The Octopus Glaucoma G1 Program

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The principal features and the clinical applications of the new Octopus glaucoma G1 program are described. The G1 is a fast program for screening and fully quantifying visual field defects. It allows separate quantification of diffuse damage, local scotomas, and fluctuation. It tests predominantly the central area and to a lesser extent the periphery up to an eccentricity of 56 degrees.

A two-level strategy for the periphery is combined with an Octopus normal strategy for the central area. The visual field indices are calculated immediately after the test and allow an easy comparison with normal values and with previous examinations.

The diagnosis of chronic open-angle glaucoma is based on findings of increased intraocular pressure (IOP), characteristic morphologic changes in the optic nerve head and the nerve fiber layer, and more or less typical changes in psychophysical test results.

Several such psychophysical tests have been shown to be useful in the diagnosis of glaucoma and glaucoma suspect, such as color vision and contrast sensitivity. None of these tests, however, has been able to replace perimetry, which at present is still the most important psychophysical parameter for the diagnosis and follow-up of established and suspected glaucoma. A further development of glaucoma perimetry, therefore, is still of great interest. It is the purpose of this article to describe a new approach for measuring and quantifying glaucomatous visual fields with the help of automated perimetry.

If new methodology is introduced in science, there is a resulting interaction between the knowledge gained and the corresponding technology involved. In regard to glaucoma perimetry, this means that new methods, used to measure visual fields, such as static quantitative automated perimetry, have provided new insights into glaucomatous visual field characteristics, and this in turn gives rise to new methods of measurement and evaluation.

Before describing these new methods, we mention very briefly some of the milestones in the development of glaucoma perimetry.

HISTORICAL BACKROUND

In 1889, Bjerrum,[1] using a tangent screen on the back of his examination room door, described the arcuate scotoma. Ronne[2] described the nasal step in 1909. In 1933, Sloan and colleagues[3] introduced static perimetry, which was further evaluated by Harms and Aulhorn.[4] In 1945, Goldmann[5] standardized the examination parameters for quantitative perimetry. This led to the description of the classical glaucomatous visual field defects, such as paracentral scotomas and the nerve fiber bundle-shaped defects. In 1972, Armaly[6] introduced the combination of kinetic perimetry with suprathreshold static testing of the most vulnerable areas of the visual field for glaucoma. In 1977, Werner and Drance[7] described increased scatter as a precursor of a definitive visual field defect.

In 1966, Dubois-Poulson and Magis[8] introduced automated perimetry, which was then further developed at several centers. Fankhauser and co-workers[9] must be credited with the development of the most sophisticated automated perimetry system, which they called *Octopus*. They introduced new standards, such as background illumination and exposure time,[10] and developed a repetitive staircase method for the threshold determination of the differential light sensitivity.[11]

A more detailed study of visual fields of

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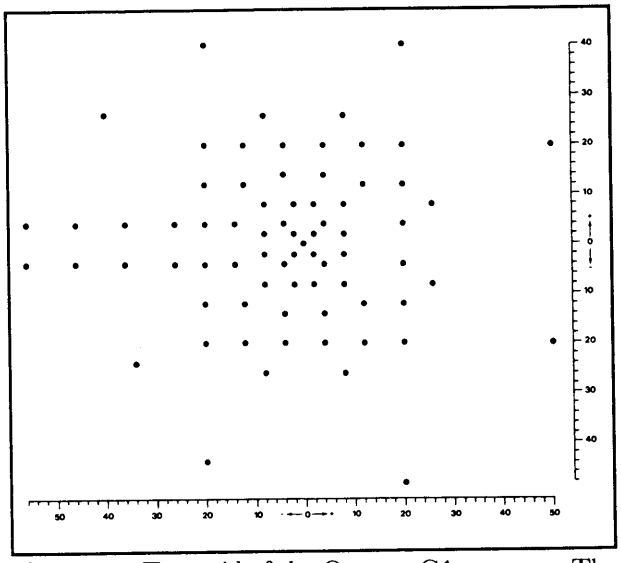

Figure 1. Test grid of the Octopus G1 program. The test locations are more concentrated near the center in order to detect small paracentral scotomas. The area of the blind spot is not tested. None of the test locations is on the horizontal or vertical axis, except the central point, to detect horizontal or vertical steps. There is an increased number of test locations on the nasal part of the periphery to detect peripheral nasal steps.

normal persons[12] and those with glaucoma[13] was now possible. The most striking findings were the occurrence and clinical relevance of unspecific changes in glaucoma, such as diffuse damage,[14] increased short-term and especially long-term fluctuation,[15] and fatigue effects.[16] While all such changes have already been observed with the help of manual perimetry, automated perimetry has emphasized the relevance of such information.[17] In the meantime, the methods for data evaluation have been further developed[18] and have led to new parameters that characterize visual fields as a whole.[19] With the help of a few numbers that have been designated "visual field indices," the global characteristics of a visual field can be described quantitatively. These indices have been tested with the help of the Octopus J0 program in normal persons and those with glaucoma.[17] The indices allow quantification and a separation of diffuse damage, local scotomas, and increased scatter; they facilitate the follow-up of visual fields.[20]

After the major characteristics of glaucomatous visual fields were established and the new methods to quantify these defects were introduced, it was time for the introduction of a new glaucoma program on the Octopus automated perimeter; a program such as this will be described in this article.

THE CONCEPT OF THE OCTOPUS GLAUCOMA G1 PROGRAM

The G1 program was designed to be so easy and fast that it could serve as a routine program in clinical practice and, at the same time, so accurate and sophisticated that it could be used for scientific studies. The following basic features characterize this program.

The Test Grid

The G1 program has 73 test locations (Figure 1). The number of test locations always has to be considered as a compromise between the spatial resolution desired and the test time available. As the area of the inner 30 degrees is considered to be most important for glaucoma, 59 test locations are in this area. To avoid scotomas caused by correction lens edges, these 59 test locations are within 26 degrees, instead of the traditional 30 degrees. The grid is denser around the center in order not to miss paracentral scotomas. The blind spot area is not tested for two reasons. First, the test of the blind spot area does not contribute essential information in the static glaucoma perimetry in our experience; second, the results interfere irregularly and unpredictably with the data evaluation applied.

Fourteen test locations are in the peripheral and midperipheral area out to an eccentricity of 56 degrees. They are more concentrated on the nasal side for the detection of a peripheral nasal step.

Test Strategy

At the 59 central test locations of the G1 program, the threshold of the differential light sensitivity (DLS) is measured with the so-called Octopus normal strategy. This is a staircase bracketing procedure. The 14 peripheral test locations, however, are tested by a fast two-level test. In addition to these two kinds of strategies, the G1 program has, like all the Octopus programs, catch trials built in.

Data Processing

The striking new feature of the G1 program is the data evaluation method. The computer calculates, automatically and without additional inconvenience to the patient or perimetrist, the visual field indices.[17] The calculation and

Table CLINICAL MEANING OF VISUAL FIELD INDICES

MS	Mean sensitivity
MD	Mean damage
LV	Loss variance
CLV	Corrected loss variance
Q′	Skewness
SF	Short-term fluctuation
RF	Rate of false responses

the clinical meaning of these indices have been described in detail[19] and are summarized in the Table. The basic object of these indices is a separation of diffuse damage from local scotomas and a separation of local deviations due to scatter from those due to real scotomas. Furthermore, these indices permit a clearly defined quantification of the visual field and, therefore, easy comparison with normal persons and with previous visual fields.

Extensive studies on normal persons are a prerequisite for meaningful use of the visual field indices. The basic concept behind the indices is an application of statistical principles to the visual field, such as the calculation of components of variance.

More than 500 normal eyes were measured, therefore, at 12 university centers with a preliminary version of the Octopus G1 program before the final version was released. This was done in order to determine the normal ranges of the visual field indices more precisely and to know their distribution in normal persons as a function of age. The normal ranges of the indices depend sensitively on examination conditions and can be translated to other Octopus programs only with some difficulty. Their direct application in other types of perimeters is not possible.

Test Sequence

In a first phase the Octopus G1 program quantitatively measures the DLS at the 59 central test locations (Figure 2). The computer then does a first analysis of the results by calculating the mean damage (MD) and loss variance (LV). The results are given to the operator. If both indices are well within the normal range, the computer recommends that the examination continue directly with phase 3, which measures the 14 peripheral test locations with a two-level test. The same is recommended if LV is far outside the normal range. This indicates that scotomas are definitely present in the patient's visual field. However, if LV is borderline, it is recommended that the examination proceed with phase 2, which is a quantitative retest of the 59 central test locations.

After this retest, the computer calculates the short-term fluctuation (SF) and corrected loss variance (CLV). Local deviations due to scatter can now be differentiated from deviations due to scotomas.

The technician has, however, the opportunity to do the second phase for other reasons. For instance, he or she may be interested in more exact results for follow-up or studies such as the effects of certain drugs.

Furthermore, between the different phases, the patient has the opportunity to relax for an arbitrary length of time. In our experience, patients have appreciated being measured with G1 program.

Phase 3 can, of course, be cancelled if the information from the periphery is not required.

Printout of the Results

The basic concept of the G1 program printout is to have all the information needed for a routine application on one sheet of paper. This

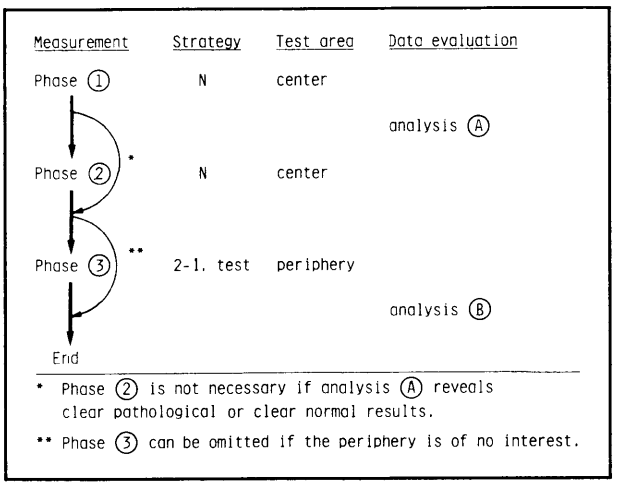

Figure 2. The test sequence of the G1 program presented schematically. After phase 1, an initial computerized analysis of the results is done (analysis A). Based on these results, the perimetrist may continue with phase 2 or go directly to phase 3. At the end of the measurement, the final analysis (analysis B) is done and all the indices are calculated. Phases 1 and 2 measure the central area quantitatively; phase 3 measures the periphery with the help of a two-level test.

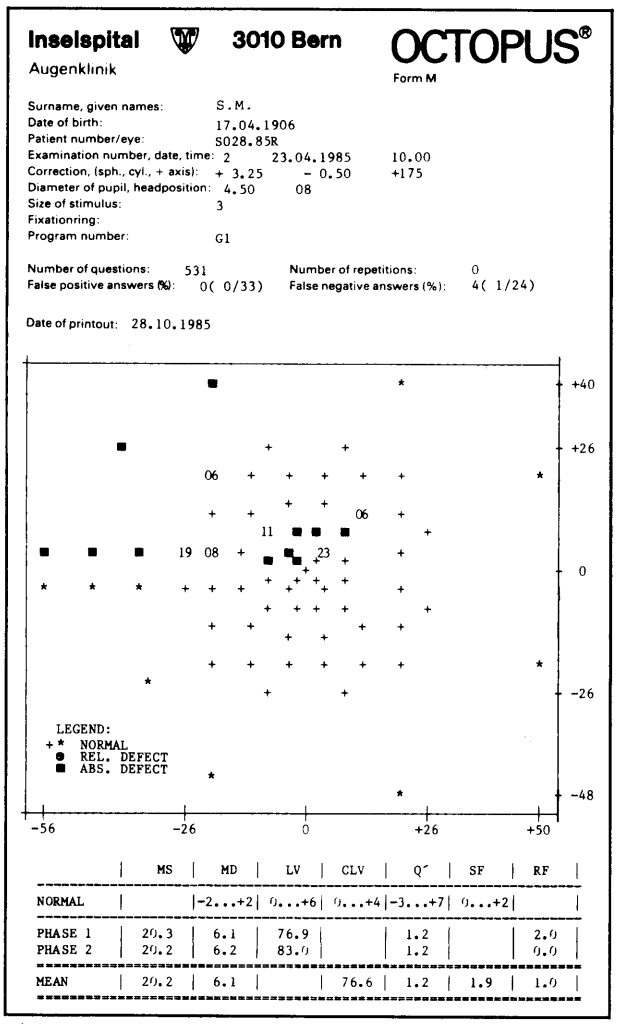

Figure 3. Example of a visual field of a glaucoma patient measured with the G1 program on the Octopus model 201. The visual field is presented graphically in the upper half. A black spot means an absolute defect and a cross indicates a value within the normal range (normal value, −4 dB). The numbers indicate the deviations of the measured threshold from the age-corrected normal threshold expressed in decibels (dB). In the lower part, the visual field indices are represented.

means that there is some kind of graphic representation combined with a table of the indices on one sheet. The technician can choose the type of graphic presentation he or she finds most useful. As an example, Figure 3 shows the result of a glaucomatous visual field displayed with the help of a printout mode called CO (comparison table). The results of the periphery are shown with symbols as are those in the central area if the outcome is within the normal range (≥ normal value, −4 dB) or if there is an absolute defect. In relative scotomas, numbers indicate the deviation of the measured values from the age-corrected normal values.

Below the graph the indices are displayed: first their normal ranges, then the results of the first and the second phase (when necessary), and finally the indices as obtained if both phases are measured.

Optionally, gray scales can also be selected. Moreover, a listing of the exact results on each phase at each test location can be obtained in the NL (numerical list) printout mode.

The print modes refer to Octopus models 201 and 2000. With Octopus 500, the printout is organized differently; however, basically the same information is provided.

APPLICATIONS OF THE G1 PROGRAM

Indication for Program Use

The Octopus G1 program has been developed as a routine program for glaucoma. It has been tested extensively in hundreds of normal persons and thousands of patients with either suspected or established glaucoma. It is used at present in a number of scientific studies for comparisons of visual fields with other psychophysical tests and also with morphologic alterations.

With the present wide clinical use of this program for glaucoma, more and more clinicians are applying it to other diseases as well. There are no objections to such use. At present, it has not yet been tested systematically for other indications.

Examination Time

Examination time was reduced markedly with the help of this new program. The number of stimuli presentations required in normal persons on the average was 498 ± 26 standard deviation (SD); in our glaucoma patients it was 524 ± 92 SD, if all three phases have been tested. The required time was, on average, 8 ± 3 minutes for phase 1, 5 ± 2 minutes for phase 2, and 2 ± 1 minutes for phase 3. As mentioned before, we may not need to utilize all phases for all patients.

Interpretation of the Outcomes

We recommend first checking the visual field indices (Figure 4). If they are normal, we know that we are dealing with a normal visual field. If they are out of normal range, the visual field is most probably pathologic and we have to

		MD	
		normal	increased
CLV	normal	normal visual field	diffuse damage
	increased	small scotomas	larger scotomas

Figure 4. The interpretation of the visual field indices CLV and MD. If MD is increased, there is a visual field defect. With the help of CLV, scotomas can be differentiated from diffuse defects. If MD is normal, there still may be small scotomas if CLV is increased.

check the graphic representation of the visual field to see the location of the defects.

Looking to the indices we first check the MD, the most important index. If the MD is out of normal range, we know that the visual field is most probably pathologic. Corrected loss variance will tell whether the defect quantified by MD is diffuse (CLV not increased) or local (CLV increased). If CLV increased, but MD stayed in the normal range, small scotomas are present. Even smaller scotomas may just increase the skewness index.[21]

If phase 2 is not measured, we check LV instead of CLV. Loss variance that is in the normal range indicates the absence of scotomas, whereas markedly increased LV indicates the presence of scotomas.

An only slight increase of LV may be due to either increased scatter or incipient scotomas. Only the additional measurement of phase 2 allows the calculation of CLV and thereby a differentiation of real local deviations from deviations due to scatter.

The SF should then be checked to see how reproducible the results are. Increased SF may signify early glaucomatous damage.[22] Since the SF is also influenced by the cooperation of the patient,[23] one should check the rate of false responses at the same time to find out whether increased SF may be due to cooperation problems.

Follow-up of Visual Fields

A main goal of the introduction of the visual field indices was to facilitate follow-up. Such follow-up is even easier with the help of a

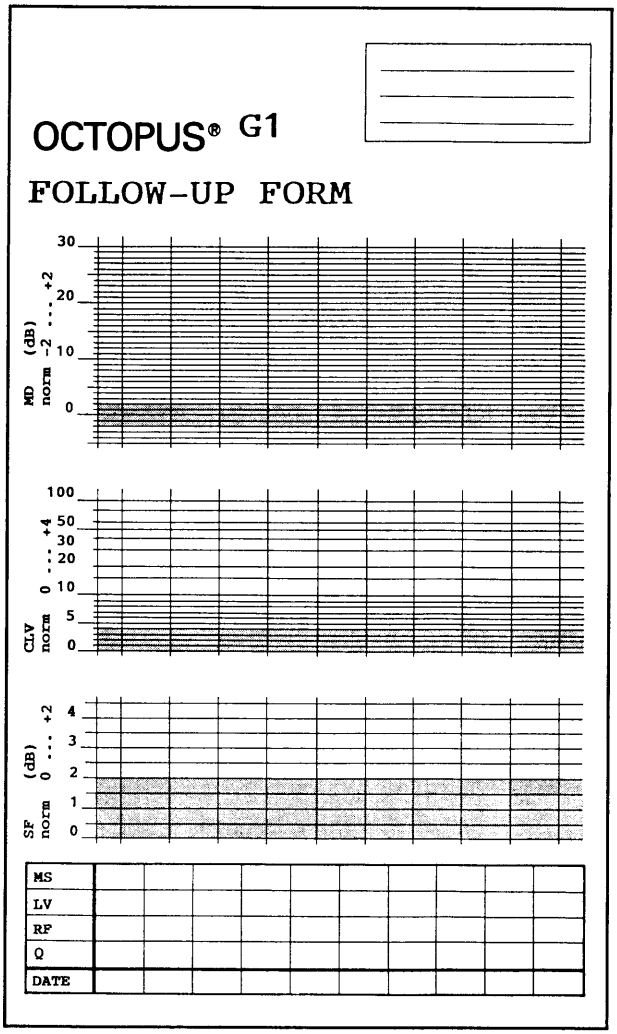

Figure 5. Follow-up sheet for the visual field indices measured with the Octopus G1 program. The gray area represents the normal range for the corresponding visual fields. MD and SF are represented linearly, whereas the y axis for CLV is proportional to the square root of CLV since it is a quadratic number (component of variance).

graphic representation of the indices (Figure 5). After each visual field test, the outcomes are drawn of the most important indices on the follow-up sheet. This is done in red ink for the right eye, and blue ink for the left eye, as is traditional for the IOP. Such a representation supplies us with the following information:

1. Are the indices out of the normal range?
2. Which type of glaucomatous defect occurs? (diffuse damage? local damage? increased scatter?)
3. Is there long-term fluctuation?

4. Is there a trend over time toward improvement or deterioration?
5. Is there a difference between the two eyes?

CONCLUSIONS

The new glaucoma G1 program is a fast program for screening and fully quantifying visual field defects. It allows a separate quantification of diffuse and local defects, and a detection of increased fluctuation. Furthermore, the calculation of the visual field indices allows a direct comparison of the global characteristics of a visual field with its normal values and its previous measurements. This is achieved by a three-phase sequence, a built-in calculation of visual field indices, and extensive studies on normal persons, the results of which are also built in. Although extensive studies on the G1 program have been carried out,[24] further studies are required to establish the sensitivity of this program in critical applications and to study its usefulness for other diseases.

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