

‘Is the Optic Disc Cupping or Sinking in Glaucoma?’

My article “ Is the optic disc cupping or sinking in glaucoma” is a hypothesis based on my personal affliction of the disease and observation of my glaucoma patients.

During my residency about 40 years ago I was found to have intraocular pressures of 30 mmHg in both eyes. Normal range is 10 to 22 mmHg. I did not receive any treatment. I still have high IOP of 30 in each eye. Yet I see 20/20, I’ve no visual field defects, and my optic discs are still healthy.

It was very puzzling why didn’t I develop glaucoma at high IOP of 30mmHg while others were developing glaucoma at normal IOP of 15?

In my article I will discuss above and other puzzling questions and how I arrived at the conclusion that the optic disc may not be cupping but instead sinking in its entirety. Before I discuss my puzzling questions I would like to talk briefly: about the intraocular pressure, glaucoma, cupping and visual field defects.

Intraocular pressure:

The eyeball contains clear liquid known as aqueous which is produced by the ciliary body.

This transparent aqueous is important for the nutrition of the transparent lens and the cornea.

The aqueous leaves through the anterior chamber angle into the trabecular meshwork and leaves via Schlemm’s canal and then rejoins the blood circulation.

Since the aqueous is in a closed eyeball it creates a pressure which is known as intraocular pressure. The normal range of intraocular is 10 to 22 mmHg.

Glaucomas: Glaucoma is defined as optic neuropathy in which there is characteristic loss of optic nerve tissue and visual field defects.

Glaucoma is a condition in which the intraocular pressure is increased due to increase in amount of the aqueous. Since the glaucoma is a vast subject therefore there are various ways to classify glaucoma. To keep it short I would like to classify into two types: Painful and Non-Painful.

The painful type is usually acute in onset in which there is a sudden rise of IOP to very high level of about 50 or above. In painful type the eye is also congested and inflamed.

The acute glaucoma is usually either a due to sudden blockage at the anterior chamber angle or in the pupillary area resulting in sudden rise in IOP.

The non-painful type of glaucoma is the most common and was termed as simple glaucoma about 150 years ago. Anterior chamber angle is open therefore it is also known as primary open angle glaucoma. The problem of aqueous drainage lies in trabecular meshwork. In simple glaucoma there is painless gradual loss of vision in a quiet eye.

My presentation is about this primary open angle glaucoma which is usually called as 'glaucoma' only.

In the past 40 years or so another type of simple glaucoma is being known as a low or normal tension glaucoma. Although in normal tension glaucoma the intraocular pressure is consistently within the normal range but it has similar pathological changes in the optic discs and visual field defects as in the case of high tension glaucoma in which the IOP is above the normal range.

Some physicians do not accept normal tension glaucoma as a separate entity. They blame undue sensitivity of the optic disc to intraocular therefore the optic disc atrophies even at lower level

such as of 12mmHg in NTG. Others believe that NTG patients have thin cornea therefore we are falsely underestimating their actual high IOP as a low.

Now I would like to talk about ‘Cupping’: Both Physiological And Pathological.

Normal optic discs have a central depression known as physiological cup.

The physiological cup is the base of the Bergmeister’s Papilla which is left over after its atrophy in fetal life. These cups vary in size from 0.0 to 1.00 which are described as cup- to- disc ratio.

The term pathological or glaucomatous cupping implies when the physiological cup starts enlarging due to damage of the nerve fibers of the optic disc in glaucoma.

After the invention of the ophthalmoscope in 1851 by Helmholtz, the ophthalmologists at the time were able to see the optic disc of chronic glaucoma patients. They described the optic disc of glaucoma patients as ‘cupped’ and for the past 150 years the term ‘cupping’ has become synonymous with glaucoma.

Arrangement Of the nerve fibers:

Retinal nerve fibers are the axons of the ganglion cells of the retina which carry the images to the brain. There are about one million nerve fibers which converge on the optic disc and then leave the eyeball as optic nerve.

Arcuate fibers which originate from the peripheral temporal retina arch above and below the macular fibers to reach the optic disc.

In this article I will be focusing on the arcuate fibers because they are selectively destroyed in the earlier stages of glaucoma.

Visual fields:

In 1889 Bjerrum discovered comma shaped visual field defect on perimetry. Ronnie later found this comma shaped defect to be finishing as arcuate field defect.

These arcuate field defects are obviously produced by the destruction of the arcuate fibers.

Now I will discuss my main puzzling question and how I looked for the answer.

My puzzling question: why do some patient develop glaucoma at normal IOP of 15mm while others don't at high IOP of 30mm?

As I mentioned earlier, some physicians believe that some optic discs are unduly sensitive to IOP . I could not convince myself about the sensitivity issue because if a particular optic disc has survived same normal level of IOP say for 50 years then why the same optic disc has become sensitive now? Therefore It appears that the optic disc has not become sensitive itself but some other factors may be involved in the development of NTG.

I could not agree that making few millimeter adjustment Of IOP based on central corneal thickness was important enough, in view of the fact that some do not develop glaucoma at high IOP of 30mmHg while others develop at very low of 12mmHg, in such a wide range,

Not agreeing with undue sensitivity or the role of central corneal thickness I chose to take the detailed medical history of glaucoma patients. I found out that patients with high tension glaucoma were usually in good health whereas those with normal tension glaucoma were sick with cardiovascular, circulatory, respiratory and surprisingly about 70% were long term smokers.

These findings suggested that normal tension glaucoma may be a systemic disease whereas the high tension glaucoma a disease of the eyeball itself.

Some of the normal tension glaucoma patients only had high myopia and no systemic disease.

Therefore glaucoma appears to be a multifactorial disease.

Now I faced another Dilemma: If glaucoma is a multifactorial disease, then it raised two more puzzling questions.

First if the high tension glaucoma is due to high intraocular pressure whereas the normal tension glaucoma is due to a systemic disease, then why are there similar kind of visual field defects and pathological changes in the optic discs of these two different types of glaucoma?

Therefore, I reasoned that there should be a **common ground** somewhere in the course of pathogenesis of these two types of glaucoma if glaucoma indeed is a multifactorial disease.

Second puzzling question was: ----- Why is it that in both high and normal tension glaucoma, the

peripheral fibers like the arcuate destroyed earlier in the disease whereas the macular or central fibers --- at the last?

I thought that arcuate field defects are perhaps the only lead we have in finding the common ground since they are produced in both high tension and normal tension glaucoma.

I focused on: Why and how are the arcuate fibers selectively destroyed? I ignored the location or any factor which couldn't *selectively* destroy the arcuate fibers in my search for the common ground.

Therefore my next questions are based on selective destruction of arcuate fibers.

Q: Can the cupping of the optic disc selectively destroy the arcuate fibers?

NOT Likely: Cupping implies that the physiological cup starts enlarging concentrically. I wanted to know what are these physiological cups and why should they enlarge?

I learned that the physiological cup is the base of the Bergmeister papilla left over after its atrophy in fetal life. The physiological cup is made of fibrous glial tissue. I couldn't understand why should this fibrous cup enlarge in response to raised intraocular pressure (IOP) and then reverse in size when the IOP is lowered with treatment?

Even if I believed that fibrous physiological cup could concentrically enlarge in glaucoma: How is it possible that glaucomatous cupping involving 360 degrees would selectively destroy only the arcuate fibers and not encompass the rest?

Since I could not convince myself that pathological cupping could selectively destroy the arcuate fibers, therefore I ruled out the phenomenon of ‘cupping’ occurring in the optic disc.

Q: Can the arcuate fibers in the optic disc be selectively destroyed by any cause?

NOT LIKELY. How is it possible that raised IOP or in fact any pathology could selectively target the arcuate fibers among the densely packed million or so nerve fibers in 1.5mm size optic disc?

I couldn't convince myself that raised IOP or any pathology could selectively destroy the arcuate fibers in a densely packed optic disc.

Therefore, I also ruled out the optic disc as the primary site of injury.

Q: Can the arcuate fibers of the retina be selectively destroyed by any cause?

NOT LIKELY. Just as in the case of the optic disc, the raised IOP or in fact any pathology could not selectively destroy the retinal arcuate fibers among the rest of million or so nerve fibers spread out in 360 degrees.

Q. Can apoptosis selectively destroy the arcuate fibers?

Not likely: Apoptosis occurs randomly or generalized in other parts of the body but I am not sure if the apoptosis in glaucoma is so precisely programmed that when activated it would begin *selectively* with only those ganglion cells which serve the arcuate fibers!

If apoptosis is indeed occurring: Then how can we explain the arcuate field defects occurring in traumatic and chronic secondary glaucoma which are not genetically controlled?

Therefore I don't believe that retina could be the primary site of injury in glaucoma.

If the optic disc or the retina could not be the primary site of injury then what is the site? We are left with the border tissue.

Can the junctional border tissue be the primary site of injury in glaucoma?

The junctional area is a circular border tissue of Elschnig which lies between the scleral edge and the optic disc.

This fibrous border tissue acts as a 'O' ring sealant and firmly secures the optic disc in the scleral foramen.

The circular border tissue and prelaminar region are exclusively supplied by the short posterior ciliary arteries either directly or via circle of Zinn-Haller or by both.

Unfortunately the central retinal artery does not take part in the blood supply of the border tissue.

The ciliary circulation supplying the border tissue is of low pressure due to the multiple branches of short posterior ciliary arteries whereas the central retinal artery is of higher pressure since it remains solitary from its origin from the ophthalmic artery.

I hypothesize that the circulation of the prelaminar and the border tissue being of lower pressure is compressed directly by the high intraocular pressure, whereas decreased systemically, due to poor systemic cardio-pulmonary and circulatory problems.

In both instances there would be chronic lack of perfusion or chronic ischemia of the border tissue resulting in its atrophy.

I believe the border tissue is the common ground in the pathogenesis of both high and normal tension glaucoma.

Next: what would happen if the border tissue atrophies?

Due to weakening of the border tissue the optic disc would start sinking in the scleral foramen.

Analogy would be a road made of nerve fibers and the manhole cover as the optic disc. If the manhole cover starts sinking due to its weak attachments then the 'road nerve fibers' would be stretched and severed at the edge due to break in surface continuity.

I think this likewise process of manhole sinking is occurring to the optic disc in glaucoma -----as evidenced by kinking of the blood vessels and other signs in the optic disc.

Now I return to my main question: Can the arcuate fibers be selectively destroyed if the optic disc is sinking?

I think it could be possible. Our genes had been kind and have already separated the arcuate fibers from the rest of the nerve fibers. Secondly the optic disc has oblique entry in the eyeball therefore its temporal part is closer to the scleral edge.

As the disc would sink the temporal fibers which include superior & inferior arcuate and centrally located macular fibers would be stretched and severed at the edge.
The Scleral edge would act as a knife.

Now the question arises: If all the temporal fibers which include superior and inferior arcuate and also the macular fibers are being severed simultaneously, then why is there sparing of the central visual fields until the end stage of glaucoma?

For this the possible answer is: Since the arcuate fibers are much less in number as compared to the macular fibers therefore the arcuate fibers would be depleted earlier giving rise to double arcuate field defects whereas the macular fibers being abundant would last till the end.

This is the way I believe arcuate fibers are being destroyed resulting in arcuate field defects.

Now what happens next once the nerve fibers are being severed and depleted?

The retinal nerve fibers anchor the optic disc in place as roots anchor a tree.

As the nerve fibers are being severed and depleted the disc becomes more loose and sinks further resulting in severing of additional nerve fibers.

This self propagating cascade of loosening and sinking would continue until all the nerve fibers are cut at the scleral edge.

It is the nerve fibers of the prelaminar region which are being severed against the scleral edge. They are being cut prior to their entry into the cribriform plate which lies below the scleral edge.

The commonly observed splinter hemorrhage may be due to severing of the smaller vessels at the edge.

The nasal shifting of the blood vessels can be due to loss of anchorage from temporal nerve fibers because of their early loss.

The area which once housed the optic disc is replaced with an empty crater due to loss of entire disc. This is what the end stage histology reveals.

Stages of the sinking optic disc:

For pictures please visit power point presentation on my website.

Early stage: There is no change in size of physiological cup. There is temporal pallor and prominent scleral edge due to thinning of the nerve fiber layer due to its depletion. There is sloping and kinking of the blood vessels at the edge due to sinking of the optic disc.

Middle stage: The physiological cup is obliterated or broken due to confluence of the cup pallor with the pallor produced by the loss of the nerve fibers and its vasculature. It may be called decupping of the optic disc. The kinking of the vessels at the edge becomes more pronounced. The temporal area becomes bald due to severing of the smaller vessels. Nasal shifting of the vessels become noticeable.

Final Stage: The optic disc area appears pale due to the loss of nerve fibers and its vasculature. The kinking of the blood vessels becomes very pronounced due to loss of nerve fibers. There is marked nasal shifting of the blood vessels due to loss of anchorage from depleted temporal fibers in early stages of disease.

Conclusion based on sinking:

Optic disc may not be cupping.

Optic disc may be sinking in its entirety.

Normal tension glaucoma may be a systemic disease.

Glaucoma appears to be a multifactorial disease. More the risk factors present, higher the likelihood and severity of development of glaucoma akin to ischemic heart disease.

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In glaucoma, the nerve fibers are being severed and depleted. At the end stage, the optic disc area which once housed the optic disc is replaced with an empty crater due to total destruction of the optic disc. **This is what the histology of end stage glaucomatous optic disc reveals.**