Glaucoma causes typical structural changes in the optic nerve head and retinal nerve fiber layer (RNFL). The identification and description of these findings and the detection of changes over time are fundamental components of glaucoma diagnosis and follow-up. The interpretation of findings from the clinical examination of the optic nerve head and RNFL are complex due to the great variability among normal optic disc sizes and shapes, and the presence of other associated diseases. Undoubtedly the most difficult task facing the clinician is longitudinal assessment of the optic disc to establish stability or progression of the disease.

In clinical practice, the evaluation of structural change is usually performed based on fundus biomicroscopy and review of optic disc stereophotographs. Such meticulous assessment at the slit lamp is useful but lacks objectivity and quantification. Optic nerve photographs are objective documents that facilitate comparison of findings over time but require subjective interpretation or color-based computer analysis, and are highly influenced by media opacity or photographic parameters (exposure, light source, digital processing) that may considerably influence the appearance of retinal structures.

Both clinical examination and photographs are part of the standard for glaucoma care. Objective and quantitative measurements of the optic nerve head and RNFL can complement the assessment of glaucomatous damage and can aid in detecting disease progression. The aim of this chapter is to present a systematic approach to the clinical interpretation of HRT II results and to review the usefulness of HRT technology at the time of a single visit.
INTERPRETING THE HRT PRINTOUT

As in any other part of the ophthalmic examination, interpretation of HRT data should be methodical. If it is the first HRT examination for a given patient, the clinician should carefully review the single-test printout. The following is a step-by-step approach to the interpretation of the printout.

1. Check image quality by noting the mean topography standard deviation (SD) at the bottom of the list of stereometric parameters. Review focus, clarity, and centration of the optic nerve head and consider any written comments documenting difficulties that may have occurred during image acquisition. Quality increases as SD value decreases (it is good under 30 µm and, if possible, it should not be over 40 µm). If the SD is greater than 40 µm, the test should be repeated to improve reproducibility or the results should be interpreted with caution.

2. Review the position of the contour line. Use both the reflectance and the topography images to place the contour line at the inner margin of the scleral ring. Sometimes it may be easier to place it on a single tomography image from the image series. HRT parameters are calculated based on the location of the contour line, so the results may vary dependent upon its placement. However, it is important to remember that once positioned on the baseline image, it will be imported to all subsequent images and parameters will change relative to the baseline result. If difficulty is encountered positioning the contour line, placing it marginally outside the scleral ring (i.e., greater than the optic nerve head boundary) is preferable to placing the contour line within the disc itself. Results incorporating small proportions of parapapillary retina give parameters that more accurately reflect the characteristics of the nerve head than those positioned within the nerve head. The only time this does not hold true is when there is parapapillary atrophy, but in such cases the identification of Elschnig’s ring is much easier and unlikely to cause difficulties.

3. Review the left half of the report to learn about the structure of the optic disc. On the topography image, the HRT draws a color-coded map. The red area represents the cup; the blue (sloped) and green (flat) areas represent the neuroretinal rim. These images are very easy to interpret by clinicians since they follow the same drawing principles that are used in clinical charts, and give an overview of the disc. The vertical and horizontal cross-section graphs beside and below the topography image give some idea of the shape of the optic nerve head. Next, look at the list of stereometric parameters. These are more useful at follow-up visits to monitor progression, but disc area, rim area, and cup/disc area ratio can provide relevant information. See below for clarification of the relevance of disc size and how it influences cup/disc ratio.
4. Review the bottom left of the report to note the global classification of either normal, borderline, or outside normal limits. The right half of the page illustrates a sector classification based upon the Moorfields Regression Analysis (see Chapter 3), in which each sector is labeled as normal, borderline, or outside normal limits. This statistical analysis qualifies the relationship between the rim and the cup after comparing patient values with a normative database. At the bottom right of the page a bar graph illustrates this comparison in more detail.

5. Finally, for more detailed information, specific parameter values within the different sectors may be reviewed at the computer screen.

The HRT single-test report should be reviewed methodically. The most important information includes the mean topography SD to assess image quality; the topography map to assess global optic disc anatomy; and the global and sector classification of the Moorfields Regression Analysis.

**CLINICAL INTERPRETATION OF HRT RESULTS**

This section will review the different applications of HRT data in glaucoma management. The HRT supplies useful, additional clinical information in several ways including quantitative measurements and the detection and location of damage. Quantitative data facilitates comparisons between the two eyes of a single individual and comparison between structural and functional data.

**1. Quantitative measures**

Optic disc size varies among normal subjects, and ranges between 0.80 and 5.54 mm$^2$ with differences between ethnic groups. Data from a population-based epidemiological study showed that mean (SD) disc area evaluated with HRT was 2.37 (0.43) mm$^2$ (range, 1.65 to .13 mm$^2$), with the smallest disc in this population smaller than the cup of the largest normal disc. In fact, 37.3% of normal optic discs had a linear cup/disc ratio over 0.3. As in routine clinical practice, this large variability present in the normal optic disc can lead to erroneous diagnosis and difficulty in the identification of glaucomatous optic neuropathy. Larger discs typically have larger physiological cups, but the resulting large cup/disc ratio does not necessarily indicate glaucomatous damage. HRT images should be assessed in combination with clinical findings including optic disc size, disc shape, and rim characteristics.

HRT provides one-, two-, or three-dimensional measurements globally and by sector, and compares the results with a normative database. HRT gives precise information about disc area and facilitates the identification of physiologically small discs, within which minimal cupping is expected, or macro discs, where cup/disc ratio may be as high as 0.9 without the presence of glaucomatous damage. A small disc with a large cup/disc ratio is more likely to have glaucoma than an optic nerve with a large disc area (Figures 4.1A, B, C).
Figure 4.1A
Small normal disc with small cup.

Figure 4.1B
Large normal disc with large physiological cup and cup/disc ratio of approximately 0.7.

Figure 4.1C
Average size optic disc with large cup/disc due to glaucomatous damage.
The most constant characteristic of the normal neuroretinal rim, independent of disc size, is the ranked size of the different neuroretinal rim sectors. In most normal eyes the inferior rim is wider than the superior sector, which in turn is wider than the nasal rim, and the temporal rim is usually the narrowest. This rule may be checked with HRT sector data by comparing rim area and/or rim volume in the different sectors. If the inferior rim is narrower than the superior rim, there is probably a loss of nerve fibers in the inferior retina (Figures 4.2A, B).

Quantitative measurements undoubtedly facilitate clinical interpretation of structural damage, but how accurate are HRT measurements? Multiple studies have shown that although HRT, as any other instrument, has certain variability, its measurements are reproducible. The relative height of each pixel or small groups of pixels vary in different measurements, and mean SD ranges from 25 to 49 µm in the worse case. Variability is greater in glaucomatous optic nerves than in normal optic nerves (Table 4.1).

HRT measurements are reproducible and show mean SD of 25 to 49 µm for relative height values and 0.04 to 0.06 mm² for rim or cup area. This reproducibility is certainly unreachable by any estimation performed at the slit lamp by an experienced clinician. Accurate quantitative measurements of the optic disc add useful information to reach clinical decisions.

**TABLE 4.1**

<table>
<thead>
<tr>
<th>Method</th>
<th>Author</th>
<th>Normal</th>
<th>Glaucoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel by pixel</td>
<td>Dohl et al.</td>
<td>38-42</td>
<td>41-49</td>
</tr>
<tr>
<td>64 x 64 pixel</td>
<td>Chauhan et al.</td>
<td>25</td>
<td>31</td>
</tr>
<tr>
<td>10 x 10 pixel</td>
<td>Cioffi et al.</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Pixel by pixel</td>
<td>Weinreb et al.</td>
<td>30</td>
<td>31</td>
</tr>
</tbody>
</table>

Reproducibility of HRT measurements. Mean standard deviation (MSD) of HRT relative height measurements (µm) as evaluated in different studies.4-7
2. Detection of damage

Moorfields Regression Analysis\(^4\) is able to identify structural damage by comparing patient data to a normative database of Caucasian eyes with refractive error under 6 diopters and disc size between 1.2 and 2.8 mm\(^2\). It evaluates the neuroretinal rim area to disc area ratio globally and at each of six sectors. Individual values are classified as within normal limits if they are inside the 95% confidence interval for normality (green check), borderline if between 95% and 99.9% (yellow exclamation mark), and outside normal limits if outside the 99.9% confidence interval (red X). (Moorfields Regression Analysis is described in detail in Chapter 3).

Many studies have evaluated HRT as a diagnostic tool for glaucoma.\(^9\)-\(^12\) Table 4.2 summarizes the results of some of these studies and demonstrates that HRT is able to classify normal and glaucoma eyes with accuracy at least as good as stereoscopic photographs evaluated by an experienced glaucoma specialist. Indeed, at the recent consensus meeting of the Association of International Glaucoma Societies on Structure and Function in the Management of Glaucoma, it was agreed that "sensitivity and specificity of imaging instruments for detection of glaucoma are comparable to that of expert interpretation of stereo colour-photography and should be considered when such expert advice is not available." Caution is recommended when evaluating very small or very large optic discs due to the limited normative database and the intrinsic difficulty to assess those eyes. Iester et al\(^13\) found that both sensitivity and specificity of HRT tend to be lower in unusually small discs.

Abnormal HRT results suggest the presence of objective structural damage, but HRT data should never be considered alone. HRT results should be assessed as part of a patient’s clinical history and examination, and need to be interpreted together with other clinical findings. HRT adds information and supports clinical decisions but does not substitute clinical examination or assessment of functional damage.
An example of how HRT data can help in clinical decision making is shown in Figure 4.3. It shows the HRT images of a 36-year-old woman with pigment dispersion syndrome, intraocular pressures of 26 to 28 mm Hg, normal and reliable standard visual fields, and large discs with no clear signs of rim thinning observed during clinical examination. HRT was able to detect early inferior rim thinning in the left eye and helped establish the diagnosis of early glaucomatous optic neuropathy.

3. Location of damage

Sector analysis is useful to locate structural damage of the rim. Use the upper right graph (reflectance image with Moorfields Regression Analysis) for this purpose. Glaucoma may affect any sector of the disc, but the disease tends to alter inferior-temporal and/or superior-temporal regions earlier than nasal or temporal sectors. HRT helps to locate and describe axonal loss as focal or diffuse. Figures 4.4A & B shows two cases of focal inferior damage, and Figures 4.4C & D show two cases of diffuse damage.

4. Comparison between eyes

It is useful to compare both eyes to interpret clinical findings. Most people have small differences in disc size and shape between eyes, and substantial cup/disc ratio asymmetry is considered suspicious of glaucoma. Nevertheless, epidemiological studies have shown that cup/disc asymmetry is more frequent than initially expected in normal eyes. The Blue Mountains Eye Study found cup/disc asymmetry over 0.2 in 6% of the normal population. Cup/disc asymmetry is most likely to be physiological if there is also a proportional size asymmetry—that is, if the larger disc also has the higher cup/disc ratio. On the contrary, a cup/disc asymmetry between two eyes with the same disc area suggests the presence of axonal loss and acquired enlargement of the cup (Figures 4.5A, B).
Figure 4.4A
Initial rim thinning.

Figure 4.4B
Relatively moderate inferior rim damage in a fairly large disc.

Figure 4.4C
Advanced glaucoma with superior and inferior rim loss.

Figure 4.4D
End-stage glaucoma with extensive diffuse loss.
Figure 4.5A

Cup/disc asymmetry with symmetric disc area. There is temporal and inferior rim thinning due to glaucoma in the right eye.

Figure 4.5B

Normal eyes with cup/disc asymmetry but simultaneous disc area asymmetry. Rim area is 1.2 mm² in both eyes, and no signs of glaucomatous damage are present.
5. Comparison of structural and functional damage

There is a relationship between degree and location of functional and structural damage in glaucoma.

Structural damage typically precedes detectable functional damage, so it is relatively common to find structural changes and a normal achromatic visual field. In general, structural and functional changes correlate well along the course of glaucoma although they don’t necessarily run parallel, and comparison of the degree of optic nerve and visual field deficits is dependent on the sensitivity of the individual test used. HRT has shown the ability to detect damage in cases with early glaucomatous field loss. In some cases, as shown in Figure 4.3, HRT may detect rim thinning before it is apparent on functional tests. Sector analysis offers the chance to compare the location of structural damage to the location of the functional deficit. When the location of optic nerve defect doesn’t match that of visual field defect, the diagnosis should be questioned. Inferior rim parameters correlate well with superior hemifield indices and vice versa, and, although considerable variability is present, the relation between optic nerve and field defects tends to follow certain topographical patterns. Inferior rim thinning is usually associated with superior field defects (Figure 4.6). Nasal visual field defects adjacent to the horizontal meridian match with rim damaged areas close to the vertical midline; rim thinning is usually temporal in the superior hemiretina and affects both sides of the vertical meridian in the inferior retina. Central and paracentral field defects are associated with rim thinning located temporal from the vertical midline, and more peripheral field defects match with the inferior and superior nasal sectors. Therefore, one should always look for correspondence between rim defects and visual field scotomas.

6. Follow-up

The most difficult task of optic nerve assessment is longitudinal assessment to establish stability or progression of the disease. Algorithms to detect progression or change have been improved in the HRT II and are described elsewhere (see Chapter 5). Initial longitudinal data by Chauhan et al indicate the HRT is particularly useful for monitoring progression in glaucoma.

CONCLUSION

In summary, HRT offers a quick and easy method of obtaining quantitative optic nerve data. It complements clinical examination and assessment of visual function in the diagnosis of glaucoma, glaucoma suspects, or ocular hypertension. Clinicians should evaluate the HRT printout looking to answer the classic questions: Is the optic disc normal? Are the discs of both eyes symmetrical? Is there rim thinning or notching? Where is it? Is there enlarging of the cup? Do structural changes match with functional deficits? Is the patient stable or progressing? Finally, the data should always be interpreted in the context of clinical history, examination findings, and other test results.
Figure 4.6
Inferior rim thinning associated with superior visual field defect.
REFERENCES


