

Urgency, Emergency, or ‘Prefergency’ The Basics of Clinically Relevant Ophthalmology

April 28, 2019

CVMA – SBCV Spring Seminar

This four-hour seminar will be broken up in to three parts. Part 1 will briefly review the pupillary light reflex. Part 2 will briefly review tonometry, and Part 3 will be broken into several case-based examples of how the PLR, tonometry can help to best manage your cases in your own practice.

The Pupillary Light Reflex

The pupillary light reflex (PLR) is a grossly underutilized tool that can be performed on every patient with minimal equipment or time. Using only a bright focal light source (eg pen light) and a dim room, stimulation of the retina with light begins a circuit of electric synapses that when intact, manifests as pupil constriction of both the stimulated eye and the fellow eye. Failure to constrict the pupil of either eye indicates a break in an otherwise intact neurologic circuit. When combined with vision reflex and response testing, a defect in the unobservable electrical circuit made up of cranial nerves and brain can be localized.

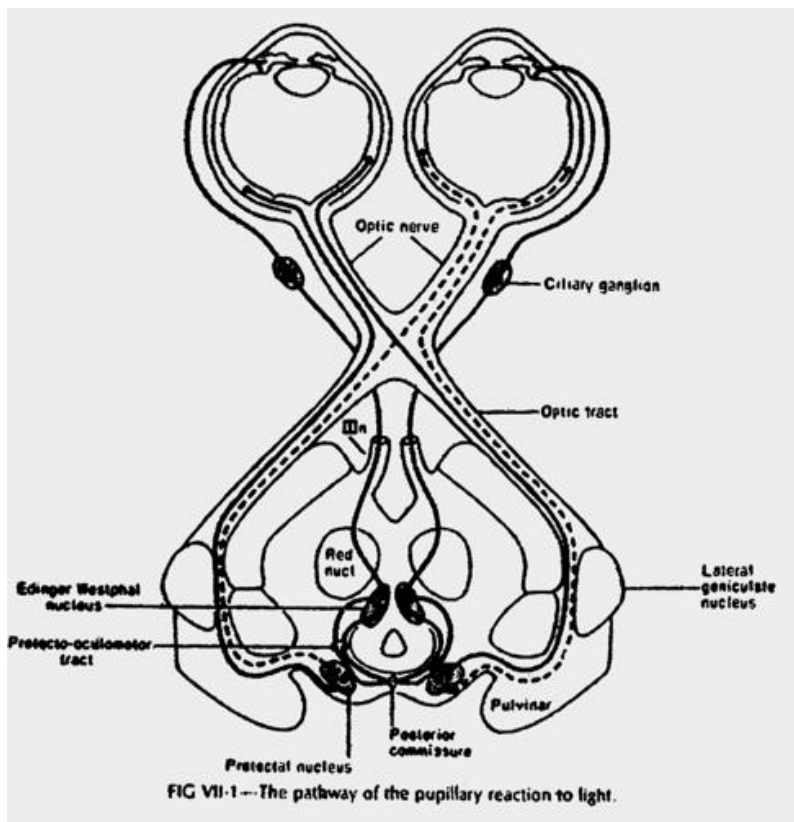


Fig 1. Diagram showing the intracranial pathway of the PLR is likely a shuddering memory from veterinary school. The drawings were always complicated, easily confused, and quickly forgotten. Happily, the pupillary light reflex is really quite simple and will be summarized below.

Specific cases will be presented to help refine the importance of the PLR in every case being evaluated.

There are two main parts of the PLR: the afferent and efferent pathways. Each pathway can be divided into four parts with a single deviation point between the two. The deviation point splits the fibers into those that will complete the PLR (~ 20%) or those that will carry on to the visual cortex (~ 80%). The fibers that carry on to the visual cortex are not considered part of the PLR. Each step starts and ends with an important nucleus, chiasma, or ganglion.

- Nuclei:** Pretectal Nucleus (PTN) – two per brain hemisphere. Located in the transition zone between the diencephalon and midbrain.
 Accessory Oculomotor Nucleus (AOMN) (previously known as the Edinger Westphal Nucleus). Two per brain hemisphere. Located in the midbrain
 Lateral Geniculate Nucleus (LGN) located in the thalamus. Two per brain hemisphere. The LGN is not technically part of the PLR but is an important destination for some nerve fibers that deviate from those that carry on completing the PLR.
- Chiasma:** The afferent optic chiasm (OC) located at the base of the hypothalamus and surrounded by the carotid artery and basilar artery, and the efferent posterior commissure chiasm located in the midbrain. The percentage of fibers that cross over at each chiasma is equal. Unilateral afferent stimulation results in a bilateral efferent effect...the basis for the consensual PLR.
- Ganglia:** The Ciliary Ganglion (CG) are located in the left and right posterior orbit.

The two parts of the PLR.

1. Afferent Pathway (eye to brain)

1. **PHOTORECEPTORS:** the PLR begins when the retina is stimulated by light. Retinal stimulation with light energy, under the influence of rhodopsin, is transduced to electrical energy¹ and passed to the retinal ganglion cell axons by way of the bipolar cells.

The arrangement of the ganglion cell axons within the ON is not random. Instead the fibers are arranged in a retinotopic manner, meaning that the precise spatial arrangement of the retina is maintained within the nerve. Fibers from the superior retina form the superior half of the optic disc, and fibers from the inferior retina¹ form the inferior half. Fibers from the central retina are in the center of the nerve, while those from the peripheral retina form the nerve periphery. This precise arrangement is a condition for the subsequent accurate projection of the visual field in both the LGN and the VC.

¹ Conversion of light energy to electrical energy in the retina is the basis for electroretinography. The electroretinogram (ERG) measures the ability of the retina only to make this conversion. The ERG does not evaluate the optic nerve or brain in any way.

2. OPTIC NERVE: All ganglion cell axons converge to form the optic nerve (CN II). The ON is a cable made up of the ganglion cell axons which converge at the Optic Chiasm (OC).

3. CHIASM: At the OC, a percentage of fibers (see Fig 2) cross over to the contralateral Pretectal Nucleus (PTN) for the continuation of the PLR, and the remaining percentage (generally those originating from the temporal retina) of fibers continue on to the visual cortex (VC) via the ipsilateral LGN. The VC is not part of the PLR. The percentage of fibres that cross over (decussate) at the OC is species specific and is correlated with frontal position of eyes. As a general (but not exclusive) rule, species with more forward-facing eyes and with larger binocular fields decussate less than those with more laterally placed eyes with narrower binocular fields of view. Because the topography of decussating fibers is characterized by spatial precision, lesions in different areas of the chiasm (or the ON) will cause specific visual deficits.

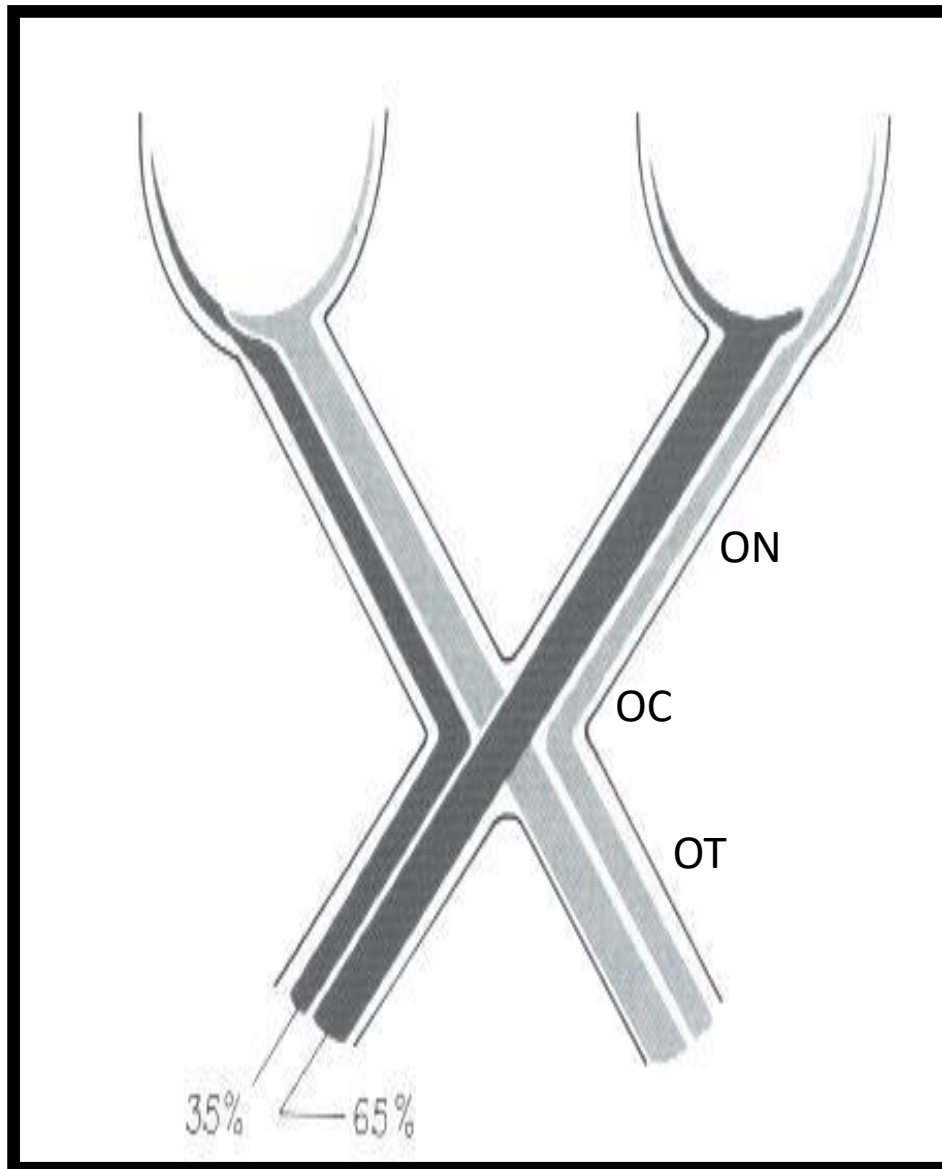


Fig 2. The optic chiasm (OC) of a cat. The more laterally placed the eyes are in the skull, the more decussation of nerve fibers.

- 100% = Bird, Fish, Reptiles, Amphibians (no consensual PLR).
- 99% = Rabbit,
- 80-90% = Pig
- 80% = Horse/Ox/Sheep
- 75% = Dog
- 65% = Cat
- 50% = Primates

ON = optic nerve
OC = optic chiasm
OT = optic tract

4. OPTIC TRACT (OT): Each optic tract contains the post-chiasmal bundles of fibers derived from the opposite visual fields of both eyes. This tract is destined to provide either left or right hemifield information from one eye and the opposite field from the fellow eye to the VC as well as fibers to complete the PLR circuit. Eg. For a cat (with 65% cross over), one OT contains fibers from the two left visual fields (nasal retina (65%) of the contralateral eye and temporal retina (35%) of the ipsilateral eye). The fibers of the OT synapse in one of four places:

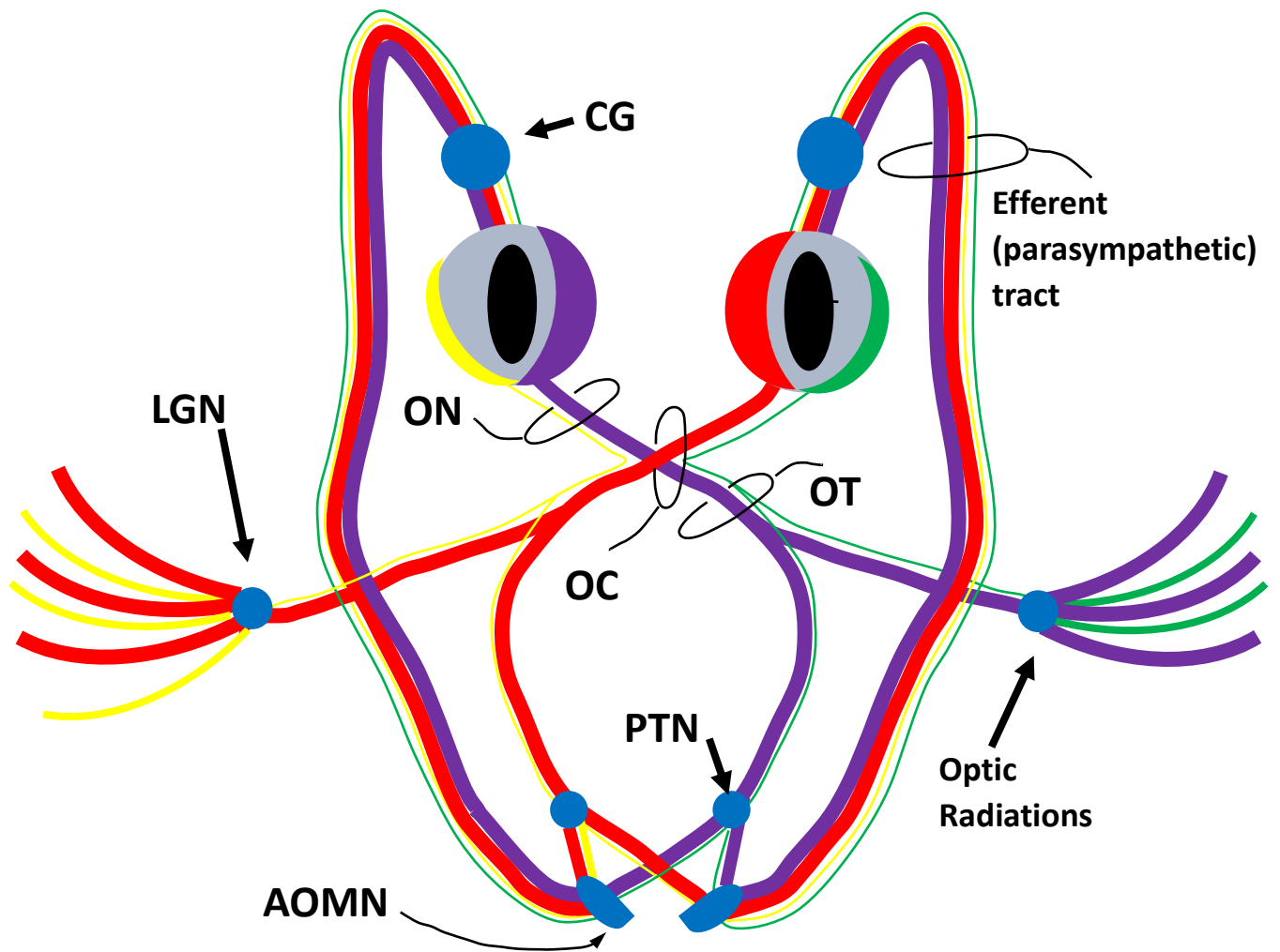
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|--------------------------|--|
| ~80% of fibers in the OT | 1) LGN – to proceed onto the Visual Cortex |
| ~20% of fibers in the OT | 2) Hypothalamus – regulates circadian rhythm
3) Rostral colliculus to: <ul style="list-style-type: none"> - regulate the dazzle reflex - regulate re-direction of gaze and movement of the head and neck in response to visual stimuli (orienting movements of the head and eyes) - project to the reticular activating system (RAS) |
| | 4) PTN – to continue with the PLR |

Deviation point

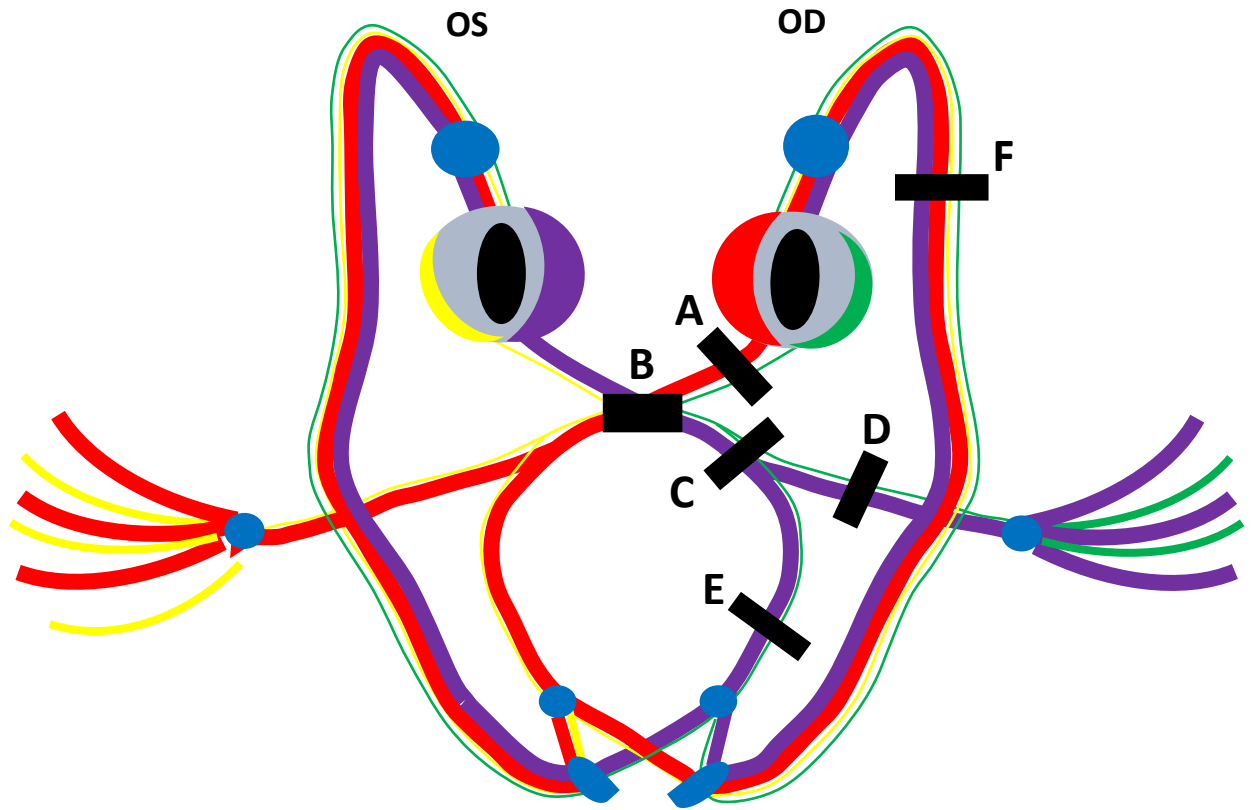
5. LATERAL GENICULATE NUCLEUS (LGN): Located in thalamus, the LGN consolidates the nerve fibers that deviated from the OT and propels them on to the optic radiations in the cerebral visual cortex located in the occipital lobe. All fibers that leave the circuit and proceed on to the VC are no longer part of the PLR. These fibers form VISION and as such, the PLR is NOT an indicator of vision. Testing the PLR and identifying a break in the circuit by the absence of a direct or consensual PLR and noting if the animal is visual or not (via reflex and response vision) testing, helps you to localize where in the circuit the break is occurring. For example, an abnormal PLR with vision loss in the opposite visual field of both eyes supports a lesion in the OT.

2. Efferent Pathway (brain to eye)

6. PRE-TECTAL NUCLEUS (PTN) – Located at the junction of the diencephalon and tectum, the fibers entering the PTN split again to enter either the ipsilateral or contralateral Accessory Oculomotor Nucleus. The percentage of fibers that cross is the same percentage as that in the OC.
7. ACCESSORY OCULOMOTOR NUCLEUS (AOMN): Previously known as the Edinger-Westphal nucleus is the origin of the parasympathetic tract. The parasympathetic nerve is closely associated with the oculomotor nerve along its journey to the ciliary ganglion. For this reason, the efferent pathway of the PLR can be considered a parasympathetic pathway.
8. CILIARY GANGLION (CG): The ciliary ganglion defines the start (post-ganglionic) and end (pre-ganglionic) of the of the parasympathetic fibers that terminate in the iris.
9. SPINCTER MUSCLES: From the CG, the fibers travel to the iris sphincter muscles which constrict the pupil with stimulation.



The pathway of the pupillary light reflex and optic radiations. ON = optic nerve, OT = optic tract, CG = ciliary ganglion, OC = optic chiasm, LGN = lateral geniculate nucleus, AOMN = accessory oculomotor nerve nucleus, PTN = pretectal nucleus.



Lesion (■) location	Direct PLR (stimulated eye response)	Indirect/Consensual PLR (fellow eye response)	V/B/H
A = Optic Nerve	-	-	B OD
B = Optic Chiasm	-	-	B OU
C = Optic Tract (OT)	+	+	H OU
D = OT to LGN	+	+	H OU
E = OT to PTN	+	+	V OU
F = Efferent pathway	-	+	V OU

Legend: LGN=lateral geniculate nucleus, PTN=pretectal nucleus, V=visual, B=blind, H=hemifield blindness, OD=right eye, OU=both eyes

Anisocoria

Definition: Unequal or asymmetric pupils at rest. May be caused by ocular or neurological disorders.

Pupil symmetry, size, and shape are observed as part of the routine examination of the eyes. When the pupils are not symmetric, you must decide which pupil is abnormal. The response of the pupils to dark and light stimulation usually helps in making this decision. The patient should first be placed in a dark environment, while you observe the amount of dilation. If one of the pupils fails to fully dilate, then the anisocoria is attributed to that eye, and further diagnostic workup should be aimed at the pathways associated with that eye. In a darkened environment both pupils are supposed to be relatively mydriatic. Miosis identified in dim light conditions suggests a lesion along the sympathetic chain. If both pupils dilate at the same rate and magnitude (ie appear normal) in dark light conditions, each eye should be separately stimulated by light. If one of the pupils fails to constrict fully, then the anisocoria is attributed to this eye, and further diagnostic work up should be aimed at the pathways associated with this eye. In bright light both pupils are supposed to be relatively miotic. Mydriasis identified in bright light suggests the potential for a parasympathetic lesion. In both environments, the pupils are supposed to be symmetrical in shape and size.

Anisocoria can be caused by ocular or neurologic disorders.

1. Ocular diseases

Abnormalities of the cornea (pigment, edema), anterior uvea (uveitis, heterochromia iridis, posterior synechia), lens (cataract), or retina (degeneration, detachment, edema)

2. Neurological diseases

Lesions located anywhere along the ipsilateral afferent pathway, along either efferent pathway, or along the sympathetic pathway can result in mydriasis or miosis. A parasympathetic lesion results in mydriasis and a sympathetic lesion results in miosis.

Localizing a lesion

Mydriasis: Unilateral

EFFERENT LESIONS can be caused by either:

- a. Ocular disease which causes reduced afferent input caused by retina, optic nerve, or optic tract disease.
- b. Neurologic disease. Reduced (or lack of) parasympathetic tone (efferent) to the iris constrictor is characterized by the absence of a direct PLR and presence of a consensual PLR to non-stimulated eye. The presence of a consensual PLR is evidence that the afferent tract is functioning in the affected eye. When the contralateral

(normal eye) is stimulated, the affected eye will remain dilated and reconfirms an efferent arm lesion. If no constriction occurs in the affected eye, then mydriasis can only be caused by pre-treatment with atropine or by iridial disease (eg iris degeneration/iris atrophy), glaucoma, or posterior synechia.

AFFERENT LESIONS can be caused by either:

- a. Ocular disease which causes lesions of the retina or optic nerve will result in partial ipsilateral mydriasis. Maximal mydriasis is lessened by the efferent input from the fellow eye. With these lesions, the pupil of the affected eye will respond to light directed at the contralateral eye because the efferent arm is unaffected.
- b. Cranial disease. An asymmetric cerebellar lesion (space-occupying disease) can result in compression of the ipsilateral CNIII or AOMN to cause partial mydriasis of the contralateral eye.

Miosis: Unilateral

- a. Ipsilateral ocular disease that results in unilateral miosis can include anterior uveitis and keratitis. Uveitis causes miosis via spasm of the iris ciliary muscle. Keratitis is painful which causes activation of the oculopupillary reflex (CN V and III) and ipsilateral miosis secondary to parasympathetic stimulation with CN III.
- b. Neurologic disease. Horner's syndrome is caused by a reduction/absence of sympathetic tone to the affected eye. Clinically Horner's syndrome manifests as a constellation of clinical signs that include miosis, ptosis, enophthalmia, and third eyelid elevation.

Mydriasis: Bilateral

Bilateral mydriasis can be caused by a lesion in either the afferent or efferent pathways of the PLR, or brain

- a- Efferent arm lesion that results in bilateral mydriasis without blindness – this lesion is in the efferent arm of the reflex arc (eg PTN, AOMN). These lesions almost always indicate brainstem involvement (severe contusion/hemorrhage/brain swelling/occipital lobe herniation) because the PTN and AOMN nuclei are very close together in the midbrain.
- b- Afferent arm lesion that results in bilateral blindness with absent direct PLRs OU – lesion is in the afferent arm of the reflex arc (retina, ON, OC, or rostral OT). Disease in the retina (retinal detachment, retinal atrophy) or ON (optic neuritis) is advanced to result in loss of a direct PLR. Note, a unilateral brain lesion does not result in bilateral blindness because of decussation in the OC.
- c- Central blindness is identified by bilateral blindness with normal PLR's and normal eye examination. The lesion of these cases must be located in the distal aspect of both OT's, in both LGN's, in both optic radiations, or in the visual cortex.

Bilateral miosis

Bilateral miosis is a sign of acute and extensive brain disease however the exact mechanism of action is not fully understood. Alternatively, bilateral miosis is caused by a lesion to the efferent, sympathetic innervation of the iris (as long as the parasympathetic tone of the oculomotor nerve is maintained). With bilateral Horner's syndrome, other clinical changes (ptosis, elevation of the nictitans, enophthalmia) will also be noted.

Midrange pupils

If retinal or optic nerve disease with ipsilateral blindness is present, the ipsilateral pupil will not be fully dilated because of influence of the fellow eye. Covering the fellow eye will result in complete mydriasis of the ipsilateral eye because of loss of efferent iris stimulation.

A quick word about vision testing

Menace Response

The menace response is a learned cortical response that is not fully developed in dogs and cats until 10-12 weeks of age, and in foals and calves until 1-2 weeks of age. Most (80%) of the ON axons are dedicated to relaying the visual signal generated by the retina to the cerebral cortex. After crossing over in the OC, the optic tract (OT) axons synapse in the LGN (thalamus) the relay the signal through the optic radiations to the VC (occipital lobe) and the visual information is then transmitted through communication fibers to different regions of the cortex and finally to the primary motor cortex, which initiates the efferent component (the blink) of the menace response. It is important to note that the menace response involves cerebral cortical integration and interpretation and therefore is not a reflex. The menace response, requires the entire peripheral and central visual pathways, as well as the visual cortex, CN II, and the facial nucleus of CN VII to be intact for the response to occur.

Dazzle Reflex

The dazzle reflex is a subcortical reflex that manifests as a bilateral, partial eyelid blink in response to a bright light shined in one eye at a time. The anatomical path of the dazzle reflex has not been fully elucidated in animals however evidence from the human literature suggests that it is present when the optic nerve is intact to the level of the midbrain, and particularly to reflex centres in the rostral colliculi and/or the supraoptic nuclei of the hypothalamus. The dazzle reflex requires an association of fibers between these nuclei to the facial nuclei in the medulla, as well as intact facial nerves. Decerebrate animals with total ablation of the striate cortex, will still blink in response to a bright light.

Clinically, the dazzle reflex is useful when the pupils cannot be observed to evaluate the PLR (severe edema/hyphema). Under these conditions, the response to very bright light should still be present. An absence of response to dazzle testing suggests a subcortical lesion in visual pathway, or a lesion in CN II or VII.

Lesion location ↓	Menace	Dazzle	Vision deficits	PLR (d + i)	Dark Room (mydriasis)	Mentation
Iris	+	+	-	d-/i+	-	N
Retina (afferent input)	-	-	+	-	-	N
CN II (afferent input)	-	-	+	-	-	N
Chiasm (afferent)	-	-	+	-	+	N
Thalamus (brain)	-	+	+	-	+	A
Visual Cortex (brain)	-	+	+	+	+	A
CN VII	-	+	-	+	+	N
Cerebellum (brain)	+/-	+	-	+	+	N
Sympathetic chain	+	+	-	+	-	N unless lesion in brain
Parasympathetic chain	+	+	-	-	+	N unless lesion in brain

HB Heller and E Bentley. The Practitioners Guide to Neurologic Causes of Anisocoria. Today's Veterinary Practice Jan/Feb 2016.

Legend: + = present, - = absent, d = direct PLR, i = indirect/consensual PLR, N = normal, A = abnormal

Tonometry and What It Can Teach Us

Tonometry (tōnom'etrē). The indirect measurement or estimation of intraocular pressure (IOP) or tension. Tonometry is a standard eye test that is performed to determine the fluid pressure inside the eye and can be used to support the diagnosis of a disease and to intermittently monitor diseased eyes for progression or response to therapy. Tonometry is a tool used to determine prognosis and guide decisions regarding treatment regimens and is not intended to be used as the sole means of achieving a diagnosis. The IOP of most animals is between 15 and 25 mmHg. Generally, the difference in IOP between fellow eyes should be less than 8 mmHg. If this is not the case, a thorough examination should be performed to identify any pathology that may be responsive for the difference. Increased pressure is a possible sign of glaucoma. Just as importantly, low pressure in the eye is a possible sign of uveitis. Both are common and potentially very serious problems if not detected and treated promptly. The pressure inside the eye is measured from the outside the eye by determining the resistance of the eyeball to indentation by an applied force. Several kinds of tonometers are used and can be divided into categories based on their mechanism of action.

1. Air-puff tonometry. The deflection of a pressurized puff of air off of the corneal surface is recorded. Air-puff tonometry does not require contact by the instrument with the eye. These tonometers are not used in veterinary medicine and will not be discussed further.
2. Indentation. Indentation methods of tonometry rely on the detection of force needed to indent or flatten the corneal surface. Tools used to accomplish this include the Schiötz tonometer or by digital palpation.
 - a. Schiötz tonometer. Following displacement of a large, convex footplate (outer ring) that results in movement of the Schiötz tonometer needle (fixed inner pin), counter weights are used to bring needle back to zero. For the footplate displacement and counter weight action to be achieved, the Schiötz tonometer must be aligned vertically and as such, perpendicular to a horizontally oriented cornea. While extremely accurate and inexpensive, proficiency in using the Schiötz tonometry can be difficult to achieve and results are not easily reproduced between different users. In addition, the footplate which is designed to match the human corneal curvature may vary in veterinary patients. Patients with large eyes and flatter corneas generate falsely low readings, whereas small eyes with greater corneal curvature tend to give falsely high readings. For these reasons, Schiötz tonometry is rarely done today.
 - b. Digital palpation. Estimates of intraocular pressure based on digital palpation are limited to intraocular pressures that are extremely high or extremely low and are altered by corneal or scleral disease as well as subjective interpretation by the examiner.
3. Applanation tonometry. Applanation tonometers record the pressure needed to flatten the corneal surface. While similar in theory to the indentation tonometers, the tone of the eye is detected by the movement of a ceramic plunger suspended within the tip of a stainless-steel probe that activates a position transducer. Recoil of the ceramic plunger following corneal contact produces a signal that is amplified, digitized, and passed through a single-chip microprocessor for display on a liquid-crystal screen. Because of the configuration, the pen can be held vertically or horizontally and applied to a cornea oriented in any direction. In addition, the

outer ring (~foot plate) is <2 mm in diameter and as such, can be applied to extremely small corneas. The stability of the outer ring and generation of a digital error margin not only improves accuracy of the recordings but also the reproducibility between users. The lowest repeatable measurement represents the IOP. Applanation tonometers are very accurate in the normal range of IOPs but tend to overestimate IOP in the low range and underestimate IOP in the high range in dogs and cats.

4. Rebound tonometers utilize an induction-impaction method to determine IOP, essentially measuring rebound action of an electromagnetically propelled probe as it contacts the eye and bounces back. Unlike the applanation tonometer (eg TonoPen), rebound tonometers must be held upright during measurements, which may make its use difficult in recalcitrant or recumbent patients. Accuracy of the rebound tonometer (eg TonoPen Vet) is comparable to the applanation tonometer (eg TonoPen).

Rebound and Applanation tonometers are the two most common tonometers on the market today. Both categories regardless of their brand, are digital, easily reproduced between different users, portable, and non-invasive for the patient. Specific models available today include:

Applanation:

- TonoPen-XL
- TonoPen-Vet
- TonoPen Avia Vet

Rebound:

- TonoVet
- i-Care Tonovet Plus

Category of Tonometer	Reproducibility between users	Format	Orientation	Topical anesthetic	Cornea size	Disposables	Ease of cleaning	Cost	Error	Maintenance and servicing	Calibration	Species specific
I	N	Manual	Horizontal	Yes	Large or small	N	mod	\$	User dependent	low	Y	N
A	Y	Digital	Any	Yes	Small	Latex Tips, Alcaine	easy	\$\$ \$	Easy to obtain a false high (restraint, neck, brachycephalic)	mod	Y/ N	N
R	Y	Digital	Vertical	No	small	plungers	easy	\$\$ \$	Tends to read higher than applanation	low	N	Y

Legend: I=indentation, A=applanation, R=rebound, Y=yes, N=no

Minimize Erroneous Readings:

1. Keep Calm and Carry On

The influence of patient stress on the accuracy of tonometry is real. The potential for falsely elevated eye pressure is increased in an animal with increased sympathetic tone (dilated pupils, eyes protruding) caused by fear or anxiety, or excessive panting secondary to heat, anxiety, or excitement. Separation of the patient from its owner can also result in increased anxiety and should be assessed on a case-by-case basis. In my experience, obtaining an IOP that is higher than that expected from my clinical examination warrants removal of the patient and owner from the examination room and retesting the pressure where the patient has been resting with the owner for several minutes. In some cases, mild sedation of the small animal patient (eg gabapentin, Trazadone) has proven to be beneficial in obtaining an accurate IOP. In large animals, sedation with xylazine or acepromazine, may significantly decrease IOP.

2. Handling – avoid eye, lid, or neck pressure

In an effort to obtain the most accurate IOP measurement, it is important to minimize eye, eyelid, or neck pressure. With the intention of helping hold the patient still, many restrainers will inadvertently pull on the patient's collar or squeeze on the neck. Pressure around the neck increases jugular venous pressure and can very easily lead to falsely elevated IOP measurements. For adequate restraint without risking pressure on the neck, the restrainer can be directed to steady the patient's head by cupping under the chin. Similarly, it is important for the person manipulating the lids to provide lid retraction without putting pressure on the globe. As a rule of thumb, the lids should not be manipulated closer to the eyelid margins than the orbital rim.

3. Aim for the clearest part of the cornea

Ocular tone can be falsely estimated by corneal disease such as scarring, pigment, or edema. To minimize error associated with an abnormal corneal influence, the IOP should be derived from the clearest portion of the cornea that is available.

4. Maintain your equipment

Digital tonometry, like all equipment, requires care and maintenance. It is important for applanation tonometers that the protective latex tip is placed correctly and per manufacturer's guidelines. On a daily to weekly basis (depending on use) applanation tonometers require dusting to prevent dirt buildup around the delicate ceramic plunger and this can be performed using compressed air directed into the tip of the tonometer. To prevent liquid from being sprayed into the tonometer, it is important that the compressed air canister is not shaken before use. After air has been forced through the tip of the tonometer, the tonometer must be returned to room temperature before calibrating. Finally, tonometers are expensive and their value warrants professional cleaning and calibration every 2-3 years, depending on use.