

Glaucoma and the Optic Nerve

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In the past, emphasis in glaucoma has been placed on aqueous dynamics and the alterations in the anterior segment which have caused elevations in intraocular pressure. Although these are certainly important factors in the evaluation and treatment of glaucoma, there are many cases in which sustained elevations of pressure above the statistically normal range have not resulted in typical glaucomatous changes in the optic nerve or visual field. Similarly, there are cases where, in spite of normal intraocular pressure, damage to the nerve and defects in the field have occurred. Therefore, increasing emphasis has shifted to the posterior segment of the eye where changes in the optic disc may be the initial sign of glaucomatous damage or of progression of the disease.

A review of the anatomy is helpful in understanding the glaucomatous changes in the optic nerve head. The intraocular portion of the optic nerve is divided into two parts: laminar (scleral) and pre-laminar (choroidal and retinal). The pre-laminar portion is the most anterior extension of the nerve and is seen ophthalmoscopically as the optic disc. It is approximately 1.5 mm in diameter, being somewhat narrower in its horizontal dimension, and represents the point of convergence of the retinal nerve fibers where they leave the globe. The fibers pass posteriorly through the choroid to emerge from the eye via a scleral opening called the scleral ring. If this ring is small, as it often is in hyperopia (farsightedness), the nerve fibers will be compacted and the disc smaller, thus leaving little room for any empty space or "cupping" in the center of the disc. Conversely, in myopia (nearsightedness), the ring tends to be large and the ocular coats thinner, therefore allowing a larger though often quite shallow cup in the disc. It is this cup that is of interest to us in glaucoma.

The size of the optic disc cup has been shown to be congenitally determined (1) and does not normally change with the aging process. It is formed by atrophy of the embryonal Bergmeister's papilla which is a mesodermal structure arising from the center of the disc to support the hyaloid artery in the fetus. The amount of atrophy of this papilla and the size of the scleral ring seem to be the factors determining the size of the optic disc cup. There is an indication that these factors are hereditary in that optic disc morphology is often similar in close blood relations.

The depth of the cup is limited by the lamina cribrosa, a fenestrated grid work of scleral fibers through which fascicles of the nerve pass at the level of the sclera. It can be seen in the base of the cup as a whitish grid, and it divides the nerve into pre-laminar and laminar portions.

The laminar and pre-laminar portions of the nerve are affected by elevations in intraocular pressure. Although previous theories as to the mechanism causing this damage have dealt with actual pressure atrophy of the nerve fibers, more recent studies indicate that this damage results from ischemia. An elevation in intraocular pressure is transmitted directly to the intraocular blood vessels, compressing them and thus increasing their resistance to blood flow. This is most pronounced in the capillary circulation of the nerve head and the immediately adjacent retinal and choroidal tissues. It is thought that this reduction in blood flow causes a gradual ischemic atrophy of the cellular structures in the nerve head.

The pre-laminar portion of the nerve head is composed of two cell types: the nerve fibers which arise from the retinal ganglion cells and travel in an arcuate pattern from the periphery of the retina to convene at the disc and turn backward to pass out of the eye, and the astroglial cells which are

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the supporting elements of the nerve. Shaffer (3) has suggested that these glial cells are the first to succumb to the effects of chronic ischemia. This would explain the fact that loss of tissue from the nerve head resulting in an increase of the cup size often occurs prior to the development of field defects. This increase in the size of the cup may be the earliest indication that damage to the eye is occurring, and normalization of the pressure at this stage may prevent further structural and functional damage. Occasionally following such normalization, the cup size will decrease indicating regeneration of astroglial cells. Thus in the evaluation of the patient with elevated intraocular pressure, the appearance of the optic nerve head is particularly important.

There are three basic instruments available for examining the optic disc: the direct ophthalmoscope, the indirect ophthalmoscope, and the slit lamp. The direct ophthalmoscope provides an enlarged upright image and can be used with a relatively small pupil. Its disadvantage is that, unlike the other two instruments, it does not allow a stereoscopic evaluation of the disc. Therefore, one is forced to define a three-dimensional structure from interpretation of a two-dimensional image.

This two-dimensional image of the optic disc is composed of three parts: the excavation or cup, the surrounding rim of disc tissue, and the blood vessels that arise from the center of the disc. The cup is recognized as the paler central portion of the disc. Its nasal and superior walls are usually steep while the temporal and inferior walls tend to slope more gently. It may occupy the entire disc leaving no rim, as in end-stage glaucoma, or it may be virtually absent in which case the surface of the disc is flat and uniformly pink.

The size of the cup is estimated as a ratio of the overall horizontal diameter of the disc to the diameter of the cup expressed to the nearest tenth. A disc in which the horizontal diameter of the cup equals one half of the overall horizontal diameter of the disc would have a cup/disc (C/D) ratio of 0.5. The horizontal diameter of the cup is measured from the nasal wall, which is easily recognized because of its steepness, to the temporal wall which is less easily defined. As the temporal wall slopes upward from the bottom of the cup, there is a gradual intensification of the normal pink color of the rim, and the temporal edge of the cup is estimated to be in the middle of this area of color change. Another aid in locating the temporal edge is to mentally project the curve of the steeper su-

perior wall down and around the temporal side of the disc.

Evaluation of the rim of the disc can help in recognizing the glaucoma suspect. A rim of uniform thickness around the superior, inferior, and temporal aspects of the disc is less likely to be associated with glaucoma. If the rim is particularly thin in the inferior temporal area or, less often, the superior temporal area, then glaucomatous damage is more likely to be present.

The position of the blood vessels is of no particular help in this problem. However, the course they follow as they cross the rim can give one a clue as to the location of the edge of the cup. Sharp angulation of the vessel as it crosses the rim often occurs where the vessel turns downward over the edge of the cup. If the cup has undermined the rim of the disc, the vessel may seem to disappear as it turns over the rim to reappear in the bottom of the cup.

All these factors are useful in determining the extent of cupping of the optic disc expressed as the cup/disc ratio. Statistical studies have shown that a C/D ratio of 0.7 or greater occurs in only 3% of the normal population (2). Therefore, anyone with a C/D ratio of 0.7 or greater should be considered a glaucoma suspect and deserves further evaluation. Also, a difference in C/D ratios between the two eyes of 0.2 or greater occurs in less than 1% of the population and should be taken as evidence of glaucomatous damage until proven otherwise.

In summary, the anatomic characteristics of the optic nerve head have been described along with the ophthalmoscopic interpretation of these characteristics. One hopes that this information combined with a knowledge of what constitutes glaucomatous abnormality in the optic disc will encourage the ophthalmic as well as non-ophthalmic practitioner to evaluate the optic nerve head and recognize those which are suspicious of glaucoma.

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