QUANTIFICATION OF GLAUCOMATOUS THRESHOLD VISUAL FIELD LOSS BASED ON NEUROMORPHOMETRIC CORRELATES

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Introduction

There has been no perimetric index or scoring method available to quantify both glaucomatous and neuro-ophthalmic threshold field defects on a continuum, with emphasis on neuronal correlates and presumed damage. The absolute-relative-total scotoma (ARTS) scoring algorithm identifies the percentage of absolute, relative and total scotoma components of static threshold perimetric results. ARTS scoring involves weighing the eccentricity level of each test location on a given test grid according to the receptive field densities of the ganglion cells of the retina, and incorporates current knowledge of neuromorphometric correlates among retina, occipital cortex and central visual field. We compared the ARTS scoring method to other scoring methods and established its retest variability in glaucoma.

Methods

In the central visual field (i.e., 30° from fixation), we calculated the quantity (Q) of ganglion cell receptive fields for each square-degree of the field of vision using the formula $Q = [0.0055 (1+0.59x)]^2$, where $x$ represents the degree eccentricity. The percentage weight of each test location of the test grid is the ratio of the number of receptive fields at a particular portion of the visual field, represented by a given test location, to the total number of receptive fields in the central visual field. Percentage weight of each test location on test grids of Humphrey Visual Field Analyzer Programs C30-2 and C24-2 are shown in Figure 1. In calculation of ARTS scores, zero decibel sensitivity at any given test location results in adding the percentage value of that point to the absolute score, and the sum of such scores forms the final $A_{5\%}$ component. Test locations with higher than zero dB sensitivity and significant devia-
Fig. 1. Percentage representation of each test location in the visual field based on retinal ganglion cell receptive field density distribution in the 30-2 and the 24-2 grid.
Fig. 2. ARTS scoring algorithm may indicate large amounts of organic damage that may lead to an apparently small scotoma. *a. Small paracentral scotomas with the scores of A 3%R23%T26% in the right eye and A 3%R26%T29% in the left eye (based on pattern deviation plots). (Field results reproduced by courtesy of Prof. Steven L. Galetta, MD.)*
Fig. 2b, c. MRI study results of the same patient showing a large left occipital cortical infarct. (Reproduced by courtesy of Prof. Norman Schatz, MD.)
Significant relative defects of between $-3$ to $-10$ dB result in one-third of the assigned percentage for that location. Defects of $-11$ to $-20$ dB result in two-thirds of the percentage value of that test point. A defect deeper than $-20$ dB, but still remaining a relative defect (i.e., measured threshold $\geq 1$ dB), is given the full percentage relative score. The sum of these relative percentage defects constitutes the final $R_\%$ score. The Total $T_\%$ score is the sum of relative and absolute components. The final score is represented as $A \times R_\% \times T_\%$.

Thus, a patient with an absolute score of 23%, a relative score of 35%, and a total score of 58%, would be assigned the notation $A_{23}\%R_{35}\%T_{58}\%$.

Figure 2 displays the ARTS scores and global field indices of homonymous scotomas caused by an occipital cortical lesion. Forty C30-2 threshold field results (18 right, 22 left) of 40 glaucoma patients (aged 19-82 years, mean 62 years) were assigned ARTS (e.g., 0-100% scale), Advanced Glaucoma Intervention Study (e.g., Stage 1-20) and Hodapp-Parrish-Anderson (e.g., early=1, moderate=2 and severe=3) scores. Spearman’s rho test was used for statistical assessment. To establish the reproducibility of the method, an independent group of ten eyes of ten patients (mean age 64 years, range 43-82 years) with glaucomatous optic neuropathy was tested twice with both FASTPAC and SITA-Standard strategies.

Fig. 3. In this glaucomatous visual field, the results from different scoring algorithms were $A_{23}\%R_{8}\%T_{31}\%$ (based on total deviation plot), AGIS = 6 and HPA = severe.
Results

Figure 3 shows the ARTS scores in a glaucomatous eye. Mean scores of the study group were $A=11\%$, $R=22\%$, $T=34\%$ (i.e., absolute=11%, range 0-86%; relative=22%, range 2-72%; total=34%, range 2-100%), AGIS=6.5 (range 0-20), and HPA=2.1 (range 1-3). Total percentage scores correlated significantly with AGIS, HPA and global field indices of mean deviation ($p<0.001$), pattern standard deviation ($p<0.02$) and short-term fluctuation ($p<0.01$), and did not correlate significantly with corrected pattern standard deviation ($p>0.05$). ARTS measured significant defects when other global field indices were within normal range and AGIS scores were zero. ARTS also indicated increasing severity of visual field loss after HPA and AGIS scores had reached their maximum. The total scotoma component of ARTS algorithm fluctuated by $6.2\pm4.3\%$ (mean ± standard deviation) with the use of FASTPAC and by $4.0\pm3.8\%$ with SITA-S ($p=0.008$).

Conclusions

The absolute-relative-total scotoma (ARTS) scoring method addresses the issue of heterogenous receptive field densities of ganglion cells of the retina for test points of different eccentricities relative to fixation. ARTS scoring provided equal or better scotoma measurement and retest reproducibility compared to other numerical results. The ARTS model emphasizes neuronal representation and the implied quantity of receptive field density, and provides a continuous scale for the measurement of threshold central field damage even when the usefulness of other methods is limited. Full details of the study will be published elsewhere.

References