Prospective Study of Brief Neuropsychological Measures to Assess Crash Risk in Older Primary Care Patients

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Background: **Practicing primary care physicians often encounter the difficult clinical situation of evaluating the older driver. We wanted to investigate the relation between self-reported driving behavior, neuropsychological measures, and crash risk to inform the development of a test battery that could predict unsafe driving behavior and was feasible for use by primary care physicians.**

Methods: **This study was a prospective follow-up of 107 drivers aged 65 years and older recruited from a primary care setting in 1995. Tests of attention, visual information processing, spatial orientation, and general mental status were administered at baseline. At baseline and after 2 years of follow-up, patients were asked about their driving history using the driving questionnaire. Risk for reported crashes in the follow-up period was assessed in relation to baseline driving history and measures of cognition.**

Results: **Baseline self-reports of driving habits and attitudes were associated with an increased risk of reporting a crash after 2 years of follow-up (relative risk ratio = 5.31; 95% confidence interval [CI], 0.63, 44.63). In addition, baseline tests of attention, visual information processing, and spatial orientation were associated with an increased risk of reporting motor vehicle crash at follow-up. For example, respondents with poor performance on the Trail Making Test - part A, were almost four times more likely to report a crash at follow-up (risk ratio = 3.15; 95% CI, 0.76, 13.07).**

Conclusion: **Although our conclusions are tempered by small sample size, this preliminary study suggests that brief cognitive tests and simple questions about driving habits warrant further investigation as indicators of crash risk with potential utility for assessing older drivers in primary care. (J Am Board Fam Pract 2002;15:11–9.)**

The evaluation of the older driver can be a difficult clinical challenge for the practicing primary care physician. Given the balance between maintaining independence and concern for public safety, at what point should physicians consider that the risk of driving is too great? Whereas clinical recommendations for office-based assessment of at-risk older drivers include static visual screening, auditory screening, Mini-Mental State Examination (MMSE), functional assessment, and review of alcohol use and medications, empirical evidence for these recommendations is limited.[1–4] For example, total MMSE score and functional status appear to be poorly associated with crash risk.[5–7] One problem is that standard tests, such as the MMSE, might not accurately assess the perceptual and attentional processes that could be more directly related to driving skill than memory or other tasks. In addition, it is possible that findings from studies conducted in specialty clinics might not generalize to the older drivers seen by the primary care physician.[8–12]

According to the Global Burden of Disease project of the World Health Organization, motor vehicle accidents will rank third behind heart disease and major depression as a worldwide cause of disability by 2020.[13] Older drivers make up approx-

Submitted, revised 12 April 2001.

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The baseline assessments were supported by a grant to Dr. Keyl from the American Association of Retired Persons. Follow-up interviews were supported by a grant to Dr. Gallo from the Maryland Academy of Family Physicians and the American Academy of Family Physicians.

This paper was previously presented at the Gerontological Society of America annual conference, 1999.

imately 13% of the current driving population and are the fastest growing segment of drivers.[14] In the United States, 33 million drivers are expected to be aged 65 years and older in the year 2020.[15] Compared with younger adults, the older driver is at a disadvantage because older adults often experience an increase in medical illness, psychopathology, and cognitive changes that influence driving ability and increase the risk of fatality. Despite a high frequency of voluntary adaptations, such as driving less at night and driving shorter distances over familiar roads, the older driver has a higher crash rate per mile driven than any other adult age-group.[15] Older drivers with Alzheimer disease and other dementing illnesses, however, might be unable to assess their driving competency correctly and fail to self-regulate their driving behavior.[16–19] At the same time, some older drivers, particularly women, might overrestrict their driving.[20] What is desirable would be a history and physical examination protocol that could be administered by the physician or ancillary staff when the question of suitability for continued driving arises.

Several aspects of cognitive and neuropsychological function, such as visual and auditory attention, have been found to correlate with driving performance, but causal inference from cross-sectional studies is limited.[21,22] When the information is obtained at the same interview, as is done in cross-sectional studies, one cannot be sure whether reports of driving behaviors and previous crashes are influenced by performance on the neuropsychological tests. For example, poor memory can influence both reports of past events and present performance on neuropsychological tests. Prospective studies have considerable advantages when compared with cross-sectional studies in assessing the temporal relation of neuropsychological tests and self-reported driving behavior and crash risk. In prospective studies, the temporal relation is clear. Despite potential problems with prospective studies, such as loss of follow-up as a result of death, refusals, or other reasons, only prospective follow-up studies can shed light on how performance at baseline predicts outcomes of interest.

Because we knew of no prospective studies of driving assessment of older adults from primary care settings, our goal was to investigate the relations between self-reported driving behavior, neuropsychological measures, and crash risk at follow-up so that we could develop a test battery that could predict unsafe driving behavior and that would be feasible for use by primary care physicians. This study was part of a larger project, the goal of which was to develop an assessment protocol that is valid and easy to administer for office-based assessment of driving.[23] We capitalized on baseline assessments conducted in 1995 in one of the primary care practices that participated in the larger project and then obtained reports of crashes after 2 years of follow-up. Our goal was to examine whether performance on the brief neuropsychological assessment conducted in primary care or self-reported driving behavior was predictive of subsequent reports of crashes 2 years later.

Methods

Baseline Driving Study

In the baseline driving study, funded by the American Association of Retired Persons (AARP), a research assistant trained to administer the neuropsychological measures and the driving questionnaire conducted baseline assessments at four primary care sites. A consecutive sample of patients seeking medical care was recruited from waiting rooms of participating primary care practices. Of the 146 patients recruited for the study, approximately 15% scored less than 24 (range 16 to 23) on the Mini-Mental State Examination, indicating mild or moderate cognitive impairment. Medical illness did not preclude participation. Older drivers recruited from the physicians' offices were given $10 for participating in the baseline assessments.

Follow-up of Older Drivers

To simplify follow-up within the constraints of available resources, we restricted our follow-up of older drivers to a single primary care site that had participated in the baseline study. Six family physicians practice at this site at which approximately 12,000 visits from older adults occur annually. This practice site is not affiliated with an academic institution. We obtained contact information on all 107 persons who were assessed in 1995 at this site. In the summer of 1997, we sent an introductory letter to the older drivers who had participated in the 1995 interviews, and then attempted to reach the participants on the telephone. For persons who consented to be interviewed on the telephone, we obtained information on changes in driving history and habits since the baseline interview. The study protocols for the baseline and follow-up interviews were approved by the Committee on Human Research of the Johns Hopkins University School of Hygiene and Public Health.

Driving History and Habits

The driving questionnaire used in baseline driving study and at follow-up was designed to assess where, when, how often, and how far patients drive. The questionnaire also elicited a history of driving habits, traffic crashes, violations, and near misses during the 2 years before the interview.

To optimize the use of information provided from previous work using the driving questionnaire, a factor analysis of responses was performed using the principal components method and varimax rotation.[23] This analysis resulted in two factors. Factor 1, driving habits and attitudes, included near misses, self-reports of irritation while driving, self-reports of changes in driving ability, and self-rating of driving safety. Factor 2, driving-related events, included getting honked at while driving, getting lost, number of tickets, and number of crashes. Based on the results of the factor analysis, two composite outcomes were created from the driving questionnaire at baseline. The first outcome ranged from 0 to 4, with 1 point added for each of the following: safety rating of 8 or less, any near misses, any self-reported change in driving ability, and reports of becoming irritated while driving or frustrated or angry at the way other people drive. The second outcome also ranged from 0 to 4, with 1 point added for each of the following: getting honked at while driving, sometimes or often getting lost, any moving violations, and any crashes.

Cognition

Our aim was to develop a battery of measures that are valid as a screening test and easy enough to be administered routinely in real-world settings, such as physicians' offices. The purpose of the testing was to characterize the cognitive functioning of older drivers who visit their primary care physician for medical care. For the AARP baseline driving study and for the follow-up study, selection of the domains to be tested was based on previous findings of our research team in a pilot study of Alzheimer disease and driving and a prospective study funded by the National Institute of Aging comparing Alzheimer disease patients with healthy older drivers.[24] Tests that were able to distinguish between drivers with and without crashes and performance on a driving simulator were selected for further study.

The battery of tests taps various aspects of attention, visual information processing, and spatial orientation. These areas of cognition were specifically targeted because they have been found to correlate with performance on a driving simulator, informant-reported crashes and near misses, and change in miles driven, which are generally thought to be important for safe driving.[24] It is recognized that there are other tests that were not included in this battery but have been shown to correlate with driving performance and crash involvement, such as Owsley and colleagues' "useful field of view" measure.[25,26] The goal of this study, however, was to develop a short screening test that can be easily implemented in physicians' offices, and some measures would not easily lend themselves to that setting. For this reason, we selected only those tests that would be easily adapted for implementation in primary care practice. Cognitive status was assessed using six brief measures, described below, with estimates of the time to complete each task. The neuropsychological measures fall into three broad areas of cognitive and motor functioning: attention, visual information processing, and spatial orientation.

Attention

The Trail-Making Test, part A (2 minutes) is a brief test of visuomotor tracking involving motor speed.[27] In this test, the participant is required to connect 25 numbers in a series. Time to completion was recorded.

The Brief Test of Attention (10 minutes) is a short test of auditory selective attention with two conditions, each with 10 trials.[28] To administer the Brief Test of Attention, a tape recorder announces a series of digits and letters. In one condition, respondents are required to report the number of digits presented. In the second condition, respondents are asked to report the number of letters presented. The number of digits and letters in the series increases from 4 to 18 in the course of 10 trials. A score of the number of trials correctly completed was recorded (total possible score of 20). Patients who could not complete the task were included in the low-scoring tertile.

Visual Information Processing

Visual Reproduction (5 minutes), a subset of the Wechsler Memory Scale, is a test of immediate visual memory.[29] Participants view a stimulus line design for 10 seconds and then are asked to reproduce the design from memory. In this study, four stimulus cards were displayed, one at a time. Drawings were scored according to standard criteria. Maximum scores for the four stimulus cards are 7, 7, 8, and 18 for a total possible maximum score of 41.

The Motor-Free Visual Perception Test (3 minutes) is a 36-item test of a variety of aspects of visual perception.[30] In this study, we included 11 items assessing visual closure. Participants are shown a card with a target figure and are asked to choose from four choices of incomplete drawings the one drawing that, if finished, would look like the target figure. The total number of items correct was recorded, with a possible maximum score of 11.

Spatial Orientation

The Standardized Road Map Test of Directional Sense (5 minutes) assesses left-right directional orientation.[31] Participants were instructed to trace, as quickly as possible, a route through a simulated street map consisting of 32 possible left or right turns. At each turn, participants were asked to specify whether the turn was to the left or to the right. Time taken to complete the route and the number of incorrect directional judgments were recorded.

Mini-Mental State Examination

In addition to the battery of neuropsychological tests, we included the Mini-Mental State Examination (MMSE, 10 minutes), a short standardized mental status examination that has been widely used for clinical and research purposes.[1] The MMSE has been extensively studied, as reviewed by Tombaugh and McIntyre[32] and by Crum and her colleagues.[33] The MMSE assesses orientation to time and place, registration, memory, attention and concentration, praxis, and constructional and language capacity. Because previous work has suggested that the copy polygon task of the MMSE might be independently related to crash risk, we examined this individual item separately.[5,6,34] The copy polygon of the MMSE was scored 0 (error) or 1 (correct). Those who made an error were compared with those who correctly copied the figure.

Thresholds

We created thresholds to sort participants for purposes of comparison. The thresholds are based on the score distributions for drivers with self-reported annual mileage of 5,000 miles or less. We selected the lowest tertile as the cut point. The same cut points were used for all participants, regardless of annual mileage. When the tests are being used routinely to assess older primary care patients, categorizing the scores according to tertile will be preferable. We present the cut point values of these thresholds for each neuropsychological measure in the results section. In the analyses, those who scored below the cut point are compared with those who scored above the cut point.

Analytic Strategy

Our analytic strategy consisted of three steps: (1) assess whether baseline measures were associated with completed interviews at follow-up; (2) relate the performance of participants on the cognitive measures administered in 1995 to crashes reported in 1997; and (3) relate the responses concerning driving habits and safety reported in 1995, such as self-reports of getting frustrated or angry with other drivers, to motor vehicle crashes reported at follow-up in 1997. For these analyses, we conducted simple comparisons of proportions using two-tailed chi-square tests of significance with α set at 0.05, recognizing that tests of statistical significance are approximations that serve as aids to interpretation and inference. To adjust selected comparisons for potentially confounding variables, we have used the multivariate form of logistic regression, performed with SPSS software.[35,36]

Results

The 107 older drivers who participated in the baseline assessments in 1995 comprised the target sample for follow-up in 1997. At baseline, the 107 older drivers had a mean age of 72.0 years (standard deviation, 5.3 years). Of this sample, 61% (65 of 107) were men, 62% (66 of 107) had completed 12 or more years of schooling, and 73% (78 of 107) were retired. Of 107 older drivers assessed at baseline, 18 were lost to follow-up, 6 patients had died; of the remaining 83 patients, 74 were contacted for follow-up. Of those contacted for follow-up, complete information on driving status at follow-up was available for 72 drivers.

Table 1. Characteristics of Study Sample According to Status at 2-Year Follow-up

Characteristics	Followed Up %	Lost to Follow-up %
Personal		
Age (older than 75 years)	32.4	27.3
Sex (male)	56.8	69.0
Marital status (married)	75.7	81.8
Education (with 12 or more years)*	68.9	45.5
Employment status		
Working	5.4	9.1
Retired	77.0	63.6
Disabled	1.4	3.0
Health status (fair or poor)	33.8	48.5
Driving habits		
Mileage (<5,000 miles per year)	50.0	54.5
Events (self-reported)		
Tickets	2.7	3.0
Accident	6.8	3.0
Near miss	41.9	48.5
Notice change in driving	43.2	45.5
Tests (scoring below cut point)		
Motor-Free Visual Perception Test—Visual Closure	23.0	15.2
Visual Reproduction*	24.3	42.4
Trail Making Test—part A	21.6	30.3
Standardized Road Map of Directional Sense		
Errors	25.7	27.3
Time to completion	27.0	33.3
Brief Test of Attention*	20.3	48.5
Mini-Mental State Examination	24.3	33.3
Combined driving factors (with 2 or more)		
Driving habits and attitudes	67.6	63.6
Driving-related events	16.2	18.2

*$P < .01$. P values relates to a comparison of persons who were able to be followed with those who were not followed up.

Loss to Follow-up

Our first analytic goal was to compare baseline personal characteristics, driving habits, and neuropsychological test performance with follow-up status (Table 1). The only personal characteristic that significantly differed between the groups was educational status. Of those who participated in the follow-up survey, 68.9% (51 of 74) reported 12 or more years of schooling, compared with 45.5% (15 of 33) of participants lost to follow-up. There were no appreciable differences in baseline driving history and habits across the two groups; however, performance on two of the neuropsychological tests differed by follow-up status. Participants who were lost to follow-up were more likely to have performed poorly on the Visual Reproduction test, a measure of visual information processing, and the Brief Test of Attention, a measure of auditory selective attention. We will address the implications of loss of follow-up in our discussion of study results.

Cognitive Measures and Crash Risk

Our second analytic goal was to relate performance of participants on the neuropsychological tests administered in 1995 to self-reported motor vehicle crashes reported at follow-up interviews in 1997. Of the 72 participants, 10 reported a crash at follow-up. The results of these analyses are presented as relative risk ratios, in which the odds of crash at follow-up for persons who scored in the lowest tertile of a given test administered at baseline are compared with the odds of crash at follow-up for persons who scored in the higher tertiles of a given

Table 2. Relative Risk for Crashes Reported at 2-year Follow-up According to Two Combined Driving Factors and Performance on Six Neuropsychological Tests at Baseline.

Test*	Risk of Crash†		
	Upper Tertiles	Lowest Tertiles	Relative Risk‡
Combined driving factors (>2)			
Driving habits and attitudes	4.35	23.08	5.31 (0.63, 44.63)
Driving-related events	17.31	10.00	0.58 (0.06, 5.08)
Trail Making Test—part A (>58.65)	11.54	40.00	3.15 (0.76, 13.07)
Motor-Free Visual Perception Test (<9)	11.76	36.36	2.83 (0.69, 11.64)
Standardized Road Map of Directional Sense			
Number of errors (<11)	12.50	28.57	2.33 (0.58, 9.44)
Time to completion (>106 min)	13.04	25.00	1.96 (0.49, 7.84)
Mini-Mental State Examination			
Total score (<25)	12.50	17.39	1.36 (0.26, 7.09)
Serial 7s (<2)	17.02	13.33	0.78 (0.15, 4.18)
Copy polygon (error)	16.67	12.50	0.76 (0.08, 6.86)
Brief Test of Attention (<11)	16.67	16.67	1.00 (0.20, 5.66)
Visual Reproduction (<26)	16.67	14.29	0.86 (0.15, 4.18)

*Thresholds reported next to test name represent scores corresponding to the lowest tertile.
†Rate per 100.
‡Parentheses show 95% confidence intervals, computed using logistic regression.

test administered at baseline, dividing the former by the latter. This relative risk approach permits a comparison between groups sorted by neuropsychological tests, both with and without statistical adjustments for baseline differences (such as age or miles driven) that might account for variations in the observed reports of crashes at follow-up. The numeric values of the cut points are displayed in Table 2.

Inspection of the risk ratios found that the association of three cognitive measures (the Motor-Free Visual Perception Test visual closure subscale, the Trail Making Test - part A, and the Standardized Road Map Test of Directional Sense) with self-reported crashes during the 2-year follow-up interval showed large estimates of relative risk, although the 95% confidence intervals for the point estimates of the relative risk included the null (Table 2). The relative risk for crash at follow-up associated with poor performance on the Trail Making Test was 3.15 (95% CI, 0.76, 13.07). The corresponding point estimate of the relative risk for poor performance on the Motor-Free Visual Perception Test was 2.83 (95% CI, 0.69, 11.64). The Standardized Road Map Test of Directional Sense resulted in two scores, number of errors and time to complete the task. For directional sense errors, persons who scored in the lowest tertile were 2.33 times (95% CI, 0.58, 9.44) as likely to report a crash at follow-up. Persons who were in the lowest tertile for time to complete the task were 1.96 times (95% CI, 0.49, 7.84) as likely to report a crash at follow-up. Point estimates were not markedly affected after entering age and miles driven into the model as continuous variables to adjust for baseline differences (data not shown).

Driving Habits and Crash Risk

Our third analytic goal was to relate the responses from the driving questionnaire in 1995 to self-reported crashes at the follow-up interviews in 1997. The total score on combined driving factor 1, driving habits and attitudes, was significantly associated with crash at follow-up ($P = .006$). Baseline reporting of two or more of the following was associated with a fivefold increased risk of crash during the 2-year follow-up period (relative risk = 5.3; 95% CI, 0.63, 44.63): near misses, low self-rating of driver safety, self-reported change in driving abilities or habits, and getting frustrated or angry at other drivers. This point estimate was not markedly affected after adjustment for differences in age or miles driven (data not shown). The relation between the driving habits and attitudes factor indicates that a simple set of questions regarding driving history and habits might be useful for recognizing at-risk drivers.

Analysis of the second combined factor, driving-related events, tending toward the null value, showed that the total score on factor 2 was not significantly related to crash at follow-up ($P = .61$), and when the analysis was dichotomized, participants scoring 2 or higher had a relative risk of 0.58 (95% CI, 0.48, 4.38) of crash at follow-up. In this sample, baseline reporting of two or more of the following was not associated with increased risk of crash occurrence during the follow-up period: crashes, moving violations, getting lost while driving, and other drivers honking. If a history of crashes or moving violations at baseline was related to loss to follow-up or cessation of driving, the estimates of the relative risk for crashing during the follow-up period might be underestimated.

Discussion

The goal of this study was to determine valid and reasonable assessment procedures that could be performed in a medical office, along with other clinical tests, to assist physicians in making recommendations about driving for older patients. We found that self-reports of driving habits, safety, and changes in driving abilities were associated with a fivefold increase in crash risk during the course of a 2-year follow-up interval. In addition, performance measures of attention, visual information processing, and spatial orientation had substantial point estimates of increased crash risk, although they did not reach standard conventions of statistical significance.

Before discussing implications for practice and further research, limitations of our study deserve comment. First, our results were obtained from a single primary care site whose patients might not be representative of most primary care practices. On the other hand, this practice was not academically affiliated and was probably similar to other practices in the region.

Second, the loss to follow-up from death, refusals, and other reasons for failure to have completed the driving questionnaire 2 years after baseline assessments could bias relative risk estimates in unknown ways. Comparing the characteristics of persons who were followed up with those who were not followed up showed no difference in driving history and habits, and only a few differences in sociodemographic characteristics (the persons lost to follow-up were less likely to report 12 or more years of schooling) and performance tests (persons lost to follow-up tended to make more errors in Visual Reproduction and the Brief Test of Attention). We point out that loss to follow-up of persons with impairments at baseline can be expected to bias our estimates of association with crash risk toward the null. In other words, our estimates of risk and confidence intervals may be conservative.

Third, the sample size is small because we did not have the resources to follow up all patients at other primary care sites. Finally, we have not considered whether medical conditions, such as diabetes, are related to neuropsychological test performance or crash risk. In general, recent studies do not provide evidence that medical conditions as such are strongly related to crash risk.[5,21,22,37]

Standardized mental status testing, exemplified by the MMSE, was not related to crash risk in our study, a finding consistent with other reports.[5,21,38] Some investigators have found that a single item on the MMSE, the copy polygon task, was associated with crash risk, but only in cross-sectional studies.[5,34] The cognitive functions tapped by the MMSE (eg, verbal memory) might not be those most relevant to driving. Several simple neuropsychological tests that assess visual attention, information processing, and spatial orientation (ie, Trail Making Test, Motor-Free Visual Perception Test, and Standardized Road-Map of Directional Sense) might relate more closely to abilities required for safe driving.

It would be premature to exclude the Visual Reproduction task and the Brief Test of Attention from further study based on our results. Although not associated with crash risk, these two measures are exactly the tests that were associated with loss to follow-up. It could be that the strong relation to loss to follow-up as a result of death or other inability to participate might explain the failure to find a relation with crash risk for Visual Reproduction and for the Brief Test of Attention.

Despite limitations, our study warrants attention because we have evidence that simple historical and neuropsychological assessments are associated with increased crash risk in older primary care patients. If driving abilities are in question, asking about driving habits and abilities as part of a clinical interview could be instrumental in deciding whether further assessment is needed. Such assessment would involve asking questions regarding near misses, irritation while driving, changes in driving ability, and self-rating of driver safety. These questions are simple and do not take much time, but alone they were the strongest predictors of future crashes. If clinical signs and answers to driving habits questions indicate possible driving impairment, an office assistant could administer the brief battery of tests. This brief battery could be used to assess older adults in primary care, helping to select those who require further testing (eg, on-road performance tests). Because most practices have limited time and reimbursement opportunities, a portion of the tests from our battery, particularly those with the strongest associations (ie, the Trail Making Test - part A, the Motor-Free Visual Perception Test, and the Standardized Road Map of Directional Sense), could be used to confirm suspicions of impairment in driving-related abilities. The more detailed and complete the cognitive assessment is, however, the more accurate the prediction of future crash risk. In some cases, poor performance on these tests could be enough, together with other clinical data, to recommend that an older adult curtail or stop driving.

In addition, the association between this brief battery with crash risk did not appear to be markedly affected by adjustment for age or miles driven. In practical terms, we believe that the unadjusted rates will be more useful clinically because they do not require physicians to carry out adjustments for age and mileage before applying the results. Not having to adjust for age or miles driven offers preliminary evidence that a brief battery could be constructed without a complicated scoring schema, suggesting that this battery of tests might not only be clinically valid but practically feasible.

This study provides evidence that it would be possible to develop brief, effective, and feasible assessment strategies that can assist physicians in evaluating older drivers in primary care practice encounters. Future prospective studies with a larger sample size are necessary to confirm these results.

Ian Steines interviewed the participants at follow-up and the physicians and patients who participated in the study.

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