Vision and Refraction
VISION AND REFRACTION

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REFRACTIVE ERRORS AND VISION LOSS

The World Health Organization estimates that 333 million people are blind or visually impaired. Nearly half of these, 154 million are suffering from uncorrected refractive error, with more than 13 million of them children.

Individuals so affected are handicapped in a variety of ways from being deprived of educational opportunities to being limited in the workplace and even being burdens to their families. The economic impact both personally and in terms of society at large is huge.

In contrast to how “blindness” is usually defined, the vision reduction from uncorrected refractive errors must be considered in a different light. It differs from other physical inborn or acquired blinding conditions for two important reasons: 1) in instances of vision loss from uncorrected refractive error, vision can in most cases be corrected to normal with proper optical correction provided with glasses or contact lenses, and 2) eyes are normal except for the improper focus.

The most commonly affected person, the myope or nearsighted individual, can usually see well even without correction if objects are held closer to the eye at what is called the far point. Vision reduction from uncorrected hyperopia (especially if it is high) and astigmatism can cause reduction in vision at all distances and in certain circumstances can lead to permanent vision loss from amblyopia.

In rare cases, prolonged uncorrected high hyperopia (farsightedness) early in life can cause permanent reduction in vision from bilateral amblyopia. More commonly, unequal refractive errors, if uncorrected, can cause permanent loss of vision in one eye, anisometropic amblyopia, affecting the eye with the higher refractive error.

Acquired refractive errors occur with aging as an involutional change called presbyopia. This affects another 150 million people. Presbyopia causes individuals in the mid to late fifth decade to experience difficulty seeing at near because of decreased focusing power of the eye. This can be remedied by use of reading glasses. Some people with a low to moderate degree of farsightedness (hyperopia) are able to see clearly in younger years because they can accommodate, but have difficulty seeing at both distance and near at age 40 and beyond because of the loss of accommodation occurring with presbyopia.

Another important cause for acquired loss of vision from uncorrected refractive error has been failure to provide adequate optical correction after surgical removal of a senile cataract, or by loss of glasses something which has been said to occur in nearly 75% of cases in the first year after cataract surgery. However with the advent of properly selected intraocular lenses placed at the time of cataract surgery, this type of vision loss is occurring less often.

The reduction in quality of life caused by uncorrected refractive error cannot be calculated with accuracy, but it is significant and deserves attention to the following details that will be discussed in the pages that follow.

- Understanding how we see and how uncorrected refractive error affects vision
- Identifying those at risk for vision reduction from uncorrected refractive error
- The technique and methods for measuring refractive error (refraction)
- The importance of prescribing and dispensing suitable glasses, and following up for the individual’s ongoing needs
How We See

The image being looked at is called the object of regard. Seeing properly, starts with light rays carrying its image focused properly on the normal retina. To achieve this, the light rays are refracted or bent by the optical system of the eye. In the resting state without any effort, the normal eye can refract parallel light rays, or those coming from infinity, resulting in an in-focus image on the retina allowing normal vision. For an object to be brought to a conscious level or actually be “seen”, the retinal image is changed from light to electrical energy and then transmitted along neural pathways to the occipital (visual) cortex. Here it is “developed” and then processed by the higher parts of the central nervous system resulting in what we call vision. We are concerned here with refraction; that is, bringing the light rays to a proper focus on the retina [Fig. 1].

Objects at “infinity”, which for practical purposes, is at 20 feet (6 meters) are represented by light rays that are parallel as they enter the eye. The normal eye is a powerful optical “device”. It is capable, in the resting state, of focusing parallel light rays entering through its front surface, the cornea, on to the retina located just 24 mm (one inch) behind. All objects located nearer than 20 feet produce light rays that are diverging as they enter the eye. To be focused on the retina these diverging rays must be made parallel, or refracted, to be seen clearly. This is accomplished by increasing the power of the eye in a process called accommodation. In youth accommodation is capable of increasing the power of the lens by as much as 14 diopters. This enables clear vision for objects only a few inches in front of the eye.

Accommodation decreases with maturity, becoming a problem as presbyopia develops causing poor vision at near, usually in the 40’s. Accommodation is lost entirely by the 60’s and beyond. The presbyopic eye is normal except for the reduced focusing power creating the need for reading glasses.

![Figure 1](image_url). In the resting state light rays from infinity enter the eye through the cornea and are focused on the retina 24 mm behind the front surface. The power of the normal human eye at rest is approximately 62 D. The cornea is the most powerful optical unit at 43 D and the lens in the resting state has a power of 19 D. With maximum accommodation, the lens power can increase to as much as 33D increasing the power of the eye to slightly more than 76 D.
What is Normal Vision?

Seeing “properly” or normal vision for the human is defined clinically as being able to distinguish objects that subtend 5 minutes of arc and have components that subtend one minute of arc when viewed at 20 feet (6 meters) [Fig. 2]. This is called 20/20, 6/6, or 1.0 vision. The block letter E of the English alphabet is the ideal symbol or “optotype” because it is naturally made up of five clearly identified components; namely, three bars and two spaces, all of equal width, with a “spine” connecting them [Fig. 3]. This optotype has four unique directional values and is suitable for testing a person who is illiterate or who is literate in a different language.

Figure 2. A This eye is seeing at 20 feet the optotype “E” that subtends 5 minutes of arc at 20 feet denoting normal vision. B The “E” becomes in effect four different optotypes when shown pointing: right, up, down, and left as shown above.

Figure 3. Normal vision is recorded as 20/20, 6/6, or 1.0. If the smallest optotype that can be seen at 20 ft subtends 5 minutes of arc at 40 ft, vision is 20/40 (the smallest object seen is twice as large). If it is at 100 ft., vision is 20/100 (the object is 5 times as large). If it is at 200 ft. vision is 20/200 (the object is 10 times as large). 20/40 = 0.5, 20/100 = 0.1 20/200 = 0.05, etc.
What About Near Objects?

Under normal circumstances, and in younger years, the power of the lens can increase naturally. This increased power, measured in diopters*, is required to focus diverging light rays that come from objects nearer than 20 ft. The increase in dioptric power occurs involuntarily on a reflex basis and is called accommodation. In the normal state, the increase in dioptric power, accommodation, is linked to the convergence angle of the eyes. This linkage results in appropriate convergence of the visual axes to maintain the image of the object of regard on the fovea or visual center of each eye [Fig. 4]. If this relationship is abnormal, resulting in over-convergence at near, a strabismus called accommodative esotropia occurs. Uncorrected hyperopia can also cause esotropia when focusing on objects at any distance because the normal accommodative convergence/accommodation ratio overcomes fusional vergence. Accommodation capacity is reduced gradually over the years. By age 45 years most people begin having difficulty seeing near objects such as the print in books, especially in subdued light. Plus lenses, usually in the form of reading glasses, are then required to see clearly at near.

A

B

Figure 4. A The lens has thickened (accommodation) becoming a more powerful optical device able to converge diverging light rays from an object nearer than 20 feet. B While doing this, the eyes converge to keep the object on the fovea of each eye.

What Can Go Wrong?

Errors in refraction cause defocus of the image of the object of regard on the retina of the eye resulting in reduced vision (from blur), eye strain, and in some cases strabismus. These errors in refraction can be genetic and inborn, from acquired disease states, trauma, or iatrogenic from surgery. The usual treatment for refractive error is glasses or contact lenses. Recently corneal surgery has been employed for some cases of myopia and to a lesser extent for hyperopia, and astigmatism.

* One diopter of focusing power will bring parallel light rays to point focus in one meter; 2 diopters of focusing power will bring parallel light rays to point focus in ½ meter, etc. The focal point is a reciprocal of the lens power.
Hyperopia

Hyperopia or “farsightedness” is insufficient power of the eye in the resting state. This results in a failure to focus parallel light rays entering the eye on the retina [Fig. 5A]. In a few cases the eye has normal focusing power but the eye is “too short”. In either case the parallel light rays come to focus behind the retina. The unfocused image on the retina is perceived as blurred. The focusing power of the hyperopic eye can be increased by reflex or automatic accommodation in younger individuals. However, this can cause eye strain (asthenopia) or crossing of the eyes which in turn results in diplopia (double vision) or one eye can be suppressed (ignored). If suppression is persistent in one eye, amblyopia or decreased vision can be a permanent result. Viewing only those light rays at the center of the light bundle, those that travel straight through the eye to the retina, can result in a clearer image in a farsighted eye [Fig. 5B]. This can be achieved by viewing through a small aperture called a pinhole or with a plus lens [Fig. 6].

**Figure 5.** A This hyperopic (farsighted) eye has insufficient focusing power (is too short) to bring parallel light rays to a point focus on the retina. B A pinhole (small aperture) that allows only central light rays that do not need to “bent/converged” or refracted produces a focused image, but the amount of light entering the eye is reduced.

**Figure 6.** Hyperopia is treated by focusing, or converging, light rays before they enter the eye. This is accomplished by adding a plus or condensing lens as shown above. A plus contact lens placed on the cornea can also be used. After cataract surgery an intraocular lens can be inserted. In youth the natural accommodative power of the lens can correct for low to moderate hyperopia resulting in good vision but running the risk of eye strain and strabismus.
Myopia

Myopia or “nearsightedness” exists when the converging power of the eye’s optical system is too powerful, or the eye is too long, and the parallel light rays come to focus in front of the retina [Fig. 7A]. Those light rays coming from infinity, converge and reach focus in the eye so that they are diverging when they reach the retina. This produces a blurred image. Objects brought closer and reaching the eye with diverging light rays can be seen clearly when a point is reached where the diverging rays from a point closer than infinity reach the retina in focus [Fig. 7B]. This is also accomplished by adding a minus lens [Fig. 8A]. As with hyperopia, those light rays at the center of the light bundle from any distance can be seen clearly when viewed through a pinhole [Fig. 8B]. A person with myopia will, in all but the most extreme cases, have a useful near point where objects can be seen clearly without the need for optical aids, a pin hole, or focusing effort by the individual. For example, a person with 2 diopters of myopia will see objects clearly at a distance of ½ meter or 1 ½ feet in front of the eye and at all distances nearer to the eye.

Figure 7. A The myopic (nearsighted) eye has excess focusing power or the eye is too long resulting in parallel light rays being focused in front of the retina producing a blurred image on the retina. B Light from closer than infinity can at the right point be focused on the retina of the myopic eye in the resting state.

Figure 8. A Myopia is treated by decreasing the effective focusing power of the eye. This is done by adding a minus lens, as shown above, in the form of a spectacle lens. A minus power contact lens placed on the cornea can also be used. Myopia is the leading indication for refractive surgery which is accomplished by reducing the refractive power of the cornea. B A pinhole (small aperture) that allows only central light rays that do not need to “bent/converged”, refracted, produces a focused image, but the amount of light entering the eye is reduced. The eye is unable to reduce power naturally.
Astigmatism

Astigmatism is the condition where the eye is more or less near or farsighted in a given meridian [Fig. 9A]. The eye with astigmatism can be compared to a perfect circle that is compressed making it “out of round”. Uncorrected astigmatism produces a distorted, “stretched” or elongated and blurred image. So-called “with the rule” astigmatism requires additional plus power at the 90 degree meridian and against the rule astigmatism requires more plus power at the 180 degree meridian. Astigmatism can also occur at any of the points between. Astigmatism is usually described in terms of the meridian that needs more plus although so called minus cylinder subjective refraction can be done after overcorrecting the patient with plus lenses [Fig. 9B].

Anisometropia

Anisometropia exists when the refractive error of the two eyes is different. It takes from 1.00 to 1.5 D diopters of difference to be significant. This can be a different amount of hyperopia, myopia, or astigmatism. One eye can be hyperopic and the other myopic in which case some call this antimetropia. The two eyes always change focus (accommodate) the same amount. There is no way for a person to correct anisometropia. This must be done with lenses. Uncorrected anisometropia is a common cause of amblyopia.

Aphakia

Aphakia is the absence of the crystalline lens [Fig. 10]. This usually occurs after surgery for cataract. It also occurs very rarely as a congenital abnormality or with trauma. Current ophthalmic practice entails replacement of the extracted cataract with an intraocular lens. The aphakic eye is severely hyperopic or farsighted and, of course, the eye cannot accommodate; that is, focus for near.
Presbyopia

Presbyopia is a decrease in the ability of the crystalline lens to increase focus in order to see near objects clearly [Fig. 11]. This occurs gradually with maturity in nearly all people. When a critical age is attained, usually in the mid-forties, decreased focusing ability, probably from stiffness of the lens, causes near objects to be defocused and blurred. This is treated with plus (reading) glasses or with a bifocal addition to spectacles already worn.

Figure 10. The aphakic eye is extremely farsighted with no ability to change focus. Current practice is to replace the cataract that has been removed with a plastic intraocular lens. The permanent IOL placed at surgery is intended to put the eye in focus, or nearly so, at distance. Plus lenses in the form of spectacles are required for intermediate vision and near reading. Some IOL’s are designed to be multi-focal and therefore be effective for focusing at near as well as distance.

Figure 11. A single vision plus reading glass or B a bifocal lens is used to treat presbyopia.
RETINOSCOPY

Basic Components

Retinoscopy is the simplest way to determine the refractive error of an individual regardless of age or level of cooperation. This procedure employs two basic components:

1. a concentrated bright light source that can be viewed through the instrument
2. hand-held lenses of plus and minus power in both spheres and cylinders
   (although not ideal, the cylinder power and axis can be determined using only spherical lenses)

A third essential component is an examiner with the skill to be able to carry out retinoscopy for the benefit of his/her patients.

Principle of Retinoscopy

The essence of retinoscopy: analysis of the light reflex created in the pupil by light reflected back from the retina for the purpose of objectively determining the refractive error. This reflected light starts with a light shining off a plane mirror of the retinoscope and then passing through the pupil to eventually shine on the retina. The light reflected back off the retina is viewed in the pupil by the examiner “peeking” through a small aperture in the center of the retinoscope mirror. Before hand held electric instruments were available, the light source of the retinoscope came from a plane mirror illuminated by a candle. The modern retinoscope operates on a similar but updated principle. Some modern retinoscopes produce a “spot” rather than a streak. These spot retinoscopes are more difficult to use.

Control of Accommodation

In order to accomplish accurate measurement of the refractive error, the eye should be in the resting state. This simulates the condition when viewing an object at infinity or for practical purposes at a distance greater than 20 feet. Accommodation is suspended with a cycloplegic agent, usually Cyclopentolate ½ or 1% or atropine ½ or 1%. In some cases accommodation is suspended by “fogging”. This is done with a plus lens over the fellow eye that is fixing a distant object. Fogging can be used in some instances instead of pharmacologic suspension of accommodation in a cooperative patient. If accommodation is not controlled, retinoscopy will erroneously measure more myopia or less hyperopia especially in younger individuals with robust accommodation. In older individuals with absolute presbyopia or those who are aphakic or pseudophakic, retinoscopy can be done without concern for accommodation which, of course, is absent in these individuals. In every case where retinoscopy is done, the pupil must be large enough to allow the light reflex from the retina to be seen clearly. In addition, the corneal surface of the eye must be regular and the cornea itself clear to allow an undistorted reflex necessary to perform retinoscopy.

Retinoscope and Its Use

There are several models of retinoscope suitable for use, with the most popular one in the U.S being the Copeland Streak Retinoscope. This concept was developed in the 1920’s by Jack Copeland. While his is the original and most popular, there are several similar instruments using the same principle. The retinoscope has a special bulb that emits a streak or spot of light reflected off a plane mirror. The streak makes it easier to recognize the light reflex and to recognize the axis of the cylinder. In order to present parallel light rays to the eye, a plus
“working distance” lens is placed in front of the eye. This is a +1.50 D lens in most cases because this is considered “arms length” for most. The Copeland retinoscope and some others have adjustments that can be used to modify the light rays, but these are seldom used, relying on the “working distance” lens instead. In cases of hyperopia when parallel light rays enter the eye, a with motion is observed when the light source is moved meaning that the light reflex in the pupil moves in the same direction, “with”, as the movement of the retinoscope light source. This movement is neutralized or disappears producing a full red reflex when the proper amount of plus lens is placed in front of the pupil. In cases of myopia greater than 1.50 when parallel light rays enter the eye, an “against” movement is observed meaning that the light reflex in the pupil moves in the opposite direction as the movement of the retinoscope light source. This movement is neutralized or disappears resulting in a full red reflex when the proper amount of minus lens, or equivalent, is placed in front of the pupil.

The Copeland streak retinoscope also has a “sleeve” that can be moved up or down to change the position of the light-emitting bulb. The amount of movement of the sleeve required to neutralize “with” motion makes it possible for the very experienced examiner to estimate the amount of hyperopia. The amount of myopia can be estimated by moving the light source (retinoscope) closer to the patient to neutralize the reflex. Let it be clear, here and throughout your career, place the sleeve in the up position and leave it there!! As long as loose lenses, a set of lenses in a paddle, or in some cases a phoroptor is available, one of these should be used. The sleeve of the retinoscope can be rotated while in the up position to identify and then align the light streak to coincide with the axis of astigmatism. Once the proper axis of the astigmatism is found, the movement of the streak at that axis ideally should be “with” to be neutralized by a plus cylinder lens.* Neutralizing this with movement makes it possible to determine the correct power at the proper axis. Remember the maximum error is always 90 degrees away from the minimum power in regular astigmatism[Fig. 12].

*It is always easier to neutralize with movement by adding a plus lens. For that reason, in cases of astigmatism correct the least plus or most minus meridian first with a spherical lens. Then find the axis with the most discrete with movement and add plus cylinder until the movement is neutralized. This action will determine the sphere and cylinder correction cases with astigmatism.

Figure 12. With the +1.50 “working distance” lens power subtracted, refraction in this case would be: +2.50 sphere + 1.50 cylinder axis 160. This is what would be written for the prescription for glasses.
The streak of light from the retinoscope [Fig. 13], held at the usual working distance” shining through the pupil of an emetropic eye, results in a so-called “with” movement; that is in the same direction as the movement of the retinoscope [Fig. 14]. This occurs in this eye when accommodation is suspended with drops and is overcorrected with a minus lens. Light rays coming from 2/3 meter (66 cm) in front of the eye (arms length) are diverging. In the emetropic (normal) eye that has had accommodation suspended, light from the retinoscope comes to focus behind the eye which cannot accommodate or focus diverging light rays from near.

Figure 13. The Copeland Streak Retinoscope

Figure 14. In a normal, emmetropic eye that has been treated with cycloplegic drop to suspend accommodation, the light reflex from the retinoscope which is held by the examiner at “arms length” (66 cm) in front of the eye creates a reflex in the pupil moving in the same direction as the retinoscope light source.
Diverging light rays entering the pupil from a discrete light source 66 cm in front can be made parallel by placing a +1.50 lens in front of the eye [Fig. 15]. This alters the light rays making them appear as if they were coming from infinity. When this happens, the light reflex coming from the retina fills the pupil. In this case, no movement is observed when the light source from the retinoscope is moved. This is the so-called "end point" of retinoscopy at least for the meridian being tested. It is customary to test the 90-degree meridian first and then check every 20 degrees from 0 to 180 degrees looking for astigmatism [Fig. 16].

**Figure 15.** The effect of placing a +1.50 lens to compensate for the "arms length" 66 cm "working distance".

Diverging light rays entering the pupil from a discrete light source 66 cm in front can be made parallel by placing a +1.50 lens in front of the eye [Fig. 15]. This alters the light rays making them appear as if they were coming from infinity. When this happens, the light reflex coming from the retina fills the pupil. In this case, no movement is observed when the light source from the retinoscope is moved. This is the so-called "end point" of retinoscopy at least for the meridian being tested. It is customary to test the 90-degree meridian first and then check every 20 degrees from 0 to 180 degrees looking for astigmatism [Fig. 16].

**Figure 16.** The initial retinoscope "streak" is usually tested at the 90-degree meridian. In this case the motion is "with" indicating that the light reflex is coming to focus behind the retina.
In the case shown in Fig. 17, addition of the +1.50 lens does not eliminate the with movement when the light source from the retinoscope is moved from side to side or up and down. This means that the eye is hyperopic, or “farsighted”. The broader and less distinct the with movement, the higher the level of hyperopia. Conversely, the sharper and narrower the reflex, the less the hyperopia and/or the closer the end point. When this point is reached, adding just a small amount of additional plus power will result in the pupil being filled with a red reflex signaling the end point of retinoscopy. If glasses are prescribed they will be plus lenses.

**Figure 17.** Movement of the light reflex after insertion of the +1.50 working lens remains with, meaning that additional plus lens should be added.

Persistent with movement at the 90-degree meridian after placement of the working lens, indicates the need for additional plus lens. Plus lens is then added until with movement is neutralized and a red reflex fills the pupil in the vertical meridian. The sleeve, while remaining in the up position, is then rotated a few degrees to a new meridian; for example 70 degrees, and the streak is moved back and forth looking for with or against movement* [Fig. 18]. This is repeated until the meridians (every 20 degrees approximately) from zero to 180 degrees have been tested. It requires just a few seconds to test in three or four meridians to find out if the reflex remains full or develops a pattern of linear with or against movement. If the pupil reflex remains red and full in all meridians then a spherical error is determined. That was the case in this eye. After subtracting the working distance (+3.75 - (+1.50), the final refraction is: +2.25 sphere.

*If against movement is noted, add minus sphere until the movement is neutralized. Then go back 90 degrees and add plus cylinder until the movement is neutralized.
Figure 18. A In the example above, persistent with movement at 90 degrees is neutralized with a +3.75 lens. B Testing the other meridians by rotating the sleeve from zero to 180 shows no change in the full red reflex. C This is the "end point" and completes retinoscopy in this eye. Subtracting the + 1.50 "working distance + 2.25 is prescribed.

Figure 19. In this myopic eye greater than – 1.50 the light rays come to focus in front of the retina. This produces “against” movement of the observed light reflex even without the + 1.50 “working distance” lens.
When the light from the retinoscope enters the myopic eye, the increased optical power, or greater length of the eye, will cause the light rays to focus in front of the retina. If the myopia is greater than \(-1.50\), the light in the pupil will move in the opposite direction of the light from the retinoscope as shown in Figure 19. If the myopic eye is less than \(-1.50\) diopters and the retinoscope is 66 cm in front of the eye, the light from the retinoscope will focus behind the retina but it will be neutralized with less than a \(+1.50\) lens. This is shown in Figure 20. For example; if the light reflex is neutralized with a \(+1.00\) lens the refraction will be: \(+1.00 – (+1.50)\) or \(-.50\) D. This means that a \(-.50\) lens will put light rays from infinity (greater than 20 ft.) in focus on the retina. This represents a slightly myopic or nearsighted person.

Figure 20. Placing a \(+1.00\) lens causes the light reflex to focus on the retina. The refraction is \(-.50\).

If a broad, dull, slow moving against movement is seen when the retinoscope light shining in the pupil is moved back and forth, this indicates the eye is myopic or nearsighted [Fig. 21]. This indicates the need to introduce a minus lens in front of the eye. The power of the minus lens is gradually increased until the movement stops and the pupil is filled with a homogenous, dull red non-moving red reflex.
When the power of minus lens in front of the pupil reaches -3.50, light rays come to focus on the retina [Fig. 22]. This results in a full red reflex in the pupil indicating the end point at the meridian checked, usually 90 degrees first. If the reflex remains full and non-moving in all the meridians then the refractive error is spherical (without astigmatism). In the case shown below the refraction would be determined as follows: 

$$-3.50 - (+1.50) = -5.00$$

$-3.50 - (+ 1.50) = -5.00$ is the spectacle correction

Figure 21. The retinoscope light reflex comes to focus in front of the retina and produces an against movement indicating myopia and the need to introduce minus lenses.

Figure 22. A -3.50 lens neutralizes the pupil reflex indicating the end point of retinoscopy. Subtracting + 1.50 for the working distance results in a refraction error of -5.00.
When performing retinoscopy, a with reflex [Fig. 23] is established in all meridians by introducing a minus lens if an against movement is encountered initially or if the eye is hyperopic a with reflex is seen immediately. Then the minus sphere is reduced or plus is added until the movement of the streak in the pupil is neutralized in the least plus meridian, the one with the most discrete, sharpest with movement. The streak of light from the retinoscope is then rotated 90 degree and the with movement is neutralized by adding plus cylinder. The retinoscopy result is the sphere power minus the +1.50 working distance plus the cylinder at the determined axis. *

Figure 23. A Establish with movement in all meridians. But you note “distorted oblique” reflex and continued with movement in all meridians but not the same degree.

Figure 23. B Find a meridian where the least plus reflex is neutralized by adding plus sphere. In this case, a + 3.00 lens is in place.

Figure 23. C Move the streak 90 degree and add + 1.50 cylinder to neutralize the with movement.

Figure 23. D The pupil reflex is neutralized in all meridians with a +3.00 sphere and a +1.50 cylinder at 45 degrees in front of the eye. Subtracting the +1.50 working distance, the retinoscopy result is +1.50 sphere + 1.50 cylinder at 45 degrees.

* A comprehensive discussion of retinoscopy can be found at www.cybersight.org
CLINICAL REFRACTION

Infant Eye

The infant eye is refracted (undergoes measurement of refractive error) any time there is a reason to do so. No infant is too young for this test or unsuitable for the examination provided the media are clear. Moreover, any time an infant is presented for an eye examination for any reason, it is appropriate to determine the refractive error. Refraction in the infant or very young child, under age 3 years, who cannot cooperate by responding to the vision chart is always carried out objectively with retinoscopy through a dilated pupil and with accommodation suspended. The drugs of choice for dilating the pupil and suspending accommodation are atropine 1 or ½% and Cyclopentolate (Cyclogyl) 1 or ½%, with the former being cheaper, available in the developing world, and suitable for darker irides. The premature and very young infant can be “dilated” with limited cycloplegia using Mydriacil 1% and Neosynephrine 2½%. The main tools used for retinoscopy are the retinoscope that projects a beam of light to reflect off the retina and lenses in some form that condense or diverge the light rays from the retinoscope before entering the pupil. The end point of retinoscopy is a “neutral” beam of light coming back through the pupil, filling the pupil and demonstrating no movement when the light source from the retinoscope is moved. The refractive “error” or refractive state of the eye is determined by subtracting the so-called working distance, usually +1.50 D, from that lens power placed in front of the eye sufficient to result in the pupil filling with light and showing no movement when the light source from the retinoscope is moved. In the process of carrying out retinoscopy, media opacities can also be identified. For example; cataract, persistent pupillary membrane, persistent hyaloid vessels, and more can be seen. If a clear reflex can be seen around a discrete opacity, retinoscopy can be accomplished, but if the opacity completely blocks the light entering the eye, retinoscopy cannot be done. Regardless of the reason for the eye examination done on an infant or young child, retinoscopy can be done (or attempted) and the results recorded in a minute or less! Every ophthalmologist who deals with infants and children should master the technique of retinoscopy! The technique is not difficult, is easy to learn, and is the only way to determine the refractive status of these young patients.

Figure 24. This infant born prematurely and followed in the intensive care nursery was returned for an outpatient examination to determine the state of the retinal vessels.

Figure 25. In preparation for studying the retina and carrying out retinoscopy 1% mydriacil drops are placed on the cornea.
Figure 26. After approximately 30 minutes and before retinal examination, a retinoscope is used to shine a light through the pupil. The retinoscope light is shifted slightly side to side while the examiner notes the direction of movement of the light reflex while holding a +1.50 D lens in front of the eye. This is carried out in several meridians and suitable lenses are introduced to neutralize movements in all meridians. In case of astigmatism this movement will be eliminated in the two principal meridians located 90 degrees apart.

Figure 27. This one year old with apparent congenital esotropia requires refraction. This will be done as described above after the pupils have been dilated and using the retinoscope and loose lenses.
Figure 28. Retinoscopy is being completed while the child is being held by his mother. This examination is entirely objective requiring an experienced refractionist, but with practice this skill can be developed rather quickly by a technician working under supervision.

Figure 29. The trial lens set contains all of the plus, minus, and cylindrical lenses required to perform refraction. The trial lens frame (spectacles) shown can accept any combination of lenses to create “spectacles” for an adult (smaller frames are available for children). These lenses accomplish the same correction as the phoropter, or the auto refractor, but have the advantage of being cheaper and more like the glasses the patient will eventually wear.
Pre-School Child

The preschool child between age 3 and 6 years can usually respond to a vision chart for testing visual acuity, but this age group may not cooperate fully with subjective refraction when a lens is placed in front of the eye by answering the question: “is this better or worse?” These children can benefit from objective retinoscopy and most can also cooperate for testing with an autorefractor. However, there are differences in the accuracy between various “autorefractors”. For this reason, the clinician should know how much to depend on the accuracy of a given instrument. Regardless of the method used for determining the refractive error, the child should always be tested using the acuity chart while wearing a trial frame containing what is determined to be the proper correction. If vision is not corrected, the refraction should be rechecked and failing improvement of vision, further examination should be undertaken to evaluate for amblyopia (especially if vision is reduced in one eye) or from a non-refractive and undetected physical defect.

Figure 30. A This 6-year-old boy is undergoing retinoscopy with loose lenses. B The same child being tested with an autorefractor. C The child is being refracted using a retinoscope and a phoropter. In each instance the full array of lens power for testing is available. D Several useful plus and minus lens powers can be incorporated in a simple refraction “paddle” for use in the clinic and in the field.
**School Age Child**

The school age child can be examined initially using retinoscopy and loose lenses, by autorefraction, or with a phoropter. At this age the child may already be wearing glasses or in other cases may be undergoing an examination for the first time. Hyperopia in this age child tends to remain stable or even reduces slightly with time. Myopia tends to increase gradually until the mid to late teens. Starting at -1.00 or -2.00 diopters of myopia and ending up at -4.00 to -5.00 D diopters or more when the myopic condition stabilizes at 16 to 18 years. It is important to recognize that there are two especially important times in life to measure and treat refractive error. The initial period is in the first two decades, with the most important time being the preschool years in a child who has failed vision screening. This is the age when the child is especially susceptible to amblyopia, when uncorrected hyperopia can cause esotropia, and, of course, is the time when the vision loss from uncorrected refractive error first develops and the need for follow up is established. Myopia seen in the pre-school or early school years can increase gradually until by the late teens progression of myopia has ceased. The second time period is the mid-forties when presbyopia develops. Refraction at other times is for maintenance and to deal with accident, injury, or other new events.

**Figure 31.** The phoropter contains all of the lenses and accessories needed for refraction. These instruments are expensive, require regular maintenance, and do nothing that cannot be accomplished with loose lenses. The phoropter can be useful in a busy clinic for follow up because the patient’s refraction can be put in the machine by a technician and small changes made quickly.

**Figure 32.** A pre-teen girl is being refracted using an auto refractor.
PREVALENCE OF REFRACTIVE ERRORS

Epidemiologic studies have shown that refractive errors do not occur with a high incidence in the infant and pre-school child. However, the prevalence of refractive errors tends to increase dramatically by the mid to late teens in some societies, and will also be different in different parts of the world. For example; a recent study of 17,000 children 3 to 6 years old in Beijing done by Lu, Zheng, Sun, Cui, Congdon, Hu, Chen, and Shi uncovered only 75 children with less than 20/60 vision and only 56 of them (0.36%) had vision reduced because of uncorrected refractive error. In a study including slightly older school children age 7 to 10 years, Helveston et.al. in the United States found that 8% required glasses to correct vision that was less than 20/30. In another study in 6,143 school children ages 4 to 16 conducted in the highlands of Ecuador (Proyecto Ver para Aprender), 16.29% of children had a significant refractive error (hyperopia greater than 2.25 diopters, myopia over 1.25 diopters and astigmatism more than 1 diopter, measured with autor-refractometer without cycloplegia). A study of older children in China, including those up to age 16 years, found that 12% of children required spectacle correction to achieve better than 20/40 distance vision. Most of these children were myopic or nearsighted. In a multi-country survey conducted with the same protocol in China, Nepal and Chile, results were widely variable. [Refractive Error Study in Children: Sampling and Measurement Methods for a Multi-Country Survey. A. D. Negrel, E. Maul, G. Pokharel, et. al. Am Journal Ophthalmol, Vol. 129, 2000, pp. 421-426.] In Nepal, the prevalence of myopia, defined as -0.50 or more in either eye, and hyperopia 2 diopters or greater in either eye, was 1.2% and 1.4% respectively. In China it was 14.6% and 2% respectively and in Chile was 5.8% and 14.5% respectively. This suggests that refractive error is a genetic trait that reaches full expression by the later part of the second decade, especially in countries like China where myopia is more common than hyperopia. Several studies have also suggested that prolonged near work increases the chance for myopia. It is also clear that there is a racial predilection with Asians being affected by myopia in a higher percentage.

It is estimated that 13 million children age 16 years and under in the developing world not being treated currently would benefit from correction of a refractive error with spectacle correction. There are several causes for this including: 1) lack of awareness of the problem or its remedy, 2) inadequate eye health screening, 3) too few eye health care professionals available to measure refractive errors and prescribe correction, and 4) limited availability of affordable, acceptable glasses.

VISION AND EYE HEALTH SCREENING

Overview

- A child should be seen for an eye examination at any age when there is a question on the part of the parents or another health care worker. No child is too young for an eye examination. This includes examination of an infant in the newborn nursery when it is deemed necessary, children with obvious congenital anomalies, and those children in families with a history for eye disease occurring early on and/or affecting multiple family members. Early examination is indicated if there is a family history of congenital cataract, glaucoma, retinoblastoma, or anything else that creates concern about the possibility of early eye disease. The child may be seen first by a pediatrician, general doctor, or health care worker who will redirect the child as indicated. Every child who has an eye examination for any reason should have be refracted as a component of the examination sequence.
School screening is carried out mostly to measure visual acuity using a simple chart and is frequently done in school by the teacher and the school nurse, who may be assisted by a parent or other volunteer.

Objective “vision” screening can be done by a technician using the technique of “photo refraction” that captures the light reflex in the pupil. The refractive error of that eye is determined immediately. Such testing can be done in the clinic or in a local setting. Using pre-determined criteria, pass/fail can be established. Failure is usually considered at more than +3.00 D or -1.50 D, but these criteria are not universally agreed on. This technique is reserved for younger, preverbal children. A vision chart is better for older pre-school and school age children.

A simple hand held device can be used to determine the refractive state of the eye directly and shown on the instrument. This eliminates the need for “off site” reading saving time, effort and cost.

Why is Vision Screening Important?

The eye of a child is not completely developed at birth. Visual capacity is estimated to be 10% of normal adult values. Development of what is considered normal visual acuity, even in an otherwise physically normal eye depends on the quality of the image received on the child’s retina during the sensitive period for visual maturation in the first weeks and months of life. If for some reason the quality of this retinal image is not adequate, amblyopia of this eye will result. Amblyopia is defined as decreased visual acuity in one or both eyes caused by some
form of visual deprivation or abnormal binocular interaction in an otherwise normal eye. Amblyopia is reversible if it is detected and corrected early in life. Amblyopia is estimated to afflict 1-4% of children. Recent large population studies project a range of 1.6%-3.6% including evidence that the rate is even higher in medically underserved populations. Various studies have found amblyopia to be the leading cause of monocular visual impairment worldwide.

Both retrospective and prospective studies have demonstrated that amblyopia screening and treatment are effective in terms of clinical outcome by reducing both the incidence and prevalence of amblyopia. A long term, 7 year, follow-up study revealed that infant vision screening, even without refractive evaluation, had a substantially better positive predictive value than a variety of other pediatric screening measures, such as those for hearing impairment, congenital heart malformation, and developmental hip dysplasia.

The total cost of treating amblyopia is minuscule compared to that of most interventions for restoring vision caused by a variety of other ophthalmologic disorders. An index based on the formula: (cost of treatment) / [number of lines of visual acuity improvement] x [number of years of life expectancy]) showed amblyopia treatment in children to be 44 times more cost effective than cataract surgery and 85 times more cost effective than macular hole surgery in adults.

**When Should Vision Screening Be Done?**

The earlier in life a visual problem can be detected and treated, the better the visual outcome will be. However, obtaining cooperation from a very young child for testing visual acuity is not always possible and any conclusions about vision potential in an infant must be made by inference based on physical findings such as there being a clear media and normal fundus and behavior such as a smile response to a human face. This is why in most countries vision screening is usually performed and recorded for statistical purposes in children between 3 and 4 years old. At this age the most frequent visual problems, refractive errors and amblyopia, can usually be treated successfully.

However, it must be emphasized that a child should be seen for an eye examination at any age if there is a question about the child’s vision or eye health on the part of the parents or a care worker. No child is too young for an eye examination. This includes examination of an infant in the newborn nursery when it is deemed necessary. It is well known that the premature child is seen very early for evaluation of retinopathy of prematurity.

**Where Should Vision Screening Be Done?**

The most cost effective place for visual screening is the pre-school or school setting. This is where the target population, made up of children, is found. In addition, at school there are usually people available who can be trained to carry out the screening. In some underdeveloped countries children may start school at age 6 years which is a bit late for initial screening. Earlier screening for the children carried out in primary health centers or community centers can be scheduled for younger children between the ages 3 and 4 years.

**Who Performs Screening and How Are They Selected and Trained?**

School screening deals mostly with visual acuity testing and is frequently done in school by the teacher and the school nurse who are already on staff. They can be assisted by parents who volunteer for the task or by others.
What are Screeners Looking for During Vision Screening?

The screener checks the visual acuity of each eye in order to find:

- Any acuity difference between the eyes
- Best visual acuity, including acuity with correcting glasses, if worn

While testing vision, the screener can also learn something about:

- Stereo vision to determine binocular status
- Speech and language development
- Attention span of the child
- Social function of the child
- Relationship between the parents (mother/father), if present, and the child

Organizing Vision Screening

Conditions

- A variety of charts with unique symbols (optotypes) are used that are also suitable for different testing distances including those calibrated for 3, 4, 5, and 6 meter testing distances.

- The charts commonly used for children have picture symbols or the “tumbling” E for use either at the 3, 5, or 6-meter test distance. The standard procedure in some countries is to test at 5 meters and in others (the U.S.) at 6 meters. For very young children, those who are retarded, or otherwise normal children who are immature or shy, a chart calibrated for 3 meters is useful because the shorter distance helps cut down the possibility of distractions. The shorter the testing distance, the more important it is to ensure that the proper testing distance be maintained. Even a small variation can result in a larger error with a chart calibrated for measuring vision at a shorter testing distance. To maintain the proper testing distance, a mark can be placed on the ground (for example, with a picture denoting footprints, a sticker or simply a line).

- The chart must be clean and have a white background with distinct black symbols/pictures (optotypes) that provide suitable contrast.

- The height of the chart should be at or near the level of the eyes of the child to be examined.

- Luminance: (as a guideline) in the room should be: 50 lux maximum; at the picture chart luminance should be between 500 and 2000 lux). It is important to avoid shadows on or around the chart. For practical purposes, those conducting vision screening should select a well-lighted area for activity and employ a brightly illuminated, clean chart with high contrast black symbols.

Preparation

First it is important to ask some questions. The following are examples:

- If a parent is present, they should be asked: “Does your child have complaints about vision or do you notice any vision problems in your child?”
Is there a family history of eye problems including "thick" glasses?

What is the child’s general health?

However in most vision screening experiences, especially those in school with no parents available screeners obtain information based on their own observations and experience.

If the child will not speak up clearly and is shy, a “key-card” with small pictures or symbols, duplicating the ones on the chart, can be used. The child simply points to the symbol on the card which matches the one pointed out on the chart. A correct match indicates a positive response indicating that the child can see the symbol.

The screener should be aware when at distance less than 5 meters, any forward leaning on the part of the child being tested, can reduce the testing distance as much as 5-10% which in turn records vision that is 5 – 10% better than it actually is.

For testing vision in one eye, the other eye must be blocked by a solid occluder. Always use an occluder, not the child’s or parent’s hand. When using a hand for “occlusion”, there is an opportunity to see through tiny “cracks”, creating a pinhole effect, that results in even better vision, especially in cases of refractive error. Screeners should start, as a rule, by testing the right eye (OD) unless there is a special reason to start with the left eye (OS). To test the right eye, the left eye is occluded and to test the left eye, the right eye is occluded.

Figure 35. This child is reducing the testing distance by leaning forward. Because of this, his vision could be recorded as better than it actually is.

Figure 36. An occluder ensures proper blocking of the eye behind. Using the hand raises the possibility of peeking and even worse, creating a "pin hole" effect that allows the person to record better vision than is actually present under normal conditions.
Start with One Eye or Both?  What About the Child Who is Wearing Glasses?

Many screeners will start the vision screening by checking best visual acuity with both eyes open. This has some advantages. Some children will be threatened initially by an occluder and will under perform. Using both eyes will provide a brief training session for the child making it more likely that he will reach full potential. Most important, children with latent nystagmus (rhythmic to and fro movement present only when one eye is covered) will have reduced vision when one eye is occluded and much better vision with both eyes open. A disadvantage to checking vision initially with both eyes open is that it adds time to the test and could give the child a chance to memorize the chart (but this is not too likely). If the child is already wearing spectacles, the examination is conducted while wearing these glasses.

Personnel

While there are variations in the makeup of the vision screening based on manpower available and personal preference, the jobs that need to be done are basically the same.

- One individual stands by the chart and points out the object (optotype) that the child is asked to see.
- A second individual holds an occluder over the eye to be blocked and provides any encouragement to the child.
- A third individual records information about the child and about the results of the screening. This person can also observe the child for the “warning signs” of eye disease including ptosis, abnormal head posture, “dancing eyes”, tearing, red eye, corneal opacity, etc.

Regardless of the number of screeners available for a given team, all of the above activities must be carried out.

Figure 37. The screening team
The examiner at the chart points out with his/her finger from below each picture (optotype). A finger is preferable to a pencil or pointer because while the screener points out the picture with a finger, which will be fixed, she can look at the same time at the child’s reaction. It is very important to look at the child during the examination and move ahead pointing to the next optotype as quickly as possible, continuing to engage the child who may have a very short attention span. It has been said that a given child has only so many optotypes that will be responded to. When that number is reached, the child quits whether the optotype can be seen or not.

The sequence for pointing out optotypes is as follows:

Start at the top of the chart and go as quickly as possible to the smaller pictures. The aim of the examination is to find the smallest line of pictures that the child can see. But first make sure that the child is familiar with the pictures (matching or reciting). As a rule, point out the first optotype of each row. When the child fails to give a correct answer, go up one row and ask the child to respond to the second and third optotype. Of course, only the smaller optotypes (denoting better vision) have more than three symbols. In cases of poor vision, for example, at the level of 20/60, 6/18 or 5/15 and less there are fewer optotypes. If a child gives correct answers to three optotypes, the examiner goes back to the next lower line and asks the child to respond. The child is “credited” with seeing any line that results in three correct responses. If one or two correct answers, but no more, are given on a row, vision is recorded as: the smallest row where three optotypes are seen correctly with a notation of one or two seen on the next lower row with smaller optotypes. For example, if a child saw at least three optotypes on the 20/40 line, but only two on the 20/30 line, vision would be recorded as 20/40 + 2. The goal in vision screening is to obtain as much information about the child’s vision in the shortest time, taking maximum advantage of what might be a very short time with the child cooperating. While carrying out the screening, it is advisable for the screeners to maintain a positive attitude and to keep encouraging the child.
Recording
The visual acuity of each eye is recorded as the line where the child can recognize correctly at least 3 optotypes. Of course, this number is less if the child stopped at a line with larger and fewer optotypes.

Crowding
In order to credit a person with achieving “normal” or physiologic vision at a given level, there is a reason why more than one optotype and preferably three should be identified correctly. This is because people with amblyopia can recognize smaller objects when they are presented singly meaning there is no competition for visual attention. Since this condition, “non competition” for visual attention, does not exist in real life, this “better vision” for isolated objects is not equivalent to actually seeing something that size in life situations. However, better vision under these circumstances does suggest that the child may experience good results with amblyopia treatment by patching or penalization. Some vision charts have extra lines (crowding bars) around the tumbling “E” to create a crowding effect for single optotypes. A child who has reduced vision in one eye but can see extra optotypes when viewing them singly probably has amblyopia and should be considered for patching of the fellow eye carried out under supervision.

Figure 39. Testing sequence: E (correct), S (correct) G (correct) O (correct) F (failed) move up one line. O,F,L,C,T (all correct). It is acceptable to let the child being tested to respond to all of the letters on a line if this is done quickly. Now move down to F (failed) Z (failed); visual acuity 20/60.
Vision screening using a chart
Snellen (1834-1908), professor of Ophthalmology, developed a chart with optotypes that fulfilled the criteria for accurate recording of visual acuity. For young children, different charts are used. The most common charts used with children are the LEA symbols, Allen Figures, HOTV chart, and variations of the “tumbling” E chart.

Figure 40. Several styles of vision charts that can be used for screening along with appropriate response cards for the child. This Lea chart is in the LogMAR format with distances between the optotypes in proportion to the size, 14 lines, geometric progression, and specific values for partial line scores. This type of chart and testing is especially valuable for research purposes.
Refraction Methods for Vision Screening

There are other automated techniques that can be employed for vision screening. However, these methods do not actually test visual acuity. Instead they test for the presence and degree of refractive errors, the primary disorder in children causing failure at vision screening.

The most common automated refraction screening methods are:

1) Autorefraction: This measures refractive errors. In small children it should be done under cycloplegia in order to obtain accurate information.

2) Videorefraction: also measures refractive errors based on the principle of photorefraction but can also detect ocular misalignment or pupillary anomalies.

Stereopsis

Stereopsis testing allows for the determination of functional depth perception. It is a simple test which can provide important information regarding the level of functioning of the binocular visual system. With a common feature of strabismus being poor binocular depth perception, stereopsis can assist in the diagnosis of binocular vision anomalies. Stereopsis is appreciated when the retinal images from each eye are properly assimilated.

There are two types of stereopsis testing: contour and randomdot testing.

**Contour (or local) testing:** Using polarized or red/green glasses, there is a horizontal separation of the targets. This type of stereopsis testing is helpful in determining
Although refractive errors are the most common problems causing visual defects in children, other eye health conditions, some causing reduction in vision, can be detected by simply observing the child during vision screening including:

- Pupillary anomalies in color, size, or position.
- Presence of nystagmus or other anomalous eye movements
- Ocular misalignment – crossed eyes
- Lid anomalies – including ptosis
- Abnormal head posture
- Tearing
- Corneal clouding

**Random dot testing:** embeds the stereo figures in a background of random dots. This test does not have any monocular cues. This type of stereopsis testing is helpful in ruling out the presence of a constant strabismus.

“Depth” can also be inferred by noting overlay, relative size, and haze, all of which can be seen with one eye.

**Screening for Other Eye Health Conditions**

Although refractive errors are the most common problems causing visual defects in children, other eye health conditions, some causing reduction in vision, can be detected by simply observing the child during vision screening including:
URGENT! Call your doctor immediately.

Left: White Pupil – May indicate cataract, tumor, inflammation or detached retina.
Middle: Lump, Swelling or Drooping of Lid – May be an inflammation, which is an emergency if it happens suddenly and the lid is red and hot. Also may indicate muscle weakness or tumor causing blockage of vision.
Right: Large Cornea in One or Both Eyes – This is a sign of glaucoma in both the newborn and infant, especially when the child’s eye waters and avoids light.

SOON Notify your doctor within days or weeks.

Far left: Eye Turns Inward or Outward – Eye(s) misaligned or “lazy eye”. May lead to loss of vision.
Above left: Tearing, Discharge, or Redness – A sign of infection or tear duct blockage.
Above right: “Dancing Eyes” – Eyes jiggle or rotate; baby does not look at you. A sign of disease of the nervous system anywhere between the eyes and the brain.
Left: Low Birth Weight - Without treatment, severe damage can occur to the retina of the eye. Your doctor will arrange for an eye exam.

NEXT VISIT Tell your doctor at your next visit.

Left: Head Tilted – Head tilted to one should, forward (chin down), or to one side. Child may be avoiding double or blurred vision.
Middle: Pupil Defect – Part of the iris is missing. May be the outward sign of a defect of the inside of the eye.
Right: Unequal Pupils – One pupil larger than the other. May be a sign of nerve damage or tumor which is visible in one eye.

Figure 42. A description of “Ten Warning Signs” of potentially serious eye disease affecting children taken from a brochure produced by the Foundation of the American Academy of Ophthalmology and the Knights Templar Eye Foundation for EyeCare America (www.eyecareamerica.org). Used with permission.
Referral Criteria

Children are said to “fail” screening and should be referred for a comprehensive eye examination based on local criteria which vary. There are no absolute or universally agreed upon standards. This should not be seen as a problem. The important thing is that screening be done well and that the results be available to those who are responsible for using this information for the benefit of the children. Some examples of criteria for “failure” and need for referral are:

American Academy of Pediatrics Referral Criteria

A child age 3 to 5 years should be referred for a complete eye examination when:
- She identifies less than four out of six figures correct on the 20/40 line with either eye, tested at ten feet.
- There is a two-line difference in vision between the two eyes, even if it is within the passing range.

A child age six or older should be referred for a complete eye examination when:
- She reads fewer than four out of six figures correct on the 20/30 line with either eye, tested at ten feet.
- There is a two-line difference in vision between the two eyes, even if it is within the passing range.

All children should be referred for a complete eye examination when:
- Any movement is seen on a cover test, except for phorias
- There are less than four of six correct responses on the Random Dot E stereo test.

Remember that interocular difference of visual acuity is sometimes more important than a slight suboptimal visual acuity equal in both eyes, since interocular difference is almost always due to amblyopia or an ocular condition that could cause amblyopia.

Follow Up with Treatment

Follow up with glasses
It is important to identify with vision screening any child who has reduced vision because of an uncorrected refractive error. But this is only the first step. To be truly effective, a child who fails vision screening because of uncorrected refractive error should trigger a process that results in this child having a careful re-check of vision, refraction, and when indicated correcting glasses. These glasses should be affordable, meet safety standards with shatter proof lenses and non-flammable frames, be available locally, and should be of a style that is acceptable to the child. Providing these glasses, for practical purposes, is best accomplished as a local enterprise. These children also need follow up because refractive errors, especially myopia, tend to increase during the first two decades. Amblyopia, if present, should also be followed up and
treated until equal vision is present in each eye. Once equal vision is achieved, follow up
should continue until the child reaches the end of the plasticity phase (around 8 years) in order
to avoid vision that decreases again in the amblyopic eye.

**Follow up with other needed treatment**

When eye disease other than refractive error is identified during screening, the child should be
referred for the appropriate treatment. As with refractive error, if the other eye diseases found
are not followed up with treatment, the effort of vision screening is meaningless.

**REFRACTION OVERVIEW**

Refraction is the term used for determining the refractive error in a person. It is just a part if the
“big picture” of optics that includes: “bench” optics, physiologic optics, measuring refractive
error prescribing, and dispensing. Moreover, clinical conditions including alignment, vision,
fusion and binocularity, amblyopia, diplopia, and asthenopia can be influenced by refraction.
The clinician should have some basic knowledge of optics, but most of the clinicians expertise
deals with the clinical aspects of refractive errors, how to measure them, and when to
prescribe glasses or other optical aids. It cannot be denied that the technician with appropriate
training and supervision can measure the refractive error, but the far reaching implications of
dealing with uncorrected or improperly corrected refractive error is the responsibility of the
clinician. In most cases, when the proper refraction is found, changes throughout life tend to
be an increase in myopia until the mid to late teens, some reduction in hyperopia, and the
onset of presbyopia in the fifth decade. Trauma or surgery can also result in a change in
refraction. The strabismologist frequently plays a continuing role in issues of refraction in
cases of refractive and accommodative esotropia, as well the need to add prism, and
supervise the placement of the bifocal in high AC/A. The pediatric ophthalmologist is the
person most likely to find the refractive error in the very young child who may be seen initially
for another reason.

- The reality today is that many sub-specialists in ophthalmology are likely to depend on
  auto refraction and technicians for determining refractive error for prescribing glasses.
- While ophthalmologists will continue to be expected to have an appreciation for all
  aspects of the refraction/optics process, this emphasis and enthusiasm will be likely to
diminish as their abilities in the diagnosis and treatment of blinding diseases increases,
more well trained technicians become available, and automated devices become more
accurate and more widely available.
- The pediatric ophthalmologist/strabismologist as well as any ophthalmologist who cares
  for young children or strabismus patients of any age should be an expert at
  refraction/retinoscopy, understand physiologic optics, be able to prescribe prism and
  bifocals, understand the aspects of vision and eye health screening, know when to
  prescribe, and appreciate a proper fit for spectacles.
**LOW VISION**

The WHO characterizes vision loss as follows: Visual impairment if best correct visual acuity is 20/60, severe visual impairment if the vision can be corrected only to 20/200, and blindness if best corrected visual acuity is 20/400 or less. Low vision, as it affects a given individual is any level of vision impairment that interferes with a person’s occupation or lifestyle. The following are basic steps for dealing with low vision:

- Correcting the underlying refractive error
- Provide magnifying lenses (this enables a better view of object held close to the eye)
- Use of a telescope (this enlarges objects at a distance at the expense of a restricted visual field)
- Use of instruments that present an enlarged image (an example is a computer that enlarges print)
- Adaptive equipment (equipment such as Braille faced watches, computer keyboards, telephone key pads, large print on any device, etc.)
- Life style training for mobility and other everyday activities

**MOVING FORWARD**

- To function optimally in the developing world, eye health care providers should have a thorough understanding of the comprehensive approach to clinical refraction.
- There should be a plan to provide for refraction services performed by the appropriate staff to support the ophthalmic sub-specialist and also the comprehensive ophthalmologist ensuring the most effective use of the ophthalmologist’s time.
- The pediatric ophthalmologist/strabismologist must be a competent refractionist (retinoscopist) and understand physiologic optics sufficiently to manage strabismus and binocular vision. The well-trained pediatric ophthalmologist will find that doing retinoscopy him/herself saves, not loses, time.
- The most accurate and cost effective auto refractors and objective refractive screening devices should be identified and used appropriately.
- Optometry for the developing world should be integrated effectively into programs for vision and eye health screening, refraction, and optical dispensing, as well as for training and supervising refractionist/technicians.

Finally, vision loss from most refractive error is genetically determined, entirely treatable, but is not capable of eradication. Therefore this problem must be met and dealt with effectively as it exists. Refractive error cannot be eradicated, but vision loss from uncorrected refractive error can and should be! This is our challenge and meeting and conquering this challenge is our goal.
APPENDIX A: TIPS FOR THE REFRACTION EXAM - ROYAL COLLEGE OF OPHTHALMOLOGY
Contributed by: Visvarya Subrayan, M.D.

The Royal College of Ophthalmology expects all ophthalmologists to be able to refract. This exam is your opportunity to demonstrate that you can do so. We expect you to pass if you have had sufficient practice/experience. There is no strict rule about what constitutes your ability to pass (e.g. it is not true that you need to obtain 6/6 or a prescription within one diopter) – but your performance, demonstration and knowledge of the art of refraction, are all taken into account.

What follows is one method of carrying out refraction. It is not by any means the only one and you do not need to follow this to the letter to pass. However this method reflects good practice and will assist you to be in a position from which you may well pass!

History
In real life the history is always paramount. This exam is not about your history taking skills. While it is prudent to take a short history, past ocular history – don’t dwell on this too long (maximum of 1-2 minutes). Knowledge of hobbies, occupation, and driving might be helpful.

Visual Acuity
Measure the vision at distance unaided, and with pin hole, and at near unaided. This tells you a great deal. Have a rough guide in your head as to what unaided vision might mean (Table 1). You need to have an idea about what vision correlates with what refractive error, and this will depend a bit on the age of your patient.

Refraction
Accepted practice is to refract with a trial frame in place. This means you need to fit the trial frame correctly (i.e. with the side arms correctly adjusted, the frame straight and not tilted, and the pantoscopic angle and back vertex distance are sensible). The frame needs to be fitted and you need to be able to remove and replace lenses without hurting the patient. This all takes practice. We will provide trial frames, but it is advised that you bring your own, one with which you are familiar.

Measure the inter-pupillary distance. There are a variety of ways of doing this, and the distance IPD is more important than that for near.

Pick up your retinoscope! You should be doing this within 3-4 minutes of the start of the examination.

Retinoscopy
In most patients you need to control accommodation. This is best done by blurring the eye you are not refracting with a positive lens enough to give an “against” reflex. (This is the so-called fogging method very useful with adults, especially those who are pre-presbyopic. Most children require cycloplegic drops as described previously). You should blur the fixing eye by about 2
diopter of plus lens as more than this can induce accommodation. You will also want to dim the
lights. We would counsel against switching all the lights off as you can’t find the lens box, let
alone any individual lens. Additionally, some patients accommodate in the dark. The target
should be non-accommodative, so use the fixation spot on the Snellen box, (vision chart) or
the green circle on a duochrome as an alternative.

You need to position yourself so that you are as near to the visual axis as possible. One trick is
to ask the patient to tell you if you occlude their view to the fixation point. Then test them by
doing just that, then coming back a fraction. You should perform retinoscopy in the right eye
with your right eye holding the instrument in your right hand, and for the left eye, your left eye
and left hand. (Some prefer to use the same hand for both eyes and this is acceptable if the
patient’s vision is not blocked).

You may carry out retinoscopy in positive cylinders, negative cylinders or in spheres. You may
draw a power cross if you want. You may put a positive lens in the trial frame that equates to
your working distance (although this adds more reflections and another lens). The choice
between positive and negative cylinders follows what you have been taught. Plus cylinders
tend to give a clear streak and it is generally considered easier to determine the end point.
Using minus cylinders may reflect the majority of patients that an individual sees (e.g. most
optometrists refract using negative cylinders, perhaps a reflection that most of their patients
needing refraction are myopic). Using minus cylinders may help control accommodation.
Whatever you do, we would advise you to be consistent; i.e. avoid refracting one eye in
positive and one in negative cylinders.

There are a number of retinoscopic techniques. Whichever technique you use, you need to
practice. Positive cylinders are especially useful when cycloplegic drops are used and the
patient’s accommodation is paralyzed. It is best to find the base sphere first (the faster,
narrower streak). Having found the base sphere, you rotate the streak 90° to locate the axis
and second power. If you feel the axis is slightly different to the direction you used to measure
the base sphere, you may need to check the base sphere (90 degrees from the positive axis).
You must write down your retinoscopy results. You will fail if you don’t – but the examiners will
remind you. It should be clear if what you have written is the net of working distance or not. It
should be clear what your working distance was. If you use a power cross, you will need to
convert this into the prescription format, net of the working distance.

Retinoscopy is a very important skill for ophthalmologists to master, particularly so if you are to
see children and those with special needs. In these patients results of the examination are
entirely in your hands because the patients cannot tell you what is “better or worse”. It is a
skill you need to practice to a level that you can perform in examination conditions.

**Subjective Refraction**

In the exam you should be on the subjective component, cooperative patient, 15 minutes into
the examination.

Start by turning the room lights back on.

Don’t be alarmed if the initial vision is not great (although it is reassuring if the patient sees 6/6
immediately!). You may not be far wrong. This is where practice and experience are helpful.
After testing the visual acuity, you check the sphere, then the axis, then the cylindrical power. You re-check the sphere, this time using the duochrome (if the red is seen better, add minus sphere, and if the green is seen better, add plus sphere). Once you have repeated the process in the second eye, you should do a binocular balance. After you have done the reading add (if necessary) you can write down your prescription. You need at least 15 minutes for all of this.

1. Refine the sphere power
The “not being tested eye” is blurred with a plus lens to reduce the chance of a younger patient accommodating. This means usually a +1.0 or +1.5 or so, but enough to blur the vision to worse than the “being tested” eye.

Direct the patient to look at the last line they could read. Pick one letter and ask them to study that letter.

The patient is always offered plus lenses first. If the visual acuity is less than 6/18, it is unlikely they will notice much difference with a +0.25. If the vision is worse than 6/18 use a 1.0 diopter lens, between 6/9 and 6/18: 0.5 diopter and better than 6/9: 0.25.

You should ask “is the letter clearer “with” (placing the lens over the visual axis) or “without” (removing the lens) or “about the same”. Give the patient a chance to decide. It may be necessary to repeat the same question with the same lens. If they respond either “with” or “about the same” – give the lens and repeat with the other +0.25.

If you have changed the lens, re-check the vision.

If the patient does not accept any more plus – you need to check to see if they will accept –0.25. This is now one of the danger areas of refracting, at least in the case of a young myope. Young myopes will try and accept more minus lenses as they see crisper. However you must not allow them to do so if it over corrects them.

On offering the negative lens, you ask “is the letter clearer, or just smaller and blacker “with” (placing the lens as before) or “without” removing the lens. With a negative lens it is so important to avoid leaving the lens up for any length of time. You can offer the lens again if required, but don’t leave a negative lens up for long or the patient will accommodate and prefer the crisper image.

2. Checking the cylinder
Once you have decided on the sphere, you now need to determine the astigmatism. If your refraction is a sphere and the vision is good, you can possibly leave it there as it is unlikely you are going to add cylinder.

If you have determined the need for a cylinder, you must check the axis and then the power. Ask the patient to look at a round letter on a line that they can read. Refine the axis by placing the handle of a Jackson cross cylinder in line with the cylinder axis and use the bracketing technique – i.e. move in 20 then 10 then 5 then 2.5 degree steps. If the vision is poor, you need to use a 1 Diopter cross cylinder rather than a 0.5 Diopter. The power you have in the cylinder will also influence the size of steps, using smaller steps for larger powers. On offering the cross cylinder, you ask “Does the O look rounder and clearer with lens 1 (offering one
direction) or lens 2 (switching the lens) or about the same?”
This technique is a common stumbling ground. You must be aware of which way to turn the
cylinder, as if you go wrong you will confuse yourself. Remember to re-check the vision after
every few steps.

It is also common for candidates to ask “Does the O look rounder and clearer with lens 1
(offering one direction) or lens 2 (switching the lens) or better without?” This is incorrect. The
cross cylinder will make the letters look worse than the lenses in the frame – it is a comparison
of the 2 new lenses being offered only.

Now refine the power of the cylinder – always aiming to minimize the negative power. Place
the power marks in line with the cylinder and ask “which is clearer, lens 1 (offering one
direction) or lens two (switching the lens) or the same. If you increase the power (for example
in a positive cylinder format) more than 0.75 diopters, you may need to correspondingly reduce
the spherical power by 0.25 diopters. Again make sure you move the correct way.

3. Duochrome
Once you have rechecked the vision, you can recheck the sphere (+0.25 first). You then need
to put up the duochrome. Remember a myope should not be on the green; equal green and
red is acceptable; red is preferable. In a myope once you have found your final refraction, you
can check by adding a –0.25 and ask if the letters are clearer on the green (obviously
removing it after). This test is less important in hyperopic patients, who are left just in the green
(therefore adding +0.25 goes to the red/equal).

You can now blur the vision with a +1.0 diopter. This should blur the vision to 6/12 or worse,
but don’t worry if the patient can see 6/9 part, particularly if the duochrome was on the red.
Depending on the initial vision of the other eye, the +1.0 can be left in the frame while you
repeat the subjective steps on the second eye.

Binocular Balance
This is a final step to try and balance any accommodation. You place a +1.0 over one eye (say
the left) and offer a +0.25 to the “being tested” eye to see if it blurs the binocular vision. You
then change the +1.0 to the other (right) eye and offer +0.25 to the left eye to check if it blurs
the vision. If it does not, give the +0.25.

Record
Record your final refraction; inter-pupillary distance and final visual acuity in each eye and with
both eyes together. Remember do not write the degrees sign on the axis – as 10 degrees can
look like 100 (the same goes for prism signs.)

Near Vision
Find out habitual reading distance and add on appropriately. Age, occupation, hobbies, etc. all
matter. As a rough guide 40-50 years old, add on +1DS to 1.5DS; 50-60 years old, add on
+1.5DS to 2.25DS; if greater than 60 years old, add on +2.5DS or more. In pseudophakia add
on +2.5 to +3 diopter sphere. Change the trial frame to the near inter-pupillary distance and
check the reading vision.
Measure the reading vision in each eye individually and record your reading add.

**Muscle balance**

The Maddox rod test is useful; however, it dissociates the eyes and disrupts what fusion the patient may have. Put back the distance correction and ask the patient to look again at the fixation spot. Place the Maddox rod (horizontally) over one eye and ask if the vertical line and spot are superimposed. You may need to occlude the eye without the Maddox rod so that the patient sees the vertical line. Consider prism inclusion at both near and distance. If you are considering a prism, confirm the direction with a cover test and ask about double vision.

**Back Vertex Distance**

It is not necessary to measure the back vertex distance (distance between the back of the correcting lens and the cornea) unless the prescription is more than plus or minus 4 diopters. However, if you have a patient with such a prescription, you should know how it is done.

**Winding Up**

Remember to write down your prescription in the boxes on the form, the inter-pupillary distance and the back vertex distance (where applicable).

You will not pass this exam by just reading this. While we hope it helps, prior experience in retinoscopy and subjective refraction is essential. We recommend at least 75 refractions using a technique that has been recommended by an experienced ophthalmologist / optometrist before you begin to make the correct decisions and 100 would be preferable.

<table>
<thead>
<tr>
<th>Unaided Vision</th>
<th>Approximate Predicted Mean Spherical Error</th>
</tr>
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<tbody>
<tr>
<td>6/5</td>
<td>Plano</td>
</tr>
<tr>
<td>6/12</td>
<td>-1.0</td>
</tr>
<tr>
<td>6/24</td>
<td>-2.0</td>
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<tr>
<td>6/60</td>
<td>-3.0</td>
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APPENDIX B: DISPENSING BASICS
Contributed by: Radhika Chawla, O.D.

Basic parts of the frame

- Front: containing the lenses.
- Temples: which attach the front and hook over the ears to hold the spectacles in place.
- Bridge: the area of the front of the frame between the lenses that rests on the nose.
- Eyewire: rim going around the lens.
- End pieces: outer areas of the frame from where temples attach.

Eye size: is the horizontal size of the lens beginning at the inside groove of one side to the farther part of the groove on the other side.

Bridge: is the distance from the inside nasal eyewire edge across at the narrowest point. Measurement is usually made from lens opening to lens opening.

Pupillary Distance (PD): measurement of the distance between the pupils in millimetres.
**Measuring Pupillary Distance (PD)**

Accurate PD measurements are necessary for proper placement of the optical centers of the lenses

**Steps to Measure Distance PD**

[1] Dispenser should be positioned at the same level directly (~ 40cm) in front of the patient whose PD is to be measured.

[2] The PD ruler should be positioned across the patient’s nose and the ruler positioned steadily in the dispensers fingers.

[3] The dispenser closes their right eye, viewing the patient’s eye with their left eye. While the patient is instructed to view the dispensers open eye, the dispenser lines up the zero mark on the PD ruler with the centre of the patient’s pupil or the temporal limbus of the right eye.

[4] After the zero mark is correctly lined up, the dispenser closes their left eye and opens their right eye. The patient is now instructed to view the dispensers open eye. The PD is read as that mark falling in the center of the patients left pupil or nasal limbus of the left eye.

** Note when using the limbus edge to measure the PD it is important to use the same sides of the limbus, either both left or both right.

**Steps to Measure Near PD**

[1] Repeat steps 1-3 as in measuring the distance PD.

[2] After the zero mark is correctly lined up, the dispenser instructs the patient to view the bridge of the dispensers’ nose. The PD is read as that mark falling in the center of the patients left pupil or nasal limbus of the left eye.

1: http://www.prlog.org/10211079-have-you-ever-ordered-prescription-eyeglasses-online-an-easy-guideline.html
2 http://www.onestopglasses.co.uk/faqs/measure-pd-pupil-distance.html
**APPENDIX C: VISION, REFRACTION, AND PRESCRIBING**

**How early in life can refraction be done?** No child is too young to have the refractive error determined. Beginning with the youngest infant, retinoscopy can be used to determine the refraction. The eyes should be dilated and cycloplegic obtained to achieve accurate results.

**How is vision determined in a child too young to cooperate?** There are several objective methods for estimating visual acuity in the very young; some examples are: visually evoked potential response to graded targets, preferential looking, and screening for refractive error where selected refractive errors are assigned specific visual acuity values. Simply observing a child’s response to the surroundings and noting nystagmus can provide information about vision in an infant.

**At what age should vision screening be carried out?** Most children can provide a useful subjective response to vision testing with a chart beginning at age 3 years. It is a good rule to do an eye examination any time there is a concern, regardless of age. The corollary is, no child is too young for an eye examination. Ideally, vision screening should be done before the school years that begin at age 5 or 6 years.

**Who should do this screening?** Pre-school and other vision screening can be carried out adequately by trained volunteers.

**Are there age limits for performing retinoscopy?** Objective testing of refractive error with the retinoscope with or without use of lenses can be employed on a patient of any age. In those too young to cooperate, glasses can be prescribed from these findings. In older patients, this estimate of refractive error is followed by the subjective refraction or which lenses work best; “which is better, one or two”.

**When does a child fail vision screening?** The lowest threshold for failing vision screening is when visual acuity in the better eye is less than 20/40 (6/12 or .5). This applies when criteria for “passing” is the ability to function. However, these standards are arbitrary. If vision is 20/30 in one eye and 20/100 in the other, for example, an eye examination would be indicated. If head posture is abnormal, nystagmus is noted, the patient is failing at near tasks or is symptomatic in any way, or if one or more of the warning signs are seen, an eye examination is indicated.

**How are glasses prescribed for myopia (nearsightedness)?** Glasses are prescribed when visual acuity level is below the acceptable standards with room for some judgment on the part of the prescriber. As a rule, myopic (minus) lenses are prescribed for children at the -2.00 level or sometimes -1.50 in slightly older children. If the children are truly myopic (nearsighted), it is likely that their refractive error will increase until the late teens and be from -4.00 to -6.00 D, with some less and others more. Children who start out with low myopic correction should be re-examined every year or two, or when they complain, until the error stabilizes. Remember, myopic children like this can always see well at near even without glasses and they can see reasonably well for short periods at the distance if they squint or employ a “pin hole”. A very small number of children have congenital high myopia on the order of -15.00 to -25.00 and more. This is inherited as a recessive trait and the children get all of their myopia at once as an infant.
How are glasses prescribed for hyperopia (farsightedness)? Children who are hyperopic, or farsighted, usually need glasses when the refractive error is greater than +3.00 D. This is not a hard and fast rule. If the child has “eye strain” or develops esotropia (crossed eyes), a lower error might be corrected, but this requires a further examination and judgment. A very small number of children are born with high hyperopia on the order of +10.00 or more. These children need glasses as soon as the error is found.

How are glasses prescribed for astigmatism? There is no good rule for this, but astigmatism of more than 1.50 diopter should be considered for correction. This is a judgment call.

Do children ever need bifocals? Yes, in the very rare case of lack of accommodation in childhood and in cases where the eyes cross at near from accommodative effort. These decisions must be made at an eye examination.

What about safety glasses? All glasses should be “shatter proof”, afford protection for ultra violet, and frames should be non-flammable.

Are drops used for every refraction? For the initial refraction, all children should have accommodation suspended with cycloplegic drops. For repeat refraction, the examiner can use judgment. Drops are much more important for hyperopia than myopia, especially in follow up.

What about other eye health issues? If other health issues are raised as noted in the “10 Warning Signs”, referral is indicated.

If a child is given glasses for failed screening, when should a re-examination be done? Can it be more screening or is a regular examination required? Follow up can be done either way.

Is screening of any value if the needed glasses are not available? The value of screening is diminished if glasses are not available and if the child will not receive them, but it is not entirely worthless because it could start action that would result in receiving glasses.

Where should screening be done? This can be done in school, health clinics, or anywhere children can be gathered.

Can screening be done with a machine? Yes, but they have no advantage over screening with a chart.

It has been stated by some that vision screening does not give sufficient return. Is this true? Most eye care professionals consider vision screening in the pre-school years to be of value.

Does need for glasses contribute to school failure? Yes, if vision is below the standard levels for referral as noted above for school performance. However, minimal refractive errors do not ordinarily cause difficulties in school unless other eye-related problems exist. Studies have shown also that there is no evidence that refractive errors of any degree, when corrected, affect reading performance.
Vision Screening Recording Sheet

Name ___________________________ Age __________ Date __________

Screening location ____________________________________________

Screeners ____________________________________________________

Complaints ___________________________________________________

Observation:  □ Ptosis  □ Strabismus  □ Squinting  □ Nystagmus

□ Abnormal head posture  □ Other

Vision:  Stereo:

OD / □ Seen

OS / □ Not seen

PASS □  FAIL □ Fails for vision □  Fails for other □

Referred to ____________________________________________

Prescription for Glasses (Basic Information)

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<th>CYLINDER</th>
<th>AXIS</th>
<th>PRISM</th>
<th>BASE</th>
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RECOMMENDATIONS:

□ Slab-off prism  □ Polycarbonate  □ Crizal Anti-Reflection

□ Verilux Progressive  □ Transitions  □ Polarized

□ Sunglasses  □ Match Case Curve  □ Bi-Focal

□ Ultra Violet  □ High index  □ Tri-Focal

& DESIGN FOR:  □ READING ONLY  □ DISTANCE  □ COMPUTER

SIGNATURE ____________________________________________

NOTE: Lenses should be shatter proof (safety lenses)