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# Examining the Association Between Age-Related Macular Degeneration and Motor Vehicle Collision Involvement: A Retrospective Cohort Study

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## Abstract

**Background—**Little is known about motor vehicle collision (MVC) risk in older drivers with age-related macular degeneration (AMD). The purpose of this study is to examine associations between MVC involvement and AMD presence and severity.

**Methods—**In a retrospective cohort study pooling the samples from four previous studies, we examined associations between MVC rate and older drivers with early, intermediate, or advanced AMD as compared to those in normal eye health. MVC data were based on accident reports obtained from the state agency that compiles this information.

**Results—**MVC rate was highest among those in normal eye health and progressively declined among those with early and intermediate disease, and then increased for those with advanced AMD. However, only for drivers with intermediate AMD was the MVC rate significantly different (lower) as compared to those in normal eye health, regardless of whether the rate was defined in terms of person-years (RR 0.34, 95% CI 0.13–0.89) or person-miles (RR 0.35, 95% CI 0.13–0.91) of driving.

**Conclusion—**These results suggest that older drivers with intermediate AMD have a reduced risk of collision involvement. Further research should investigate whether self-regulatory driving practices by these drivers (avoiding challenging driving situations) underlies this reduced risk.

### Keywords

driving; age-related macular degeneration; vision impairment

## INTRODUCTION

Driving is the primary source of personal transportation in many countries. Older drivers are the fastest growing group of drivers in the United States and the United Kingdom, both in terms of the number of drivers behind the wheel and number of miles driven per year.[1,2] Older drivers have among the highest rates of crash involvement of all drivers.[3] Once in a collision they are at higher-risk for death or disabling injury.[4] Driving is inarguably a visual task,[5] and thus it is important to examine what types of eye conditions and vision impairment common in late adulthood could be contributing to older adults increased risk for unsafe driving.

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Age-related macular degeneration (AMD) is the leading cause of irreversible vision impairment in older adults in many countries.[6] Previous studies on driving and AMD have largely focused on self-report data -- questionnaires and focus groups. Drivers with AMD report greater driving difficulty as compared to those without AMD, with the degree of difficulty being worse with greater disease severity.[7,8] Focus groups show that driving problems are a frequently cited visual complaint of daily living [9–11] Studies also reveal that drivers with AMD, compared to drivers free of the disease, are more likely to report self-regulatory driving behaviors, specifically avoiding challenging driving situations (e.g., night, rush hour traffic,),[12,13] limiting their driving exposure (e.g., mileage on the road),[14] and stopping driving altogether. [11,15–17] These behaviors, if implemented, could be viewed as adaptive in that they can reduce risk for collision involvement.

Yet surprisingly little is known about AMD and crash risk as summarized in a recent review of the literature.[18] Previous epidemiological studies on older drivers have not found an association between AMD and MVC involvement.[19–21] However these studies were not well positioned to address the question for several reasons; they focused broadly on older drivers in general with very few cases of AMD in the sample, contained no information on disease severity, and/or relied on self-report of AMD presence. In a driving simulator study persons with AMD exhibited slower braking response time, slower driving speed and more lane crossings, compared to those without AMD.[13] However performance in a driving simulator has questionable generalizability to their actual on-road driving. No studies to date have examined on-road driving performance by drivers with AMD.

The purpose of this retrospective cohort study is to examine associations between MVC involvement and AMD presence and severity as defined by fundus photography and an AMD severity grading system, making use of a pooled sample of drivers from four previous studies on AMD.[22–25]

## MATERIALS AND METHODS

This study was approved by the Institutional Review Board of the University of Alabama at Birmingham (UAB). Individuals who had participated in four previous studies on AMD[22–25] conducted in the Department of Ophthalmology, University of Alabama at Birmingham (UAB) between 2001 and 2008 were pooled for the purpose of this retrospective cohort study. Participants from all four studies were recruited through the same sources, the retina and comprehensive ophthalmology services of the UAB Department of Ophthalmology. Inclusion criteria for participants in all studies were persons aged ≥ 55 years who had either AMD or normal retinal health. At the time of enrollment in each of the original studies, AMD presence and severity was determined by fundus photography and subsequent grading of images. Stereoscopic color 30° fundus photographs were taken with a FF450 Plus fundus camera (Carl Zeiss Meditec, Dublin, CA) after dilation of the pupil to at least 6 mm. Photographs were evaluated using the Age-Related Eye Disease Study (AREDS) severity scale for AMD[26] by a trained grader masked to the clinical and functional characteristics of participants. AMD disease presence and severity is defined for the eye with better visual acuity as follows: AREDS grade 1 = normal eye health, AREDS grade 2 – 5 = early AMD, AREDS grade 6 – 8 = intermediate AMD, and AREDS 9 – 11 = geographic atrophy in central or peripheral macula or choroidal neovascularization.

In all studies, persons were excluded from enrollment if the medical record or a general health interview indicated that they had glaucoma, optic neuropathy, or any ocular conditions other than AMD, neurological diseases such as Alzheimer's disease, Parkinson's disease, or multiple sclerosis, history of stroke, or diabetes. At the time of enrollment in each original study, we collected demographic and general health information and best-corrected

visual acuity in each eye using the Early Treatment of Diabetic Retinopathy Study (ETDRS) chart expressed as logarithm of the minimum angle of resolution.[27] Contrast sensitivity was assessed using the Pelli-Robson chart[28] and the letter-by-letter scoring method.[29]

Because the current study focused on driving, we excluded those participants from the original samples who at the date of their enrollment in that study had either stopped driving or did not have a driver's license in the State of Alabama. Verification of licensure was provided by the Alabama Department of Public Safety (ADPS), the state agency responsible for driver licensing.

The primary outcome of interest was motor vehicle collision (MVC) involvement between the enrollment date in the original study (between 2002 and 2008 depending on the study) and March 2009, the designated end date of the retrospective follow-up period. This information was obtained from Alabama Department of Public Safety in the form of hard-copy accident reports. These reports indicated whether the driver (our participant) was designated at-fault for the MVC by the police officer at the scene. In 2009 we contacted participants by telephone to administer the Driving Habits Questionnaire[30] in order to obtain an estimate of their annual mileage. The questionnaire also addressed if and when the participant had stopped driving during the follow-up period.

Demographic, clinical and visual function characteristics were compared according to AREDS severity using t- and chi-square tests, as appropriate, and Poisson regression was used to compare the total number of MVC per person-year and per mile driven according to AREDS grades using AREDS grade 1 (i.e., normal eye health) as the referent. Person-miles of travel was estimated using: (a) person-years, which is the chronological time between enrollment in the original study and March 2009 or the date of self-reported driving cessation, whichever came first and (b) self-reported annual mileage. Logistic regression was used to compare the risk of being involved in at-least one MVC also using those in normal eye health as the referent.

## RESULTS

Table 1 presents demographic and visual function information on the pooled sample, stratified by AMD presence and severity. There was a progressive increase in age with increasing disease severity though there were no significant differences with respect to gender or race. The average annual self-reported mileage was 8,500 miles with those in normal eye health reporting higher mileage (9,125) than those with advanced disease (7,436); however these differences were not statistically significant owing to the wide variability within each group. Both visual acuity and contrast sensitivity worsened with increasing disease severity; this was true for both the better and worse eye.

Table 2 presents the MVC risk and rates (per 100 person-years and 1,000,000 person-miles) as well as risk and rate ratios and associated 95% confidence intervals. MVC risk was highest among those in normal eye health (38.1%) and progressively declined among those with early (19.6%) and intermediate (8.2%) disease only to increase among those in the advanced disease group (16.0%). This pattern was replicated for both sets of MVC rates (person-years and person-miles). However, the decreased MVC risk and rates were only significantly depressed (between ~60–80%) among those with intermediate disease compared to those in normal eye health; none of the other risk or rate ratios for other levels of AMD severity were significantly different from those in normal eye health. Adjustment for age did not change this pattern of results nor did it meaningfully change the point estimates.

## DISCUSSION

This is the first study to examine MVC risk in older drivers with AMD as a function of disease severity. AMD has a very wide spectrum of severity from a structural standpoint, and also functional vision in AMD can range from very minor impairment to central vision blindness. Thus grouping all levels of disease severity together in an analysis of MVC risk is likely to lead to un-interpretable results. In the present study we found that older drivers with intermediate AMD have a reduced risk of crash involvement compared to drivers in normal eye health. At first glance this may seem contrary to expectation since those with intermediate AMD will typically have moderate vision impairment that could impact driving performance and road sign recognition. Yet drivers with intermediate AMD may be far enough into their disease course that they recognize a need to compensate for visual problems by exercising a great deal of caution on the road. There is evidence that older drivers with AMD avoid challenging driving situations (e.g., night, rush hour traffic),[12,13] however these studies did not examine this issue as a function of disease severity. To what extent these self-regulatory practices reduce MVC risk in older drivers with AMD is a question worthy of investigation.

It is interesting that drivers with early AMD did not have a significantly elevated MVC rate compared to those in normal eye health. It could be that their vision is not yet impaired to a level that threatens driving performance, or alternatively, they may not be fully aware of the driver safety ramifications of the vision impairment that they do have, given that they are early in their disease course. However, previous research on drivers with early AMD suggests that some do acknowledge driving difficulty, particularly at night, and seek to avoid night driving.[8,10] Impaired dark adaptation and reduced scotopic sensitivity is characteristic of early AMD, even when visual acuity is normal.[31–33]

Our results imply those older drivers with advanced AMD do not have a reduced MVC risk as do those with intermediate AMD. However, caution is appropriate in making such a conclusion since the sample size for advanced AMD was considerably lower than the other groups. In addition, the advanced AMD group was a mixture of those with geographic atrophy (GA) and choroidal neovascularization (CNV), types of AMD that can have differential functional ramifications. However, when we looked at MVC risk separately for those with GA and CNV, the risk and rate ratios were similar to each other and to that for the subgroups combined.

Study strengths and limitations should be noted. This is the first study on MVC risk in older drivers with AMD where the crash data were not based on self-report by the participant driver, but rather, were obtained from the government agency that complies accident report files on each licensed driver. Self-report crash data is notoriously unreliable.[34] AMD disease severity was defined in terms of a standard, accepted, and commonly used grading system and coded by a masked and experienced grader. A number of limitations must also be acknowledged. The cohort of study participants was pooled from several ongoing studies and thus is not population-based and may not be generalizable to all drivers with AMD. The pooled sample size was relatively low for a MVC risk study given that MVCs are rare events.

In conclusion, our results suggest that older drivers with intermediate AMD have a reduced risk of collision involvement. Further research should be designed to not only confirm this association with a sample with large numbers of drivers at each level of disease severity, but should probe the self-regulatory driving practices used by AMD drivers to determine how these strategies may impact collision risk.

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**Table 1**

Demographic and visual function characteristics stratified by disease presence and severity

| | No AMD AREDS 1 (N=63) | Early AMD AREDS 2–5 (N=56) | Intermediate AMD AREDS 6–8 (N=61) | Advanced AMD AREDS 9–11 (N=25) | p-value | Total (N=205) |
|---|---|---|---|---|---|---|
| **Age, years, mean (SD)** | 69.2 (5.7) | 72.7 (6.7) | 75.0 (6.2) | 75.9 (6.9) | <0.0001 | 72.7 (6.8) |
| **Gender, n (%)** | | | | | 0.68 | |
| Males | 27 (42.9) | 29 (51.8) | 32 (52.5) | 13 (52.0) | | 101 (49.3) |
| Females | 36 (57.1) | 27 (48.2) | 29 (47.5) | 12 (48.0) | | 104 (50.7) |
| **Race/Ethnicity, n (%)** | | | | | 0.64 | |
| White | 59 (93.7) | 54 (96.4) | 60 (98.4) | 25 (100.0) | | 190 (96.6) |
| African American | 3 (4.8) | 2 (3.6) | 1 (1.6) | 0 (0.0) | | 6 (2.9) |
| Hispanic | 1 (1.6) | 0 (0.0) | 0 (0.0) | 0 (0.0) | | 1 (0.5) |
| **Annual Mileage, mean (SD)** | 9,125 (5,444) | 8,137 (3,032) | 8,622 (8,153) | 7,436 (2,875) | 0.60 | 8,500 (5,684) |
| **Visual Acuity, logMAR, mean (SD)** | | | | | | |
| Better eye | 0.03 (0.11) | 0.15 (0.20) | 0.18 (0.17) | 0.26 (0.22) | <0.0001 | 0.13 (0.19) |
| Worse eye | 0.12 (0.20) | 0.31 (0.35) | 0.42 (0.40) | 0.44 (0.40) | <0.0001 | 0.30 (0.36) |
| **Contrast Sensitivity, log sensitivity, mean (SD)** | | | | | | |
| Better Eye | 1.48 (0.13) | 1.40 (0.19) | 1.32 (0.26) | 1.29 (0.26) | <0.0001 | 1.39 (0.22) |
| Worse Eye | 1.45 (0.14) | 1.31 (0.31) | 1.12 (0.44) | 1.14 (0.47) | <0.0001 | 1.27 (0.37) |

## Table 2

Number of collisions, collision risk and collision rate during the observation period, stratified by disease presence and severity

| | No AMD AREDS 1 (N=63) | Early AMD AREDS 2–5 (N=56) | Intermediate AMD AREDS 6–8 (N=61) | Advanced AMD AREDS 9–11 (N=25) |
|---|---|---|---|---|
| **Collisions** | 24 | 11 | 5 | 4 |
| **Collision Risk (%)** | 38.1 | 19.6 | 8.2 | 16.0 |
| **RR (95% CI)** | 1.00 | 0.48 (0.20–1.18) | 0.22 (0.08–0.64) | 0.46 (0.14–1.54) |
| **Collision Rate** * | 5.84 | 4.00 | 2.04 | 5.46 |
| **RR (95% CI)** | 1.00 | 0.67 (0.32–1.39) | 0.34 (0.13–0.89) | 0.93 (0.31–2.77) |
| **Collision Rate** ** | 6.38 | 4.67 | 2.21 | 7.07 |
| **RR (95% CI)** | 1.00 | 0.73 (0.36–1.50) | 0.35 (0.13–0.91) | 1.11 (0.38–3.19) |

* Per 100 person-years

** Per 1,000,000 person-miles