Fundus photography and fluorescein angiography

Anatomy

An integral part of the optical system in fundus photography is the subject eye. The condition of the intra-ocular media therefore is an important factor to the image quality of the resultant picture, and since the eye does play such an important role, it is desirable that the ophthalmic photographer become familiar with its structures.

Only a small portion of the eyeball is seen, the major part of it resting in the orbit. The average eye measures 24 mm in diameter along the antero-posterior axial diameter, with a normal range of 22 to 27 mm (Newell and Ernst, 1974). The eyeball is surrounded by fatty and connective tissue and is controlled by six muscles which arise from the orbit. The optic nerve forms the connecting link from the eyeball to the brain, along which images are transmitted to the brain in the form of electrical impulses. The globe is made up of three chambers, the anterior and posterior chambers and the vitreous cavity (Figure 8), and consists of three main layers, the outer layer (sclera), middle layer (uvea) and the inner layer (retina).

The outer layer

The sclera is a tough layer of tissue which makes up the entire posterior portion of the eye and is avascular, but is covered by a thin membrane (bulbar conjunctiva), which does have fine blood vessels passing through it. The anterior portion of the sclera consists of a central, transparent layer (cornea), the center of which forms the anterior pole. The points of junction between the cornea and sclera are called the corneo-scleral limbus. The posterior pole is located at the posterior curvature of the eyeball, while the equator is the imaginary line which lies mid-way between the anterior and posterior poles and is about 16 mm posterior to the corneo-scleral limbus.

The middle layer

The uvea is made up of the choroid, ciliary body and iris. The choroid is a highly vascular layer which forms the blood supply to the outer layers of the retina and extends from the optic nerve posteriorly to the ciliary body anteriorly. The ciliary body is an intermediate, ring-shaped structure that lies between the iris and the choroid. This body is divided into two parts, the uveal and epithelial portions (Figure 9). The ciliary muscle is located in the uveal portion of the ciliary body and controls the ability of the lens to change its powers of refraction. When the muscle is at rest (Figure 10), the zonular fibers (which extend from the ciliary body and attach to the lens) are taut, and the lens is at its narrowest;
conversely, when the ciliary muscle is tensed, the zonules become slack, enabling the elastic properties of the lens to increase its thickness, and in that manner, its power of refraction.

The epithelial portion of the ciliary body faces the vitreous cavity and consists of the pars plicata and pars plana. The pars plicata is formed by numerous folds (ciliary processes) which range in number between 60 and 70. The zonular fibers arise from the areas between the ciliary processes and extend toward the lens where they attach to the lens capsule. The points at which the pars plana meet the retina have a scalloped appearance and are known as the ora serrata.

The iris is a thin, flexible curtain located in the eye anterior to the ciliary body, in the center of which is an opening (pupil) which expands and contracts to control the amount of light entering the eye.

**The inner layer**

The retina is the innermost layer of the eye and is the layer on which the visual image is formed, then transmitted to the brain via the optic nerve. The retina is divided into two main parts; the outer layer is the retinal pigment epithelial layer and is made up of a single layer of cells firmly attached to Bruch’s membrane of the choroid. It is the pigment epithelium which gives the fundus a granular appearance. The more complex part of the retina is the inner layer, or sensory retina. The sensory retina is divided into nine substrata (Figure 10).

**Topography of the retina**

The portion of the optic nerve that is seen ophthalmoscopically is the optic disc (Figure 11), which measures about 1.5 mm in diameter. Normally, the optic disc is uniform in color, with fairly well defined margins. The major vessels providing circulation to the retina are the central retinal artery and the central retinal vein. These vessels bifurcate at the surface of the disc and branch nasally and temporally both superiorly and inferiorly. The nasal branches arch in a fairly direct, straight fashion, whereas the temporal branches curve from the disc superiorly and inferiorly forming arches that are referred to as superior and inferior temporal arcades.

Outlined within these temporal arcades is the central retina, in the center of which is seen a dark, oval-shaped reflex. This dark ring, which represents a thicker layer of pigment cells than its surrounds, is the fovea centralis. In the center of this ring is a brighter reflex area, the foveola. The foveola is the point of central fixation. Often, the ophthalmic photographer will encounter the terms “macula,” “macular area” or “macular dark spot” when receiving instructions for photography.
systems produce pictures with an angle of view of about 30°. This enables the photographer to obtain pictures of the "posterior pole" to include the entire disc (including the nasal rim); the central retinal arteries and central retinal veins; the central retina; both superior and inferior arcades; and about a full disc-diameter temporal to the foveal area. Any other view outside of these boundaries, therefore, constitutes equatorial and/or peripheral fundus photography. Since a 30° view photograph shows only a portion of the fundus, a number of overlapping "survey" photographs are required (Figure 13) if you want to show any widespread changes in the fundus.

The lens

The front surface of the lens is situated immediately behind the iris at the level of the papillary area and is adjacent to the vitreous body. On clinical examination the lens appears to be totally clear. However, under high magnification and slit-beam illumination, one can see that this is not so. The lens is a symmetrical, convex structure encased in an elastic capsule and held in place by very fine zonular fibers. Controlled by the ciliary muscle, these fibers tense or relax, as was described earlier, which allows the lens to change its shape. This changing of the lens shape in the anterior-posterior dimension is known as accommodation (Stein and Slatt, 1971) and is a trait which diminishes with age.

The vitreous body

The vitreous body is a transparent, gel-like tissue which fills the vitreous cavity and which is in firm contact with the retina. It is attached firmly to the ciliary body and retina at the ora serrata anteriorly, as well as to the margins of the disc posteriorly.

Abnormalities of the eyeball

In the normal (emmetropic) eye, parallel rays of light are brought to a focus on the retina due to a combination of factors, namely, the axial length of the globe in respect to the combined refractive powers of the cornea, lens and other intra-ocular media. Each element possesses its own refractive power, the cornea being an average of 43 diopters, the lens 17 diopters and the total refractive power about 58 diopters. If the eyeball is abnormally short (hyperopic) or abnormally long (myopic) in its axial length, the correlation of the refractive power of the eye,
the accommodative ability of the lens and the length of the eye, will not permit proper focusing of parallel rays of light on the retina. Thus, in the physiologically hyperopic eye, the rays of light come to a focus at some point behind the retina, whereas in the myopic eye the rays are brought to a focus somewhere in front of the retina. These conditions are compensated for with corrective lenses; similarly, the photographer must choose the appropriate diopter lens for fundus photography.

Astigmatism occurs in an eye in which the refractive powers are not the same in all meridians, and thus will not permit the proper resolution of an image on the retina. Therefore, if there is a differential in resolving power of the lens between the horizontal and vertical planes, that difference represents the degree of astigmatism in the lens. If the lens suffers defects in only these two planes, the condition is referred to as “regular” astigmatism; however, if more than two planes are involved, the condition is known as “irregular” astigmatism. Astigmatism in the eye can also be the result of differences in the curvature of the cornea in the horizontal and vertical planes. The greater the differential in these curvatures, the more severe the condition in the eye. In hyperopic astigmatism, the focal points will be somewhere behind the retina, and in myopic astigmatism, the focal points will be somewhere in front of the retina. It is obvious then, that unless correction for astigmatism is undertaken in fundus photography, it is possible that parts of the image will suffer. If an astigmatic correction control is available on the camera, its use will assist in yielding optimum photographic results.

Factors in image formation and quality

In the healthy, normal state, all of the intra-ocular media are essentially transparent. Any alteration in this normal state will affect the quality of photography. The ophthalmic photographer should become familiar with the factors of dilatation and alterations in the antra-ocular media in order to know the best approach to take for optimum photographic results.

Dilatation

The pupils must be well dilated for photography. The greater the degree of dilatation, the better the photographic results, since more light is allowed to enter the eye. Since the iris is the involuntary diaphragm mechanism of the eye, the pupils constrict by contraction of the iris sphincter muscle when a bright light...
strikes it. Therefore, in order that retinal examinations and fundus photography may be performed, eye drops are utilized to temporarily neutralize the functioning of these muscles. These drugs are generally divided into two major groups, mydriatics and cycloplegics. Both act as dilators, but mydriatic drugs act only on the iris muscle, whereas cycloplegic drops act on both the iris and ciliary body musculature. One recommended protocol for dilatation of the pupil is the use of quick-acting drops such as Mydriacyl 1% in combination with Neosynephrine in viscous solution. The following is one recommended order of application:

1. One drop of Mydrialcyl 1%.
2. Mydriacyl 1% followed 1-2 minutes later by a drop of 10% Neosynephrine.
3. Repeat the dosage six times for the next 15 minutes.

The average time required for satisfactory dilatation is in the order of 30 to 60 minutes. The diabetic patient often presents a problem in achieving adequate dilatation and may require a considerably longer period of time to be prepared for photography. Some patients will not dilate well no matter how many doses they are given, thus making photography difficult.

**Precautions.** Generally speaking, ancillary health personnel may perform within the framework of programs established by the physician and may administer medications if done under direct supervision. The application of dilating drops is generally performed by ancillary health personnel according to guidelines established by the physician for that office. It would be unwise for ancillary health personnel to apply dilating drops to an unknown patient, since the act of dilating a pupil may provoke an attack of acute angle-closure glaucoma. In the event this does occur, a physician should be notified immediately in order to initiate corrective steps.

Patients being referred to the laboratory for fundus photography or angiography from an ophthalmologist’s office have already been screened by a doctor, and therefore may be dilated by the laboratory staff, following the established protocol. It is imperative that special instructions sent along with the patient by his doctor be noted and adhered to strictly. If any questions do occur, the doctor should be consulted before any action is taken. Patients who are kept on a program of medication to control glaucoma must be instructed by their doctors to alter this program at the time of the fundus photography appointment in order to allow the dilating drops to function. Any glaucoma patient who has taken his medication on the day on which photography is scheduled generally cannot be photographed because the dilating drops will not be effective. In some instances, photography can be attempted through a poorly dilated or an undilated pupil in an effort to get some information. In these cases, it is acknowledged that the results will usually be compromised.

**Alterations in the intra-ocular media**

**Cornea.** Changes in the clarity of the cornea may be encountered that will be disruptive to image formation. These changes include drying of the tear film layer that normally covers the cornea, or excessive tearing. These conditions are of a transient nature and may occur at any time during the photographic session. In the event that the patient is capable of maintaining a fixed gaze for a considerable length of time without blinking, instruct him to blink just prior to exposure in order to restore the tear film layer. If the patient tears due to sensitivity of light, rest periods should be given in order to dry off the excess moisture over the cornea. Photographs done through a dry cornea will appear out-of-focus, whereas those taken through excessive moisture may have flare or specular highlights.

A number of eye testing and examination procedures such asplanation tomometry, indentation tonography or contact lens examination require a direct application of an instrument to the cornea. It is recommended that all important photographic and angiographic work be scheduled before these procedures in order to avoid the possibility of obtaining pictures with poorly resolved images. Generally, tonometry or tomography do not cause problems in this regard, since the corneal tissues are not affected. However I can cite a personal experience in which this was the case.

A patient, in the course of a visit to an ophthalmologist, was examined by the physician and then routed through the office for several test procedures before arriving in the photography laboratory for an angiogram. Upon initiating photography, it was discovered that a critically resolved image could not be obtained on this patient, though the chart indicated completely normal and clear intra-ocular media. When the patient was directed back into the examining room and was re-examined with a slit-lamp microscope by the doctor, disturbances of the epithelial layers of the cornea were discovered. These disturbances were not noted on the initial examination. Tracing the patient’s route through the office, each apparatus was carefully examined, and finally, a close inspection of the footplate of a tonographer disclosed a small, unusual spur which caused the disturbances. This plate was immediately removed and sent out for repair. The patient was re-scheduled for photography.

A contact lens examination of the eye requires the use of a viscous contact lens lubricant applied over the cornea leaving a residual film which obstructs visibility. This lubricant generally cannot be satisfactorily washed off to enable good image resolution, and therefore, this type of examination should not be scheduled immediately prior to fundus photography. If the physician must perform a contact lens examination in order to arrive at a clinical diagnosis and if photography must also be done, allow some time to pass before proceeding with the photography. In these photographs, image quality will suffer, and fine details may be lost.

In the presence of mild corneal edema where the cornea, being excessively hydrated, swells and loses transparency, the application of a small amount of glycerol by a doctor will temporarily dehydrate the cornea, long enough for photography to be satisfactorily performed. Other corneal pathology, eg., central opacifications, will probably be too disruptive to the quality of image resolution to warrant serious photographic consideration.

**Lens.** By definition, any decrease in the transparent quality of the lens is a cataract, and how disruptive these changes are is determined by two factors. The more important of these factors is the location of the changes within the lens; the second factor is the density of the opacities. The photographer may encounter other terms used to describe these changes, eg., “lens opacities” or “lenticular changes.” It is possible to obtain very satisfactory results, despite the presence of lens changes, by manipulating the camera so that the image-forming rays pass through clear lens material. This, of course, requires patient cooperation and precise camera
technique. The resultant photograph may not be sharp throughout the entire picture area, since part of the illuminating beam may be passing through some of the opacities. This is not important, if the area of primary interest is rendered sharply on film. Central lens opacities (Figure 14A) will be bothersome for posterior polar views in that the photographer cannot obtain a single photograph in which the image of important landmarks or pathology is well-resolved. In these cases, a montage of photographs should be made to provide a complete photographic record. The quality of peripheral fundus photographs will suffer if there are cortical peripheral opacities (Figure 14B), and good results may be obtained only if there is clear lens material between the opacities for the image-forming rays to pass through. No attempt at fundus photography should he made if one is able to visualize a cataract grossly by penlight or by ambient room illumination. Once the cataract has been surgically removed, and a clear optical pathway to the retina has been restored, and excellent pictures may usually he obtained.

Vitreous. Hemorrhage into the vitreous body is probably the most common change that the photographer will encounter, and often the photography must be postponed until the vitreous becomes clear enough for good image resolution. It would be helpful, under these circumstances for the physician to be familiar with the capabilities of the photographic system to recognize when the photographer will not be able to produce pictures of diagnostic value. Often the doctor will find it difficult to correlate the view that he is able to get through his indirect ophthalmoscope to the poor image quality of the resultant picture due to a vitreous hemorrhage. The illumination of the indirect ophthalmoscope is brighter than that of the photographic system, and is therefore capable of penetrating through the hemorrhage to a greater degree than the light of the fundus camera.

Another type of vitreous opacification is asteroid hyalosis. This opacification appears as a suspension of calcium soap particles that are bound within the vitreous gel. These particles obscure retinal details and are recorded with ordinary white-light fundus photography, but are not seen in the fluorescein angiogram.

If it is necessary to study the retinal circulation of an eye with asteroid hyalosis, there should be no hesitation to perform the procedure, even though the view of the fundus may seem to be almost completely obliterated.

Figure 14A—Central lens opacity. Photographs taken through central lens opacities (bubbles at about 12:00 and 6:00 o’clock near the specular highlights) do not clearly delineate important landmarks or pathology. 14B—Cortical peripheral opacities obstruct image-forming rays in peripheral fundus photography.