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Imaging for Glaucoma Detection and Progression

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Abstract

All types of glaucoma involve glaucomatous optic neuropathy. The key to the detection and management of glaucoma is understanding how to examine the optic nerve head (ONH). The rate of structural progression is highly variable with some individuals progressing very slowly over many years, while others exhibit a much more rapidly progressing picture. This talk covers a series of related topics, the characteristics of a normal and a glaucomatous ONH, the strategies by which to measure progression (clinical judgement, event, and trend analysis), and instruments that can assist the clinician in the detection and monitoring of structural progression (ONH photography, optical coherence tomography, and confocal scanning laser ophthalmoscopy). The talk is illustrated with examples of clinical imaging, and suggestions for further reading are given.

Introduction

All types of glaucoma involve glaucomatous optic neuropathy. The key to detection and management of glaucoma is understanding how to examine the optic nerve head (ONH) [1]. The rate of structural progression is highly variable with some individuals progressing very slowly over many years, while others exhibit a much more rapidly progressing picture.

This talk covers a series of related topics: normal characteristics of the ONH, characteristics of a glaucomatous ONH, strategies to measure progression, and instruments used for measuring structural progression.

Normal Characteristics of the Optic Nerve Head

The ONH or optic disc is a round/oval 'plughole', down which more than a million nerve fibres descend through a sieve-like sheet known as the lamina cribrosa (fig. 1). These fibres are then bundled together behind the eye as the optic nerve, which continues towards the brain. The retinal nerve fibres are spread unevenly across the surface of the retina in a thin layer, which has a 'feathery' appearance, best seen immediately above and below the disc. As the nerve fibres converge on the edge of the disc, they pour over the scleral ring (which marks the edge of the disc) and

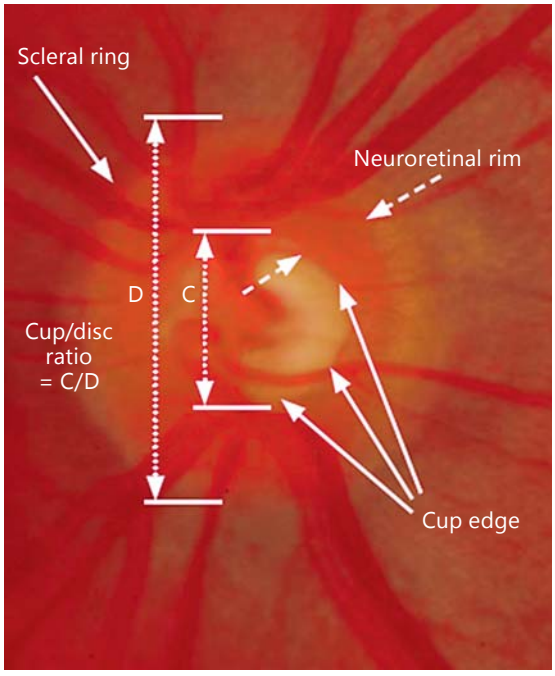

Fig. 1. Characteristics of the normal ONH.

then down its inner surface. This dense packing of nerve fibres just inside the scleral ring is visualised as the neuroretinal rim. The cup is the area central to the neuroretinal rim. The cup edge (where it meets the neuroretinal rim) is best seen by the bend in small- and medium-sized blood vessels as they descend into the cup. A colour difference should not be used to distinguish the cup edge; a change in the direction of blood vessels is a more reliable indicator. The inferior rim is usually thicker than the superior rim, which is thicker than the nasal rim, and the temporal rim is the thinnest (this is known as the ISNT rule).

Characteristics of a Glaucomatous Optic Nerve Head

Clinically observable characteristics of a glaucomatous ONH include [2]:

1 generalised/focal enlargement of the cup (fig. 2a);
2 disc haemorrhage (within 1 disc diameter of ONH) (fig. 2b);
3 thinning of the neuroretinal rim (usually at superior and inferior poles) (fig. 2c);
4 asymmetry of cupping between a patient's eyes;
5 loss of the retinal nerve fibre layer (RNFL) (fig. 2c), and
6 parapapillary atrophy (more common in glaucomatous eyes).

Various instruments are commercially available to assist in the detection of glaucomatous optic neuropathy. These include optical coherence tomography (OCT), scanning laser polarimetry, and confocal scanning laser ophthalmoscopy. The instruments give an indication of normality/abnormality of various ONH and RNFL parameters by comparing acquired measurements with those of a normative database that varies by manufacturer (fig. 3).

Strategies to Measure Progression

The appearance of any of the features of a glaucomatous ONH, or the exacerbation of these features compared to a previous record, is indicative of progression or worsening of the disease.

The speed or manner of structural progression is poorly understood with opinion divided on whether progression occurs as a continuous linear process where tissue and function are gradually affected, or as a stepwise process where an acute event causes sudden structural damage that is followed by a period with minimal change until another acute event occurs. It is possible that both patterns may coexist in certain subpopulations or might occur in the same patient in different phases of the disease. For this reason, there are different methods to assess glaucomatous progression.

In order to determine if progression is occurring, there are three main strategies: clinical judgement, event analysis, and trend analysis.

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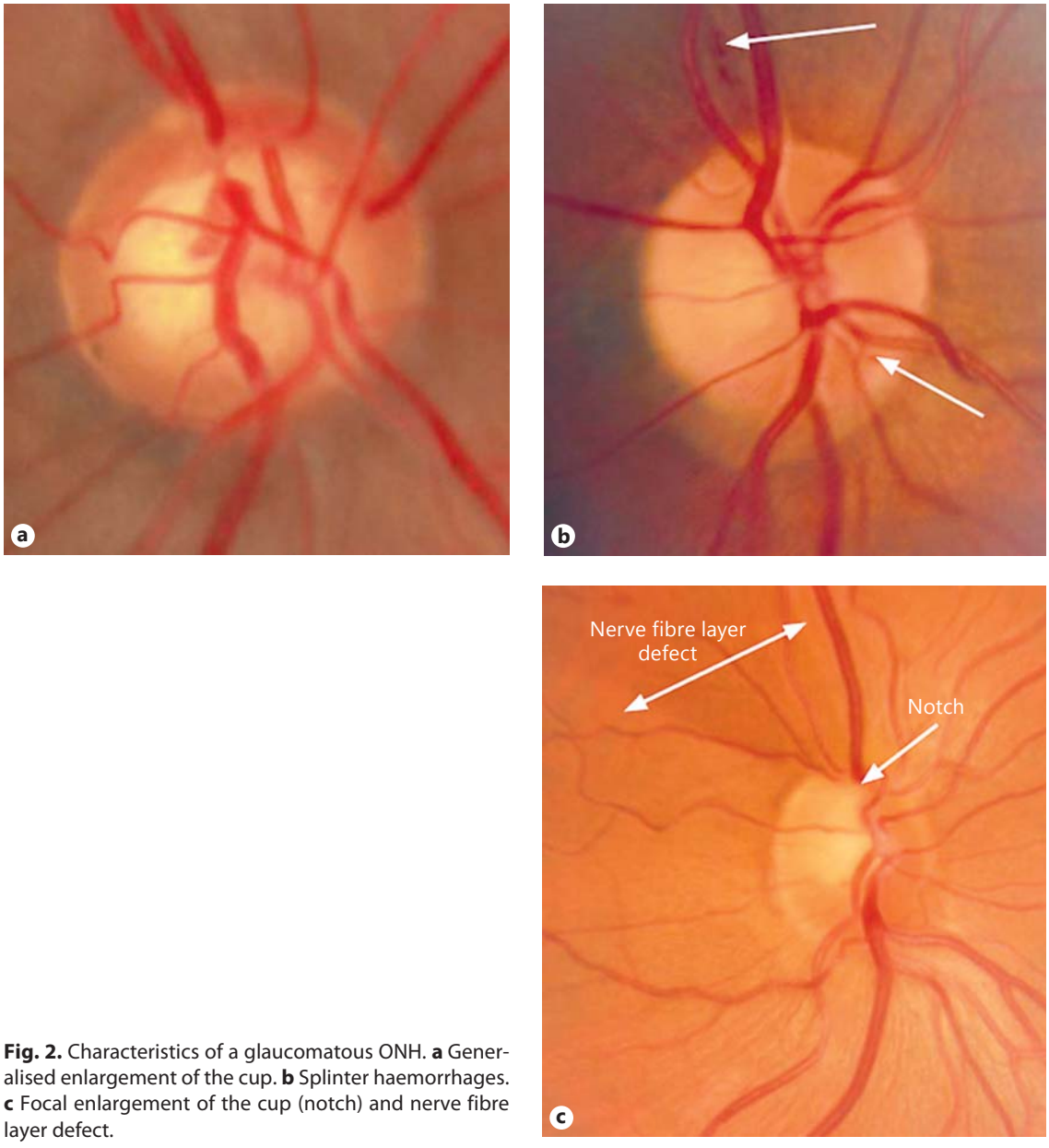

Fig. 2. Characteristics of a glaucomatous ONH. **a** Generalised enlargement of the cup. **b** Splinter haemorrhages. **c** Focal enlargement of the cup (notch) and nerve fibre layer defect.

Clinical Judgement

Clinical findings are observed over time. They are assessed subjectively. Experience of normal and glaucomatous ONH features allows one to determine if 'conversion' has occurred from a state of normality or if progression of the disease has occurred in an eye which already exhibits structural features of glaucoma.

Event Analysis

Progression is defined when a follow-up measurement exceeds a pre-established criterion for

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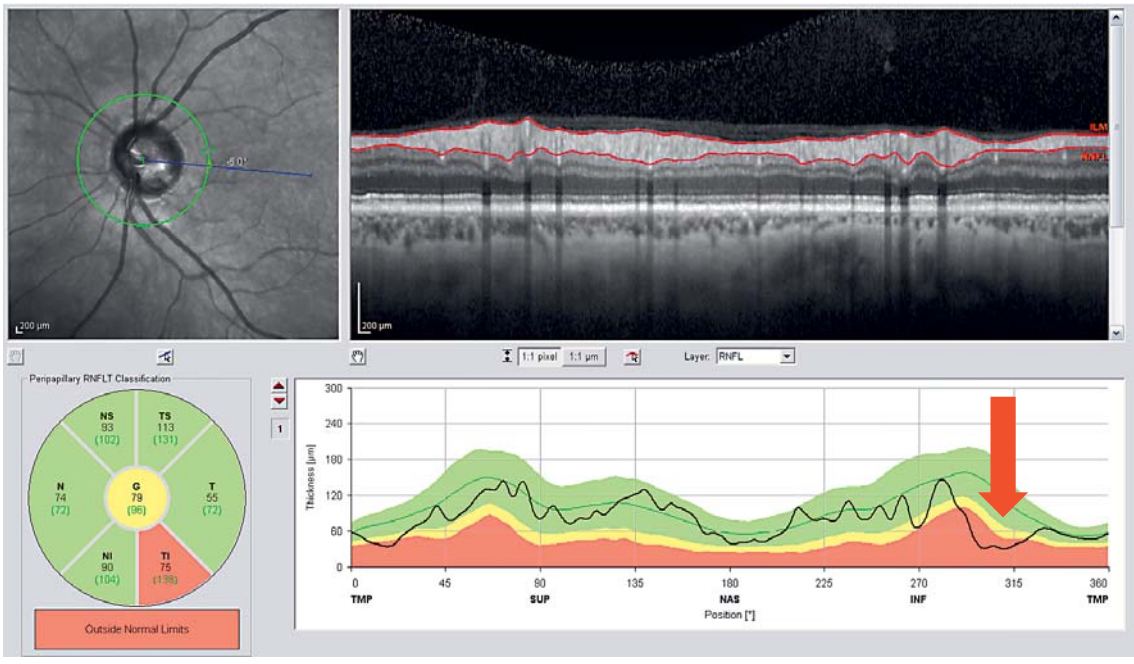

Fig. 3. ONH imaging with the SD-OCT, Heidelberg Spectralis instrument. Note the abnormally thin RNFL inferotemporal sector (marked in red).

change from baseline. It is assumed that any change below this threshold is due to natural age-related loss and/or measurement variability, while changes exceeding the threshold represent true progression. Defining the threshold for a change is an important aspect of event analysis. A higher threshold results in greater specificity because only situations with marked change will be flagged. However, this reduces sensitivity for detecting less dramatic changes. Conversely, a lower threshold improves sensitivity while simultaneously decreasing specificity. Event analysis is geared toward detecting a gradual change over time that reaches a threshold or identifying an acute event that exceeds a threshold. Event analysis is used with some imaging techniques; for example, the Heidelberg retina tomograph (HRT; Heidelberg Engineering, Heidelberg, Germany) system incorporates topographic change analysis (TCA) software (fig. 4).

Trend Analysis

Trend analysis identifies progression by monitoring the behaviour of a parameter over time. A regression analysis of a dependent variable (i.e. RNFL thickness) is performed on follow-up measurements, providing a rate of progression over time. This method is less sensitive to sudden changes and the variability among consecutive tests, as it is neutralized by the overall rate of change. Another important advantage of this method is the ability to extrapolate the rate of progression, which allows for the prediction of the time required to reach certain milestones. Trend analyses are employed by the majority of OCT instruments.

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