Retinoscopy, also called skiascopy, is a technique by which the refractive or dioptric state of the eye can be determined objectively. The principal procedures of retinoscopy involve observing characteristic light rays or reflexes that are created by illuminating the retina with a band or circular beam of light emitted from a retinoscope. The nature of these reflexes, and how they are influenced both by the properties of incoming light and by refractive lenses placed between the eye and the retinoscope, indicates the refractive power of the eye. Retinoscopy is the only practical means of clinical refraction in veterinary ophthalmology, and with a certain level of experience on the part of the examiner, it can be both reasonably accurate and reliable. The technique has been used to define the normal, pathologic, and surgically induced refractive state of the eyes in dogs,1–7 and numerous other domestic,8–10 laboratory,11–14 and exotic15–21 animal species. The purpose of this article is to define the optical principles relevant to retinoscopy and to describe the technique of spherical refraction using streak retinoscopy in the veterinary patient.

The Retinoscope and Trial Lenses

The basic design of the retinoscope is characterized by a light projection system and an examiner observation system. The projection system has a tungsten bulb filament that, for streak retinoscopes, projects a linear band of light toward the patient’s eye. Spot retinoscopes, which are less widely used, emit a circular beam of light. The projection system also has a condensing lens which focuses light onto an angulated, plane mirror, which in turn reflects light out the head of the instrument. A sleeve that moves
up and down is located in the handle of the retinoscope and controls the vergence of the emitted light by changing the orientation of the mirror and light source. For Welch Allen and Heine retinoscopes, completely lowering the sleeve projects light rays that are very slightly divergent (plane mirror effect), and completely raising the sleeve causes convergent light rays to be emitted. Copeland style retinoscopes have an opposite sleeve orientation such that a sleeve up position creates a plane mirror effect. By rotating the sleeve clockwise or counterclockwise, the examiner can also control the direction of the streak and therefore the ocular meridian to be examined, by projecting a horizontal or vertical streak, or any direction of streak between these two. The observation system is an aperture of specific design in the reflecting mirror that allows the examiner to view emergent light rays from the eye through the peephole.

When performing retinoscopy, refracting lenses from a trial lens set may be used. These lenses typically contain plus and minus spherical lenses in 0.25D increments, and plus cylinder lenses for spherocylindrical refraction techniques (discussed later). The veterinary patient is generally refracted with a skiascopy (lens) bar or rack, which is a bar with a handle containing a series of spherical plus and minus lenses in increments of 0.5D to 1.0D. In the United States, these bars are generally color coded, with black marking representing plus lenses and red marking indicating minus lenses. The color coding is the reversal of this in many European countries. The skiascopy bar allows the retinoscopist to easily and quickly place lenses in front of the patient’s eye for more rapid refraction.

**Optical Principals of Retinoscopy**

Table 1 lists basic definitions of refraction and refractive properties of the eye. A key principal in retinoscopy is that emerging light rays reflecting from an illuminated retina leave the eye and are refracted according to the same optical system as the incident light rays entering the eye. Emergent light rays (that are projected onto the eye from infinity) leave an emmetropic eye as parallel rays, a hyperopic eye as diverging rays, and a myopic eye as converging rays. The far point of an eye is defined as a point in space that is conjugate with, or corresponding to, the retina. In retinoscopy, a far point may also be considered to be the location in space at which emergent light rays form a focal point or plane.
Emergent light rays leaving an emmetropic eye have a far point at infinity. Emergent light rays leaving a hyperopic eye have a far point beyond infinity because they will not come to a focal point, and those from a myopic eye have a far point in front of infinity because they have already come to a point. Note that this is analogous to incident light rays, i.e., incident light rays from infinity in an emmetropic eye have a focal point on the retina, incident light rays in a hyperopic eye have a focal point beyond the retina, and incident light rays in a myopic eye have a focal point in front of the retina (in the vitreous). With emergent light rays, the further the far point is from infinity, the greater the refractive error of the eye, and with incident light rays, the further the focal point is from the retina, the greater the refractive error of the eye.

Emergent light rays from a retina illuminated by a retinoscope exit the eye and form a virtual image of the streak in front of the eye being examined, and appear as a varying shaped band of light in the pupil with a shadow adjacent to the band as the light streak is passed across the patient’s pupil. The appearance of these retinal reflexes depends on the location of the retinoscope’s peephole in relation to the far point of the eye being examined and on whether the emergent rays a) are diverging or parallel, b) have come to a focal point and crossed or c) are at the far point (in the process of crossing). As the retinoscope’s streak of light is passed across the pupil, emerging light rays that have not converged to a point source (or the farpoint) appear to the examiner to move in the same direction as the sweep of band of light. This is referred to as a with motion. If the emerging light rays have already come to the far point, crossed, and begun to diverge, the band of light in the pupil appears to move opposite the direction of the movement of the streak. For example, if one is sweeping with a vertical band of light from left to right across the pupil, the retinal reflex appears to move in the pupil from right to left. This is referred to as an against motion. Against motion is generally more difficult to interpret than with motion. If the retinoscope and examiner are at the far point, the pupil appears to fill completely with reflected light and no movement of the streak is seen. This is referred to as neutralization. An alternate way of considering this is if the far point is between the eye and the retinoscope, an against motion is seen, and if the far point is beyond the
retinoscope, a with motion is seen. The optical details behind these reflexes and the with and against phenomena are discussed in more detail elsewhere.\textsuperscript{22–24,26}

If these reflexes were observed at a location close to infinity, those from the emmetropic eye and the hyperopic eye would appear as a \textit{with motion} as they have not converged to a point. Those reflexes from the myopic eye would exhibit an \textit{against motion}, as they have converged, crossed, and begun to diverge. Optical infinity (>6 meters) is too distant from the eye to perform retinoscopy, but infinity can be recreated by positioning the retinoscope at a known distance from the eye (\textit{the working distance}) and placing a \textit{working lens} in the path of the reflected light rays. A working distance of 66cm is standard when performing retinoscopy, and a +1.5D working lens is used at this distance. Note that a +1.5D lens would bring parallel light rays, as would be emerging from an emmetropic eye, to a focal point of 66cm (1 meter/1.5D = 0.66m or 66cm). Therefore, when retinoscopy is performed on an emmetropic eye at 66cm, with a +1.5D lens, neutralization is seen. All ammetropias under the same conditions would show either a with motion if the eye is hyperopic, or an against motion if the eye is myopic. For the hyperope, placing additional plus lenses in the light path would converge the light rays and move the far point \textbf{in} to the retinoscope at 66cm. For the myope, placing negative lenses in the light path would diverge the rays and move the far point \textbf{out} to the retinoscope at 66cm. A corollary to this is that if a with reflex is seen during retinoscopy, plus lenses should be added to the light path to reach neutralization (the far point), and if an against motion is seen, minus lenses are added to reach neutralization (the far point). The dioptric power of these additional lenses, which are referred to as the \textit{correcting lens}, is the measure of refractive error in the eye. Because it is inconvenient to hold two lenses (the working lens and correcting lens) in front of the eye at the same time, a single lens can be used to reach neutralization and achieve a gross refraction. Subtracting the working lens power (or working distance power) from the gross refraction then yields the net refraction. As examples:

\begin{verbatim}
@ 66cm, neutralization is seen with a +3.00D lens
+3.00D (gross refraction)
-1.50D* (working lens or distance power)
+1.50D (net refraction)
\end{verbatim}
or: @ 66cm, neutralization is seen at -3.00D  
-3.00D  
-1.50D*  
-4.50D net refraction  

*Subtract 2.00D if a 50cm working distance is used.  
*Note that subtraction of the working distance power with a minus gross refraction yields a higher minus net refraction.

**Technique and Observation of the Retinal Reflexes**

Retinoscopy is performed in a semi-darkened examination room with an assistant steadying the animal’s head and attempting to line the animal’s gaze with the examiner. The retinoscope is held in the palm of one hand, and the examiner places the thumb on the sleeve to control vergence and meridian of the streak. The trial lens or lens bar is held in the remaining hand. The retinoscopist is positioned at a working distance of 66cm from the eye. It is critical to keep this distance accurate and, when learning retinoscopy, it should be routinely checked with a measuring tape or string, as variations in the working distance will affect results. Individuals with shorter arms may prefer a working distance of 50cm. At this shorter distance there is more opportunity for distance error and the working distance correction is 2.00D (i.e., 2.00D is subtracted from the gross refraction) rather than 1.50D at 66cm.

The vergence is set to the plane mirror effect by moving the sleeve down, and the streak is generally first positioned vertically. The streak is projected onto the eye, and the critical step of optical alignment is next performed. Optical alignment ensures the examiner is projecting incident light rays along the optical axis of the eye and is achieved by aligning the Purkinje images from the anterior cornea and lens surfaces such that they are roughly superimposed and positioned in one side of the center of the patient’s pupil. Because the emerging light rays are a conical shape, errors in alignment will cause major errors in identifying neutrality, much more so than small errors in working distance. The retinoscope is placed on the examiner’s brow, and by moving the head slightly, or gently rocking the instrument, sweeps of the streak are made across the patient’s pupil, **perpendicular** to the streak axis. Note that retinoscopy measures the dioptic power of the ocular meridian in the direction of the sweep, rather than in the orientation of the sweep itself. For example, the vertical streak, when swept horizontally, is measuring the
power of the horizontal or 180 degree meridian. The streaks are brought into the pupil with a slow, deliberate motion. This is first performed for the vertical degree streak by shaking your head back and forth slightly. The sleeve is then rotated to produce a horizontal degree streak, sweeping the band by shaking your head up and down. When performing retinoscopy, it is important for the examiner to keep both eyes open, and it is useful to practice using both the dominant and nondominant eye. Lenses are held between the thumb and forefinger (trial lens), or in the palm (lens bar handle) of the opposite hand, which is gently rested or stabilized on the patient’s forehead. When refracting, the lenses are brought into the path of the emerging light rays and are held at a point as close as possible to the patient’s cornea, generally 1-2cm. Keeping this refracting lens to cornea distance, known as the vertex distance, to a minimum is especially important when using high power lenses (i.e., ≥10D).

Identifying Neutrality

The examiner should first observe the retinal reflexes at the working distance and determine whether they are a with motion, an against motion, or at neutralization. All emmetropes and almost all ammetropes will show a with motion at 66cm with no refractive lens. An against motion will only be seen if >1.5D of myopia are present. When observing a with motion, progressively stronger plus lenses are added in front of the eye until neutralization is reached. When observing an against motion, progressively stronger minus lenses are used to reach neutralization. Against motion is more difficult to interpret than with motion, and a simple technique to help confirm against motion is to reverse the vergence of the incident light by raising the sleeve on the retinoscope. At the same working distance, the against motion should now become a with motion. The sleeve is again lowered and refraction is continued. Because against motion is difficult to interpret, neutrality is generally approached from the with motion side. This is achieved by adding progressively stronger minus lenses until the against motion is converted to a with motion, then bracketing back to neutralization by adding plus lenses (or by reducing minus lenses). When refracting with a lens bar using 0.5D increments, the examiner may see a recognizable with motion with
one lens and an against motion with the next higher power lens, and never visualize true neutrality. In this case the neutral zone lies somewhere between the power of these two lenses and should be extrapolated.

Several characteristics of the neutralization reflex can assist in determining how proximate the examiner is to this zone. At great distances from the far point (as would be seen with high refractive errors), the reflex is dull, slow moving, and the streak is fairly broad. Within 4 diopters of neutralization, the streak becomes narrow and distinct, and then the streak again becomes progressively broader within the last 2 diopters of the endpoint of neutralization. The observed streak also becomes progressively faster (appears to move faster as the sweep is made) and brighter with closer proximity to neutrality. The reflex is infinitely fast and very bright just prior to neutralization. These characteristics are more prominent when viewing from the with motion side, and they are critical in assisting the examiner in estimating the distance from the far point and, therefore, what power of lens will need to be placed to reach neutralization. In tapetal animals, the brightness of the reflex is an especially useful tool to determine neutrality. Neutralization is not a point but actually a zone between the last recognizable with motion and the first recognizable against motion. It has been suggested that the endpoint be judged slightly on the with motion side of this zone,24 or at the point when the last recognizable, slight with motion is seen. Neutralization should also be confirmed by leaning forward slightly from 66cm to observe a with motion, and leaning backward slightly to observe an against motion. This switch from with motion to against motion on either side of the far point is why neutralization is also referred to as the reversal point.

**Estimating Refractive Error**

It is sometimes very useful to quickly estimate refractive errors prior to introducing any lenses in front of the eye. This is particularly relevant with fractious veterinary patients because, by estimating the error first, fewer refractive lenses are placed before the eye and total refraction time is decreased. The technique for estimating gross hyperopia involves enhancement of the retinal reflex24 and is used if a with motion is noted without refractive lenses. Enhancement involves evaluating the thickness of the projected beam of light from the retinoscope in the pupil and comparing this to the thickness of the beam outside of
the pupil. At the working distance, the vergence of the incident light rays is changed by slowly raising the sleeve until the band of light in the pupil (the retinal reflex) is the thinnest and crispest band possible. This usually occurs with the sleeve approximately 1/2 of the way up. The width of the retinal reflex at this point is compared with the width of the band outside the pupil, on the iris or the patient’s face (the intercept, or face band). With low degrees of gross hyperopia (<1.0D), the retinal band will not enhance, i.e., it will not become thinner. At 1–3D of gross hyperopia, the retinal band becomes thinner prior to the face band, and the enhanced retinal band is approximately 3/4 to 1/2 the width of the face band (which is broad with these errors), respectively. With 4–5D of hyperopia, the retinal band may be enhanced to a very thin streak, and it is only slightly narrower than the face band. Figure 4 illustrates the appearance of these enhanced bands with different refractive errors. Both meridians should be enhanced, and since this technique estimates gross hyperopia, the estimated error should approximate the total lenses necessary to reach neutralization. Recall that an emmetropic eye refracted at 66cm will have +1.5D of gross refractive error or a with motion without lenses. Therefore, with enhancement, an emmetrope will have a retinal band approximately 3/4 the width of the intercept, and this face band will be broad.

Estimating net myopia involves far point determination. If an against motion is observed at the working distance without lens, >1.50D of myopia are present. Change the vergence by moving the sleeve up to confirm and produce a with motion. Move the sleeve back down and, while streaking the pupil, slowly move towards the eye until a with motion is seen. Then slowly recede from the eye until neutralization is seen, and estimate the distance from the eye. Because myopic eyes have a far point progressively closer to the eye with higher degrees of refractive errors, estimating this distance provides an estimate of net myopia, with the distance between the eye and the retinoscope representing the dioptric equivalent of the refractive error. This estimating technique becomes progressively less accurate with high myopic errors due to distance error.

Retinoscopic reflexes from eyes with high refractive errors can be difficult to interpret as they are very dim and mimic the dull reflexes caused by opacities in the ocular media such as corneal edema, lenticular opacities, or pseudophakic capsular opacification. When a dim reflex is encountered, it is useful
to first introduce high power lenses (+5D or −5D). If no change in the brightness of the reflex is seen, media opacification is probably present. If a brighter reflex, and a with or against motion is identified, a high refractive error is likely present.

**Astigmatic Refractive Errors**

When refracting a spherical eye (i.e., one without astigmatism, either an emmetrope or a spherical ammetrope), neutralization is seen with both the vertical and horizontal streaks (and in fact, with any orientation of the streak) using the same lens. Because astigmatic eyes have more than one far point or plane of focus, neutralization is seen with different power lenses in different meridians. A corollary to this would be that in an astigmatic eye, when neutralization is reached in one meridian, and the streak is rotated 90 degrees, a with or against motion is then seen with the same lens. An astigmatic eye may be hyperopic or myopic in one meridian and emmetropic in the opposite meridian (simple astigmatism), hyperopic or myopic in both meridians (compound astigmatism), or myopic in one meridian and hyperopic in the other (mixed astigmatism). The **major or principal meridians** are defined as the least and most refractive meridians of an astigmatic eye and are generally oriented with axes at or near 90 degrees (vertical) and 180 (horizontal) degrees (see Fig. 6 for standard axes or ocular meridian denotation). Shifts in the axes of the principal meridians such that they are no longer located at 90 and 180 degrees are referred to as oblique astigmatism, and occur with less frequency. In regular astigmatism, the axes of the principal meridians are 90 degrees apart, while with the rare irregular astigmatism, the principal meridians are not perpendicular.

When the axes of the principal meridians in an astigmatic eye are shifted from 90 to 180 degrees, the retinal reflex and the intercept assume a characteristic appearance known as a **break phenomena**. Specifically, the retinal reflex will not line up with the intercept or face band when the streak is oriented vertically or horizontally, but instead is oriented in the general direction or axis of a principal meridian. The break phenomena is generally only seen with astigmatism >1.0D,23 and is most visible when the retinal band is enhanced, or made as thin as possible by changing the beam vergence as is performed when
estimating hyperopia. When a break phenomena is encountered, the examiner should rotate the streak such that the two bands line up and then sweep perpendicular to this direction. The reflex is brightest when the two bands are in the correct orientation with one another. The opposite principal meridian is almost always perpendicular to this first meridian, so that after the first meridian is neutralized, the streak is rotated 90 degrees to neutralize the second meridian. This break phenomena is important to recognize because the correct lens to reach neutrality cannot be applied if the streak is off axis.23

In veterinary ophthalmology, retinoscopy is almost always performed by neutralizing with spheres only, e.g., by using a lens bar or rack. A spherical lens applies its refractive power in all meridians. When using a spheres only technique, the examiner simply neutralizes one meridian (i.e., using the vertical streak), notes the gross refraction, then rotates the streak 90 degrees and neutralizes the opposite meridian. The refractive state in an astigmatic eye is often denoted as an average spherical refraction by averaging the net results of the two meridians. The results may also be designated with a lens cross, which is a pair of lines drawn through the principal axis or meridians with two spherical corrections and the axes noted at the tips of each line.

An astigmatic eye can also be neutralized by retinoscopy with a spherocylindrical refraction method, using a spherical lens in the most refractive meridian, combined with a cylinder lens in the least refractive meridian. The cylinder lens applies its refractive power in only one meridian, perpendicular to the axis of the cylinder. In this fashion, both meridians can be neutralized with the same combination of lenses. In humans, this is generally performed using a refractor (machine that contains all the lenses), or a trial lens frame that holds multiple lenses. Alternatively, more than one trial lens (a spherical lens and a cylinder lens) must be held in one hand in front of the patient. This spherocylindrical refraction method is much more accurate than refraction by spheres only, and is more crucial in humans when correction of the astigmatic refractive error is intended. Because it generally is not practical in veterinary patients, the principles will not be described here. Details of this refraction method may be found in clinical refraction texts.22,23,25
Practical Aspects of Veterinary Retinoscopy

The veterinary retinoscopist is confronted with many of the challenges facing the human pediatric ophthalmologist in terms of patient cooperation and the necessity of a rapid refraction method. A skiascopy bar or rack and refraction with a spherical lenses only method is most practical for the veterinary patient. If a trial lens set is all that is available, a makeshift retinoscopy rack can be constructed by placing a series of lens in a standard 35mm slide viewing sheet. A good assistant to steady the patient's head and direct the gaze is invaluable. The estimating techniques previously described can reduce refraction time and frustration level, especially if a high ammetropia is present. They can also be used to cross check the refraction obtained with the lens bar, and increase examiner confidence in identifying the true refractive state. Optical alignment is critical in achieving accurate results and is sometimes challenging to maintain due to patient movement. The position of the Purkinje images should be checked constantly to maintain this alignment. Sedation or, rarely, general anesthesia may be used if necessary; however, ketamine anesthesia should be avoided due to its tendency to induce nystagmus. Sedation with acepromazine generally elevates the nictitans, and if opiates are used in dogs, pharmacological mydriasis may be necessary to counteract the induced miosis. It should be noted that anesthetic agents, presumably by altering ocular volume, may affect retinoscopy results, and therefore should be used only if refraction cannot be performed otherwise.

Cycloplegia with atropine or cyclopentolate are routinely used to relax accommodation when refracting children. As most domestic animals that a veterinarian would refract in a clinical setting have limited accommodative ability, cycloplegia is generally unnecessary. Retinoscopy values with and without cycloplegia were similar in two refractive studies conducted in dogs. Darkening the examining room will generally induce a sufficient pupil size to perform retinoscopy in animals. If miosis hinders visualization of the retinal reflexes, tropicamide may be administered, and the animal refracted after approximately 10 minutes, when the pupil size is midposition. Though many beginners prefer to perform retinoscopy through a widely dilated pupil, the size of the neutral zone, and therefore the difficulty in identifying the endpoint, varies directly with the size of the pupil. Full mydriasis may also be associated with irregular
reflexes which can make identification of neutrality difficult. These reflexes are often characterized by a swirling or scissors motion, where the reflex comes together like blades on scissors, and are induced by inherent optical irregularities and differences in the refractive properties between the central and peripheral cornea and crystalline lens. The scissors motion, while annoying, generally occurs near neutrality if no pathologic changes in the eye are present, i.e., corneal scarring, and is an indication that this endpoint is near. If retinoscopy is performed through a widely dilated pupil, it is critical to interpret only the reflexes in the center of the pupil, in the optical zone of the cornea, and ignore the reflexes occurring in the periphery of the pupil. As mentioned previously, the brightness of the reflex at neutralization in a tapetal animal is a useful indication of the end point of neutrality.

Aphakic and pseudophakic veterinary patients can also be difficult to refract due to several factors. Many have ocular media haziness caused by corneal edema, aqueous flare or capsular opacification. If refraction is performed soon after surgery, it is not uncommon to encounter surgically induced astigmatism, which may be irregular. The reflexes at the periphery of the intraocular lens and the pupillary margin (aphakic area) can also be confusing, and the examiner should again concentrate on the center of the pupil and avoid full mydriasis.

Conclusions

Regarding the reliability (a measure of repeatability) of retinoscopy, two studies in which skilled ophthalmologists refracted the same human patients at separate intervals have documented that a ±0.5D spherical power variability between these two intervals was common. Performing a number of replicative measures and then averaging the results increases reliability. The accuracy (proximity of the retinoscopic refraction to the “true” refractive state) is perhaps most influenced by examiner experience, but is also affected by patient cooperation. It has been suggested that errors of ±1.0D spherical power may be common when refracting young, restless children. Retinoscopic values are generally confirmed with subjective refraction in humans and experienced ophthalmologists can routinely refract human patients to within 0.25D of their objectively determined refractive status. Because a subjective refraction
cannot generally be obtained in animals, the accuracy of streak retinoscopy in the veterinary patient is difficult to determine with certainty. A goal of refraction within ±0.5D of the true refractive state seems reasonable for the veterinary ophthalmologist and should be obtainable in a clinical setting with a moderate degree of examiner experience. More accurate results and confidence in these results can be obtained with considerable more experience. Care in bracketing neutrality, ensuring optical alignment, and maintaining a correct working distance are important factors to achieve a correct refraction. Accurate and rapid retinoscopy is an art, requiring many hours of practice to become proficient. An instructional manual and practice with a good quality schematic eye, designed to simulate different refractive states, are a necessity for those attempting to learn this technique.
References


**Ammetropia** – an eye with a refractive error, generally from variations in axial length of the eye, astigmatism, or a shift in position or absence of the crystalline lens.

**Astigmatism** – an aspherical ammetropia caused when the refractive surfaces of the eye have different radii of curvature in different meridians, generally caused by differences in corneal curvatures. Such an eye has two principle focal points.

**Diopters (D)** – a measure of lens power, defined by its focal point in meters (e.g., 5 diopter lens has focal point of 0.2m or 1m/5D).

**Emmetropia** – an eye without refractive error where the plus lenses of the cornea and crystalline lenses refract light to a point source on the retina.

**Hyperopia** – an eye with a refractive error caused by relatively too little refractive power, generally often caused by a shorter than normal axial length.

**Meridian** – an imaginary line on the surface of a spherical body. A corneal meridian is this line marking the intersection with the corneal surface and an anteroposterior plane passing through the apex of the cornea.

**Myopia** – an eye with a refractive error caused by relatively too great a refractive power, generally caused by a longer than normal axial length.

**Optical Infinity** – any distance greater than 6 meters.

**Refraction** – bending of light rays, as with a glass lens or the lens systems of the eye. Plus lenses (convex) converge parallel light rays which minus lenses (concave) diverge light rays.

**Vergence** – the character of light rays, defined by the curvature of its wave front. The rays may have negative (divergent), positive (convergent) or plano (parallel) vergence.