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Optic disc imaging

Optic disc imaging forms an essential part of the management of glaucoma suspects and patients with established glaucomatous visual field loss. The widest application of optic disc imaging is in glaucoma management and is the perspective of this review.

Technological advances have brought imaging devices into clinical practice, and these offer considerable advantages over previous methods of recording the appearance of the optic disc, such as drawings and monoscopic photographs. In this review, the various forms of imaging are outlined and their clinical application in diagnosis and management is considered.

The various forms of imaging permit quantitative measurement of optic disc and retinal nerve fibre layer (RNFL) structure. There are potential advantages of quantitative imaging over perimetry, particularly in early disease process.[1]

A number of different instruments, each making use of different optical principles, has been introduced over the last 15 years. The technologies are continually evolving and each is at a different stage of development and clinical evaluation.

Stereoscopic photography

The only CE marked, dedicated stereoscopic optic disc camera available in the UK is the Discam (Marcher Enterprises Ltd). Stereoscopic image pairs are taken in succession at video frame rates. Newer instruments are full colour and this is an advantage over all forms of scanning imaging devices (below). The field of view is 12∞ and pupil dilatation is required for imaging. The images provide a high magnification, stable picture that can be easier to evaluate than the image obtained with indirect ophthalmoscopy. New software enables an observer to make magnification-corrected measurements of optic disc features. The measurements are, however, subjective, and have greater between-observer variability than the semi-automated scanning devices.

Scanning laser tomography

This technology, in the form of the Heidelberg retina tomograph (HRT, Heidelberg Engineering GmbH), has been available for around 10 years. A compact version (the HRT II) has been released more recently for clinical use. The field of view is 15∞ and imaging can be performed through an undilated pupil. Images are monochromatic and the confocal optics enable the determination of a surface height map (topography). The margin of the optic disc is outlined by an observer and a reference plane is positioned parallel to the surface and set below the surface.[2] Structures that lie within the disc margin (contour) and above the reference plane are denoted as neuroretinal rim. Space below the reference plane is denoted as optic cup (Figure 1).

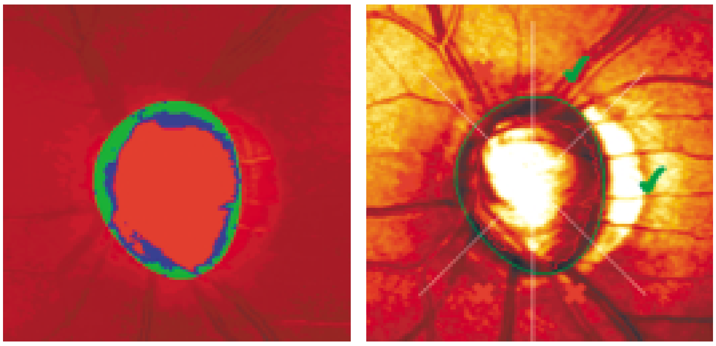

Figure 1. *HRT II scan of the left eye of a patient with normal tension glaucoma. Left panel: surface map (topography). Blue and green areas represent neuroretinal rim, red represents optic cup. Right panel: false colour reflectivity image.*

Scanning laser polarimetry

This first prototype of this instrument was developed about 10 years ago, and was first released commercially as the GDx Nerve fiber analyzer (Laser Diagnostic Technologies Inc). The second generation product is called the GDx Access. The field of view is 15∞ and imaging should be performed through an undilated pupil. The polarised laser scans the fundus, building a monochromatic image. The state of polarisation of the light is changed (retardation) as it passes through birefringent tissue (cornea and RNFL). Corneal birefringence is eliminated (in part) by a proprietary 'corneal compensator'. The amount of retardation of light reflected from the fundus is converted to RNFL thickness. Sub-optimal compensation of corneal birefringence is currently being addressed by the manufacturer with hardware and software modifications.

Low-coherence interferometry

The first commercial application of this technology was released by Humphrey Instruments (now Zeiss Humphrey Systems) in 1995, as the Optical coherence tomography scanner. Second and third generations have been produced, giving faster scanning and greater depth resolution. The principle is analogous to B scan ultrasonography, using a light source instead of sound. Imaging is performed through a dilated pupil. The OCT 3 performs a linear scan on the retina with a near infrared (low coherence) light beam. The depth resolution is ≤10 µm. OCT software locates borders (changes in reflectivity) such as the vitreoretinal interface, the interface between RNFL and inner retinal layers, and the outer retina/choroid interface.

Laser optical cross-sectioning

The commercial instrument utilising this principle is the Retinal thickness analyzer (RTA, Talia Technology Ltd). The RTA projects a narrow slit of green laser light at an angle on the retina and acquires an image from a different angle on a digital camera. An optical cross-section of the retina is seen, with reflectance peaks that correspond to the RNFL/inner limiting membrane and the retinal pigment epithelium. The software measures the distance between the peaks to obtain retinal thickness. The macula, peripapillary area and optic disc may be scanned. Software to derive an optic disc topography has also been developed.

The clinical application of imaging is both for the diagnosis of glaucoma and the detection of progressive disease. Illustrations will be made with examples from one of the more mature technologies: HRT. The other instruments may have a significant clinical role as they are developed further.

Diagnosis

None of these instruments, used on its own, is diagnostic. They provide measurement information that should be integrated with other clinical information, such as intraocular pressure level and visual field status.

The instruments have a database of measurements from normal eyes. The structural measurements are related to normative data in the same way that visual field sensitivity is related to normative data in perimetry. Classification is purely statistical and thresholds for abnormality should be considered only as levels of probability. Abnormalities other than glaucoma, such as tilted discs, may cause measurements to fall outside the normal range. There is an overlap of measurements between normal and glaucomatous eyes, so that classifications such as 'within normal limits', 'borderline' and 'outside normal limits', as seen in the HRT II (Figure 2) and GDx software, are appropriate.

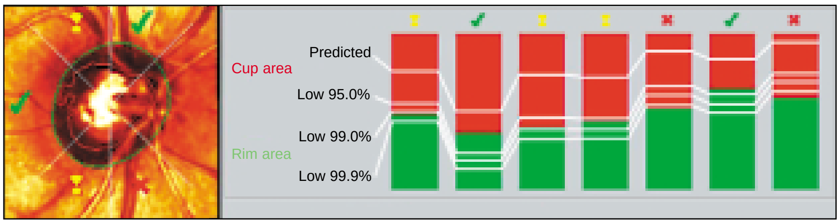

Figure 2. *HRT II: Moorfields regression classification. 3 Measured rim area is compared to normal ranges for the whole disc (right panel, first column) and six predefined segments (left panel and remaining columns, right panel). The green tick indicates 'within normal limits', the yellow exclamation mark 'borderline', and the red cross 'outside normal limits'. The most abnormal segment gives the overall classification for the disc.*

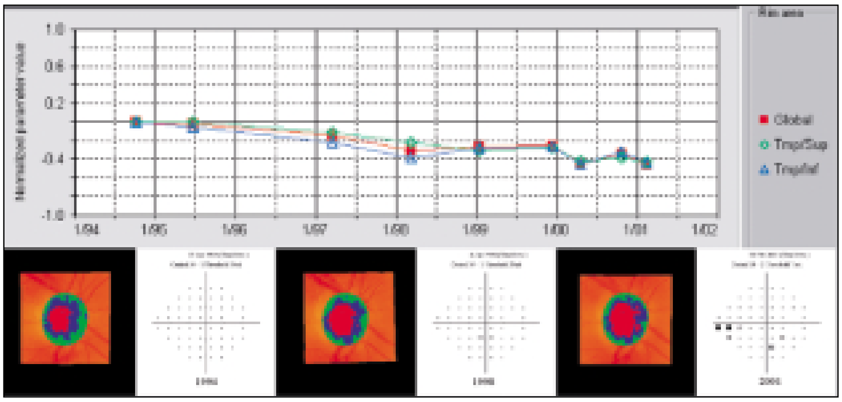

Figure 3. *Serial HRT neuroretinal rim area measurements, made over a period of 7 years in a patient with ocular hypertension, demonstrate rim loss at least 3 years before the visual field shows a reproducible defect.*

With the Moorfields classification,[3] approximately 80% of normal eyes are identified as 'within normal limits' and 7% as 'outside normal limits'. Approximately 67% of eyes with early glaucoma are 'outside normal limits' and a further 20% are 'borderline'. Studies comparing HRT, GDx and OCT have found that their ability to discriminate between normal and glaucomatous eyes is generally similar.[4,5] The GDx performed slightly less well.[4] However, it is anticipated that improved compensation for corneal birefringence will result in an improved discriminating ability.

Progression

The greatest potential use of imaging instruments is in the detection of glaucomatous progression. The good reproducibility of measurement data increases the sensitivity of these instruments to detect progression. Approaches to the statistical treatment of measurement data include a 'change probability' analysis for surface height measurements[6], similar to the 'change probability' in the Statpac software for Humphrey perimetry.

It is also possible to apply trend analysis to measurements, such as neural rim area, made at different points in time (Figure 3). The potential advantage of this form of analysis is that it gives an estimate of the rate of change.

Mr David Garway-Heath
Consultant Ophthalmologist , Moorfields Eye Hospital

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17 CORNWALL TERRACE LONDON NW1 4QW TEL: 020 7935 0702 FAX: 020 7935 9838