Ther Adv Ophthalmol

1–7

DOI: 10.1177/2515841418827268

© The Author(s), 2019.
Article reuse guidelines: sagepub.com/journals-permissions

Comparison of the clinical estimation of cup-to-disk ratio by direct ophthalmoscopy and optical coherence tomography

Angela Ofeibea Amedo, Nana Yaa Koomson, Emmanuel Kobia Acquah, Tchiakpe Michel Pascal, Johnson Atuahene, Prince Kwaku Akowuah, Philip Tetteh Djeagbo and Richard Baafi

Abstract

Objective: To compare the clinical estimation of cup-to-disk ratio determined by direct ophthalmoscopy and optical coherence tomography in glaucoma diagnosis and monitoring.

Methods: A retrospective, cross-sectional study involving a review of 71 optical coherence tomography scans dating from June 2011 to January 2012 at a private imaging lab in Ghana. At the respective referring facilities, only 31 out of the 71 corresponding patient records were successfully reviewed.

Results: Majority (54.84%) of the 31 patient records successfully reviewed were women. The mean age was 44.54 ± 16.15 years. Cup-to-disk ratio was grouped into ⩽0.4, >0.4–0.6, >0.6–0.8, and >0.8–1.0 based on direct ophthalmoscopy values. The overall mean cup-to-disk ratio estimated by the optical coherence tomography and direct ophthalmoscopy were 0.72 ± 0.21 and 0.60 ± 0.26, respectively. Overall, there was no statistically significant difference in the mean cup-to-disk ratio estimation by direct ophthalmoscopy and optical coherence tomography [right eye ($p = 0.0629$); left eye ($p = 0.0766$)]. There was a statistically significant difference between direct ophthalmoscopy and optical coherence tomography cup-to-disk ratio estimation for values ⩽0.4 [right eye ($p = 0.0061$); left eye ($p = 0.0063$)] and values >0.4–0.6 [right eye ($p = 0.0243$); left eye ($p = 0.0498$)]. There was no statistically significant difference between conventional direct ophthalmoscopy and optical coherence tomography cup-to-disk ratio estimation for cup-to-disk ratio >0.6.

Conclusion: We recommend clinicians document which method they use in evaluating optic nerve head parameters. This is to ensure that subsequent clinical decisions are not influenced by an apparent change in these parameters, especially cup-to-disk ratio as different methods might give different values.

Keywords: cup-to-disk ratio, glaucoma, ophthalmoscopy, optical coherence tomography, suspicious disk

Received 24 December 2017; revised manuscript accepted 9 January 2019.

Correspondence to:
Prince Kwaku Akowuah
Vision Research Group, Department of Optometry and Visual Science, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
prince.k.akowuah@gmail.com

Angela Ofeibea Amedo
Nana Yaa Koomson
Emmanuel Kobia Acquah
Tchiakpe Michel Pascal
Philip Tetteh Djeagbo
Vision Research Group, Department of Optometry and Visual Science, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Richard Baafi
Soyuz Medical and Imaging Center, Kumasi, Ghana

Johnson Atuahene
Vision Research Group, Department of Optometry and Visual Science, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
johnson@gmail.com

Introduction

Glaucoma is an ocular condition, which exhibits a characteristic optic nerve neuropathy that may result in progressive visual field loss. It may or not be associated with increased intraocular pressure (IOP).[1] It is estimated that, globally, over 67 million individuals have glaucoma, and reports indicate that this figure is likely to rise to 79.6 million by the year 2020.[2] Glaucoma is the leading cause of irreversible blindness and accounts for an estimated 4.5 million blindness globally, second only to cataract.[3]

In glaucoma, early diagnosis is key to preventing blindness. The major parameters of concern in glaucoma diagnosis and monitoring are optic nerve head (ONH) and retinal nerve fiber layer (RNFL) changes, visual field changes, and IOP.[4] ONH and

Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (http://www.creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (https://us.sagepub.com/en-us/nam/open-access-at-sage).

RNFL evaluation assesses structural changes while visual field assessment determines functional changes of retinal ganglion cells (RGC). Structural changes often precede and are predictive of functional changes, highlighting the importance of structural changes assessment.[5,6] However, some studies have reported functional changes preceding structural changes in glaucoma.[7,8] There are several ways of assessing ONH changes in glaucoma. The traditional way is via the subjective means of direct or indirect ophthalmoscopy. However, with advances in imaging technologies, new and objective techniques of assessing ONH such as optical coherence tomography (OCT) and confocal scanning laser ophthalmoscopy have been developed.[9–11]

Ophthalmoscopic estimation of cup-to-disk ratio (CDR) of the ONH is important in the diagnosis and monitoring of glaucoma patients and suspects. In the clinical setting, funduscopy is often used for CDR estimation, but it has a moderate interobserver agreement and relies mainly on observer experience.[12,13] OCT measures a number of parameters than traditional ophthalmoscopy, and its results are more reproducible. The reproducibility of OCT in estimating especially CDR has been reported by studies to be sufficient.[14,15] The aim of the study was to compare the clinical estimation of CDR determined by direct ophthalmoscopy and OCT in glaucoma diagnosis and monitoring.

Methods

Study design

A retrospective, cross-sectional study involving a review of patient's records to compare CDR as determined by conventional ophthalmoscopy and OCT. Data reviewed involved all cases referred to a private imaging and diagnostic laboratory at Bantama, Kumasi, Ghana, within the period June 2011–January 2012.

Procedure

The available data of all OCT scans (Zeiss Stratus OCT) from June 2011 to January 2012 were reviewed, and the OCT measurements of the optic nerve parameters were recorded for both eyes. In each patient record reviewed, the parameters of interest were date of scan, patient demographics (age and sex), optic nerve head analysis result (optic disk size and CDR), retinal nerve fiber layer (RNFL) analysis result (nerve fiber layer thickness), reason for OCT scan referral, and the referring eye care facility. A total of 71 good image quality OCT scans were reviewed.

The respective referring eye care facilities were visited and the corresponding patient records were also reviewed. In the review of patient records at the eye care facilities, the parameters of interest were ophthalmoscopy findings (CDR) on date of referral for OCT scan, date of ophthalmoscopy, and final diagnosis. In total, 31 (43.66%) patient records of the 71 OCT scans were successfully reviewed at the referring eye care facilities. For the 40 OCT scans whose corresponding patient records could not be reviewed, the records were either not available or not accurately recorded. After the review, 29 CDR measurements were obtained for the right eye (OD: Oculus dexter; OS: Oculus sinister), 30 for the left eye, and 25 for both eyes.

The CDR reviewed were then grouped into the following categories based on direct ophthalmoscopy values:

- CDR $\leq$ 0.4: CDR estimations from 0 to 0.4 inclusive;
- CDR $>$ 0.4–0.6: CDR estimations greater than 0.4 but less than or equal to 0.6;
- CDR $>$ 0.6–0.8: CDR estimations greater than 0.6 but less than or equal to 0.8;
- CDR $>$ 0.8–1.0: CDR estimations greater than 0.8 but less than or equal to 1.0.

Ethical consideration

The study conformed to the tenets of the Declaration of Helsinki and was approved by the Board of Department of Optometry and Visual Science, Kwame Nkrumah University of Science and Technology (DO/R/48/VOL.1). Approval was sought from the authorities of the private imaging and diagnostics laboratory and the respective referring eye care facilities.

Data analysis

The data collected for this study was analyzed using the Statistical Package for Social Scientists (SPSS) version 16.0. The Microsoft® Excel (2007) was used to generate tables to represent results. Student's paired t test was used to evaluate the difference in the CDR estimations between the OCT and the conventional direct ophthalmoscopy. Intraclass correlation coefficients (ICCs) as described by Shrout and Fleiss,[16] using

Table 1. Participant characteristics.

Characteristics		Participants [*N* (%)]
Sex	Male	14 (45.16)
	Female	17 (54.84)
Age (years)	18–30	7 (22.58)
	31–50	13 (41.94)
	51–70	7 (22.58)
	>70	4 (12.90)
Reason for OCT request	Suspicious disk	16 (51.61)
	Known glaucoma	10 (32.26)
	Ocular hypertension	5 (16.13)
Period between CDR estimation by direct ophthalmoscopy and OCT	<6 months	31 (100)
	⩾6 months	0

CDR, cup-to-disk ratio; OCT, optical coherence tomography.

two-way mixed effects model, were used to determine the agreement between OCT and conventional direct ophthalmoscopy in CDR estimation. The Pearson correlation coefficient was used to evaluate the correlation between the Stratus OCT and the conventional direct ophthalmoscopy in CDR estimation. A *p*-value of less than 0.05 was set for statistical significance. No mathematical correction was made for multiple comparisons.

Results

Participant characteristics

Majority (17, 54.84%) of the 31 patient records successfully reviewed were that of females. The ages of patients ranged from 19 to 75 years with a mean age of 44.54 ± 16.15 years. In total, 10 (32.26%) were known glaucoma patients, 16 (51.61%) were diagnosed of suspicious disk, and 5 (16.13%) were diagnosed of ocular hypertension. All 31 patients (100%) had the OCT scan in less than 6 months after their CDR were estimated by direct ophthalmoscopy (Table 1).

Comparison of direct ophthalmoscopy and OCT scan

CDR estimations by OCT and direct ophthalmoscopy. The overall mean CDR estimated by the OCT was 0.72±0.21 (OD: 0.71±0.22, OS: 0.73±0.21) with the smallest and biggest CDR being 0.28 and 1.0, respectively ((OD) Oculus dexter; (OS) Oculus sinister)). The overall mean CDR estimated by conventional direct ophthalmoscopy was 0.6±0.26 (OD: 0.59±0.26, OS: 0.62±0.26). The smallest and biggest CDR measured by direct ophthalmoscopy were 0.2 and 1.0, respectively (Table 2).

Difference in CDR estimation. In the ungrouped comparison of CDR, there was no statistically significant difference between the mean CDR estimation by conventional direct ophthalmoscopy and OCT in the right eye ($p = 0.0629$) and left eye ($p = 0.0766$). CDR values obtained via OCT were, however, higher than that obtained by conventional direct ophthalmoscopy. There was a statistically significant difference between conventional direct ophthalmoscopy and OCT CDR estimation for CDR values ⩽0.4 in both the right ($p = 0.0061$) and left eye ($p = 0.0063$) and for CDR values >0.4–0.6 in both right ($p = 0.0243$) and left eye ($p = 0.0498$). There was no statistically significant difference between conventional direct ophthalmoscopy and OCT CDR estimation for CDR >0.6 (Table 3).

Correlation and agreement between stratus OCT and direct ophthalmoscopy. Overall, there was

Table 2. CDR estimations by OCT and direct ophthalmoscopy.

Categories		OCT [mean (SD)]	Ophthalmoscopy [mean (SD)]
CDR (ungrouped)	OD	0.71 (0.22)	0.59 (0.26)
	OS	0.73 (0.21)	0.62 (0.26)
CDR (⩽0.4)	OD	0.33 (0.17)	0.21 (0.15)
	OS	0.35 (0.14)	0.24 (0.16)
CDR (>0.4–0.6)	OD	0.55 (0.11)	0.48 (0.12)
	OS	0.56 (0.10)	0.50 (0.13)
CDR (>0.6–0.8)	OD	0.73 (0.12)	0.69 (0.11)
	OS	0.74 (0.10)	0.71 (0.11)
CDR (>0.8–1.0)	OD	0.89 (0.10)	0.87 (0.08)
	OS	0.92 (0.09)	0.90 (0.12)

CDR, cup-to-disk ratio; OCT, optical coherence tomography; SD, standard deviation.

Table 3. Mean differences between Stratus OCT and direct ophthalmoscopy in CDR estimation.

Categories		Mean difference (SD)	95% CI	*p*-value
CDR (ungrouped)	OD	0.12 (0.063)	−0.007 to 0.247	0.0629
	OS	0.11 (0.061)	−0.012 to 0.232	0.0766
CDR (⩽0.4)	OD	0.12 (0.042)	0.036 to 0.2043	0.0061
	OS	0.11 (0.039)	0.032 to 0.188	0.0063
CDR (>0.4–0.6)	OD	0.07 (0.03)	0.009 to 0.131	0.0243
	OS	0.06 (0.03)	0.0001 to 0.119	0.0498
CDR (>0.6–0.8)	OD	0.04 (0.03)	−0.021 to 0.101	0.1911
	OS	0.04 (0.027)	−0.024 to 0.084	0.2736
CDR (>0.8–1.0)	OD	0.01 (0.024)	−0.028 to 0.068	0.4039
	OS	0.020 (0.027)	−0.035 to 0.075	0.4681

CDR, cup-to-disk ratio; OCT, optical coherence tomography; SD, standard deviation; OD, Oculus Dexter, OS, Oculus Sinister.

good correlation and agreement between the CDR measurements obtained by both techniques for both eyes, except for CDR of less than ⩽0.4. For CDR values ⩽0.4, there was weak agreement between OCT and direct ophthalmoscopy for both right (ICC = 0.33) and left eyes (ICC = 0.29). The agreement between OCT and direct ophthalmoscopy increased as CDR values increased, with the highest agreement obtained for CDR values >0.8–1.0 for both right (ICC = 0.84) and left eyes (ICC = 0.85) (Table 4).

Discussion

Assessment of ONH is crucial for diagnosis, management, and monitoring of glaucoma. ONH

Table 4. Correlation and agreement between CDR measurements obtained by direct ophthalmoscopy and Stratus OCT.

Categories		ICC	Pearson correlation (*r*)
CDR (ungrouped)	OD	0.75	0.85
	OS	0.70	0.77
CDR (⩽0.4)	OD	0.33	0.41
	OS	0.29	0.33
CDR (>0.4–0.6)	OD	0.51	0.63
	OS	0.54	0.67
CDR (>0.6–0.8)	OD	0.71	0.78
	OS	0.74	0.82
CDR (>0.8–1.0)	OD	0.84	0.90
	OS	0.85	0.91

CDR, cup-to-disk ratio; OCT, optical coherence tomography; ICC, intraclass correlation coefficient.

assessment involves qualitative and quantitative parameters. Qualitative parameters include contour of the neuroretinal rim, optic hemorrhages, peripapillary atrophy, appearance of the RNFL, and so on. Quantitative parameters include optic disk size, rim–disk ratio, CDR, and so on.[17,18] Various studies have tried to find the most appropriate approach to ONH assessment. A number of recent studies have reported the ability of OCT to differentiate between healthy and glaucomatous eyes.[19–21]

The aim of this study was to compare the clinical estimation of CDR determined by direct ophthalmoscopy and OCT in glaucoma diagnosis and monitoring. It was found that in all groups, CDR estimations by OCT were higher than estimations by direct ophthalmoscopy. This suggests that direct ophthalmoscopy is biased toward underestimation compared to OCT. This conforms to reports from similar studies which report both direct and indirect ophthalmoscopy (subjective forms of ONH assessment) to underestimate CDR compared to objective forms of ONH assessment.[22–25] Watkins and colleagues[22] reported both direct and indirect ophthalmoscopy to be biased toward underestimation of CDR compared to Heidelberg retina tomography (HRT). The underestimation of CDR by direct ophthalmoscopy is probably due to the fact that observers considered optic disk pallor rather than the bending of the vessels as the beginning of the cupping or included Elschnig's ring as speculated by Ikram and colleagues.[23] Correnti and colleagues[26] compared ONH assessment with a digital stereoscopic camera, scanning laser ophthalmoscopy and stereophotography and reported that digital stereoscopic camera, a subjective form of ONH assessment underestimate scanning laser ophthalmoscopy and stereophotography which are objective forms of ONH assessment. These studies in addition to our study conform to the notion that subjective assessment of ONH generally produces an underestimation compared to objective assessment.

Overall, there was no statistically significant difference between the mean CDR estimation by OCT and direct ophthalmoscopy for both the right and left eyes. For CDR estimates ⩽0.4, there was a statistically significant difference between estimations by OCT and direct ophthalmoscopy in both the right and left eyes. For lower values of CDR, OCT tends to give higher estimates than direct ophthalmoscopy, but the difference decreases as the degree of cupping increases. This is similar to findings from the study of Arnalich-Montiel and colleagues.[24] Arnalich-Montiel and colleagues reported that for both vertical and horizontal CDR estimations, OCT provided higher values than ophthalmoscopy and the difference in estimation by OCT and ophthalmoscopy reduced as the cupping increases. The difference, however, between our study and that of Arnalich-Montiel and colleagues is that we considered direct ophthalmoscopy while they considered indirect ophthalmoscopy.

There was a generally increasing agreement between CDR estimates by direct ophthalmoscopy and OCT as values of CDR increased. In general, our results showed a good correlation between the overall CDR estimation by OCT and direct ophthalmoscopy. There was, however, poor correlation between OCT and direct ophthalmoscopy estimates for CDR $\leqslant$ 0.4. This again highlights the points that for lower values of CDR estimates by OCT are significantly higher than estimates by direct ophthalmoscopy. This finding is similar to that in the study by Wolf and colleagues,[25] which reported moderate overall correlation between CDR measurement by OCT and direct ophthalmoscopy. The correlation between CDR estimate by OCT and ophthalmoscopy, however, became lower as disk size and cupping decreased.

A limitation of the study is that CDR estimation by direct ophthalmoscopy was conducted by different examiners. CDR estimation by subjective means such as direct ophthalmoscopy has been reported to have a weak-to-moderate interobserver reliability.[12,13] Harper and colleagues[13] reported a weighted kappa value of 0.46 between observers for CDR estimation, which is indicative of a weak interobserver reliability.[27] Also, due to the retrospective nature of the study, most of the data was not available. Out of the 71 OCT scans accessed at the imaging and diagnostic facility, only 31 (43.66%) of their corresponding patient records at the referring eye care facilities were successfully reviewed. The others were either not available or not accurately recorded.

Conclusion

In conclusion, a good agreement was found between CDR estimates by OCT and direct ophthalmoscopy when evaluating greater CDR (CDR > 0.6). However, for smaller CDR (CDR $\leqslant$ 0.6), OCT tends to give higher values than direct ophthalmoscopy. We recommend clinicians document which method they use in evaluating ONH parameters. This is to ensure that subsequent clinical decisions are not influenced by an apparent change in these parameters, especially CDR as different methods might give different values.

Acknowledgements

The authors thank the authorities of the private imaging and diagnostic laboratory, especially Dr Victor Dedjoe, and all the referring eye care facilities for allowing the use of their facilities for the study and also various staff members of these facilities who assisted us in any form during the study.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Conflict of interest statement

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ORCID iD

Prince Kwaku Akowuah https://orcid.org/0000-0003-3657-6768

References

1. Kanski JJ. *Clinical ophthalmology*: A systematic approach. 2nd ed. Boston, MA: Butterworth-Heinemann, 2007, p. 629.
2. Quigley HA and Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. *Br J Ophthalmol* 2006; 90: 262–267.
3. Courtright P and Lewallen S. Global blindness 2010: what do we know? *Expert Rev Ophthalmol* 2011; 6: 385–392.
4. Pavithra G, Manjunath TC and Dharmanna L , *et al*. Different clinical parameters to diagnose glaucoma disease: a review. *Int J Comput Appl* 2015; 116: 42–46.
5. Artes PH and Chauhan BC. Longitudinal changes in the visual field and optic disc in glaucoma. *Prog Retin Eye Res* 2005; 24: 333–354.
6. Medeiros FA, Zangwill LM and Bowd C , *et al*. The structure and function relationship in glaucoma: implications for detection of progression and measurement of rates of change. *Invest Ophthalmol Vis Sci* 2012; 53: 6939–6946.
7. Harwerth RS, Carter-Dawson L and Shen F , *et al*. Ganglion cell losses underlying visual field defects from experimental glaucoma. *Invest Ophthalmol Vis Sci* 1999; 40: 2242–2250.
8. Harwerth RS and Quigley HA. Visual field defects and retinal ganglion cell losses in patients with glaucoma. *Arch Ophthalmol* 2006; 124: 853–859.

9. Fechtner RD and Lama P. Advances in optic nerve head analysis in glaucoma. *Semin Ophthalmol* 1999; 14: 180–188.
10. Pache M and Funk J. New diagnostic tools in the diagnosis of glaucoma. *Klin Monbl Augenheilkd* 2006; 223: 503–508.
11. Sakata LM, Deleon-Ortega J and Sakata V , *et al*. Optical coherence tomography of the retina and optic nerve: a review. *Clin Exp Ophthalmol* 2009; 37: 90–99.
12. Lichter PR. Variability of expert observers in evaluating the optic disc. *Trans Am Ophthalmol Soc* 1976; 74: 532–572.
13. Harper R, Reeves B and Smith G. Observer variability in optic disc assessment: implications for glaucoma shared care. *Ophthalmic Physiol Opt* 2000; 20: 265–273.
14. Paunescu LA, Schuman JS and Price LL , *et al*. Reproducibility of nerve fiber thickness, macular thickness, and optic nerve head measurements using StratusOCT. *Invest Ophthalmol Vis Sci* 2004; 45: 1716–1724.
15. Gonzalez-Garcia AO, Vizzeri G and Bowd C , *et al*. Reproducibility of RTVue retinal nerve fiber layer thickness and optic disc measurements and agreement with stratus optical coherence tomography measurements. *Am J Ophthalmol* 2009; 147:1067–1074, e1.
16. Shrout PE and Fleiss JL. Intraclass correlations: uses in assessing rater reliability. *Psychol Bull* 1979; 86: 420–428.
17. Anton A. Measuring structural changes in the optic nerve head and retinal nerve fibre layer. *Eur J Ophthalmol* 2001; 11(Suppl. 2): S50–S56.
18. Cherecheanu AP, Iancu R and Dascalu A-M , *et al*. Assessment of clinical and imagistic structural progression in glaucoma. *Rom J Ophthalmol* 2015; 59: 129–132.
19. Greaney MJ, Hoffman DC and Garway-Heath DF , *et al*. Comparison of optic nerve imaging methods to distinguish normal eyes from those with glaucoma. *Invest Ophthalmol Vis Sci* 2002; 43: 140–145.
20. Vessani RM, Moritz R and Batis L , *et al*. Comparison of quantitative imaging devices and subjective optic nerve head assessment by general ophthalmologists to differentiate normal from glaucomatous eyes. *J Glaucoma* 2009; 18: 253–261.
21. Mwanza JC, Oakley JD and Budenz DL , *et al*. Ability of cirrus HD-OCT optic nerve head parameters to discriminate normal from glaucomatous eyes. *Ophthalmology* 2011; 118: 241–248. e1.
22. Watkins R, Panchal L and Uddin J , *et al*. Vertical cup-to-disc ratio: agreement between direct ophthalmoscopic estimation, fundus biomicroscopic estimation, and scanning laser ophthalmoscopic measurement. *Optom Vis Sci* 2003; 80: 454–459.
23. Ikram MK, Borger PH and Assink JM , *et al*. Comparing ophthalmoscopy, slide viewing, and semiautomated systems in optic disc morphometry. *Ophthalmology* 2002; 109: 486–493.
24. Arnalich-Montiel F, Munoz-Negrete FJ and Rebolleda G , *et al*. Cup-to-disc ratio: agreement between slit-lamp indirect ophthalmoscopic estimation and stratus optical coherence tomography measurement. *Eye* 2007; 21: 1041–1049.
25. Wolfs RC, Ramrattan RS, Hofman A, *et al*. Cup-to-disc ratio: ophthalmoscopy versus automated measurement in a general population: the Rotterdam Study. *Ophthalmology* 1999; 106: 1597–1601.
26. Correnti AJ, Wollstein G and Price LL , *et al*. Comparison of optic nerve head assessment with a digital stereoscopic camera (Discam), scanning laser ophthalmoscopy, and stereophotography. *Ophthalmology* 2003; 110: 1499–1505.
27. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med* 2012; 22: 276–282.

Visit SAGE journals online journals.sagepub.com/home/oed

SAGE journals