

Pointwise and Region-Wise Course of Visual Field Loss in Patients With Glaucoma

Samaneh Sabouri¹, Saeedeh Pourahmad¹, Koenraad A. Vermeer², Hans G. Lemij², and Siamak Yousefi^{3,4}

¹ Department of Biostatistics, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran

² Rotterdam Ophthalmic Institute, the Rotterdam Eye Hospital, Rotterdam, The Netherlands

³ Department of Ophthalmology, University of Tennessee Health Science Center, Memphis, TN, USA

⁴ Department of Genetics, Genomics, and Informatics, University of Tennessee Health Science Center, Memphis, TN, USA

Correspondence: Siamak Yousefi, Department of Ophthalmology, University of Tennessee Health Science Center, 930 Madison Ave., Suite 726, Memphis, TN 38163, USA. e-mail: siamak.yousefi@uthsc.edu

Received: March 29, 2021

Accepted: June 12, 2022

Published: July 25, 2022

Keywords: visual field (VF); progression; pointwise; region-wise; regression; standard automated perimetry (SAP); glaucoma

Citation: Sabouri S, Pourahmad S, Vermeer KA, Lemij HG, Yousefi S. Pointwise and region-wise course of visual field loss in patients with glaucoma. *Transl Vis Sci Technol.* 2022;11(7):20. <https://doi.org/10.1167/tvst.11.7.20>

Purpose: Accurate assessment of visual field (VF) trend may help clinicians devise the optimum treatment regimen. This study was conducted to investigate the behavior of VF sequences using pointwise and region-wise linear, exponential, and sigmoid regression models.

Materials and Methods: In a retrospective cohort study, 277 eyes of 139 patients with glaucoma who had been followed for at least 7 years were investigated. Linear, exponential, and sigmoid regression models were fitted for each VF test location and Glaucoma Hemifield Test (GHT) region to model the trend of VF loss. The model with the lowest root mean square error (RMSE) was selected as the best fit.

Results: The mean age (standard deviation [SD]) of the patients was 59.9 years (9.8) with a mean follow-up time of 9.3 (0.7) years. The exponential regression had the best fit based on pointwise and region-wise approaches in 39.3% and 38.1% of eyes, respectively. The results showed a better performance based on sigmoid regression in patients with initial VF sensitivity threshold greater than 22 dB (71.6% in pointwise and 62.2% in region-wise approaches). The overall RMSE of the region-wise regression model was lower than the overall RMSE of the pointwise model.

Conclusions: In the current study, nonlinear regression models showed a better fit compared to the linear regression models in tracking VF loss behavior. Moreover, findings suggest region-wise analysis may provide a more appropriate approach for assessing VF deterioration.

Translational Relevance: Findings may confirm a nonlinear progression of VF deterioration in patients with glaucoma.

Introduction

Glaucoma, the second leading cause of blindness worldwide,¹ is a progressive disorder characterized by changes in the optic nerve head accompanied by visual field (VF) loss. It typically affects subjects who are 40 to 80 years old and nearly 3.5% of this population. It is estimated that approximately 111.8 million people will develop glaucoma by 2040.¹⁻³

VF tests are used routinely in clinical practice to assess glaucoma. Standard automated perimetry

(SAP) measures the sensitivity of VF in patients with glaucoma to localize functional changes in the damaged areas.^{4,5} Assessing a longitudinal series of VF enables clinicians to detect early progression of the disease to direct treatment resources optimally toward worsening cases.^{6,7} VF global measures, such as mean deviation (MD), fail to ascertain local changes.⁸ As such, some researchers have suggested using pointwise or region-wise models to better capture the local characteristics of VF loss.^{9,10}

Numerous studies have been conducted to model longitudinal VF sensitivity for each VF test location

great caution for clinicians in the case of facing normal sensitivities that may progress later in a sigmoid shape. Although, biologic underpinnings of glaucoma disease may not be represented by models accurately, it may provide valuable insights for clinicians regarding VF changes through a simplified form of progression. This would be attained by identifying the model that fits the data more truly. Our study showed the superiority of the exponential regression over the other two models and in conditions with more aggressive form of decay, sigmoid regression had a better performance. Although the pointwise approach enabled us to evaluate local changes, such models suffer from a high degree of variability.³⁵ Hereon, region-wise analysis may partially address the VF variability.

A major limitation of our study is the unknown number of incisional surgeries, such as trabeculectomy, the implantation of a large drainage tube, or laser trabeculoplasty. Although we believe only a handful of patients went through surgical intervention, the models may be influenced by these interventions. Thus, the results should be interpreted with caution as these interventions may change the trend of VF loss into a nonlinear pattern during the follow-up time.

Conclusion

We compared pointwise and region-wise VF worsening over time based on linear, exponential, and sigmoid regression models and observed that sigmoid provided overall lower RMSE in both pointwise and region-wise analyses. However, the exponential model provided the largest number of best fits (least RMSE) in both pointwise and region-wise analyses. Our analyses also suggested the sigmoid regression consistently provided the best fit in subjects with (pointwise and region-wise) VF sensitivity values corresponding to the first visits in the normal range but (pointwise and region-wise) VF sensitivity values corresponding to the last visits in the total loss range. This fact may suggest that rate of VF worsening is not constant and may change across the course of the disease.

Acknowledgments

The present paper was partially supported from the dissertation of Samaneh Sabouri and was supported by Grant no. 20843 (23360-01-01-99) and ethics code: IR.SUMS.REC.1400.082 from Shiraz University of Medical Sciences, Shiraz, Iran. The authors would like to thank The Rotterdam Ophthalmic Institute

for providing us this dataset under the license agreement and we are also thankful of Shiraz University of Medical Sciences, Shiraz, Iran and Center for Development of Clinical Research of Nemazee Hospital and Nasrin Shokrpour for editorial assistance.

Disclosure: **S. Sabouri**, None; **S. Pourahmad**, None; **K.A. Vermeer**, Acoustic Insight and Novo Research Consultancy, Voorburg; **H.G. Lemij**, None; **S. Yousefi**, None

References

1. Muacevic A, Adler J, Allison K, Patel D, Alabi O. Epidemiology of Glaucoma: The Past, Present, and Predictions for the Future. *Cureus*. 2021;12(11):e11686.
2. Jones PR, Philippin H, Makupa WU, Burton MJ, Crabb DP. Severity of Visual Field Loss at First Presentation to Glaucoma Clinics in England and Tanzania. *Ophthalmic Epidemiol*. 2020;27(1):10–18.
3. Tham Y-C, Li X, Wong TY, Quigley HA, Aung T, Cheng C-Y. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. *Ophthalmology*. 2014;121(11):2081–2090.
4. Wu Z, Medeiros FA. Comparison of visual field point-wise event-based and global trend-based analysis for detecting glaucomatous progression. *Transl Vis Sci Technol*. 2018;7(4):20.
5. Chen A, Nouri-Mahdavi K, Otarola FJ, Yu F, Afifi AA, Caprioli J. Models of glaucomatous visual field loss. *Invest Ophthalmol Vis Sci*. 2014;55(12):7881–7887.
6. Bryan S, Vermeer K, Eilers P, Lemij H, Lesaffre E. Robust and Censored Modeling and Prediction of Progression in Glaucomatous Visual Fields. *Invest Ophthalmol Vis Sci*. 2013;54:6694–6700.
7. Taketani Y, Murata H, Fujino Y, Mayama C, Asaoka R. How many visual fields are required to precisely predict future test results in glaucoma patients when using different trend analyses? *Invest Ophthalmol Vis Sci*. 2015;56(6):4076–4082.
8. Bengtsson B, Heijl A. A visual field index for calculation of glaucoma rate of progression. *Am J Ophthalmol*. 2008;145(2):343–353.
9. Caprioli J, Mohamed L, Morales E, et al. A method to measure the rate of glaucomatous visual field change. *Transl Vis Sci Technol*. 2018;7(6):14.
10. Morales E, de Leon JMS, Abdollahi N, Yu F, Nouri-Mahdavi K, Caprioli J. Enhancement of visual field predictions with pointwise exponential