

PREDICTING GLAUCOMA?

THE EXAMINATION CAN PREDICT GLAUCOMA DAMAGE

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Figure 1. Heidelberg Retinal Tomograph II

We have a new instrument, the Heidelberg Retinal Tomograph (HRT II), seen in Figure 1 that will help us predict who will suffer visual damage from glaucoma. To explain how this can happen, I will give you a brief explanation of the anatomy of the visual system that describes the events causing glaucoma damage, our current understanding of glaucoma, and the two tests that are most sensitive and accurate in diagnosing glaucoma.

First of all, what is it that gets damaged in glaucoma and how can we tell? The optic nerve becomes damaged as a result of individual nerve fibers that do not send their pictures to your brain. Many of you know that the rods and cones in your retina send information about an image in your field of vision through the individual nerve fibers in your optic nerve to your brain. With glaucoma, individual nerve fibers die and that information does not get back to your brain. If your brain cannot receive the information, the corresponding part of the retina is blind.

The understanding of glaucoma is explained by the anatomy of the retina and optic nerve. Figure 2 shows a view of the optic nerve and macular region of your eye.

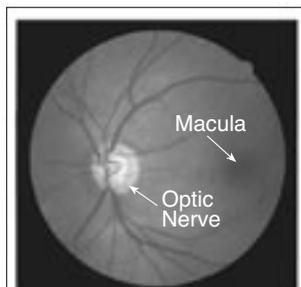


Figure 2. Photo of optic nerve and macular area (darker area to the right).

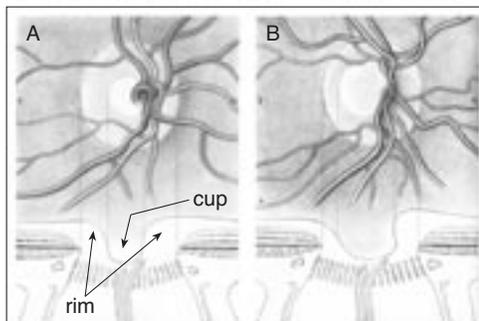


Figure 3. This schematic compares the optic nerve surface appearance to the side view of depth.

Figure 3 shows a cross section of the optic nerve in two configurations. The first 3A shows a smaller central cup while the second 3B shows a larger central cup. What is important is not that one of the cups is larger than the other. The important information is that if the shape of the optic nerve in 3B started

out looking like the shape of the optic nerve in 3A, there must have been a loss of optic nerve tissue in the rim in 3B. If there is a loss of optic nerve rim tissue, those lost individual nerve fibers will leave blind spots in your field of vision.

Figure 4 shows two cross sections of the retina, one schematic and the other a photomicrograph. You can see that the rods and cones line up in the outer portion of the retina. The rods and cones measure and transmit information about images that bathe their sensors. A nerve fiber (axon) passes inward from the rod or cone and connects with a ganglion cell just beneath the nerve fiber layer (innermost) of the retina. Another axon leaves the ganglion cell, merges with other axons in the nerve fiber layer and enters the optic nerve on the way to the visual cortex of the brain. There are approximately 1.5 million individual nerve fibers that make up the optic nerve. Depending on the diameter of the canal that exits through the white sclera at the back of the eye, the optic nerve presents a shape that frequently shows a depression (cup) in the center of the optic nerve surface. There may be no cup or there may be a cup of any size. The cup is described as a percentage of the nerve surface. Cups that are larger than .5 (50% of the nerve surface) have a higher incidence of developing glaucoma damage over time.

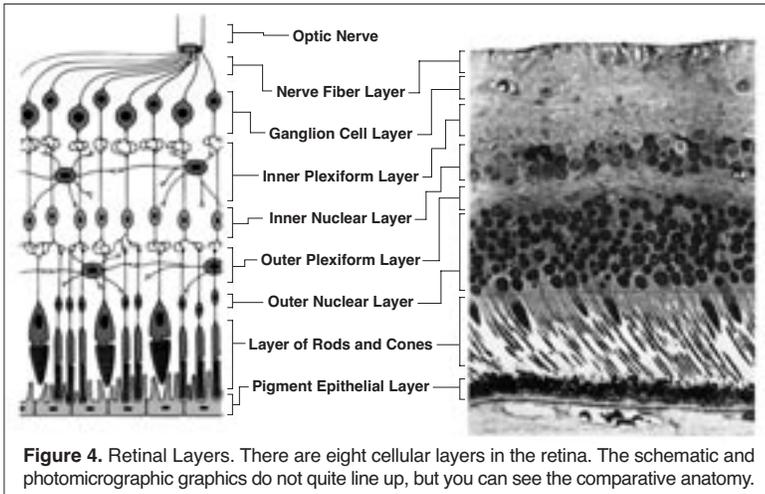


Figure 4. Retinal Layers. There are eight cellular layers in the retina. The schematic and photomicrographic graphics do not quite line up, but you can see the comparative anatomy.

Glaucoma specifically damages the ganglion cell (in the layer just beneath the nerve fiber layer in figure 4), the cell slowly dies and its axon withers away. Whatever the original anatomy of the optic nerve surface, as the number of dying ganglion cells increases, there are two results. The first is a slow change (takes many years) in the shape of the optic nerve from the loss of the individual nerve fibers. The second is when a sufficient number of ganglion cells die (along with their nerve fibers), a measurable loss of a portion of the field of vision can be found (see the lower field in Figure 5 and the series of fields in Figure 6).

Glaucoma used to be thought of as damage to the optic nerve from having too high fluid pressure inside the eye. Because of that, the treatment has been, and still is, to lower the fluid pressure inside the eye. This allows more blood to enter the eye and glaucoma damage to the optic nerve is lessened or stopped. Studies confirm that the blood supply to the optic nerve is still the critical component to its health. However, your ocular fluid pressure can be completely normal or even low and glaucoma damage can still occur. This means two things: (1) an impaired blood supply can occur even with normal intraocular fluid pressure and, (2) there are other factors that cause cell death and glaucoma damage.

The gold standard for diagnosing glaucoma has been the visual field examination (Figures 5 and 6). During this test, each eye is tested to determine how sensitive it is to projected spots of light of various intensities onto a white surface in front of the eye. If the patient perceives the

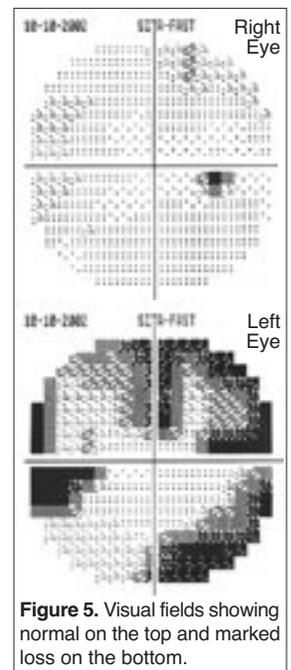


Figure 5. Visual fields showing normal on the top and marked loss on the bottom.

lighted projection, the patient presses a button and the instrument records that the light was seen. If the projected light is not

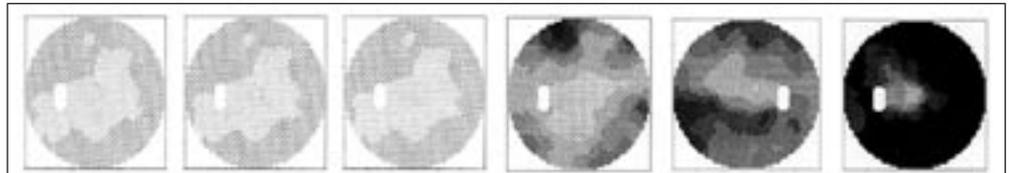


Figure 6. Progression from a normal full field to loss of greater than 90% of the field.

seen, the patient makes no response and the instrument records the absence of a response. Projected spots that are either not seen or not seen well are recorded onto a printout showing the damaged or missing areas. In the early to moderate stages of glaucoma, visual field defects are not noticed by the patient, but they will show up on a visual field test.

The gray pattern seen in the first three printouts in Figure 6 is normal. As damage occurs, there is a progression toward black and increased field loss. The black area on the right side of the upper visual field in Figure 5 is the blind spot. This is the optic nerve area where there are no visual cells. The white areas in Figure 6 are the blind spots in a different color. When we find these damaged areas and if the appearance of the optic nerve is consistent with the visual field damage, a diagnosis of glaucoma is made. Unfortunately, it takes years of cellular damage (ganglion cell and optic nerve fiber death) to occur before a visual field defect can be found. We know that physical damage has to happen before a visual field defect occurs. We take photos of optic nerves to help follow their appearance over time. Good photos are very helpful, but they cannot show minor changes in the surface of the optic nerve (e.g., a change from a small cup to a slightly larger cup).

Now comes the revolutionary change in diagnosing glaucoma. The HRT II can accurately measure the actual three-dimensional shape of the optic nerve head. Figure 7A shows photos of the right and left optic nerves of a patient. Figure 7B (HRT II graphical height maps) shows the

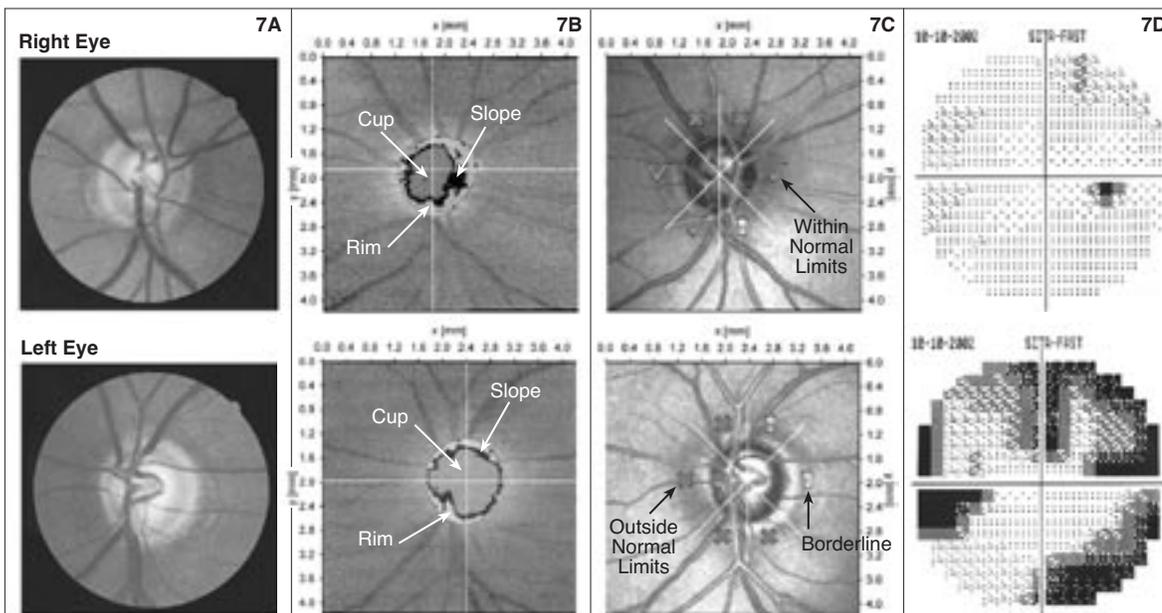


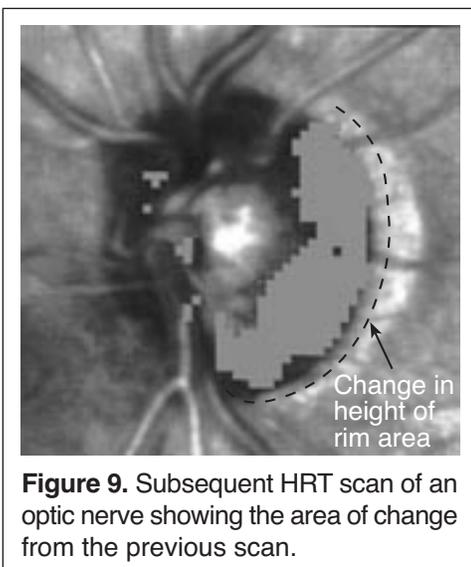
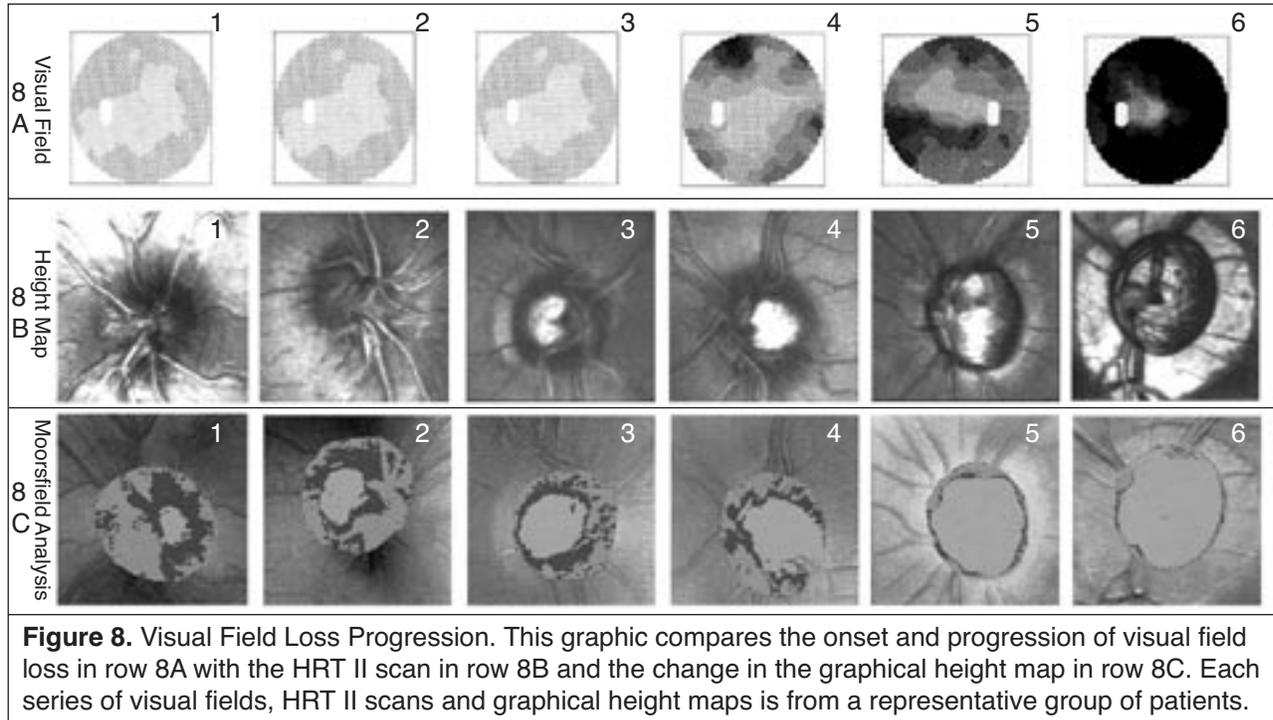
Figure 7. Optic Nerve/HRT Photo. Compares actual optic nerve appearance (7A) to its HRT height map (7B), Moorfields regression analysis (7C) that identifies abnormal sectors and the visual field (7D) showing any areas of visual impairment.

actual cup and rim/slope of each optic nerve. Even with the detailed photos on the far left, you can see in the second set of graphics a more accurate view of the cup and rim. The difference between the two graphics is dramatic and surprising. Figure 7C shows a Moorfields evaluation of the data seen in 7B (the height maps). The Moorfields analysis

compares six sectors of the height map with a database and labels each sector's rim/slope area (the tissue that takes the picture back to the brain) as to being within normal limits (50% of the

population has a larger rim/slope area), borderline (95% of the population has a larger rim/slope area) or outside normal limits (99% of the population has a larger rim/slope area). Figure 7D shows the comparative visual fields for the right and left eyes.

Figure 8 shows a general representation of serial visual field findings (8A), HRT II scans (8B) and graphical height maps (8C). The HRT II findings show the rim/slope area decreases (the cup becomes larger - 8B 2 & 3 and 8C 2 and 3) before a visual field defect can be seen with visual field testing (8A 4). **That is the important fact.** In Figure



9, the HRT II makes it easier to see the changes with subsequent HRT II scans. The HRT II shows the earlier scan in grayscale and highlights in color (gray here) any changes measured on the subsequent scan.

So what does this mean? It means that we can take serial HRT II scans over time that can document minute changes in the optic nerve anatomy. This helps us to predict which optic nerve has a tendency to develop visual field damage before the visual field examination can show the defect. This does not negate the value of a visual field examination. It just means that we have a wonderful new tool that will help us identify and treat glaucoma and glaucoma suspect patients earlier in the course of their disease.

We are currently performing HRT II scans on our glaucoma and glaucoma suspect patients.