The Heidelberg Retina Tomograph II

Contents

1 Technological background

The Heidelberg Retina Tomograph is a confocal laser scanning system for acquisition and analysis of three-dimensional images of the posterior segment of the eye. The data created serve to quantitatively describe the retinal topography and the follow-up topographic changes. The typical application of the HRT is the assessment of the glaucomatous optic nerve head.

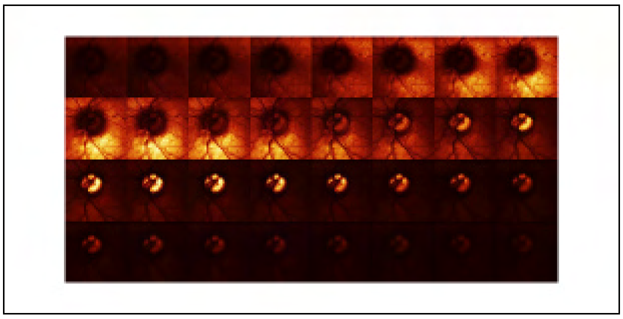

Figure 1

A three-dimensional image acquired with the HRT is a series of optical section images at different locations of the focal plane, e.g., of an optic nerve head as shown in figure 1.

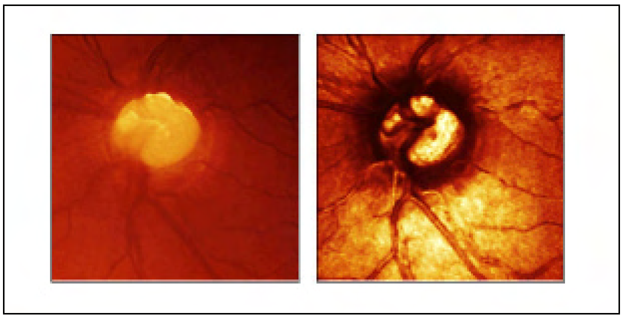

Figure 2

From this layered three-dimensional image, a topography image is computed consisting of more than 65 thousand local measurements of the retinal surface height (figure 2, left). The topography image is color coded, with dark colors representing elevated structures and light colors representing depressed structures.

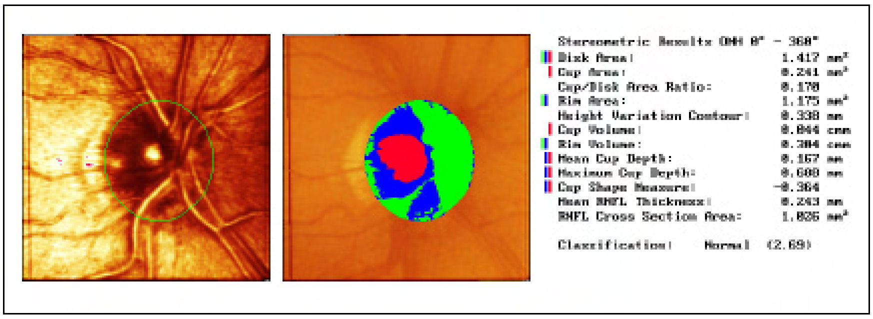

Figure 3

In the case of optic nerve head analysis, after the definition of the disk margin the HRT software computes a set of stereometric parameters that quantitatively describe the shape of the optic nerve (figure 3). The results of the topographic description are used to classify an optic nerve head as being normal or outside normal limits. Furthermore, the stereometric parameters are used to describe glaucomatous progression.

2 Clinical background

More than a decade of research with the Heidelberg Retina Tomograph and similar instruments showed that the quantification of the optic nerve head topography provides an important tool for glaucoma detection and follow-up. It has been shown that the variability of the topographic measurements is small enough to make these measurements clinically useful. The reproducibility of the local height measurements at each of the 65 thousand locations of a topography image is between 10 and 20 microns [Bathija et al., J Glaucoma 1998;7:121-127]. The coefficients of variation of the stereometric parameters are about 5% [Rohrschneider et al., Ophthalmology 1994;101:1044-1049].

Methods have been developed to separate glaucomatous eyes from normal eyes, and to detect even very early glaucomatous damage to the optic nerve head. The most important methods are multivariate discriminant analysis procedures [Iester et al., Ophthalmology 1997;104:545-548] that showed the highest diagnostic precision in a comparative study [Nakla at al., Invest Ophthalmol Vis Sci 1999;40:S397], and the regression analysis of the rim area to disk area that showed very high sensitivity and specificity to detect early glaucoma [Wollstein et al., Ophthalmology 1998;105:8,1557-1563], and even allows to pick up pre-perimetric glaucoma [Kamal et al., Br J Ophthalmol 1999;83:290-294].

In addition, methods have been developed to quantitatively follow-up glaucomatous progression: The analysis of the stereometric parameter values vs. time, and the computation and analysis of topographic difference images and of change probability maps. The latter two preserve the spatial resolution and show the location and the amount of the progression.

Therefore, the HRT has a broad scientific background. The measurement results are useful for the clinical routine. On the other hand, the HRT has originally been developed primarily with the research in mind. It allows topographic measurements of all parts of the anterior segment and offers a variety of measurement options. This is why the correct use of the instrument - during image acquisition and during data analysis - requires some skills, and hardens its daily routine use.

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Figure 4

Heidelberg Engineering therefore used the research results obtained with the HRT during the last 10 years, the clinical routine procedures developed with the HRT, and combined this with the latest advances in optics, electronics and opto-electronics, and in software technologies, and developed a new instrument, the Heidelberg Retina Tomograph II (figure 4).

The HRTII is designed as a clinical routine instrument, specifically for topographic optic nerve head analysis, and it provides the essence of what has been learned with the HRT over many years.

This restriction to topographic optic nerve head analysis allowed to create an almost completely automatic system: Pressing one single button initiates the complete data acquisition and analysis process. All image acquisition parameters are either fixed or determined and set automatically. The size of the field of view is fixed at 15 degrees, but at a resolution of 10 µm per pixel; the correct settings of the focal plane, of the scan depth, and of the sensitivity, are done completely automatic during image acquisition. Also, there is an internal fixation target that centers the optic nerve head in the image.

After image acquisition, there is a rather simple presentation of the essential examination results, which are mainly the results of the classification and progression analysis. The total examination time is only a few minutes; the system is small, light, even portable; it can be operated with a notebook computer. The data is fully compatible to the HRT data. Last but not least, the HRTII already runs under Heidelberg Engineering's new Windows software platform, the Heidelberg Eye Explorer.

4 Operation of the Heidelberg Retina Tomograph II

The first step in an examination with the HRTII is to enter the patient's name and to select Acquisition. The camera switches on and is in live mode automatically. Next is a rough setting of the examined eye's refraction at the camera. Then the camera is adjusted to the eye so that the laser beam enters the pupil, while the patient fixates the internal fixation light that automatically centers the optic nerve head in the image. If the adjustment is satisfactory, the 'acquisition' button on the rear of the camera is pressed.

The camera then performs an automatic pre-scan with 4 to 6 mm depth. From the images obtained in this pre-scan, the software computes and automatically sets: the correct location of the focal plane, the required scan depth for that eye, and the proper sensitivity to obtain images with correct brightness.

Immediately afterwards, the system automatically acquires three three-dimensional images with the pre-determined acquisition parameters. The size of the field of view is fixed at 15° x 15°, and digitization is performed in frames of 384 x 384 pixels. That means, even so the size of the field of view is 15 degrees, the spatial resolution is the same as in 10 degree HRT images (10 µm/pixel). The number of image planes acquired per series depends on the required scan depth; 16 images per mm scan depth are acquired. There is an automatic online quality control during image acquisition: If one or more of the acquired image series cannot be used for any reason (e.g., the patient lost fixation), then automatically additional images are acquired, until three useful image series have been obtained.

When image acquisition is completed, the camera is switched off automatically. The acquired images are saved on the hard disk and the three topography images, as well as the mean topography image are computed automatically. This concludes the image acquisition process.

At this point, the only manual step in the analysis process is required, the definition of the optic disk margin. The procedure, however, is much simplified compared to the HRT. After definition of the disk contour, the automatic analysis continues with the computation of the stereometric parameters, the classification of the eye, a comparison to previous exams (if exiting), and the presentation of the results.

5 Sample examination results

The examination results presented have a layered structure with different degrees of information in each layer. The superficial layer 1 is a pure graphical presentation of only the essential results of the classification and progression analysis. This is the default display. Additional data and measurements are presented on request in layers 2 and 3.

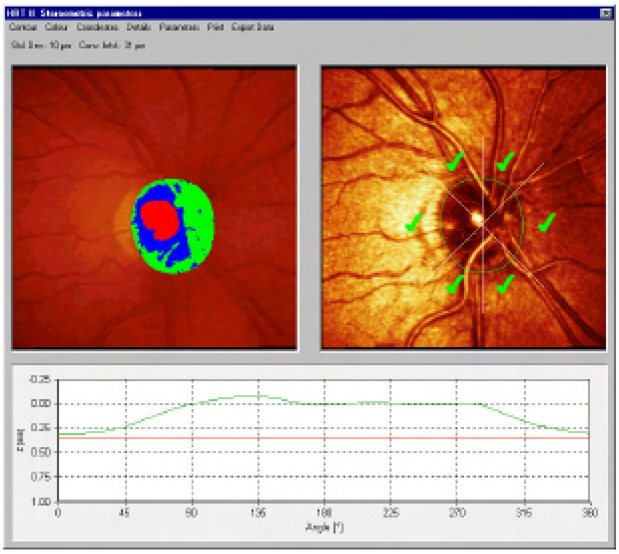

Figure 5

Figure 5 is the graphical result of the classification of an optic nerve head. The classification is on the basis of the Moorfields regression analysis [Wollstein et al., Ophthalmology 1998;105:8,1557-1563]. Each sector of the optic nerve head is marked with a green tick mark as being within normal limits, or with a red cross if it is outside normal limits.

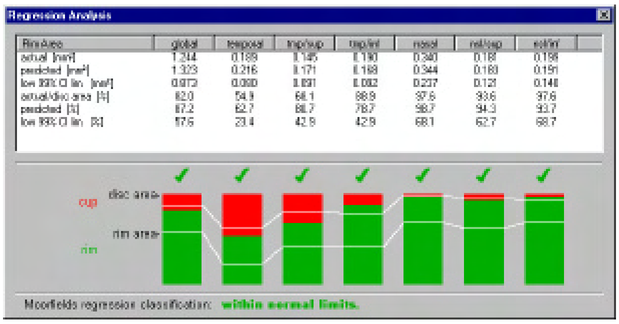

Figure 6

The details of this classification can be displayed (layer 2 presentation; figure 6).

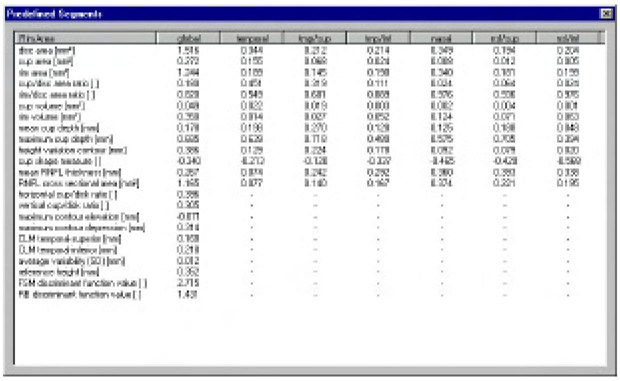

Figure 7

And also the full set of stereometric parameters (layer 3; figure 7).

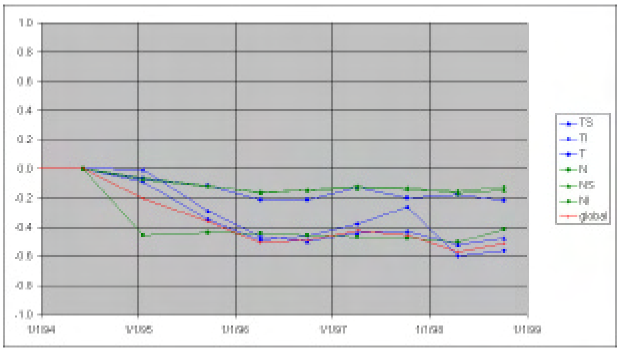

Figure 8

The initial (layer 1) presentation of the result of the progression analysis is a diagram of stereometric parameters along the time axis as shown in figure 8.

6 Technical data

It must be pointed out, that the Heidelberg Retina Tomograph II does not replace the original Heidelberg Retina Tomograph. The HRTII is a clinical routine instrument, dedicated and restricted to optic nerve head analysis. The HRT is research oriented instrument with a much broader range of applications which include besides optic nerve head analysis also the topographic analysis and follow-up of macular holes, macular edema, retinal detachments, tumors, etc. The HRT also can be combined with the Heidelberg Retina Flowmeter for measuring the retinal microcirculation. The latter is not possible with the HRTII; on the other hand, the HRTII is much easier to operate, as it is as far as possible automatic.

The following table is a comparison of technical specifications between the HRT and HRTII:

		HRT II	HRT
field of view	transverse longitudinal	15° x 15° 1.0 mm to 4.0 mm	10° x 10°, 15° x 15°, or 20° x 20° 0.5 mm to 4.0 mm
digital image size	2D image 3D image	384 x 384 pixels 384 x 384 x 16 to 384 x 384 x 64 voxels	256 x 256 pixels 256 x 256 x 32 voxels
acquisition time	2D image 3D image	0.025 sec 1.0 sec typical (2 mm depth)	0.032 sec 1.4 sec
focus range		-12 to +12 diopters	-12 to +12 diopters
optical resolution (limited by the eye)	transverse longitudinal	10 µm 300 µm	10 µm 300 µm
digital resolution	transverse longitudinal	10 µm / pixel 62 µm / plane	10 µm to 20 µm/pixel 16 µm to 128 µm/plane
laser source		diode laser, 675 nm	diode laser, 675 nm