Original Article

Early Detection of Primary Open Angle Glaucoma by Using Optical Coherence Tomography (OCT)

Abdul Majeed Malik, Saima Irum, Kashif Ali

Pak J Ophthalmol 2015, Vol. 31 No. 2

See end of article for authors affiliations

Correspondence to:
Abdul Majeed Malik
Prof of (0phthalmolgy
BUM & DC)
Classified Eye Specialist
PNS Shifa Naval Hospital
Karachi
Mail: majeed2413@hotmail.com

Purpose: To measure and analyze thickness of retinal nerve fiber layer using Optical Coherence Tomography (OCT).

Material and Methods: This study was conducted in ophthalmology department PNS Shifa, Karachi. From March 2013 to Jan 2015 for 23 months. A total of 350 glaucoma suspect patients were selected. A detailed history of ocular or systemic diseases was taken. Intraocular pressure (IOP) was measured using Goldmann Applanation tonometer. Optical Coherence Tomography (OCT) images were taken using Heidelberg HRA + OCT Spectralis machine.

Results: Patients with a mean age of 35 ± 12 years were included. Out of 350 patients, 140 (40%) patients were female and 210 (60%) were male. Mean IOP was 25 ± 5 mm Hg, mode was 23 mm Hg and median 26 mm Hg. Out of these 350 suspects, only 28 patients were found to have nerve fiber layer thickness outside the normal limits i.e. decreased in half a quadrants or more.

Conclusion: Ocular coherence tomography nerve fiber layer thickness analysis is a quick and effective method to diagnose early and borderline cases of glaucoma.

Key Words: Optical coherence tomography (OCT), retinal nerve fiber layer (RNFL), glaucoma, intraocular pressure (IOP).

Glaucoma is an optic neuropathy characterized by ganglion cell death that manifests clinically as characteristic optic nerve head (ONH) and retinal nerve fiber layer (RNFL) changes with correlating visual field defects.

Early diagnosis of glaucoma and the early detection of glaucomatous progression is a challenge.

Optical coherence tomography (OCT), first described in 1991, is a noncontact, noninvasive imaging technique that can reveal layers of the retina by looking at the interference patterns of reflected laser light.[1] Automated software segmentation algorithms are able to outline the retinal nerve fiber layer with much precision, which is relevant in glaucoma since this layer is thinned as ganglion cells are lost. It is well known that significant structural RNFL loss occurs prior to the development of functional visual field loss.[2]

Spectral domain OCT (SD-OCT) is a recent technique that enables the imaging of ocular structures with higher resolution and faster scan rate compared with the previous version of this technology. Several studies have been performed to assess the diagnostic capability of SD-OCT in perimetric glaucoma. One representative study compared the diagnostic capability of SD-OCT to TD-OCT RNFL thickness scans in subjects with early and moderate glaucoma as well as normal age-matched subjects. When using the average RNFL thickness at the 5% level compared to the normative database (yellow coloring on RNFL deviation map), SD-OCT had a sensitivity of 83% and a specificity of 88% compared to 80% and 94%

respectively for TD-OCT. When using the average RNFL thickness at the 1% level (red coloring on RNFL deviation map), the specificity for both SD-OCT and TD-OCT was 100% but the sensitivity was only 65% in SD-OCT and 61% in TD-OCT.[3]

ONH parameters have also been found to have excellent ability to discriminate between normal eyes and eyes with even mild glaucoma. The parameters found to have the greatest diagnostic capability are vertical rim thickness, rim area, and vertical cup to disc ratio. These ONH parameters were found to be as good as RNFL thickness parameters in diagnosing glaucoma.[4]

Standard Automated Perimetry, (SAP) the once gold standard to evaluate glaucomatous neuropathy and to monitor disease progression has poor sensitivity for detecting early glaucoma.

MATERIAL AND METHODS

This cohort observational study was carried out at the Department of Ophthalmology PNS Shifa, Karachi, extending over 23 months from 1st March 2013 to 31 Jan 2015. Non probability consecutive sampling was done. A total of 350 patients were enrolled in our study so fulfilling the criteria of preliminary glaucoma suspect (n = 350), with Optic C:D ratio of more than 0.6 at least in one eye, intra ocular pressure (IOP) higher than 20 mm Hg, and age more than 20 years. Subjects previously diagnosed as cases of glaucoma (POAG, PACG and secondary glaucomas), previous intra ocular surgery, and optic neuropathy due to other causes were excluded. Systemic diseases were also ruled out .Permission was taken from hospital ethical committee. Written informed consent was taken. Both IOP and OCT images were taken on the same day with calibrated instruments. Intraocular pressure of both eyes was measured with help of Goldmann applanation tonometer using 2% fluorescein eye drops by the same physician to avoid inter examiner and inter tonometer variation, between 9 to 11 AM to minimize the effect of diurnal variation. Central corneal thickness was also measured. Three readings of each eye were taken at 30 minutes interval and mean calculated. OCT images were taken using Heidelberg HRA+OCT Spectralis by a single person to avoid inter examiner error.

RESULTS

Patients had a mean age of 35 ± 12 years. Out of 350 patients, 140 (40%) patients were female and 210 (60%) were male. Mean IOP was 25 ± 5. Mode was 23 and median 26.

Out of these 350 suspects, only 28 (8.0%) patients were found to have nerve fiber layer thickness outside normal limits i.e. decreased in half a quadrant or more.

They were further investigated and documented with visual field analysis and IOP phasing.

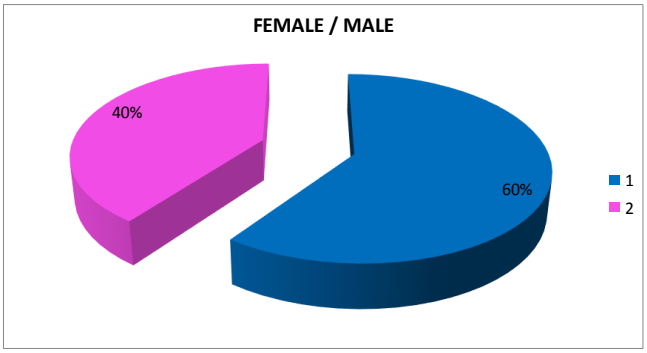

Fig. 1: Male Female Percentages.

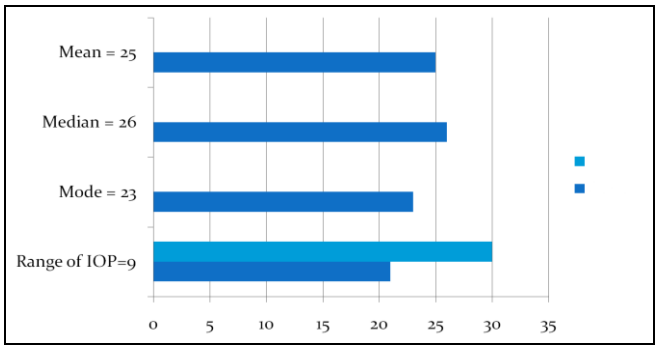

Fig. 2: IOP Distribution.

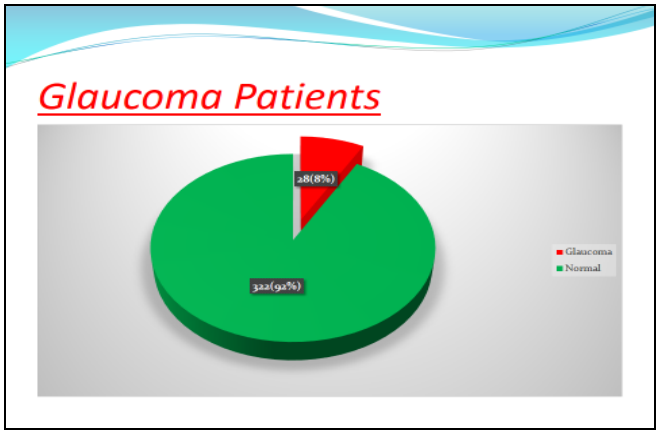

Fig. 3: Total Glaucoma suspects = 350
Glaucoma Patients = 28 (8%)
Non Glaucomatous = 322 (92%)

DISCUSSION

Glaucoma is a progressive disease characterized by death of ganglion cells and degeneration of retinal nerve fiber layer leading to irreversible loss of vision.

Although automated perimetry has been the standard method for detecting progressive disease, it is known that many patients can have progressive structural damage that precedes detectable associated changes in the visual field.

There are three main parameters relevant to the detection of glaucomatous loss i.e. retinal nerve fiber layer, optic nerve head, and the "ganglion cell complex." Latest spectral domain ocular coherence tomography (SD-OCT) was used to measure retinal nerve fiber layer (RNFL) thickness around optic nerve head. SD-OCT can directly measure and quantify RNFL thickness by calculating the area between the internal limiting membrane (ILM) and RNFL border (how the edge of the RNFL is determined and how blood vessels are handled is different between different machines, which do not have interchangeable measurement outputs).[5] Its software was used to see any abnormality in retinal nerve fiber layer thickness in different quadrants around optic nerve by comparing with normative preloaded data in the software. SD-OCT is a superior technology than conventional time domain (TD- OCT) with reference to scanning speed up to 200 times faster and higher axial resolution (3 to 6 µm). Progressive RNFL thinning measured on SD-OCT can often be used to detect progressive disease. The top three RNFL progression patterns are: widening of an existing RNFL defect, deepening without widening of an existing RNFL defect, or development of a new RNFL defect. In one study, the inferotemporal quadrant was the most frequent location for RNFL progression[6]. In such pre perimetric disease, SD-OCT RNFL is especially useful in helping to diagnose glaucoma prior to the onset of visual field loss. In the presence of perimetric disease, finding RNFL bundle loss on SD-OCT with a corresponding abnormality in the visual field served by those retinal ganglion cells can help confirm the diagnosis of glaucoma. In early to moderate glaucoma, progressive thinning of RNFL thickness measured by SD-OCT is a very useful tool to judge progression of disease. At advanced stages however, SD-OCT is less clinically useful due to a "floor effect" of RNFL thickness. With advanced loss, RNFL thickness levels off, rarely falling below 50 µm and almost never below 40 µm due to the assumed presence of residual glial or non-neural tissue including blood vessels.[7] At this level of disease, serial visual fields are more useful to judge progression.

Scanning laser polarimetry (SLP), provides quantitative estimates of the thickness of the RNFL with potential use for diagnosis and follow-up of glaucoma patients. It is based on the principle that polarized light passing through the RNFL undergoes a measurable phase shift, known as retardation, which is linearly related to histologically measured RNFL tissue thickness.

Myopic eyes have thinner RNFL measurements, which can confound comparisons to the normative database. Additionally, myopic eyes can have unique distributions of RNFL bundles. With increasing myopia, the superotemporal and inferotemporal RNFL bundles tend to converge temporally.[8] This may result in the temporal shift of the superior and inferior RNFL bundle peaks of normal magnitude.

While the limitations of the normative database may hinder the utility of SD-OCT in diagnosing glaucoma using a single scan, serial SD-OCT scans can be very useful to judge glaucomatous progression by setting a baseline scan against which to judge progressive thinning on subsequent scans. Therefore, each patient can be his or her own "normative database" to diagnose glaucoma in such difficult settings as high myopia. With this approach, clinicians should be aware that RNFL thickness decreases with age in normal, healthy individuals. Based on a longitudinal study, the age-related rate of reduction in RNFL thickness has been estimated to be -0.52 µm/ year, -1.35 µm/year, and -1.25 µm/year for average, superior, and inferior RNFL respectively.[9] In one study, artificially defocusing an image scan by +2 diopters resulted in an artifactual 10 µm thinning of the RNFL.[10] Similarly, a 9.3% increase in mean average RNFL thickness was seen after cataract surgery in a study of 45 patients.[11] It is important to look at the segmentation lines produced by any SD-OCT machine's software algorithm to ensure that they are appropriately placed. Lines should not come together (go to zero). Occasionally, one will find that the segmentation lines are misplaced along the retina leading to errors in the calculation of RNFL thickness. These segmentation errors are more common in the presence of poor signal strength, tilted discs, staphylomas, large peripapillary atrophy, epiretinal membranes, and posterior vitreous detachments. Studies have found a decreased incidence of such segmentation errors in SD-OCT compared to TD-

OCT[12]. Cataracts can affect RNFL thickness measurements. One study found a 4.8 μm increase in RNFL thickness measurement after cataract surgery. This effect was most pronounced in cortical cataracts, followed by posterior subcapsular cataracts. Interestingly, nuclear cataracts were not found to affect signal strength or RNFL thickness measurements.[13]

CONCLUSION

Glaucoma can be easily screened by routine ophthalmoscopy done by general medical practitioner. Any glaucoma suspect can be diagnosed early by using new imaging technique like ocular coherence tomography nerve fiber layer thickness analysis by an ophthalmologist. Doubtful cases of glaucoma should be further investigated and documented with visual field analysis and IOP phasing.

SD-OCT is a powerful objective structured assessment tool that can greatly assist clinicians in diagnosing and managing glaucoma (especially early disease), when used in conjunction with visual field testing and clinical examinations.

Author's Affiliation

Prof. Dr. Abdul Majeed Malik
Prof (0phthalmolgy BUM & DC) / Classified Eye Specialist PNS Shifa Naval Hospital, Karachi

Dr. Saima Irum
Classified Ophthalmologist CMH Cherat

Dr. Kashif Ali
Classified Ophthalmologist PNS Shifa Karachi

REFERENCES

1. **Aref AA, Budenz DL.** Spectral domain optical coherence tomography in the diagnosis and management of glaucoma. Ophthalmic Surg Lasers Imaging. 2010; 41: S15-27.
2. **Quigley HA, Dunkelberger GR, Green WR.** Retinal ganglion cell atrophy correlated with automated perimetry in human eyes with glaucoma. Am J Ophthalmol. 1989; 107: 453–64.
3. **Chang RT, Knight OJ, Feuer WJ, Budenz DL.** Sensitivity and specificity of time-domain vs spectral-domain optical coherence tomography in diagnosing early to moderate glaucoma. Ophthalmology. 2009; 116: 1257-63.
4. **Mwanza JC, Durbin MK, Budenz DL, Sayyad FE, Chang RT, Neelakantan A, Godfrey DG, Carter R, Crandall AS.** Glaucoma diagnostic accuracy of ganglion cell-inner plexiform layer thickness: comparison with nerve fiber layer and optic nerve head. Ophthalmology. 2012; 119: 1151-8.
5. **Leite MT, Rao HL, Weinreb RN, Zangwill LM, Bowd C, Sample PA, Tafreshi A, Medeiros FA.** Agreement among spectral-domain optical coherence tomography instruments for assessing retinal nerve fiber layer thickness. Am J Ophthalmlol. 2011; 151: 85-92.
6. **Leung CK, Yu M, Weinreb RN, Lai G, Xu G, Lam DS.** Retinal nerve fiber layer imaging with spectral – domain optical coherence tomography: patterns of retinal nerve fiber layer progression. Ophthalmology. 2012; 119: 1858-66.
7. **Hood D, Kardon R.** A framework for comparing structural and functional measurements of glaucomatous damage. Prog Retin Eye Res. 2007; 26: 688-710.
8. **Leung CK, Yu M, Weinreb RN, Mak HK, Lai G, Ye C, Lam DS..** Retinal nerve fiber layer imaging with spectral-domain optical coherence tomography: interpreting the RNFL maps in healthy myopic eyes. Invest Ophthalmol Vis Sci. 2012; 53: 7194-7200.
9. **Leung CK, Yu M, Weinreb RN, Ye C, Liu S, Lai G, Lam DS.** Retinal nerve fiber layer imaging with spectral-domain optical coherence tomography: a prospective analysis of age – related loss. Ophthalmology 2012; 119: 731-7.
10. **Balasubramanian M, Bowd C, Vizzeri G, Weinreb RN, Zangwill LM.** Effect of image quality on tissue thickness measurements with spectral – domain optical coherence tomography. Opt Express. 2009; 17: 4019-36.
11. **Mwanza JC, Bhorade AM, Sekhon N, McSoley JJ, Yoo SH, Feuer WJ, Budenz DL.** Effect of cataract and its removal on signal strength and peri-papillary retinal nerve fiber layer optical coherence tomography measurements. J Glaucoma. 2011; 20: 37-43.
12. **Ho J, Sull AC, Vuong LN, Chen Y, Liu J, Fujimoto JG, Schuman JS, Duker JS.** Assessment of artifacts and reproducibility across spectral- and time-domain optical coherence tomography devices. Ophthalmology. 2009; 116: 1960–70.
13. **Lee DW, Kim JM, Park KH.** Effect of media opacity on retinal nerve fiber layer thickness measurements by optical coherence tomography. J Ophthalmol Vis Res. 2010; 5: 151-7.
14. **Savini G, Barboni P, Parisis V, Carbonelli M.** The influence of axial length on retinal nerve fibre layer thickness and optic-disc size measurements by spectral-domain OCT. Br J Ophthalmol. 2012; 96: 57-61.
15. **Mwanza JC, Chang RT, Budenz DL, Durbin MK, Gendy MG, Shi W, Feuer WJ..** Reproducibility of peripapillary retinal nerve fiber layer thickness and optic nerve head parameters measured with cirrus HD-OCT in glaucomatous eyes. Invest Ophthalmol Vis Sci 2010; 51: 5724-30.
16. **Kontas A G P, Irkec M T, Teuas M A, Cvenckle B, Astakhov Y S, Sharpe E D, Hollo G, Mylopoulos N,**

Bozkurt B, Pizzamiglio C, Potyomkin VV, Alemu AM, Nasser QJ, Stewart JA, Stewart WC. Mean intraocular pressure and progression based on corneal thickness in patients with hypertension. Eye 2009; 23: 73-8.