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Editorial

Cup-Disc Ratio Grading

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Introduction

Globally, glaucoma is a leading cause of irreversible visual impairment that is estimated to affect up to 100 million people.[1] It is a visually debilitating disease that is usually asymptomatic until the late stage and so early diagnosis, identification of onset and progression are crucial. With the invention of the ophthalmoscope in the 1850s by Hermann von Helmholtz, a better understanding of optic disc topography changes in optic neuropathies such as glaucoma became possible. The optic vertical cup-to-disc ratio (VCDR) is one way of determining optic disc structural damage in glaucoma. This chronic condition is characterised by raised VCDR and corresponding peripheral visual field defect. One of the most common ways to screen for glaucoma is the use of colour photography of the optic disc (Fig. 1) which could reveal the following features indicating risk of glaucoma: 1) increased VCDR of >0.5, 2) asymmetry of VCDR of >0.2 between fellow eyes of the same person, 3) thinning of the superior or inferior parts of the neuroretinal rim, 4) optic disc haemorrhage, and 5) wedge defect of the retinal nerve fibre layer (RNFL) arising from the optic nerve head (ONH).

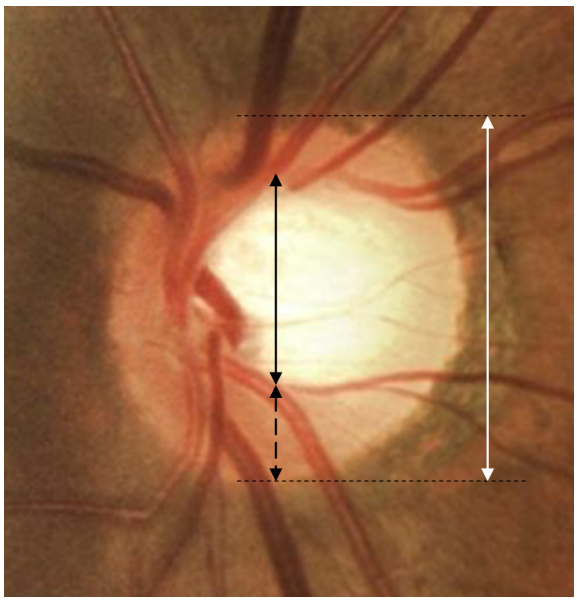

Fig. 1. A magnified colour photograph of the optic nerve head. Black arrow line indicates the vertical cup height, white arrow line indicates the vertical disc height and black dashed arrow line indicates the neuroretinal rim. The ratio of the length of the black arrow line to white arrow line indicates the vertical cup-disc ratio.

Determinants of VCDR

Many population-based studies have provided a range of "normal" VCDR but there are ethnic- and age-specific differences. Locally, the Tanjong Pagar survey showed that the 97.5th percentile of the VCDR distribution was 0.7.[2] The Singapore Malay Eye Study further showed that higher VCDR was correlated to male gender, higher intraocular pressure, lower diastolic blood pressure and lower body mass index.[3]

Different Ways of Grading VCDR: Colour Disc Photographs, Heidelberg Retina Tomograph, Scanning Laser Polarimetry and Optical Coherence Tomography

Colour photographs of the ONH have several advantages which include better accessibility, familiarity with interpretation by primary care physicians, lower cost and less susceptibility to changes in imaging technology. By taking pairs of ONH images simultaneously with beam splitting prisms of a fundus camera or sequentially with a spatial shift that provides image disparity, stereoscopic ONH photographs are obtained. This photographic technique gives a 3-dimensional (3D) view of the ONH in order to qualitatively assess optic disc cup depth and rim thickness. In addition, optic disc haemorrhages, parapapillary atrophy, changes in real optic disc colour and blood vessel position can be captured and used for clinical follow-up and monitoring.[4] However, one disadvantage is that the overall diagnostic accuracy in the assessment of stereoscopic optic disc photographs for glaucoma is only 80.5% when performed by ophthalmologists (as reported by Reus et al).[5] The large variability in diagnostic accuracy and agreement of clinicians was outperformed by machine classifiers or imaging devices.[5]

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Currently, imaging alternatives which can provide quantifiable parameters from ONH imaging include confocal scanning laser ophthalmoscopy (via Heidelberg Retina Tomograph [HRT]), scanning laser polarimetry (via GDx) and optical coherence tomography (OCT). These imaging systems use laser to construct a topographic image of the ONH or RNFL.

In confocal scanning laser ophthalmoscopy (via HRT), a diode laser (670 nm) scans the retinal surface at multiple consecutive, parallel focal planes to arrive at a reconstructed ONH image. From these images, quantitative measurements are derived that assist clinicians in the diagnosis of glaucoma and detection of topographic ONH changes over time. While HRT image acquisition is fully automated, the image analysis requires an operator to manually define the edge of the ONH by drawing a contour line so that a reference plane parallel to the retinal surface is set automatically at 50 um below the contour line at the temporal disc margin (at the papillo-macular bundle) to allow measurements of the 3D shape of the ONH topography.[4] This method of contour line drawing is a disadvantage of HRT as it gives rise to subjectivity especially when ONH margin is not so distinct.

The polarised near-infrared (780 nm) light in scanning laser polarimeter technique (via GDx) elicits RNFL birefringence (a change in retardation of passing polarised light) which is correlated to the RNFL thickness. Because other parts of the eye such as the cornea and lens are also birefringent, the accuracy of measurements may be affected. Measures (e.g. cornea compensators) to neutralise the overall anterior segment birefringence are applied on scanning laser polarimetry instruments in order to obtain actual RNFL thickness. OCT applies the principle of interferometry to interpret reflectance data from a series of multiple side-by-side A-scans combined to form a cross-sectional image with the use of a low coherent light from a broadband light source produced from a super-luminescent diode.[6] To generate neuroretinal rim estimates in OCT images, a peripheral boundary is defined (in OCT, this is represented by Bruch's membrane termination). Currently, OCT imaging of ONH and macula is the most popular modality due to its superior imaging quality, more robust normative database and industry support.[7] However, OCT devices from various manufacturers present different normative databases for RNFL thickness due to differing scan protocols, segmentation algorithms and subjects' characteristics in databases. Therefore, RNFL thickness readings are not interchangeable between OCT machines.[4]

Even though ONH and RNFL imaging are already well established alternatives to biomicroscopy or photography for the evaluation of ONH appearance, no method has yet been recognised as optimal.[5] Agreement between optic disc parameters (e.g. vertical cup:disc ratio, cup:disc area ratio, optic disc and rim areas, etc.) measured across the mentioned imaging devices is poor and therefore not interchangeable. Variability in the resulting measurement values may lead to inaccurate interpretation and compromise disease detection and monitoring.

Limitations of VCDR Grading

Reproducibility and Reliability of VCDR

There is significant variation in the determination of VCDR which might be related to graders' experience, image quality and optic disc morphology.[8]

Optic Disc Size and Cup

VCDR is limited by the size of the optic disc and position of the cup. Healey et al showed that in a population-based study of normal eyes without glaucoma, larger optic disc sizes are correlated with larger VCDR.[9] An optic cup that is eccentric is far more likely to be glaucomatous than a concentric one.

Optic Disc Tilt and Torsion

Clinically, there is significant variation in optic disc morphology such as optic disc tilt/torsion and peripapillary atrophy which make it challenging to accurately determine optic disc and cup margins. In particular, optic disc tilt is associated with myopia and astigmatism, which is common in Asian populations.[10]

Optic Disc Neuroretinal Rim

VCDR does not take into account the amount of loss of nerve fibres in the neuroretinal rim, which directly determines the loss of glaucomatous visual field.[11]

Conclusion

VCDR grading[12] is a quick method of optic disc assessment in the clinical setting to aid glaucoma diagnosis and evaluation over time but it is imperfect and crude. The development and application of ONH imaging modalities have afforded a more objective and quantitative approach to detect and monitor glaucoma. However, these new imaging technologies have their share of limitations and imperfections. In order for clinicians to arrive at a sound diagnosis and needed treatment measures, they must learn to integrate all aspects of the patient's disease features based on accurate history, clinical examination and supporting diagnostic modalities.

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