OCT in Glaucoma

Dr. Valsa Stephen MS DO DNB, Dr. Arup Chakrabarti MS DO, Dr. Sonia Rani John DNB, Dr. Meena Chakrabarti MS DO DNB

Glaucoma is the clinical manifestation of irreversible damage to the retinal ganglion cells resulting in retinal nerve fibre layer loss. This becomes functionally evident as visual field loss which is detected on perimetry. It is now known that structural damage detected by RNFL defects precedes functional loss. 40 % axonal loss has to occur before any detectable change occurs in visual function. \(^1\) Another study \(^2\) showed that RNFL loss was detected nearly six years before visual field defects occurred in ocular hypertensives. The recognition of RNFL loss in patients with normal visual fields has led to the concept of “Pre-perimetric” glaucoma, signifying early glaucomatous damage not evident on standard automated perimetry. RNFL loss also precedes optic disc changes which occur before visual field changes. It has also been shown that early treatment is important in lowering the patient’s risk of glaucoma progression. \(^3\) However, clinical evaluation and photography of the RNFL is a difficult technique, is subjective, qualitative and variably reproducible. With the advent of Optical Coherence Tomography (OCT) or scanning laser polarimetry (GDx), highly reproducible RNFL assessment and quantification is possible, thus enabling improved management of glaucoma.

Validity of OCT for glaucoma:

1. OCT measurement were found to be highly reproducible \(^4\) especially in a circle diameter of 3.4 mm and with internal fixation.
2. Ability to distinguish normal from glaucomatous eyes is greater as established by several studies \(^5,6,7\).
3. Effect of age : OCT normative values have been developed to adjust for the RNFL thinning with age.

OCT SCANS FOR DETECTING GLAUCOMA

The OCT enables scanning three regions for glaucoma detection-

1. The Peripapillary retinal nerve fiber layer (RNFL)
2. The macular region.
3. The optic nerve head.

1. RNFL Measurement

RNFL measurements with OCT have sensitivity and specificity in differentiating glaucomatous from normal subjects. \(^8,9\) Of these, RNFL thickness in the inferior region and mean RNFL thickness are the best to detect early to moderate glaucoma.

2. Macular Thickness

The mean macular thickness of glaucomatous eyes has been shown to be significantly lower than that of normal control eyes. \(^10\) A significant correlation between OCT macular thickness and visual field mean defect in glaucomatous eyes has been demonstrated. \(^11\) However this is inferior to RNFL measurements.
3. Optic Nerve Head (ONH) Analysis

The utility of this needs to be further evaluated as variation may occur, for example disc margin evaluation may be influenced by changes in the RPE- choriocapillaris layer.

However, a study has shown the rim area and horizontal integrated rim width as the best ONH parameters, while another has shown the cup disc area ratio as the best ONH discriminator. 12

IMAGE ACQUISITION

There are 2 basic OCT scan patterns- lines and circles.
1. Scan placement for RNFL protocols : These are circle scans centred in the middle of the optic disc.
2. Optic Nerve head Protocols : These are line scans arranged like spokes of a wheel the center of which should be in the middle of the optic disc.

GLAUCOMA SCAN PROTOCOLS

The OCT scan protocols (Fig. 1) described for glaucoma detection and management include the following:

I. RNFL Protocols
   a. RNFL thickness (3.4): Consists of 3 circle scans of 3.4 mm diameter around the optic disc which are averaged.
   b. RNFL thickness (2.27 x disc) : a single circular scan around the optic disc that is 2.27 times the radius of the aiming circle.
   c. Fast RNFL thickness (3.4) : acquires three 3.4 mm diameter scans in 1.92 seconds and compresses them into one scan.
   d. RNFL Map : consists of a set of six concentric circle scans at increasing distances from the disc margin.

II. ONH Protocols
   (a) Optic Disc  (b) Fast optic disc : Compresses six optic disc scans into one scan in 1.92 seconds.

III. Macular Thickness Protocols
   a. Macular Thickness Map
   b. Fast Macular Thickness Map : Compresses six macular thickness scans into one scan in 1.92 seconds.

Fig 1. Glaucoma scan protocols

Fig 2. RNFL Analysis

Fig 3. ONH Analysis
ANALYSIS PROTOCOLS FOR GLAUCOMA
(Fig. 2 & 3)

1. RNFL Thickness (Single Eye)

The normal RNFL graphs appear as a “double hump” : e.g. due to increased RNFL thickness at the superior and inferior poles of the disc. The output chart includes circle characteristics like quadrant and clock hour RNFL thickness averages. The RNFL is depicted in hot colours i.e. a red band superficial to the green retina (Fig. 4)

![Image of RNFL thickness report]

Fig. 4. RNFL thickness report

2. RNFL Thickness Average (OU)

Two maps, one showing RNFL thickness using a colour code (A) and the other showing average RNFL thickness in microns (B) are created (Fig 5).

The black graph represents the RNFL thickness of the eye being tested in the nasal, superior, temporal and inferior quadrants. The OCT has incorporated normative age- matched RNFL thickness data. The software displays graphs which are colour coded according to the probability of the RNFL thickness measured in the particular patient being normal when compared to age- matched controls.

![Image of RNFL thickness analysis]

Fig. 5. RNFL thickness average showing normal thickness of RNFL in both eyes

Of the normal population (Fig 6)

: 5 % fall within the white band
: 5 to 95% fall within the green band
: 1 to 5 % fall within the yellow band.
: 1 % fall within the red band (Outside normal limits)

![Graph showing probability of distribution of RNFL thickness in the normal population]

Fig. 6. Graph showing probability of distribution of RNFL thickness in the normal population

The output chart also provides RNFL thickness values in clock hours and quadrants using the same colour code. (B). Summary parameters which include average thickness in each quadrant, maximum RNFL thickness in superior and inferior quadrants and ratios of RNFL thickness in various quadrants (I max/S max, S max/I max; S max/ T avg; I max/ T avg) are also provided (C). Usually the
inferior RNFL is the thickest and the I max/ S max ratio is greater than 1.0. In glaucoma, the ratio may be less than 1.0 due to inferior RNFL loss.

3. **RNFL Thickness Serial Analysis (OU)**

This allows comparison of RNFL thickness over time for up to 4 visits which are superimposed on the same chart (A) and each visit is colour coded (B) (Fig. 7). RNFL thickness change analysis shows the difference in RNFL thickness in two visits (Fig. 8).

![Fig. 7. RNFL thickness serial analysis showing no progression](image)

![Fig. 8. RNFL thickness change analysis showing progression](image)

4. **Optic Nerve Head (Single Eye)**

The algorithm detects and measures all features of the disc anatomy based on the anatomical markers (disc reference points) on each side of the disc where the RPE ends. It locates and measures the disc diameter by tracing a straight line between the two disc reference points (Blue line A) and measures cup diameter on a line parallel to the disc line and offset anteriorly by 150 µ (Red line, B). The output chart measures the optic disc, optic cup, neuroretinal rim and cup/disc ratio using these measurements. (Fig. 9).

![Fig. 9. Optic nerve head analysis showing normal ONH](image)

5. **RNFL Thickness Map (OU)**

Two maps, one representing RNFL thickness using a colour code and the other the average RNFL thickness in the inner and outer areas of eight map sectors are generated.

6. **Macular Thickness Map**

Two maps, the upper one showing retinal thickness using a colour code and the lower one showing average retinal thickness in microns in each area are seen.
**Normal OCT**

The normal optic disc is seen on OCT as a cross section through the optic nerve head. The cup is shallow with sloping edges. The neuroretinal rim is seen as a wide red zone straddling the disc margin (Fig. 10).

The RNFL thickness analysis shows the characteristic double hump pattern signifying increased thickness at the inferior and superior pole of the optic nerve head. The graph falls well within the green colour region and all quadrants are flagged in green indicating normal RNFL thickness (Fig. 11).

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In the section of the optic disc, the cup walls appear vertical and the depth of the cup is increased. The neuroretinal rim is very thin (Fig 12).

RNFL thickness will be reduced; the superior and inferior hump may be flattened and the graph is seen to be encroaching in the red and yellow areas. The average RNFL thickness in the quadrants in which it is reduced will be flagged in red or yellow (Fig. 13).

**OCT in the Clinical Management of Glaucoma**

1. **To Confirm the Integrity of RNFL in Disc Suspects:** (Fig. 14)

Disc suspects are defined as those eyes with a cup-disc (C/D) ratio > 0.7 or a neuroretinal rim width of less
Fig. 13. RNFL analysis showing RNFL thinning than 0.1 of the CD ratio between 11 to 1 o’clock or 5 to 7 o’clock, but no definite field defects.

Disc suspects require followup since they could possibly be preperimetric glaucoma, not detected on conventional automated perimetry. OCT helps to quantify RNFL changes for followup and to determine any progressive loss which if present points to a diagnosis of early glaucoma.

2. Monitor Followup of Patients with Ocular Hypertension

OHT is a condition characterized by elevated IOP without definite disc or field changes. The OHTS (Ocular Hypertension Treatment Study)\(^2\) investigated the predictive factors for development of glaucoma and found that increased IOP, increased CD ratio and thinner corneas were major risk factors. Serial RNFL analysis can help monitor RNFL loss in these group of patients. (Fig. 7)

3. Establish a Suspicion of Preperimetric Glaucoma: (Fig. 15)

The spectrum of glaucoma ranges from normal healthy eye through undetectable disease to detectable, asymptomatic disease to functional impairment and eventual blindness. During the asymptomatic stage, demonstration of RNFL loss in OCT analysis points to a diagnosis of pre perimetric glaucoma before field changes are demonstrable in automated perimetry. Early diagnosis is imperative for early treatment and prevention of visual loss across this continuum.

4. Monitor Asymmetric POAG

In patients with unilateral established glaucoma and normal fellow eye with increased IOP, OCT helps in followup. Such cases may need to be treated as there is 40% chance of developing visual field loss over a 5 year period. Hence early detection of RNFL defects is of importance.

5. Monitor Patients Unable to Perform Visual Field Tests Reliably

In such situations OCT may provide extra structural evidence to substantiate the clinical impression.
6. Help Monitor Patients when Visual Field Interpretation may be Fallacious due to Non Glaucomatous Causes.

7. Follow up of Established Glaucoma Patients to Detect Progressive RNFL Loss.

Conclusion

Thus OCT helps in the early diagnosis and monitoring of glaucoma even before functional visual loss in the form of visual field loss occurs. This is useful in preventing progression of glaucoma.

However, as with any other imaging modality, OCT should never be interpreted in isolation. Correlation with the clinical findings, field changes and IOP helps in the management of glaucoma in a more scientific manner.

References


Fig. 15 (A & B) showing normal C 30-2 (15 B) but mild thinning inferiorly of RNFL (15 A) on OCT in the left eye.
Spectacles have been around for a long time but it is uncertain when and where they were first used. They probably just evolved over a period of time.

Though the Roman Emperor Nero used an emerald while watching gladiatorial contests, it is not known whether this was as a symbol of power or to see better.

The first recorded reference to using a lens to improve vision was in 1262 by the Franciscan Friar, Roger Bacon. He may not have been the first person to observe the magnifying properties of sphere segments but he certainly recognized their use in old people and those with poor eyesight. He thus recommended the use of loupes and magnifying glasses which were the forerunners of today’s spectacles.

Bacon was a truly remarkable man who possessed one of the most commanding intellects of his own or perhaps of any age. In spite of the disadvantages and discouragements to which he was subjected, he made many discoveries and came near many more. He was an enthusiastic proponent and practitioner of the experimental method of acquiring knowledge.

The exact date and place of Bacon’s birth are unknown. It was probably in 1214 at Ilchester in Somerset, England. His father was a wealthy landowner and Bacon had the advantage of early training in Geometry, Arithmetic, Music, and Astronomy. He studied at Oxford and Paris and later taught at both places. He was an unconventional scholar being interested in Philosophy, Alchemy and Magic, even while championing the cause of Experimental Science.

Bacon’s wide range of interests included Optics and the refraction of light through lenses. He described telescopes and microscopes, flying machines, motorized ships and cars, pulleys and the making of gun powder. He also sought to reform the Julian calendar which was then in use, and was interested in Astronomy.

He first recognized the visible spectrum in a glass of water, centuries before Sir Isaac Newton. He stressed the importance of Mathematics in the understanding of all Science and his greatest contribution was to insist that a study of the natural world by observation and exact measurement was the surest foundation for truth.

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