Vision in Dogs and Cats

“Hey Doc, how well does my dog see?”
Such a simple question for which the answer is, well….not. Visual ability of normal animals is seldom discussed in the veterinary literature. What is known is that vision is the collective summary of a) the ability to perceive light and motion, b) visual perspective, c) field of view, d) depth perception, e) visual acuity, and f) colour vision.

Owing to a paucity of published information regarding vision in animals, the following section is based heavily on the excellent review articles by Dr. Paul Miller et al. I am hoping to dovetail these previously published works with visual examples during this seminar. For additional information, I encourage you to review Dr. Miller’s papers and the references he has cited.

a. Sensitivity to light
Cats and dogs are more sensitive to light than humans. Cats are well adapted for nocturnal vision with a minimum light detection threshold (MLDT) up to 7 times greater than humans. This is because of the following adaptations:
- tapetum (which reflects up to 130 times more light than human fundus)
- vertical slit pupil
- large cornea (lets more light into eye)
- a relatively posteriorly located lens which produces a smaller but brighter image on the fundus
- a retina that is dominated by rod photoreceptors
- a form of rhodopsin that continues to increase in sensitivity to light for up to 1 hour (bleaching)
Dogs have the same adaptations as cats but to a lesser extent and do not possess a vertical slit pupil. The tapetum, greatly enhances vision in dim light by reflecting light back through the retina a second time. In cats, the tapetum also shifts short wavelengths (blue) to wavelengths that are closer to rhodopsin’s maximal sensitivity (fluorescent shift). This shift brightens a blue-black evening (night sky), and enhances the contrast between sky and objects silhouetted against it. The superiorly located tapetum in all animals may also brighten the view of the usually darker ground, and the inferiorly located, normally darkly pigmented tapetum nigrum (non-tapetal fundus) reduces light scattering originating from a bright sky. In dogs, the tapetum is a less efficient reflector than cats, but its enhancement of vision in dim light is still undoubtedly substantial.

Animals and humans are more sensitivity to motion than to stationary objects. In bright light, humans detect moving objects 10-12 times better than cats because of cone-rich fovea. In dim light, domestic mammals have a greater ability to detect motion than do humans when the object is viewed peripherally, or when the object moves at a speed to which the retina is particularly attuned. Because of the large peripheral visual field, dogs and cats probably only detect motion or brightness in this area, as most dogs and cats ignore stationary objects in their peripheral visual field but reflexively chase them if they move.

Flicker Fusion Frequency (FFF) is the frequency at which flickering light no longer appears to flicker (ie appears as a constant illumination). The FFF provides insight into the functional characteristics of an animal’s rods and cones.
and is crudely correlated with the speed with which retinas can update an image. Generally the faster a species moves through its environment the higher its FFF. For example, some falcons have FFF greater than 100 Hz (1 Hz = 1 image/second), dogs = 70-80 Hz (therefore a TV screen (60 Hz = 60 times/sec) is seen as a rapid flicker to dogs), and humans = 15-20 Hz and as such, TV looks fluidly moving story.

b. Visual Perspective  The height of the eyes above the ground has a major impact on the perception an animal has of its environment, and the height varies in dogs (< 8 inches at the shoulder to > 34 inches). For example, to a Shih Tzu, grass must appear as impenetrable brush vs Irish Wolfhound. Some breeds have developed behavioural traits (leaping in the air while searching for objects) which may enhance their visual perspective.

c. Visual Field is the area that can be seen by an eye when it is fixed on one point. The visual field varies by breed (e.g. brachycephalic (short nose, lateral eyes) vs mesocephalic (long nose, forward eyes). The average dog visual field = 240 degrees (cats = 200 degrees, humans = 180 degrees). Dogs have a 120 degree ipsilateral visual field, a 15-30 degree contralateral visual field, and therefore a total monocular field of view of 135-150 degrees.

d. Depth Perception  A wide visual field allows for a better ability to scan the horizon which is enhanced with stereopsis (binocular depth perception). Binocular vision results when the two eyes view the world from slightly different vantage points and the resulting image is fused into a single image. If the two images are not fused, double vision may result. Most dogs probably have 30-60 degrees of binocular overlap (vs cats and humans = 140 degrees). Animals with one eye can still perceive depth from monocular cues that include relative brightness, contour, areas of light and shadows, object overlay, linear and aerial perspective, density of optical texture, and motion parallax.

e. Visual Acuity is the ability to see the details of an object separately and unblurred. Visual acuity depends on the optical properties of the eye, the retina’s ability to detect and process images, and the ability of higher visual pathways to interpret images sent to them. In normal animals, visual acuity is usually limited by the retina.

d.i. Optical Factors in Visual Acuity
In humans failure of the clear optical media (cornea, aqueous humor, lens, vitreous humor) to properly focus light on the retina commonly results in refractive errors (RE’s) and astigmatism which require correction and optimization with contact lenses or glasses. These options are generally not available for animals. Myopia (near sightedness) occurs when light is focused in front of the retina. Hyperopia (far sightedness) occurs when light is focused behind the retina. The extent of a RE can be expressed by the formula, diopters (D)= 1/f, where f = the focal length (meters) of either the lens or optical system has a whole. (e.g. an eye that is 2D myopic is focused ½ meter in front of the eye). The average resting refractive state of cats and dogs is near emmetropia, but some can be significantly myopic as is seen in brachycephalics, German Shepherds, Rottweiler’s. Astigmatism occurs when the media fails to focus parallel rays of light in a uniform fashion and is generally thought to be uncommon in dogs and cats. Accommodation (adjustable focusing) is needed if objects at different distances are to be seen with equal clarity. Accommodation is limited in dogs and cats and is probably less than 2-3 D (50-33 cm) in dogs or 4 D (25 cm) in cats and may explain was dogs and cats use other senses (smell/taste) to investigate very near objects. Aphakia (lens removed following cataract surgery) results in severe hyperopia (-14 D), and a reduction in
visual acuity to 20/800 or worse unless a corrective lens is used. This degree of hyperopia can be simulated by setting a direct ophthalmoscope to -14D and viewing the room through the view-port. -14D hyperopia is debilitating to some dogs but most are still able to visually navigate their environment but not perform visually challenging tasks.

d.ii. Retinal Factors in Visual Acuity
In dim light, enhanced vision typically requires a greater number of photoreceptors to synaptically converge on a single ganglion cell. In primates a peak ratio of 1 cone to 1 ganglion cell in the fovea has been identified. In cats a 4:1 (cone:ganglion cell ratio) has been identified. This greater convergence in cats increases the detection of light and reduces visual acuity (similar to how high speed film produces a “grainy” image in bright daylight). In all species there are fewer ganglion cells in the periphery of the retina than in the center. This results in reduced visual acuity in the peripheral visual field.

Topography is the distribution of photoreceptors and is different between humans who have a densely packed fovea, and dogs and cats who have a visual streak. The visual streak in dogs and cats is an oval zone, is slightly superior and temporal to the optic nerve in the tapetal zone, and has a short temporal and longer nasal extension. The tapetal location of the visual streak further enhances vision in dim light, but also degrades visual acuity secondary to light scattering. The oval shape may promote binocular vision and the nasal linear extension of the streak may facilitate scanning of the horizon. In domestic dogs, two different types of visual streaks have been found and both forms can occur within the same breed.

d.iii. Estimates of Visual Acuity
The Snellen Fraction is a common method for describing visual acuity in humans, with the normal person having a visual acuity of 20/20 (the test subject can discern the details of an image (letters on a chart) from 20 feet away that a normal person could differentiated from 20 feet away). When this scheme is applied to animals, the visual acuity of the typical dogs is about 20/75 (this means that from 20 feet away, normal dogs could distinguish the details of an object that a person with normal vision could differentiate from 75 feet away. The visual acuity of the typical cat is between 20/100-200.

The most common ways of evaluating vision in animals (menace response, following a cotton ball) only crudely estimate visual acuity because they test the motion sensitivity of virtually the entire retina. Positive response with these tests may still be present even if visual acuity is < 20/800 and a person with such vision deficits would be legally blind. Remember, visually distinguishing details of an object is less important for a dog or cat’s lifestyle than it is for people.

f. Colour Vision
Dogs, and to a lesser extent cats, possess and use colour vision, although they have many fewer colour sensitive cone photoreceptors than humans do. Dogs appear similar to humans who lack green cones and are “red-green colour blind” (ie, they see blue and yellow), whereas cats have a limited, but detectable capacity for colour vision if the stimuli are large and differ greatly in spectral content (colour). Wavelengths at the two ends of the blue-yellow spectrum probably provide the most saturated colours. Intermediate wavelengths are less intensely
coloured, appearing as if they were blends with white/grey. Unlike a “red-green colour blind” human, dogs have fewer numbers of cones and provide less colour saturation and the canine spectral neutral point is shifted towards the blue end of the spectrum (480 nm), whereas, in people the spectral neutral point is a greener (505 nm) region of the spectrum. Limitations in colour vision are probably of little consequence to a dog or a cat in dim light however, as insufficient light is available to stimulate cone photoreceptors. It may be problematic, however, to teach dogs to distinguish among red, orange, yellow, and green objects solely on the basis of colour. A guide dog is unable to differentiate among the signals at a stop light on the basis of colour alone and uses other clues (position, relative brightness, smells, tastes, and textures) to differentiate between similarity coloured objects. Interestingly, dogs have been reported to be able to differentiate perfectly among closely related shades of gray that are indistinguishable to the human eye. This ability is a greater aid in visual discrimination in low light levels than is enhanced colour vision, which requires bright light.
Medical and surgical management with a review of current protocols

Most ocular conditions interrelate which is why eyes are tested so broadly. All eyes should be tested for intraocular pressure, fluorescein stain, Schirmer tear test where indicated. If you are uncertain if you have a uveitis or glaucoma, please send case for tonometry (another local clinic, emergency clinic). All cases being treated with a topical steroid should have the cornea stained for the presence of an ulcer first.

The following information is provided to serve as a guide. The medical treatment plans provided are considered initial and what I believe would be safe starting points unless otherwise indicated. All medical conditions can change quickly rendering the initial treatment plan inappropriate or even harmful. Frequent rechecks are recommended. Always consult with an ophthalmologist if you are unsure of any ocular changes that may be developing or to discuss long-term care. There are no ‘blanket’ recipes or regimens for treating eye conditions.
1. Uveitis

**Clinical signs:** conjunctival hyperemia, blepharospasm, miosis, corneal edema

**Causes:** The CAUSES of uveitis are innumerable (see Table 1)

**Testing:** TEST for the most likely (protozoal, bacterial, neoplastic) (see Table 2)
RE-TEST if no response to medical therapy

**Treatment:** TREAT for the most common (protozoal, traumatic, bacterial, immune-mediated) (see Tables 3a,3b,4)
DO NO HARM (ie do not treat with systemic steroids/anti-fungals without checking titers).

**Sequelae:** Intraocular scarring
Cataract formation
Glaucoma
Retinal detachment
Blindness
Phthisis bulbi
2. Keratoconjunctivitis sicca (KCS) “dry eye”

Precorneal tear film -lipid (adjacent to air) – keeps the aqueous layer from evaporating
-aqueous (middle) - this is the layer that is usually deficient in KCS
-mucoid (adjacent to corneal epithelium) – keeps the aqueous layer adherent to the cornea.

Clinical signs of KCS worsen with increased duration and increased extent of dryness.
- Conjunctival hyperemia (mild - marked)
- Blepharospasm (mild intermittent – marked persistent)
- Mucoid/mucopurulent discharge (thin intermittent – persistent tenacious)
- Dull cornea to keratitis (vascularization, pigmentation, ulceration)
- Blepharitis and meibomian adenitis
- Periocular dermatitis

Testing  Schirmer Tear Test (STT I) = reflex and basal tear production (no topical anesthesia). STT II = basal tear production (not commonly measured).

- STT I ≥ 15 mm/min = normal production dog
- STT I 11-14 mm/min = early/subclinical KCS dog
- STT I 6-10 mm/min = moderate/mild KCS dog
- STT I ≤ 5 mm/min = severe KCS dog

Do not extrapolate your test values to one minute if test strip is placed for less than 1 min.
Always interpret your values in terms of breed, corneal health, and clinical signs. Always ensure that all testing is performed on a day that NOTHING has been applied to the eyes before the appointment (even to clean or lubricate the eyes). If eyes have been treated/cleaned, a low STT is significant (exactly how significant you do not know). Try to schedule KCS patients in the morning so patients do not wait the whole day without lubrication.

Causes of KCS (see Table 5). Autoimmune dysfunction of the lacrimal gland is the leading cause of keratoconjunctivitis sicca in dogs.

Treatment (see Table 6).
- Cyclosporine and Tacrolimus

Sequelae: Chronic corneal fibrosis/pigment, corneal ulceration, blepharitis / eyelid margin scarring
3. Corneal Ulcers

**Definition:** A break in the corneal epithelium that exposes the underlying corneal stroma.

**Clinical signs:** lacrimation, blepharospasm, photophobia, conjunctival hyperemia, corneal edema, ± miosis and aqueous flare

**Anatomy:** The cornea is the clear part of the eye. Epithelium covers the outer surface of the normal cornea. The epithelium is heavily innervated, provides a water barrier to the eye, and measures approximately 8-15 cell layers thick. The middle layer of the cornea is called the stroma. This layer is made up almost entirely of precisely organized collagen fibers, has fewer nerves, and makes up approximately 90% of the corneal thickness. The Descemet’s membrane is the basement membrane for the endothelial cells and becomes thicker with age because it is continuously produced. The endothelial cells are hexagonally shaped cells that are approximately 2500 cell/mm². Endothelial cells increase in size and decrease in number with age. Centrally the cornea is 562 ± 6.2 µm (approximately 0.5 mm) thick, and peripherally is slightly thicker. Corneal thickness increases gradually with age. Corneal sensitivity is highest in dolichocephalic skull types, followed by mesaticephalic, and lowest in brachycephalic skull types. The central cornea is most sensitive, followed by the nasal, temporal, dorsal, then ventral corneal regions. Dogs with diabetes have reduced corneal sensitivity.

Injuries to the cornea are usually the result of trauma secondary to mechanical injury or abrasion of an unhealthy cornea by the eyelids. Any corneal ulcer can become infected with bacteria, fungus, or both. A shallow ulcer, when treated appropriately usually heals quickly and with minimal scarring. Ulcers that become infected may be more difficult to treat. In these cases, the ulcer may become very deep or the cornea may start a process called "melting" (see below).

When ulcers don’t heal it is because they are Infected, the Inciting cause is still present, or Infected

a. **Indolent Ulcers (Spontaneous Chronic Epithelial Defects (SCCEDs)**
(also known as: canine recurrent erosions, refractory corneal ulcers, Boxer ulcers, nonhealing erosions, persistent corneal erosions, recurrent epithelial erosions, idiopathic persistent corneal erosions).

Indolent ulcers occur in older animals secondary to a reduced ability of epithelial tissue to stick to the underlying stromal tissue. These ulcers are superficial and not infected. I like to think of indolent ulcers as being mechanical and as such, they are treated mechanically. Without proper treatment, these ulcers can become infected and deepen. Treatment options (all with proparacaine applied) include: a) debridement (use dry cotton tipped applicator’s (CTAs) to debride loose epithelial tissue from the cornea. Do not roll CTAs), b) Diamond Burr keratotomy (to smooth the edges of the debrided epithelium), c) grid/striate keratotomy ((dogs only) ± collagen shield and temporary tarsorrhaphy – using a 25 ga needle (bevel is pointed up), three directions of superficial scratches are made over the ulcer and edges of ulcer. If no blood vessels are present in the cornea, extend the scratches over the limbus. Dog may be sedated if anxious (dog or vet)), d) keratectomy +/- collagen shield and temporary tarsorrhaphy (refer these).
What to do, what not to do for indolent ulcers

**DO**
- Topical antibiotic **solution** – not ointment
- Prescribe pain control – if necessary
- E-collar

**Do NOT**
- Debride the cornea **unless indolent**
- Debride the cornea every 3 days
- Use Gentamicin ophthalmic
- Prescribed serum unless ulcer is deep/melting (it is not harmful, just overkill)
- Prescribe a topical anti-inflammatory
- Trust the dog not to scratch/rub eye

b. Stromal ulcers (deep/melting)

Definitions:

Superficial ulcer = an ulcer that involves loss of epithelial tissue. Generally not an emergency however, can progress quickly, especially in brachycephalic breeds therefore must be treated appropriately and rechecked frequently.

Stromal ulcer = an ulcer involving corneal tissue below the epithelial layer. Superficial or deep.

Fluorescein stain is retained in the base of the ulcer. See above regarding brachycephalic breeds.

Descemetocoele = loss of all stromal tissue and no fluorescein stain is retained at the base of the ulcer.

Emergency.

Melting ulcer = a complicating component of any corneal ulcer. During the normal corneal healing process, proteases and collagenases are produced that help remove devitalized cells from the cornea. Corneal epithelial cells, fibroblasts, PMN leukocytes and some bacteria or fungi produce proteases and
collagenase. These enzymes contribute to the progressive breakdown and rapid “melting” of the corneal stroma. A "melting" cornea can slough away in a matter of hours and the eye can rupture if treatment is delayed. Melting ulcers and deep ulcers are considered emergencies. These ulcers may require intensive treatments for several days until healing begins. Often, inflammation of structures inside the eye accompanies deep or melting corneal ulcers, and this can be as vision-threatening as the corneal disease. With healing, melting ulcers and deep ulcers can result in noticeable scarring. If these scars are large, visual impairment may result.

Deep ulcers or melting ulcers may sometimes require surgery in addition to medical therapy to prevent rupture of the eye. These surgeries usually involve placement of a flap of conjunctiva to provide a vascular supply as well as tectonic support. These permanent flaps actually incorporate into the cornea at the site of the ulcer, forming a dense scar in a matter of weeks.

Treatment: see Table 7

Generally speaking, the deeper the ulcer, the thinner (clearer) the treatment. (ie, ointment (thickest) – gels – oils – suspensions – solutions (thinnest). Some antibiotics ie. fluoroquinolones (eg Ciprofloxacin, Marbofloxacin, Moxifloxacin, Ofloxacin) kill the protease producing bacteria. These are not first line antibiotics. Serum helps stop the “melting” process. Serum contains α-2 macroglobulins and α-1 proteinases which inhibit the proteases and collagenases.
What to do, what not to do for melting ulcers

**DO**
- topical antibiotic solution – not ointment
- use a combination of narrow and broad spectrum topical antibiotics
- prescribe a mydriatic unless there is a sealed laceration
- prescribe pain control
- E-collar

**Do NOT**
- debride the cornea unless indolent
- do not use gentamicin ophthalmic or prescribe a topical anti-inflammatory
- trust the dog not to scratch/rub eye
- leave it for a week
- do third eyelid flap if planning to refer

Surgical treatment for descemetoceles or lacerated corneas

1. Primary corneal sutures (laceration or very small descemetocele)
2. Conjunctival graft (pedicle graft, island graft, bridge graft) – desmetocele/laceration
3. Corneal-scleral transposition (descemetocele)
4. Corneal transplant – rare (desmetocele)
4. Herpes (FHV-1) (gk. herpein - “to creep”)

“Herpes is the glitter of craft supplies” – Demetri Martin

Overview
Feline Herpesvirus- 1 (FHV-1) is an alpha herpesvirinae. Other alpha herpesvirinae include human Herpes Simplex Virus -1 (cold sores) and HSV-2 (genital lesions), varicella zoster virus (chicken pox, shingles), bovine HV-1 (respiratory disease, abortion), equine HV-1 (respiratory disease, abortion, +/- neurologic disease), suid HV-1 (aka pseudorabies) + Aujeszky’s disease (respiratory disease, abortions, neurologic disease), canid HV-1 (neonatal puppy mortality, respiratory and ocular disease), infectious laryngotracheitis virus (chicken respiratory disease), Marek’s disease (MDV) (immunosuppression and T cell lymphoma). FHV-1 has a short replication cycle which leads to cell lysis, induces lifelong neuronal latency (primarily in trigeminal ganglion), has a narrow host range (species specific to domestic and wild cats), and causes feline viral rhinotracheitis in approximately 50% all URT infections in cats, ocular lesions. 75-95% of cats are seropositive for FHV-1. FHV-1 is labile in environment (lasts up to 18 hours) and susceptible to drying, disinfectants, fluorescein, rose Bengal, and proparacaine

Pathogenesis
Acute infections mainly affect susceptible kittens and juveniles. Kittens are normally protected by passive immunity until 2 months old. Kittens with residual passive immunity may not show clinical signs when exposed but can still become latently infected.

Infection
- from acutely infected cats (oronasal and ocular secretions) or reactivated latently infected cat.
- virus to cell surface, virion travels to nucleus for replication and transcription

Replication
- nucleus of cell of mucosae of the mucosae of the nasal septum, turbinate, nasopharynx, conjunctivae, and upper trachea, tonsils and mandibular lymph nodes. Replication of the virus in the upper respiratory tract (URT) causes severe URT disease in susceptible animals

Incubation period = 2-6 days
Transcription
- in the nucleus
- lytic viral genes – result in clinical illness, self-limiting
- LAT viral genes – symptom free. Life-long

There are two mechanisms of pathogenesis:
1. cytolytic virus causes ulceration of epithelial cells of mucosae and cornea
2. immune-mediated effects cause stromal keratitis

Acute phase
Respiratory
- fever, inappetence, and sneezing, followed by serous to mucopurulent nasal discharge
- excessive salivation and drooling of saliva, +/- coughing and dyspnea
- lung involvement - sporadic

Ocular manifestations
- ophthalmia neonatorum (neonatal kittens) – symblepharon
- acute hyperemic conjunctivitis, ocular discharge, chemosis + URT signs
- corneal ulceration
- dendritic (pathognomonic) to geographic epithelial
- acute ulcers - may heal spontaneously
- chronic ulcers – incite a dense vascular response, immune med’ed stromal keratitis
Systemic signs
- pregnant queens – abortion – rare
- neonatal kittens – neurologic signs, high mortality rate

Latent Phase
- Latent signs – same as Acute signs but less severe
- FHV-1 DNA persists in episomal form (in nuclei of Trigeminal ganglia)
- FHV-1 RNA transcription = very limited and infectious virus is not produced.

Recrudescent disease – huge variation in severity
- Generally conjunctivitis is less severe than with primary infection
- Secondary inflammatory cell infiltrate results in thickened conjunctiva and redness

Latency-Reactivation Cycle: requires three steps – establishment, maintenance, reactivation
  Establishment: requires that the virus reaches the target tissue (neuronal ganglion) from the site of replication (mucosa) during acute phase via sensory nerves (retrograde axonal transport) to infect neurons at the sensory ganglia.
  Maintenance: requires that lytic gene expression is inhibited and latency-associated transcript (LAT) is expressed which yields several RNA species (LAT’s) by splicing.
  - low level/sporadic transcription of immediate-early and early genes can occur but it is not sufficient to initiate a productive infection therefore no infectious virions can be detected in the ganglia during latent infection.
  - reversible under stress (physiologic (illness, surgery, environmental changes, pregnancy and lactation, idiopathic) or pharmacological (CCS’s, vaccinations))
  Reactivation - reactivation of latent viral DNA (4-11 days after stressor) travel back to the periphery (mucosa) via the same sensory nerve “highway” used to reach the ganglia. Infectious virions (viral shedding) can be detected for approximately 6 days but detection of FHV-1 DNA (PCR) is inconsistent. Reactivated virus can still be a significant source of exposure and primary disease in fully susceptible hosts that are in close contact with the shedding animal. Less than 0.05% of latently infected ganglia reactivate and when they do reactivate, they die. This is why sensory nerve deficits are not clinically associated with reactivation.
  Furthermore, the reserve of ganglia is large so repeated reactivation can take place throughout the life of the host. (eg 20 year old cat with 100 reactivations/year).

- spontaneous reactivation = uncommon
- 18% - reactivation associated with moving to a new environment
- 40% - reactivation associated with lactation
- 70% - reactivation associated with corticosteroid (oral/topical) administration
A quick word about LAT (Latency-Associated Transcripts)
- acute infection of trigeminal neurons (viral replication) produces toxic gene expression products that induce cellular DNA damage and cell death via stimulation of the mitochondrial pathway of apoptosis.
- Herpesvirus tries to counteract apoptosis and thus enhance their replicative ability, by encoding several antiapoptotic genes (one of which = the LAT gene)
- acute phase has redundancy in the viral antiapoptotic capabilities therefore apoptosis during this phase is prevented fairly efficiently. Apoptosis must also be prevented during the establishment and maintenance stages of latency.
- LAT exerts its antiapoptotic properties through micro-RNAs (mi-RNAs) via targeting TGF-β (a potent inducer of apoptosis)

Testing
There is overlap in symptomatology between calicivirus and acute FHV-1. FHV-1 is associated with pyrexia and corneal lesions. Calicivirus is more often associated with ulcers of the tongue, palate, and pharynx.

The most common lab diagnostic methods to demonstrate presence of FHV-1 (tissue/swabs) = FA, VI, PCR
  
  FA (conjunctival/corneal tissue) – avoid using fluorescein stain first
  VI (oronasal/conjunctival swabs) = Gold Standard
  PCR (oronasal/conjunctival swabs)

Three aspects of laboratory diagnosis of FHV-1 that frustrate the testing process:
  1. importance of confirming that chronic lesions are caused by FHV-1 is complicated by the lack of shedding during the maintenance or latent phases.
  2. FHV-1 or viral 1 DNA can be detected in samples from clinically normal cats therefore is a positive result coincidental, consequential, or causal?
  3. VN antibodies can be low/slow to develop and as such, a low level of neutralizing antibodies does not imply the absence of protection against clinical disease.

Treatment
1. Supportive care:
   Broad-spectrum oral antibiotics (acute cases) to prevent 2° respiratory infections
   Palatable and flavourful food – many cats are anorexic secondary to inability to smell, oral lesions
   Hydration
   Nasal decongestants, mucolytic drugs, and nebulization with saline
   Eye drops or ointments – several times daily

2. Antivirals (nucleoside analogues) and adjunct therapies (non-nucleoside analogues) (see Table 8)

3. Topical antibiotic if ulcerated (see Table 7)

Nucleoside Analogues: All antiviral medications are virustatic not virucidal because viruses are not truly “living” organisms and require host cells for replication.
Similarity between FHV-1 and other alpha herpesvirinae (specifically human Herpes Simplex Virus -1 (cold sores)) has led to the empirical use of HSV-1 therapies for FHV-1. Unfortunately, these medications have had less than desirable effects in cats. Similarly, HIV and feline retroviruses have similar treatments but these have not as extensively exploited as with FHV-1.

Nucleoside analogues are structurally analogous to nucleosides used in viral and host DNA and RNA synthesis but modified to disrupt the virus replication cycle by preventing DNA chain elongation. Efficacy: Trifluridine>>Ganicyclovir>Idoxuridine>Cidofovir>Pencyclovir>Vidarabine. Acyclovir / Trifluridine and INF-α have been reported to be synergistic in vitro.

Adjunct Therapies: Muro, Lysine, Lactoferrin, Interferon, Vitamins, Antioxidants, Serum, Lubrication

L-lysine. Arginine is an essential amino acid in the cat and is required for viral replication. Lysine antagonizes arginine. When treated with lysine, cats have a decreased incidence of recrudescence but not a decreased severity or shedding of the virus. The duration of an outbreak is unchanged.

Interferon’s (INFs) are related glycoproteins released from host cells in response to viral infection and can induce an antiviral state within other host cells. Two major classes: Type I and Type II. Type I INFs (INF-α = leukocytes, INF-β = fibroblasts, INF-ω, and INF-T (trophoblast) are induced by viruses, bacteria, and protozoa. Type II INF (INFγ = T-lymphocytes or NKC’s) are induced by antigens, bacteria, and protozoa. When released from infected cells, INFs trigger a series of events that regulate transcription of certain regions of the host DNA that reduce mRNA translation and activation of the endonuclease activity within the cell. This reduces the virus ability to infect the cell and begin replication (ie host cell less likely to become infected). INFs do not act directly on FHV. INF’s greatest efficacy is found in same species from which it is derived, but cross-species antiviral effects have been seen.

Lactoferrin is a mammalian iron-binding glycoprotein shown to inhibit FeHV-1 replication in vitro, potentially as a result of interfering with the receptor binding of FeHV-1 and/or viral penetration into susceptible cells.

Reasons for failure of anti-viral drugs
1. Anti-viral medications cannot distinguish between infected and non-infected cells therefore causes host cell toxicity. (The ideal anti-viral would suppress viral replication without suppressing host cell function – yet to be developed).
2. Frequency of application
3. Cost
4. Stings
Immunity and Vaccines
Primary FeHV-1 infection = humoral and cellular immune responses.
Active immunity via natural FeHV-1 infection / immunization protects cats from disease, but not from infection.
Passive immunity persists for 2 to 10 weeks (depending upon colostrum concentration and intake).
  Low maternally derived antibodies -may develop subclinical infection and latency
  High maternally derived antibodies -may interfere with vaccination at 12–14 weeks of age

European Advisory Board for Cat Diseases (ABCD) recommends:
  Primary series = 9 weeks old, 12 weeks old, then annual boosters

American Association of Feline Practitioners Feline Vaccine Advisory Panel recommends:
  Primary series = 6 weeks of age, then q3-4 weeks until 16 weeks of age, then 1 year.
  Subsequent booster doses are then administered every 1–3 years

All current commercial systemic vaccines against FVR are trivalent (FVR, FCV, FPV) = FVRCP. Protection induced is lowest against FHV-1.
  Modified-live vaccine – may have residual virulence and may induce clinical signs. Protection in 2-3 weeks
  Inactivated vaccine – used in pregnant queens, cats infected with FeLV or FIV. Protection in 2-3 weeks
  Intranasal vaccine – protection in 1 week

5. Glaucoma

Definition = an increase in intraocular pressure beyond the limits compatible with the health of the eye.
Glaucoma is a group of diseases characterized by decreased retinal ganglion cell sensitivity function that progresses to retinal ganglion cell death, loss of optic nerve axons and ultimately to incremental reduction in visual function and blindness.

NORMAL IOP = 15-25 mmHg

Stages of glaucoma
Is it here (early, non-congestive glaucoma or acute, congestive glaucoma) = Emergency
Has it been (blind +/- buphthalmic) = End-stage (absolute) glaucoma
Is it coming? Watch the fellow eye

Primary Glaucoma Occurs in the absence of disease whereby a progressive narrowing of the iridocorneal angle with biochemical changes in the trabecular meshwork results in decreased aqueous fluid draining from the eye.
Primary glaucoma will happen to both eyes...not necessarily at the same time therefore, if one eye has / had glaucoma, the fellow eye should also be treated.

Diagnosis
History: How long has the problem been going on? What signs have been noticed? Has there been a decrease in activity / appetite?

Clinical signs
Conjunctival hyperemia, Blepharospasm, Mydriasis, Diffuse corneal edema, Buphthalmia

Diagnostic Testing
Tonometry (the tone of the eye) - digital pressure – unreliable
- Shiotz tonometry (indentation/displacement)
- applanation tonometry (TonoPen, TonoVet, Avia)

Gonioscopy
Fundoscopy – optic nerve and retinal vessels indicate chronicity

Treatment
What are you going to do about it? Be Decisive Be Accurate
Ask yourself... Is the dog still visual (check for a consensual PLR – from the bad eye to the good eye)? What caused it? Should you be treating the other eye?
End goal: Vision and comfort achieved by decreasing aqueous production and increasing aqueous outflow

Medical therapy (see Tables 9 and 10)
Add an anti-inflammatory to help prevent reperfusion injury and decrease iridocyclitis associated with 1°/2° glaucoma. Dexamethasone or Prednisolone (top) for iris, Dexamethasone/prednisone for iris, retina and optic nerve.

1. Hyper-Osmotic Agents
Reduce aqueous flow by decreasing the rate of plasma ultrafiltration in the choroidal blood vessels. Distribution in the extracellular fluids increases plasma osmolality which promotes diffusion of water from the intraocular fluids back into the plasma. This affects the intraocular pressure (IOP) in 2 ways: impairs the ultrafiltration process of aqueous humor formation, and decreases the volume of the vitreous (causes a caudal shift in the plane of the iris-lens diaphragm opens ICA to improve aqueous drainage).

Mannitol has a high molecular weight and therefore there is less diffusion into uveitic eyes (like glycerin). It can quickly expand extracellular fluid volume and overload the cardiovascular system and its use may precipitate pulmonary edema in patients with cardiac compromise or in patients under general anesthesia. Mannitol should only be used in patients with normal renal function. In high concentrations, mannitol decreases renal blood flow and GFR which may negatively affect an already compromised kidney. Urine output should be monitored and is expected to increase following administration. Mannitol crystallizes when cool therefore dissolve crystals in a hot water bath (not microwave) before using.
2. Carbonic Anhydrase Inhibitors (CAIs)
CAIs decrease aqueous humor production. Topical applications need to inhibit 98.5% of CA to be effective at reducing IOP. 71% inhibit carbonic anhydrase in proximal renal tubule epithelium which causes diuresis and metabolic acidosis. Hypotension occurs secondary to decreased bicarbonate ions (HCO-3) leading to decreased Na+ and H2O in the aqueous fluid, and the induction of systemic acidosis also inhibits aqueous humor formation and enhances hypotension. Oral CAIs have been associated with hyperchloremia and hypokalemia. Take care with anorexic or pre-existing hypokalemic patients.

3. Beta-adrenergic antagonists (β1, β2 Blockers)
Beta blockers decrease aqueous humor production only. Widely used in human medicine. All but Betaxolol (β1 specific blocker) block both β1 and β2 receptors. The exact mechanism of action is not known but classically has been that β-blocking agents lower aqueous humor flow by altering the adrenergic neuronal control of aqueous humor formation by blocking β-receptors in the ciliary processes to reduce blood flow. Do not use Timolol with corneal ulcers as it has been shown to be toxic to regenerating corneal epithelium. Side effects include second degree heart block (type I and II).

4. Prostaglandin Analogues
Prostaglandins reduce IOP by increasing uveoscleral outflow. The prostaglandin analogues used for the treatment of glaucoma (latanoprost, travoprost, bimatoprost, unoprostone) are prodrugs that are activated in the cornea and have a high affinity and selectivity for the prostanoid FP receptors in the anterior segment of humans, monkey’s and dogs. In contrast, the IOP-lowering action of prostaglandins in the cat is mediated by EP3 and not FP receptors. The mechanisms by which activation of FP receptors lead to an increased uveoscleral outflow are still under investigation. In addition to IOP-lowering effects, latanoprost increases blood velocity in the optic nerve head. This increase perfusion may be important for preservation of visually function in glaucomatous eyes.

5. Adrenergics (α2-agonists)
Adrenergic agonists act on α and β-adrenergic receptors in the ciliary body and filtration angle to decrease aqueous production (β, α) and increase outflow (α). The exact mechanism is not known but it is thought that aqueous humor formation is reduced by decreasing blood flow in the ciliary body, through a vasoconstrictive action upon the vasculature of the ciliary body. Rarely sufficient to control glaucoma unless combined with a cholinergic miotic.

6. Cholinergics - Parasympathomimetics (muscarinic receptors)
Cholinergics open up the filtration angle by constriction the pupil to increase aqueous outflow (increase trabecular outflow). These are direct acting or indirect acting. Direct acting (Acetylcholine (Ach)-like) cholinergics are irreversible and not recommended for the treatment of glaucoma. These direct acting cholinergics act on muscarinic receptors which cause contractions of the longitudinal fibers of the ciliary muscle which widens the scleral spur to decrease resistance to aqueous humor passage through the outflow pathway (ie increases outflow). Indirect acting cholinergics (Acetylcholinesterase (AchE) inhibitors) are reversible and increase outflow by inhibiting AchE. Inhibition of AchE prevents Ach from binding/degrading and therefore accumulates at the cholinoreceptive sites. Indirect acting cholinergics need to be compounded.
A quick note about Pilocarpine (direct acting, irreversible cholinergic)
Pilocarpine is a potent miotic, inexpensive, and readily available. Pilocarpine does help to lower intraocular pressure however, Pilocarpine promotes uveitis (it is used as a research tool to create inflammation), has a low pH (4.5-5.5) so causes blepharospasm, epiphora, conjunctival hyperemia, and third eyelid elevation. Today, there are much better alternatives to Pilocarpine for the treatment of glaucoma!

Surgical Options for the control of glaucoma
- laser- or cryo- ablation of the ciliary processes – on blind/visual eyes
- chemical ablation of the cells of the ciliary processes – on blind eyes
- enucleation – on blind eyes
- evisceration – on blind eyes

6. Third Eyelid Gland Prolapse (aka “cherry eye”)

Third eyelid gland prolapse occurs in all breeds of dog and cat but is most commonly seen in Cocker Spaniels, Lhasa Apsos, Pekingese, Beagles, and English Bulldogs before age of two years. Prolapse of the third eyelid gland is not believed to be painful or considered to be an emergency. The third eyelid gland contributes approximately 30% of the precorneal tear film. Long term studies have concluded that dogs treated with surgical replacement of the gland had a lower incidence of KCS later life than those not treated or the gland excised.

There are many surgical methods for replacement of the third eyelid gland and this highlights the unreliable success of one method for all surgeons. Occasionally prolapse of the third eyelid gland is exacerbated by a structural deformity (bend) of the cartilage of the third eyelid (scrolled cartilage). Correction of this bend may be via excision of the cartilage or simply by correction of the position of the prolapsed gland.
The most common surgical technique used by me for gland replacement is the Morgan Pocket Technique. An orbital tacking suture is sometimes also required in breeds that “fail” with the Morgan Pocket Technique alone (eg Bulldogs, Cocker Spaniels).

Before surgery is recommended, a manual attempt to reposition the gland using a CTA is made. A topical steroid medication (eg Tobradex, Maxidex) may also be prescribed to reduce swelling of the gland provided the cornea does not retain fluorescein stain. If these preliminary techniques fail, surgical repair should be performed.

**New Techniques**

- Details of these techniques will be presented at the meeting. New references are becoming available between the time of this submission and this presentation.

1. Use of Adequan
2. Use of placenta, amniotic membrane
3. Gene therapy
4. Genetic testing - Optigen OPTIGEN provides DNA based diagnoses and information about inherited diseases of dogs. Through the collaborative efforts of veterinary ophthalmology, molecular diagnostics, and genetics, genetic testing procedures are developed by research scientists and veterinarians, and are extensively field-tested in cooperation with breeders of dogs. There are over 130 breeds for which genetic testing is available.  [www.optigen.com](http://www.optigen.com) – great website to explore.

**References**

Campbell FW, Green DG “Optical and retinal factors affecting visual resolution” J. Physiol. (Lond.) 181:576-93. 1965


Odom JV et al “Canine visual acuity: retinal and cortical field potentials evoked by pattern stimulation” Am. J. Physiol. 245:R637-41, 1983
Pretterer G et al “Brightness discrimination in the dog” J. Vis. 4:241-249, 2004