



Glaucoma and Driving

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Abstract

Purpose of Review Loss of the ability to drive is highly associated with depressive symptoms in older persons. There are many reasons why an individual may give up driving, poor vision being an important one. Given the high prevalence of glaucoma in this population and the critical role that vision plays in the ability to drive, it is therefore important to consider how glaucomatous vision loss plays into the ability to drive safely.

Recent Findings In this review article, we will summarize the literature on the topic of glaucoma and driving and the studies that have been done to evaluate this topic. Studies of both the self-perceived impact of glaucomatous visual field loss on driving as well as studies that include on-road and simulated driving experiments will be reviewed.

Summary We will discuss how patients with glaucoma may be assessed for their driving safety and review how we treat and evaluate these patients in our own practices.

Keywords Glaucoma · Driving · On-road driving experiments · Simulated driving · Legal requirements

Introduction

Among older adults, the ability to drive is strongly correlated with an improved quality of life [1]. Even after controlling for other demographic and health variables, driving cessation is often synonymous with an adult's loss of independence and has been associated with an increase in both depressive symptoms and in the risk of requiring admittance into a long-term care facility [2, 3]. People with glaucoma consistently rank the ability to travel outside the home among their most important visual priorities [4].

According to data from the Centers for Disease Control (CDC), motor vehicle crashes (MVCs) rank second among the most common causes of unintentional injury-related deaths among all adults over the age of 65 years [5]. As the

baby boomer generation continues to age, it has been estimated that one-fifth of all drivers will be 65 and older by the year 2030 [6]. More than any other adult age group in the USA, drivers aged 70 and older show a sharp increase in MVC rates and a higher risk of MVC-related fatal injuries than other age groups [7]. Understanding the factors that are significantly associated with increased vehicle crashes in older drivers is thus critically important.

Clear vision is one major component of safe driving and many studies have looked at the link between visual impairment and driving [8, 9]. Glaucoma is a leading cause of irreversible vision loss in adults in the USA and the most common cause of irreversible vision loss worldwide. Glaucoma patients thus represent a potentially large number of drivers. Many studies conducted over the past several decades have suggested that individuals with glaucoma have a higher rate of MVCs than individuals without glaucoma, though other studies have not shown this clear association. In this review article, we will summarize the current literature looking at the association between glaucoma and driving. We will look at studies of both the self-perceived impact of glaucomatous visual field loss on driving as well as studies that include on-road and simulated driving experiments. We will discuss how patients with glaucoma may be assessed for their driving safety and review how we treat and evaluate these patients in our offices.

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Background

Glaucoma is the most common cause of irreversible blindness worldwide. It has been estimated that 80 million people will be affected by glaucoma in 2020 [10]. In the USA alone, more than two million people are estimated to be affected by open-angle glaucoma (OAG). Due to the rapidly aging population, this number has been expected to increase to more than three million by 2020 [11]. Patients with OAG suffer progressive deterioration of the optic nerve that results in characteristic, and most commonly, peripheral and eventually potential central visual field loss [12]. This loss of vision may result in a significant change in a patient's quality of life and affect many activities of daily living, such as driving ability.

Information regarding the effect of glaucoma on a patient's ability to drive originates from multiple sources. Studies of self-report from glaucoma patients, databases of MVCs, on-road driving assessments, and driving simulators all provide information on this important topic. This article will review studies from each of these categories in order to provide more information regarding the association between glaucoma and driving ability.

Database Studies and Studies of Self-Report

In one retrospective population-based study of 2000 licensed drivers aged 70 years and older who reside in north-central Alabama, after adjusting for mental status, age, and gender, drivers with glaucoma had a 1.65 (95% confidence interval 1.20–2.28, $p = 0.002$) times higher MVC rate than drivers without glaucoma. Among individuals with glaucoma in this study, the MVC rates were highest among those drivers with severe visual field loss. Impairment in the left, upper, or lower field was associated with higher rates of MVCs, with the highest relative risk being an impaired left visual field (RR = 3.16, $p = 0.01$). Interestingly, there was no association found between impaired visual acuity or contrast sensitivity and MVC rate [13•]. In a second retrospective study of 438 drivers with glaucoma, drivers with severe binocular visual field defects as determined by pattern standard deviation (defined as a PD < -3.97 in this study) were twice as likely to have an at-fault MVC compared with drivers with glaucoma of less severity [14]. These studies show that there appears to be an increased risk of MVCs in individuals with glaucoma, and the risk is higher in those persons with severe visual field loss.

However, not all studies show this same correlation. In one study, after adjusting for demographics, medical data, and visual acuity, individuals with glaucoma were 40–50% less likely than those without glaucoma to be involved in MVCs. Glaucoma individuals were more likely than individuals without glaucoma to avoid night and highway driving, as well as

driving in the rain or fog, suggesting that perhaps drivers with glaucoma are self-limiting their on-road exposures and thus have decreased chances for MVCs [15]. Similarly, in India, though patients with glaucoma report greater driving difficulty than patients without glaucoma, patients without glaucoma had higher numbers of self-reported accidents, which again, implies that patients with glaucoma may be restricting their own driving [16]. In a study of 247 POAG patients in Japan, there was no correlation between MVCs and binocular visual field damage, suggesting a less than straightforward relationship between driving and visual function [17]. It is also possible that individuals may not be accurately reporting MVC data. One study showed that individuals' self-reported motor vehicle collision data did not actually reflect police records of the same car crash data [18] so it is important to take into account the limitations inherent in studies based upon self-reported data.

Multiple studies have also looked at the association between glaucomatous visual field loss and driving cessation. In one study of 99 patients with glaucoma, 19% reported stopping driving completely. There was a significantly higher percentage of individuals with moderate or severe glaucoma that reported a cessation in driving (33%) compared with individuals with mild-stage disease (8%). Those with moderate-severe disease also were more likely to self-report difficulty with glare and dark adaptation than those with less severe disease [19•]. In another cross-sectional study comparing the driving patterns of 81 glaucoma subjects with 58 glaucoma suspect controls between the ages of 60 and 80, 23% of glaucoma subjects had ceased driving compared with 6.9% of controls. Glaucoma subjects were more likely to report driving limitations (such as not driving more than 1 hour away from home or not driving at night) than controls [20]. Similarly, among 211 Japanese subjects with POAG, moderate- and severe-stage disease in the better eye was associated with driving cessation [21]. While visual field loss is certainly the reason that some individuals with glaucoma stop driving, visual acuity has also been found to be an important parameter [22].

Most studies looking at the association between glaucoma and driving look at individuals with POAG. This data however may not be representative of individuals with other types of glaucoma, as the pattern of visual field loss, rate of progression, and age at diagnosis may differ greatly. One cross-sectional study of 1988 consecutive patients with different types of glaucoma compared the stage of visual field loss among different types of glaucoma in regard to driving ability. In this study, patients with advanced binocular or severe visual field loss were classified by the authors as unable to drive, patients with no visual field loss in one eye and any degree of loss in the other eye as able to drive and all others questionably able to drive. Interestingly, based solely on binocular visual field data, the percentage of patients unable to drive/

questionably able to drive was, respectively, found to be: 11.5%/29.2% for POAG patients, 19.6%/43.1% for normal-tension glaucoma (NTG), 14.6%/30% for primary angle-closure glaucoma, 16%/22% for pigmentary glaucoma, and 9.1%/16.7% for pseudoexfoliation glaucoma [23••]. These numbers are likely highest for NTG patients since they are most likely to have visual field loss near fixation, and thus, the type of glaucoma that a patient has seems to be very important when assessing one's ability to drive safely. To this point, very few studies of driving in the context of glaucoma have classified patients by the type of glaucoma that they have and thus should be interpreted cautiously.

On-Road Driving Assessments

On-road driving evaluations have been used to study how glaucomatous visual field loss may impact a patient's ability to drive safely. The real-life driving environment used in these studies provides an obvious advantage over studies of self-report and simulated driving experiments. However, these studies are also limited. They take place in one sitting with the presence of a driving instructor in cars with double brake mechanisms and thus are not completely representative of "normal" driving.

Bhorade et al. completed a case-control pilot study comparing the on-road driving performance of 21 patients with moderate or advanced glaucoma (mean deviation 6 dB or less in the better eye) to 38 community-dwelling controls without glaucoma. After completing a comprehensive clinical evaluation by an occupational therapist, all participants in this study underwent a 50–60 minute, 13-mile on-road driving evaluation with a rehabilitation specialist. The specialist graded the overall driving performance as pass versus marginal/fail and recorded the number of wheel or brake interventions required during the test. The authors found that compared with 21% of controls, 52% of glaucoma patients scored a marginal/fail on the driving evaluation and that glaucoma patients had a higher rate of wheel interventions. When glaucoma participants who passed were compared with those who failed the driving test, there were no significant differences found between groups for binocular distance or near visual acuity, contrast sensitivity or glare. The authors concluded that in order to accurately assess the driving safety of individuals with glaucoma, both a complete clinical assessment and on-road driving evaluation should be done [24]. In a second study by Wood et al., 75 drivers with glaucoma and mild-moderate visual field loss and 70 age-matched controls performed an on-road assessment. Types and locations of driving errors as well as overall driving safety were compared between the two groups. Compared with the age-matched controls, glaucoma drivers made more driving errors in categories of maintaining lane position, changing lanes, planning ahead, and accurate observation of

the road. In addition, drivers with glaucoma made twice the number of critical driving errors, defined as those that required the driving instructor to intervene either by applying the brakes or taking control of the steering wheel, and were determined to be overall less safe on the road [25•].

Finally, Kasneci et al. assessed both the on-road driving performance of patients with binocular visual field loss using a driving instructor (10 patients of which had glaucoma) and the compensatory mechanisms used by drivers in the study. They found that only four of the 10 glaucoma patients in the study were rated as fit to drive by the driving instructor. Of the drivers with visual field defects that passed the test, many compensated for their field defects by an increased number of glances towards the side of their field loss [26]. In a second study that looked at visual scanning behavior in 13 older drivers with glaucoma compared with 10 normal controls on a closed-road driving circuit, individuals with glaucoma demonstrated larger saccades than the controls, though head movements did not differ between the two groups. Though the individuals with glaucoma had significantly worse driving scores than the controls, the larger saccades were associated with better driving scores. The authors of this study concluded that altering visual scanning behavior may improve driving safety in individuals with glaucoma [27].

Driving Simulation

Simulated driving studies have also been done in individuals with glaucoma. Kunimatsu-Sanuki et al. used a driving simulator to assess driving fitness in individuals with advanced glaucoma (defined as a mean deviation in both eyes of worse than – 12 dB) and compared these results with those in normal age-matched controls. Among individuals with glaucoma, a value for binocular integrated visual field (IVF) was calculated from an individual's merged monocular HVF 24-2 test results. They analyzed the number of collisions with simulated hazards and the braking response time in both groups and found that patients with advanced glaucoma were involved in a significantly higher number of collisions. When the simulated hazard was located within or near an area of the IVF deficit, a collision was more likely [28]. The authors posited that a simulated driving experience may be useful to help educate patients about their own driving safety. This same group also assessed the role of the location of the visual field defect in individuals with advanced glaucoma and its impact of collision with oncoming cars in a simulated driving experiment. In this study, the inferior hemifield was associated with more collisions in these patients with advanced glaucomatous disease [29].

Vega et al. used a simulated driving experiment to look at the differences in the ability of glaucoma patients and normal controls to maintain a car in the right lane of a two-lane

highway when speed was automatically maintained at 100 km/h. Glaucoma patients were able to maintain lane position and avoid obstacles without any statistical difference compared with the controls, and both groups had similar eye scanning behaviors as well. However, patients with glaucoma demonstrated more steering input and missed more peripherally projected stimuli than controls [30]. In a simulated driving experiment under fog conditions, glaucoma individuals had a steeper increase in driving risk than controls. This was especially true for patients with a MD below -9 dB in the better eye [31]. Finally, in a simulated driving test with and without mobile telephone use, though glaucoma patients reported using mobile telephones as often as healthy controls, the glaucoma group demonstrated statistically longer reaction times to peripheral stimuli than control patients when using mobile telephones [32].

Interestingly, different results have been found when assessing for simulated visual field defects in normal individuals. Glen et al. looked at the impact of the location of a simulated visual field defect on hazard detection in a computer-based driving test in normal individuals. In this study, superior defects were found to have a greater impact on driving performance than identical inferior defects [33]. The reason for these differences between normal and glaucoma individuals is not known and thus, it is important to assess each patient individually rather than make generalized recommendations. Ungewiss et al. looked at the agreement between on-road driving performance and driving simulator testing in patients with binocular visual field loss (glaucomatous or retrochiasmal lesion-induced) and found that the pass/fail rates were comparable between groups [34]. Thus, a driving simulation may be an acceptable way to evaluate patients' driving safety.

Legal Driving Requirements

Legal driving requirements differ depending on the state in which a patient lives and thus, it is important to know the state requirements where one practices in order to appropriately counsel patients. All states have visual acuity requirements, but these requirements are not the same in each state. Currently, there are 16 states in the USA that do not have any horizontal visual field requirements for drivers. In the 34 states that do have horizontal visual field requirements, they differ depending on the state [35].

In Pennsylvania, where the authors practice, the horizontal visual field between both eyes must be at least 120 degrees in the horizontal meridian, excepting the normal blind spots. The binocular Humphrey Esterman visual field test and the binocular kinetic Goldmann IV4e target visual field test are currently used by many providers, including us, to assess a patient's peripheral vision in the driving setting. The Humphrey

Esterman visual field test uses a 10-dB stimulus, which may be suprathreshold in the area of a visual field defect, and there are more points tested in the lower field than in the superior field.

We know that there may be differences in visual field assessments depending on the type of visual field test taken. In one study in Sweden comparing threshold testing with the SITA-FAST 24-2 monocular Humphrey visual field (HVF) with the binocular Humphrey Esterman visual field (HEVF) test for driver licensing in subjects with glaucoma, the HEVF was less efficient in finding visual field defects [36]. Given that monocular testing algorithms utilize threshold testing whereas the binocular testing algorithms use a 10-dB stimulus which may be suprathreshold in many areas of the field, monocular testing may be better able to delineate a visual field defect. Similarly, in a study comparing Humphrey and binocular Goldmann visual fields with regard to driving in Australia, patients with severe field defects on conventional automated perimetry may still meet the Goldmann standard visual field test for driving [37]. With binocular testing, overlap from an intact field in one eye may compensate for a visual field defect in the fellow eye. The authors have similarly found that some patients perform quite differently on binocular Esterman visual field testing compared with those on monocular Humphrey visual field testing (see Fig. 1). Thus, it may be important to do this additional testing to determine a patient's ability prior to counseling them otherwise.

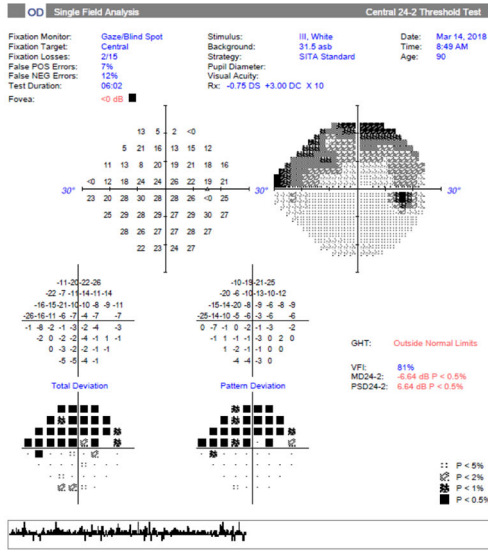
Counseling Patients

In addition to monitoring a patient's visual field and ensuring it meets driving requirements, it is also important to optimize other components of vision. Patients should be given the correct eyeglass prescription with or without anti-reflective coating if needed, can consider amber-tinted lenses to decrease glare and improve contrast, and can consider cataract surgery to improve their visual acuity when indicated and appropriate. Driver training courses at rehabilitation centers can be considered in order to evaluate driving ability and teach techniques to improve a patient's driving skills.

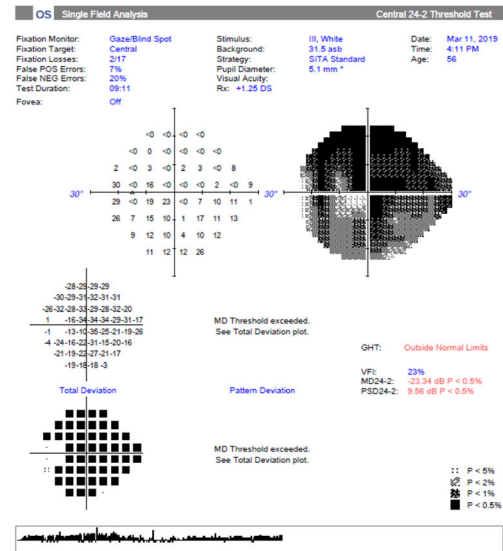
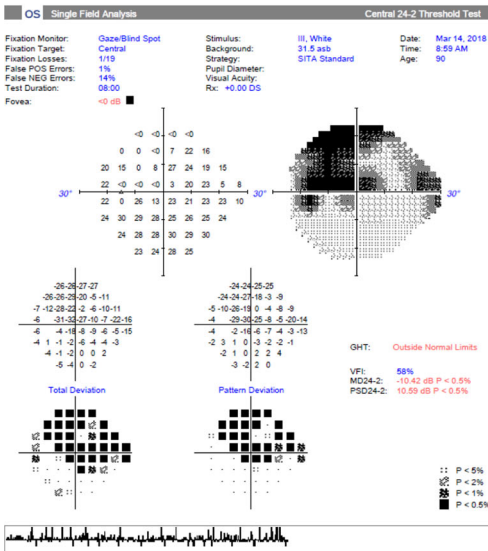
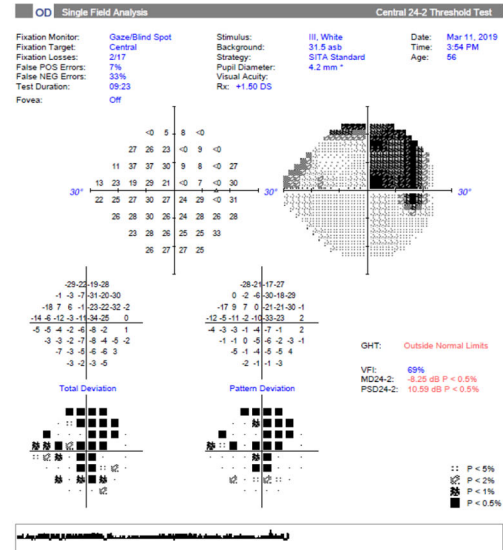
Importantly, no test done in an ophthalmology clinic should supersede a patient that does not feel that they are safely able to drive. Ultimately, a patient and his or her family members must use common sense about whether he or she feels comfortable and safe to drive. Vision is only one parameter of safe driving and there are many other factors such as

Fig. 1 **a** Patient 1: Humphrey Monocular Visual Field. **b** Patient 1: Humphrey Binocular Esterman Visual Field. **c** Patient 2: Humphrey Monocular Visual Field. **d** Patient 2: Humphrey Binocular Esterman Visual Field

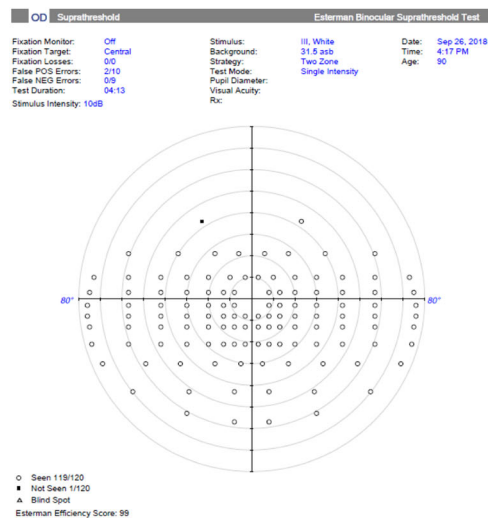
a. Patient 1: Humphrey Monocular Visual



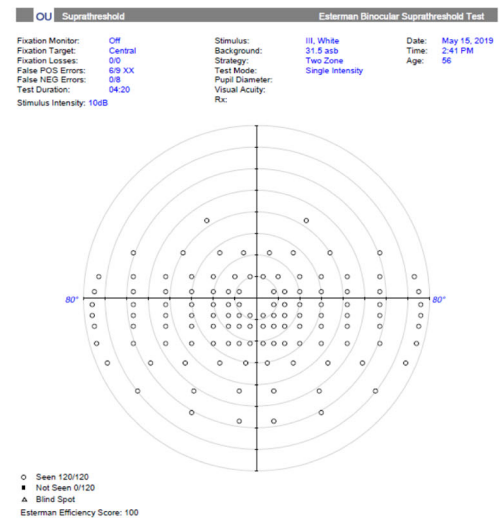
c. Patient 2: Humphrey Monocular Visual Fields



b. Patient 1: Humphrey Binocular Esterman Visual Field



d. Patient 2: Humphrey Binocular Esterman Visual Fields



overall health, cognition, and response time that go into this determination. If after undergoing the appropriate testing, an ophthalmologist feels strongly that a patient lacks the visual requirements to drive safely; this should be communicated to the patient. If the patient does not follow these recommendations, it may be necessary to report these concerns to the state. As physicians, it is our responsibility to protect both our patients and other drivers on the road as well.

Conclusion

In this review article, we have attempted to summarize some of the major studies that have looked at the association between glaucoma and driving. Though most of the studies presented do show an association between worsening glaucoma severity and less safe driving, other studies show that some glaucoma patients are able to compensate for their limitations with more frequent eye tracking and head-turning behavior and still maintain safety on the road. As previous authors have also suggested, until a standard set of tests can be developed that clearly measure a driver's ability to drive safely, it is important to use individualized assessments when counseling patients [38].

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

1. Fonda SJ, Wallace RB, Herzog AR. Changes in driving patterns and worsening depressive symptoms among older adults. *J Gerontol B Psychol Sci Soc Sci*. 2001;56(6):S343–51.
2. Freeman EE, Gange SJ, Munoz B, West SK. Driving status and risk of entry into long-term care in older adults. *Am J Public Health*. 2006;96(7):1254–9.
3. Ragland DR, Satariano WA, MacLeod KE. Driving cessation and increased depressive symptoms. *J Gerontol A Biol Sci Med Sci*. 2005;60(3):399–403.
4. Aspinall PA, Johnson ZK, Azuara-Blanco A, Montarzano A, Brice R, Vickers A. Evaluation of quality of life and priorities of patients with glaucoma. *Invest Ophthalmol Vis Sci*. 2008;49(5):1907–15.
5. 10 leading causes of injury deaths by age group highlighting unintentional injury deaths, United States. 2017 [Available from: https://www.cdc.gov/injury/wisqars/pdf/leading_causes_of_injury_deaths_highlighting_unintentional_2017-508.pdf].

6. Lyman S, Ferguson SA, Braver ER, Williams AF. Older driver involvements in police reported crashes and fatal crashes: trends and projections. *Inj Prev*. 2002;8(2):116–20.
7. United S. Improving transportation for a maturing society. [Washington, D.C.]: U.S. Department of Transportation, Office of the Assistant Secretary for Transportation Policy. 1997. 1 v. (various pagings) p.
8. Charman WN. Vision and driving—a literature review and commentary. *Ophthalmic Physiol Opt*. 1997;17(5):371–91.
9. Owsley C, McGwin G Jr. Vision and driving. *Vis Res*. 2010;50(23):2348–61.
10. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. *Br J Ophthalmol*. 2006;90(3):262–7.
11. Friedman DS, Wolfs RC, O'Colmain BJ, Klein BE, Taylor HR, West S, et al. Prevalence of open-angle glaucoma among adults in the United States. *Arch Ophthalmol*. 2004;122(4):532–8.
12. Varma R, Lee PP, Goldberg I, Kotak S. An assessment of the health and economic burdens of glaucoma. *Am J Ophthalmol*. 2011;152(4):515–22.
13. •• Kwon M, Huisinigh C, Rhodes LA, McGwin G Jr, Wood JM, Owsley C. Association between Glaucoma and At-fault Motor Vehicle Collision Involvement among Older Drivers: A Population-based Study. *Ophthalmology*. 2016;123(1):109–16 **This large population-based study examines the association between glaucoma and motor vehicle collision (MVC) involvement among older drivers, showing that older drivers with glaucoma are more likely to have a history of at-fault MVC involvement than those individuals without glaucoma.**
14. McGwin G Jr, Huisinigh C, Jain SG, Girkin CA, Owsley C. Binocular visual field impairment in glaucoma and at-fault motor vehicle collisions. *J Glaucoma*. 2015;24(2):138–43.
15. McGwin G Jr, Mays A, Joiner W, Decarlo DK, McNeal S, Owsley C. Is glaucoma associated with motor vehicle collision involvement and driving avoidance? *Invest Ophthalmol Vis Sci*. 2004;45(11):3934–9.
16. Deshmukh AV, Murthy GJ, Reddy A, Murthy PR, Kattige J, Murthy VR. Older drivers and glaucoma in India: driving habits and crash risks. *J Glaucoma*. 2019;28(10):896–900.
17. Yuki K, Asaoka R, Tsubota K. The relationship between central visual field damage and motor vehicle collisions in primary open-angle glaucoma patients. *PLoS One*. 2014;9(12):e115572.
18. McGwin G Jr, Owsley C, Ball K. Identifying crash involvement among older drivers: agreement between self-report and state records. *Accid Anal Prev*. 1998;30(6):781–91.
19. • Tam ALC, Trope GE, Buys YM, Yang Y, Shen C, Jin YP. Self-perceived Impact of Glaucomatous Visual Field Loss and Visual Disabilities on Driving Difficulty and Cessation. *J Glaucoma*. 2018;27(11):981–6 **This study looks at the self-perceived impact of glaucomatous visual field loss and visual disability on driving ability and found that patients with moderate-severe glaucomatous visual field loss were more likely to report driving cessation.**
20. van Landingham SW, Hochberg C, Massof RW, Chan E, Friedman DS, Ramulu PY. Driving patterns in older adults with glaucoma. *BMC Ophthalmol*. 2013;13:4.
21. Takahashi A, Yuki K, Awano-Tanabe S, Ono T, Shiba D, Tsubota K. Association between glaucoma severity and driving cessation in subjects with primary open-angle glaucoma. *BMC Ophthalmol*. 2018;18(1):122.
22. Shakarchi AF, Mihailovic A, West SK, Friedman DS, Ramulu PY. Vision parameters most important to functionality in glaucoma. *Invest Ophthalmol Vis Sci*. 2019;60(14):4556–63.
23. •• Gramer G, Gramer E. Stage of visual field loss and age at diagnosis in 1988 patients with different glaucomas: implications for

- glaucoma screening and driving ability. *Int Ophthalmol*. 2018;38(2):429–41 **This important study compares stage of visual field loss and age at diagnosis between patients with different types of glaucoma with regard to driving ability.**
24. Bhorade AM, Yom VH, Barco P, Wilson B, Gordon M, Carr D. On-road driving performance of patients with bilateral moderate and advanced Glaucoma. *Am J Ophthalmol*. 2016;166:43–51.
 25. • Wood JM, Black AA, Mallon K, Thomas R, Owsley C. Glaucoma and driving: on-road driving characteristics. *PLoS One*. 2016;11(7):e0158318 **This study used a standardized on-road assessment to assess the types of driving errors and locations most problematic for older drivers with glaucoma compared with those without glaucoma.**
 26. Kasneci E, Sippel K, Aehling K, Heister M, Rosenstiel W, Schiefer U, et al. Driving with binocular visual field loss? A study on a supervised on-road parcours with simultaneous eye and head tracking. *PLoS One*. 2014;9(2):e87470.
 27. Lee SS, Black AA, Wood JM. Scanning behavior and daytime driving performance of older adults with glaucoma. *J Glaucoma*. 2018;27(6):558–65.
 28. Kunimatsu-Sanuki S, Iwase A, Araie M, Aoki Y, Hara T, Nakazawa T, et al. An assessment of driving fitness in patients with visual impairment to understand the elevated risk of motor vehicle accidents. *BMJ Open*. 2015;5(2):e006379.
 29. Kunimatsu-Sanuki S, Iwase A, Araie M, Aoki Y, Hara T, Fukuchi T, et al. The role of specific visual subfields in collisions with oncoming cars during simulated driving in patients with advanced glaucoma. *Br J Ophthalmol*. 2017;101(7):896–901.
 30. Prado Vega R, van Leeuwen PM, Rendon Velez E, Lemij HG, de Winter JC. Obstacle avoidance, visual detection performance, and eye-scanning behavior of glaucoma patients in a driving simulator: a preliminary study. *PLoS One*. 2013;8(10):e77294.
 31. Diniz-Filho A, Boer ER, Elhosseiny A, Wu Z, Nakanishi M, Medeiros FA. Glaucoma and driving risk under simulated fog conditions. *Transl Vis Sci Technol*. 2016;5(6):15.
 32. Ogata NG, Daga FB, Jammal AA, Boer ER, Hill LL, Stringham JM, et al. Mobile telephone use and reaction time in drivers with glaucoma. *JAMA Netw Open*. 2019;2(4):e192169.
 33. Glen FC, Smith ND, Crabb DP. Impact of superior and inferior visual field loss on hazard detection in a computer-based driving test. *Br J Ophthalmol*. 2015;99(5):613–7.
 34. Ungewiss J, Kubler T, Sippel K, Aehling K, Heister M, Rosenstiel W, et al. Agreement of driving simulator and on-road driving performance in patients with binocular visual field loss. *Graefes Arch Clin Exp Ophthalmol*. 2018;256(12):2429–35.
 35. Steinkuller PG. Legal vision requirements for drivers in the United States. *Virtual Mentor*. 2010;12(12):938–40.
 36. • Ayala M. Comparison of the monocular Humphrey visual field and the binocular Humphrey Esterman visual field test for driver licensing in glaucoma subjects in Sweden. *BMC Ophthalmol*. 2012;12:35 **This study compares and shows significant differences between use of the monocular Humphrey visual field and the binocular Humphrey Esterman visual field test for drivers licensing among individuals with glaucoma in Sweden.**
 37. McLean IM, Mueller E, Buttery RG, Mackey DA. Visual field assessment and the Austroads driving standard. *Clin Exp Ophthalmol*. 2002;30(1):3–7.
 38. Montana CL, Bhorade AM. Glaucoma and quality of life: fall and driving risk. *Curr Opin Ophthalmol*. 2018;29(2):135–40.

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