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

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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

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
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. However, some studies have reported functional changes preceding structural changes in glaucoma. 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.

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. 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. 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 ≤ 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, using
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 $\leq 0.4$ 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 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)            |
| $\geq$6 months  | 0                   |

CDR, cup-to-disk ratio; OCT, optical coherence tomography.
good correlation and agreement between the CDR measurements obtained by both techniques for both eyes, except for CDR of less than \( \leqslant 0.4 \). 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 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 \( \leqslant 0.4 \) | 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 \( \leqslant 0.4 \) | 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.
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. 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.

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. Watkins and colleagues 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. Correnti and colleagues 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. 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

| 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.
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 $\leq 0.4$. 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, 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. Harper and colleagues reported a weighted kappa value of 0.46 between observers for CDR estimation, which is indicative of a weak interobserver reliability. 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 $\leq 0.6$), 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.

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Conflict of interest statement

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