
- Dynamic contour tonometry
  - DCT represents a novel technology that non-invasively measures IOP without being affected by the structural characteristics of the cornea and sclera.
  - The device is also capable of measuring ocular pulsatility, which is considered an indirect indicator of choroidal vascular perfusion.
  - A piezo-resistive pressure sensor rapidly obtains multiple pressure readings without indenting or deforming the cornea. The contour of the surrounding curved footplate has been designed to closely resemble the curvature of the human cornea.
  - This “human specific” design, combined with duration of recording of 5 secs and the requirement to mount the tonometer on a table-mounted slit-lamp, likely means that the instrument will be of limited applications in the clinical management of glaucoma in veterinary patients.

- Ocular response analyzer (ORA)
  - The influence of central corneal thickness (CCT) on many forms of tonometry as well as the potentially confounding effects of other corneal biomechanical properties (e.g. “elasticity”) on IOP measurement have long been recognized.
  - Until recently, only CCT could be quantified.
  - The Reichert ORA is a type of non-contact applanation tonometer based on an air-puff and electro-optical mechanism.
  - A precisely metered, collimated air pulse applanates the cornea and then shuts off. The cornea returns to its normal shape, first passing through another applanated state (similar to the process that occurs during Mackay-Marg tonometry). Damping of the applanation events by the cornea’s viscoelastic properties results in a lag in applanation events, resulting in two different pressure values. The difference between “applanation pressure 1” (corresponding to the time of “in” signal peak), and the lower “applanation pressure 2” (corresponding to the “out” signal peak) represents corneal hysteresis.
  - By compensating for corneal biomechanical properties, highly reproducible IOP measurements can be obtained.

- “Through the lid” tonometry
  - These tonometers are intended to allow “at home” monitoring of IOP by human glaucoma patients. However, their accuracy and reproducibility are questionable.
  - The Proview eye pressure monitor is a spring compression device calibrated, originally, in millimeters of mercury, against a Goldmann tonometer. It consists of a probe with a flat applicator the same diameter as the Goldmann tonometer.
    - The Proview uses a psychophysical test based on the entoptic phenomenon of pressure phosphenes, a sensation of light elicited by non-photic stimuli, to evaluate IOP.
The basis of its operation is thought to (loosely) follow the Imbert-Fick law: the perception of a phosphene occurs when the retina is deformed, which occurs with the application of a force over a given area, which can then be related to pressure. The assumption is that phosphene generation correlates with IOP: the threshold pressure for creating a phosphene spot should provide an indication of IOP.

Accuracy and reproducibility is very dependent on positioning.

If a patient continues to apply a force after the phosphene is observed, the tonometer displays the maximum pressure applied, not the pressure at which the phosphene was generated.

**Diaton tonometer** also measures IOP through the eyelid.

- The measurement principle is based on the acceleration of a free falling rod with a known weight and its interaction with the elastic ocular surface through the eyelid.
- This tonometer tends to underestimate IOP.

### Continuous IOP monitoring by telemetry:

- has been attempted in a range of species, including dogs, cats and rabbits.
- Pressure sensing devices have included contact lens mounted devices, scleral implants and intraocular devices inserted into the anterior chamber or as intraocular lenses.
- Unfortunately, thus far these have generally been disappointing and have only worked in the short term and further refinement is required.
- The SENSIMED “Triggerfish” (Lausanne, CH) soft contact lens continuously monitors changes in corneal curvature via a micro-strain gauge has demonstrated accentuated nocturnal fluctuation in IOP in human glaucoma patients. Complex, surgically-implanted transducers have been used to demonstrate the dramatic extent of continuous fluctuation in IOP in non-human primates by telemetry. However, no clinically applicable, cost-effective options are currently commercially available for use in veterinary patients.

### IV. Tonography:

Involves continuous tonometry over 2-4 minutes, to provide an estimation of the facility of aqueous humor outflow (C) from the anterior chamber via the trabecular meshwork. The force applied by the tonometer increases aqueous outflow, and the resultant decline in IOP over time is recorded.

#### Theory: Assumptions:

- That flow of aqueous humor is constant at all times
- That the rate of aqueous humor formation is not affected by tonography
- The rise in aqueous outflow facility is constant during tonography
- There are no changes in uveal tract blood volume
- The eye is in a steady state
- The facility for aqueous outflow can be calculated based on simplified formula and standardized tables applied:

\[ C = \frac{V_c}{T (P_{av} - P_o)} \]

- Where \( C \) = the coefficient of aqueous outflow facility
- \( V_c \) = change of ocular volume
- \( T \) = time
- \( P_{av} \) = Average IOP
- \( P_o \) = IOP before placement of tonometer probe

#### Practical Application:

- Heavy sedation or general anesthesia is required in animals to ensure that the eye is immobilized throughout the procedure. Care is required to ensure that the sedation protocol chosen does not have a significant impact on ocular perfusion and IOP.
- Either a Schiotz indentation tonograph (which is rather cumbersome and challenging to use) or Pneumotonograph applanation tonometer may be used.
- Topical anesthetic is applied and, if necessary, palpebral nerve blocks are performed to prevent blinking.
The tonometer is applied for 2-4 minutes continuously. Both the eye and the tonometer must remain steady during the procedure.

While outflow facility has been shown to be reduced in dogs and humans with glaucoma, there is no clear distinction between the glaucomatous and normal population that can be made based on tonographic outflow facility alone.

The real value of the technique is in examining response to IOP lowering drugs.

- Other techniques for examining aqueous humor dynamics:
  - Two-level constant pressure perfusion
  - Fluorophotometry

REFERENCES:
TWENTY THORNY QUESTIONS IN CLINICAL TONOMETRY

1) What does a tonometer measure?

2) What is the IOP cut-off point for differentiating glaucomatous from non-glaucomatous dogs with the TonoVet?

3) I’m feeling lucky! My Tono-Pen calibrates “Good” this morning – does this mean that it will accurately measure IOP?

4) I get a reading of 52mmHg in a Cocker spaniel. Does this dog have glaucoma?

5) I get a reading of 7mmHg in a Cocker spaniel. Can I rule out glaucoma? Or does this mean it must have uveitis?

6) I don’t get it! What’s the difference between an air puff tonometer and pneumotonometer?

7) The Tono-Pen displays individual readings of 3, 18, 16 and 17mmHg but then displays a final reading of 17mmHg with <5% deviation. Is it working properly?

8) With my Tono-Pen I get average readings of 26, 23 and 18mmHg each with 5% deviation, is one reading more accurate than the other? Should I average the 3 readings to increase accuracy?

9) In an equine patient, I get averaged readings of 48, 32, 33, and 26 mmHg, each with 10% standard deviation. Is there something wrong with the Tono-Pen? What could be causing these widely differing readings?

10) I forgot to use proparacaine before obtaining IOP readings with the Tono-Pen (and my boss told me not to bother). How will this affect the IOP?

11) Should I use the Tono-Pen or TonoVet to check for ocular hypertension 2 hours after phacoemulsification surgery?

12) My resident-mate tends to get IOP measurements that are 2-3 mmHg higher than mine. Which one of us is right?

13) A cat with conjunctivitis has an IOP reading of 27mmHg in the affected eye. Does this cat have glaucoma?

14) Another cat has chronic severe stromal keratitis related to FHV-1 infection. It also has chronic uveitis and secondary glaucoma is a concern. Should I choose the Schiotz, Tono-Pen XL or TonoVet tonometer to measure IOP?

15) I’m worried about glaucoma in a dog with a corneal erosion after retinal re-attachment surgery yesterday. I have already placed a therapeutic soft contact lens. Do I have to remove the contact lens to measure IOP with a TonoVet or Tono-Pen Vet?

16) A very diligent general practitioner measures IOP with his Schiotz in a 7 year old Shih Tzu during a routine physical prior to vaccination. The IOP is 35mmHg so he applies a drop of pilocarpine and sends the dog to you immediately. Your Tono-Pen IOP measurement is 16mmHg and you find only mild goniodysgenesis on gonioscopy and he has a smallish pupil but otherwise the ophthalmic exam is pretty normal. What’s going on?

17) You are feeling a bit nervous about the above case so you repeat tonometry before sending the dog home. This time the IOP is 22mmHg! Why did the IOP go up?!

18) Which tonometer should I use to measure IOP in mice?
19) Which tonometer should I use to measure IOP in cats?

20) I’m monitoring IOP in a dog that I am treating for glaucoma. At the last visit IOP was 14mmHg, today it is 18mmHg – is IOP less well controlled??

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44. Kato, K., Comparison of two handheld applanation tonometers and the association of central corneal thickness, age, and intraocular pressure in normal and diseased canine eyes. Veterinary Ophthalmology, 2014: p. n/a-n/a.


