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Heart failure is a risk factor for incident driving cessation among community-dwelling older adults: Findings from a prospective population study

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Abstract

Background—Heart failure (HF) patients often depend on driving for access to specialty care. We analyzed a public-use copy of the Cardiovascular Health Study (CHS) data to determine if HF is a risk factor for driving cessation and to identify other risk factors for driving cessation among those with HF.

Methods and results—Of the 5383 community-dwelling drivers ≥65 years (mean age, 73 years, 55% women, 13% African American), 839 had HF: 246 had baseline prevalent HF and 593 developed incident HF before driving cessation during 9 years of follow-up. Incident driving cessation occurred at rates of 3980 and 3709 per 10,000 person-years of follow-up for those with and without HF, respectively (unadjusted hazard ratio {HR} associated with HF as a time-varying variable, 2.13; 95% confidence interval {CI}, 1.83–2.47; $p < 0.001$). This association remained unchanged after multivariable risk adjustment (HR, 1.43; 95% CI, 1.21–1.68; $p < 0.001$). Among the 839 older drivers with HF, independent predictors for incident driving cessation were age ≥75 years (HR, 1.99; 95% CI, 1.44–2.73; $p < 0.001$), female gender (HR, 1.93; 95% CI, 1.37–2.74; $p < 0.001$), difficulty walking half a mile (HR, 1.47; 95% CI, 1.04–2.08; $p = 0.028$), vision problems (HR, 1.47; 95% CI, 1.07–2.02; $p = 0.018$), and stroke as a time-varying covariate (HR, 1.96; 95% CI, 1.38–2.79; $p < 0.001$).

Conclusion—HF is an independent risk factor for incident driving cessation among community-dwelling older drivers. Several patient characteristics predicted driving cessation in older HF patients, which may be targets for interventions to prevent driving cessation among these patients.

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Keywords

Heart failure; incident driving cessation; older adults; population study

Heart failure (HF) is common among older adults and is associated with poor outcomes including functional decline. Driving cessation, also common in older adults, is known to be associated with negative social and health consequences,¹⁻³ as driving is essential for functional independence and access to quality care. Because HF is a progressive disease often requiring specialty medical care, driving cessation in patients with HF may adversely affect their health care and outcomes. However, it is not well known if HF patients are at higher risk of driving cessation than those without HF. Further, the predictors of driving cessation among those with HF have not also been adequately studied. In the current study, we used a public-use copy of the Cardiovascular Health Study (CHS) data obtained from the National Heart, Lung and Blood Institute (NHLBI) to study if HF is a risk factor for driving cessation and to identify predictors of driving cessation among those with HF.

Methods

Study design and participants

The CHS is an NHLBI-sponsored, ongoing population-based longitudinal study of risk factors for cardiovascular disease in adults ≥ 65 years.⁴ The rationale and design of the CHS have been previously described.⁴⁻⁶ Briefly, an initial cohort of 5201 community-dwelling older adults was recruited between 1989 and 1990 from Sacramento County, California, Washington County, Maryland, Forsyth County, North Carolina, and Pittsburgh, Pennsylvania. A second cohort of 687 African-American older adults was recruited between 1992 and 1993 from three of the same communities (excluding Washington County) using the same sampling and recruitment methods. The primary objective of the CHS was to identify the risk factors for development and progression of cardiovascular disease in older adults.⁴

Of the 5,888 CHS participants, 5,795 were included in the public-use copies of the datasets (93 participants did not consent to be included in the de-identified public-use data). At baseline, CHS participants were asked a question related to their driving vision: “*Do you have enough vision to drive*”. The response were recorded as either “Yes”, “No” or “Don’t drive”. For the purpose of the current analysis, we first excluded 236 participants that had missing values for the baseline driving vision question, and then excluded another 176 participants that had responded “Don’t drive” to the above question. Thus, of the 5,795 participants, 5,383 were used in the current analysis.

Data collection

Comprehensive information on health related variables was collected at baseline and annually thereafter in standardized fashion from all CHS participants. Clinic examinations were performed and telephone contacts made annually from 1989-1990 (baseline) to 1998-1999. Standardized questionnaires were administered at a baseline home interview, at annual clinic visits, and during telephone contacts. Descriptions of data collection methods, including instruments and protocols, have been reported previously.⁴

Prevalent and incident heart failure

Diagnoses of prevalent HF and incident HF were centrally adjudicated by the CHS Events Committee in a process that has been well-described in the literature.⁵⁻¹¹ Briefly, self-reported data of physician-diagnosed HF and medical records were used by the CHS Events

Committee to determine if a diagnosis of HF could be confirmed. The diagnosis of HF was adjudicated through a constellation of symptoms, physical signs, and other supporting findings suggestive of HF, which included the use of medications commonly used for HF and by follow-up surveillance.⁵⁻¹¹ Additional cases of HF were also adjudicated from participants, who did not self-report physician-diagnosed HF based on medical records. Of the 5,383 CHS participants included in the current analysis, 246 had baseline prevalent HF and 593 developed incident HF during follow-up but before driving cessation. Thus a total of 839 (246+593) patients had HF before driving cessation.

Other covariates

Age, sex, race, marital status, living alone, years of education, income, social support score, self-reported general health, depression score, Mini Mental State Examination (MMSE) score, a vision problem, impaired hearing, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, cancer, and arthritis were based on self-reports at baseline. Extensive baseline data were also collected for laboratory variables, electrocardiography and echocardiography.

The time-varying covariates HF, stroke and acute myocardial infarction were ascertained either through regular surveys initiated by the CHS field centers or by participants contacting the local site. Investigator-initiated ascertainment occurred primarily during annual clinic visits and surveillance calls, when participants were asked to provide information on all hospitalizations and outpatient end point diagnoses since the last CHS contact.

Incident driving cessation

The primary end point of the current study was incident driving cessation during 9 years of follow-up. Because CHS did not collect data on driving cessation, we assessed this outcome by analyzing CHS participants' response to a vision-related driving question asked during annual follow-up interviews in 1990-1991, 1992-1993, 1993-1994, 1994-1995, 1996-1997, 1997-1998 and 1998-1999. Participants were asked: "*Do you have enough vision to drive?*" and their responses were recorded as either "*Yes*", "*No*" or "*Don't drive*". Those who responded "*Don't drive*" to the above question were considered to have stopped driving. The time to driving cessation was measured as the time from baseline enrollment (1989-1990) up to the year of the annual visit when the participants reportedly stopped driving. For participants who did not quit driving, time to censoring was based on their time to death or time to the last annual interview (1998-1999).

We validated driving cessation, based on the vision-related driving question, by comparing it with responses to another "*direct*" driving-related question that was asked *only* during the 1997-1998 annual interviews. During that interview, 450 participants were considered to have stopped driving, based on their response "*Don't drive*" to an "*indirect*" driving question "*Do you have enough vision to drive?*" Of these, 94% (423/450) also responded "*No*" to the "*direct*" driving-related question "*Do you currently drive a car?*" asked during the same 1997-1998 annual interviews.

Statistical analysis

Multiple imputation approach was used to impute values for unobserved demographic and health-related characteristics. Baseline characteristics of participants with and without HF were compared using chi-square and Student's t-tests as appropriate. Cox proportional hazard models were used to calculate hazard ratios (HRs) and 95% confidence intervals (CIs) for the association between HF (used as a time-dependent covariate) and incident driving cessation. In the model, HF was the predictor variable and driving cessation was the

dependent variable. We constructed several multivariable models. In model 1, age greater than 75 years old (1=yes, 0=no), sex (female=1), and race (African American=1, all other races=0) were entered into the model, followed by marital status (married=1, else=0), living situation (alone=1, else=0), education (6 categories; Table 1), annual income (4 categories; Table 1), and social support score (used as a continuous variable) in model 2. In model 3, the following additional covariates were forced into the model: self-reported general health (fair-to-poor=1, else=0), the Center for Epidemiologic Studies depression scale and MMSE scores (as continuous variables), and vision (impairment=1, else=0), and hearing (impairment=1, else=0). In the final model, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, cancer, arthritis, atrial fibrillation, left ventricular hypertrophy, left ventricular systolic dysfunction, acute myocardial infarction and stroke were entered into model 3. Acute myocardial infarction and stroke were used as time-varying covariates. Similar models were used to determine the predictors of driving cessation among the 839 HF patients and 4544 participants without HF. P-values of 0.05 (two-sided) were considered statistically significant. SPSS version 18 (Chicago, Illinois) and SAS version 9.2 (Carry, North Carolina) was used for the analysis.

Results

Participants had a mean ($\pm$ SD) age of 73 ($\pm$ 5) years, 55% were women and 13% were African American. Baseline characteristics of the study population by HF are presented in Table 1. Compared to participants without HF, those with HF were older and more likely to be men, less educated, and have a lower income. They were also significantly more likely to report fair to poor general health, have lower MMSE scores, and a greater prevalence of comorbid conditions (Table 1).

Overall, 1,376 (25.6%) older drivers reported driving cessation during 9 years of follow-up. Incident driving cessation occurred in 205 (incidence rate, 3980/10,000 person-years) and 1171 (incidence rate, 3709/10,000 person-years) participants with and without HF (unadjusted hazard ratio {HR}, 2.13; 95% confidence interval {CI}, 1.83–2.47; $p=0.001$), respectively (Table 2). This association remained significant despite multivariable adjustment (adjusted HR, 1.43; 95% CI, 1.21–1.68; $p<0.001$; Table 2). The independent association between HF and incident driving cessation was homogenous across a wide spectrum of participant subgroups, categorized by age (cutoff of 75 years), sex, race, marital status, living situation, education, income, self-reported general health status, vision problem and diabetes mellitus (data not presented).

Among the 839 older drivers with HF, significant independent predictors for driving cessation included age ≥ 75 years (HR, 1.99; 95% CI, 1.44–2.73; $p<0.001$), female gender (HR, 1.93; 95% CI, 1.37–2.74; $p<0.001$), difficulty walking half a mile (HR, 1.47; 95% CI, 1.04–2.08; $p=0.028$), presence of vision problem (HR, 1.47; 95% CI, 1.07–2.02; $p=0.018$), and stroke as a time-varying covariate (HR, 1.96; 95% CI, 1.38–2.79; $p<0.001$; Table 3). Predictors of incident driving cessation among older drivers without HF are displayed in Table 4.

Discussion

The findings from the current analysis demonstrated that HF was associated with driving cessation among community-dwelling older drivers, and that this association was independent of other known risk factors for driving cessation. Further, the findings from the current study also identified a number of baseline characteristics that predicted driving cessation among older drivers with HF. These findings are important as driving plays a crucial role in mobility and functional independence in developed nations, and driving

cessation may negatively affect access and quality of care received by HF patients. To the best of our knowledge, this is the first report of a significant association between HF and driving cessation in older drivers, based on a large prospective population study, in which HF was centrally adjudicated.

The strong bivariate association of HF with incident driving cessation was substantially attenuated after multivariable risk adjustment. This is in part explained by the significant imbalances in various baseline characteristics between participants with and without HF. For example, those with HF were older and more likely to have functional impairment, characteristics associated with an increased risk of driving cessation.¹²⁻¹⁷ On the other hand, HF patients in our study were also more likely to be male, a characteristic that has been shown to be associated with a reduced risk of driving cessation.^{18, 19} Therefore, the unadjusted association between HF and incident driving cessation, observed in our study suggests that age and physical function of older drivers with HF were stronger confounders of driving cessation than male gender was protective. However, the significant multivariable-adjusted association also suggests a potential intrinsic association.

Because driving does not involve much physical activity, it is not clear how HF by itself can increase the risk of driving cessation. However, it is possible that as HF advances and patients become symptomatic with minimal exertion, it may be difficult to walk to and from the vehicle and operate the vehicle controls. It is also possible that HF patients develop other risk factors of driving cessation that act as mediators of driving cessation. Although we were able to adjust for many potential time-varying confounders, such as stroke and acute myocardial infarction, other modifiable confounders may have become imbalanced during follow-up. For example, it is possible that those with HF were more likely to develop diabetes and hypertension and subsequent complications of these conditions, such as diabetic and hypertensive retinopathy and cognitive impairment, which are known to adversely affect driving ability. Though we had no data on stroke severity, it is possible that stroke in HF patients was more severe, thus adversely affecting driving.

Several earlier studies have reported the association of HF and driving cessation.^{12, 14, 20} However, in none of these studies was HF centrally adjudicated. This is an important distinction as HF is a clinical diagnosis, and there is potential for misclassification bias without central adjudication.²¹ To the best of our knowledge, this is the first study to report predictors of driving cessation in a prospective cohort of community-dwelling older drivers with centrally adjudicated HF. The current study is also distinguished by the use of HF as a time-dependent covariate, which may have minimized the regression dilution that would have resulted from development of incident HF among those without HF at baseline.

The findings of the current study have potential clinical and public health implications. HF is the leading cause of hospitalization among older adults and is also associated with increased mortality. HF is also a progressive condition often requiring specialized care in tertiary-care centers. In addition to adversely affecting function and mobility,¹⁻³ driving cessation may limit access to specialized health care and thus adversely affect the timely intervention of appropriate medical measures in older adults with HF. Future studies need to determine whether driving cessation adversely affects quality of care and outcomes in older adults with HF, and if addressing modifiable risk factors for driving cessation may delay or prevent driving cessation among those with HF. However, many HF patients may voluntarily quit driving for other reasons, such as a vision problem or cognitive decline, and therefore, strategies to delay or prevent driving cessation need to be individualized. HF patients, who become home-bound as a result of driving cessation, may benefit from community outreach care programs, such as the Home-Based Primary Care program of the United States Department of Veterans Affairs.²²⁻²⁵

This study has several limitations. Driving status at baseline and during follow-up annual visits was based on data from self-reports of vision-related driving problems and not driving cessation *per se*. Furthermore, driving cessation was not a prespecified outcome in the CHS. However, as mentioned previously, there was a high level of agreement between the measure of driving cessation used in the analysis and an explicit measure of driving cessation available during one of the annual study visits. Moreover, any random misclassification of persons who did not stop driving, as having stopped driving, and vice versa, is likely to result in dilution regression and underestimation of the observed association, thus not posing any serious threat to the validity of our findings. Other limitations include lack of data on the duration of HF for those with prevalent HF at baseline, the frequency of ventricular arrhythmias, the use of implantable cardioverter-defibrillator devices, and prior motor vehicle accidents.

In conclusion, among community-dwelling older drivers, HF is an independent predictor of incident driving cessation, and several baseline characteristics predicted driving cessation among older drivers with HF. Future studies need to examine the impact of driving cessation on quality of care and outcomes of older adults with HF and develop and test interventions to reduce driving cessation in these patients.

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Table 1

Baseline characteristics of Cardiovascular Health Study with and without heart failure

n (%) or mean ($\pm$ SD)	No heart failure (n=4544)	Heart failure (n=839)	P value
Age, years	73 ($\pm$ 5)	75 ($\pm$ 6)	<0.001
Female	2616 (58%)	362 (43%)	<0.001
African-American	602 (13%)	96 (11%)	0.153
Married	3130 (69%)	556 (66%)	0.127
Living alone	812 (18%)	156 (19%)	0.642
Education			
Grade 8 or less	639 (14%)	143 (17%)	0.001
Some high school	598 (13%)	137 (16%)	
High school graduate	1268 (28%)	214 (26%)	
Technical college or some college	1045 (23%)	196 (23%)	
4-year college	508 (11%)	69 (8%)	
Graduate or professional	486 (11%)	80 (10%)	
Income			
$\leq$ \$11,999	1014 (22%)	237 (28%)	<0.001
\$12,000-\$24,999	1616 (36%)	327 (39%)	
\$25,000-\$35,000	804 (18%)	111 (13%)	
$\geq$ \$35,000	1104 (24%)	164 (20%)	
Social support score	8 ($\pm$ 3)	8 ($\pm$ 3)	0.052
Center for epidemiologic studies depression scale	4 ($\pm$ 4)	5 ($\pm$ 5)	<0.001
Mini Mental State Examination score	28 ($\pm$ 3)	27 ($\pm$ 3)	<0.001
Self-reported fair to poor general health	958 (21%)	344 (41%)	<0.001
Past medical history			
Vision problems	1098 (24%)	245 (29%)	0.002
Hearing problems	1323 (29%)	294 (35%)	<0.001
Acute myocardial infarction *	491 (11%)	373 (45%)	<0.001
Hypertension	2012 (44%)	475 (57%)	<0.001
Diabetes mellitus	636 (14%)	226 (27%)	<0.001
Stroke *	458 (10%)	182 (22%)	<0.001
Chronic obstructive pulmonary disease	585 (13%)	148 (18%)	0.001
Arthritis	2326 (51%)	437 (52%)	0.638
Cancer	675 (15%)	116 (14%)	0.452
Dizziness	254 (6%)	76 (9%)	<0.001
Able to walk half a mile without difficulty	3893 (86%)	616 (73%)	<0.001
Clinical examination			
Body mass index, kg/m ²	26 ($\pm$ 4)	27 ($\pm$ 4)	0.002
Pulse, beats per minute	68 ($\pm$ 11)	69 ($\pm$ 12)	0.004

n (%) or mean (±SD)	No heart failure (n=4544)	Heart failure (n=839)	P value
Systolic blood pressure, mm Hg	135 (±21)	140 (±24)	<0.001
Diastolic blood pressure, mm Hg	71 (±11)	70 (±12)	0.030
Laboratory values			
Hemoglobin, g/dL	14.1 (±1.3)	14.0 (±1.4)	0.572
Serum creatinine, mg/dL	0.94 (±0.35)	1.10 (±0.53)	<0.001
Serum potassium, mEq/L	4.17 (±0.37)	4.20 (±0.42)	0.086
Serum albumin, g/dL	4.0 (±0.3)	4.0 (±0.3)	0.090
Serum uric acid, mg/dL	5.6 (±1.5)	6.2 (±1.7)	<0.001
Serum total cholesterol, mg/dL	212 (±39)	203 (±38)	<0.001
Serum triglyceride, mg/dL	139 (±77)	149 (±85)	0.001
Serum low-density lipoprotein,mg/dL	130 (±35)	125 (±34)	<0.001
Serum insulin, µIU/mL	16 (±20)	23 (±47)	<0.001
Serum C-reactive protein, mg/dL	4.4 (±8.1)	6.3 (±8.9)	<0.001
Serum fibrinogen, mg/dL	321 (±64)	335 (±71)	<0.001
Serum interleukin-6, units/ml	2.11 (±1.75)	2.74 (±1.97)	<0.001
Coagulation factor VII	124 (±29)	121 (±33)	0.014
Electrocardiogram			
Atrial fibrillation	80 (2%)	69 (8%)	<0.001
Left ventricular hypertrophy	156 (3%)	96 (11%)	<0.001
Echocardiogram			
Left ventricular systolic dysfunction	280 (6%)	193 (23%)	<0.001

* Time-varying covariates

Table 2

Association of heart failure (as a time-varying variable) and driving cessation in Cardiovascular Health Study

	Events (incidence rate/10,000 person-years)		Absolute rate difference (/10,000 person-years)	Hazard ratio (95%CI)	P value
	No heart failure (n=4544)	Heart failure (n=839)			
Model 1: Unadjusted	1171 (3709)	205 (3980)	+ 271	2.13 (1.83–2.47)	<0.001
Model 2: Model 1 + age75plus, sex, race	---	---	---	1.96 (1.69–2.27)	<0.001
Model 3: Model 2 + other demographics*	---	---	---	1.74 (1.50–2.02)	<0.001
Model 4: Model 3 + geriatric symptoms [†]	---	---	---	1.53 (1.31–1.78)	<0.001
Model 5: Model 4 + medical history [‡]	---	---	---	1.43 (1.21–1.68)	<0.001

* Other demographics: marital status, living alone, education as multi-categorical, income as multi-categorical, social support score

[†] Geriatric symptoms: self-reported general health, depression score, Mini Mental State Examination score, vision problem, hearing problem, frequent falls, dizziness, and difficulty walking half a mile

[‡] Medical history: hypertension, diabetes mellitus, chronic obstructive pulmonary disease, cancer, arthritis, atrial fibrillation, left ventricular hypertrophy, left ventricular systolic dysfunction, and acute myocardial infarction and stroke as time varying covariates.

Table 3

Predictors of driving cessation among Cardiovascular Health Study participants with heart failure

	Unadjusted hazard ratio (95%CI); P value	Adjusted hazard ratio [*] (95%CI); P value
Age ≥75years	2.21 (1.67–2.92); p<0.001	1.99 (1.44–2.73); p<0.001
Female	2.02 (1.53–2.68); p<0.001	1.93 (1.37–2.74); p<0.001
Difficulty walking half a mile	2.04 (1.52–2.78); p<0.001	1.47 (1.04–2.08); p=0.028
Vision problem	2.16 (1.63–2.86); p<0.001	1.47 (1.07–2.02); p=0.018
Stroke (time varying covariate)	1.92 (1.39–2.66); p<0.001	1.96 (1.38–2.79); p<0.001

* Also adjusted for race, marital status, living alone, education as multi-categorical, income as multi-categorical, social support score, self-reported general health, depression score, mini mental state exam score, hearing problem, frequent falls, dizziness, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, cancer, arthritis, atrial fibrillation, left ventricular hypertrophy, left ventricular systolic dysfunction, and acute myocardial infarction as a time varying covariate.

Table 4

Predictors of driving cessation among Cardiovascular Health Study participants without heart failure

	Unadjusted hazard ratio (95%CI); P value	Adjusted hazard ratio [*] (95%CI); P value
Age ≥75years	3.02 (2.69–3.39); p<0.001	2.42 (2.13–2.74); p<0.001
Female	2.06 (1.81–2.35); p<0.001	2.17 (1.88–2.51); p<0.001
Live alone	1.57 (1.35–1.84); p<0.001	0.69 (0.56–0.86); p=0.001
Self-reported fair to poor general health	2.19 (1.93–2.48); p<0.001	1.27 (1.10–1.47); p<0.001
Decline in Mini Mental Status Examination score (30-item)	1.15 (1.12–1.16); p<0.001	1.06 (1.04–1.09); p<0.001
Vision problem	1.98 (1.75–2.23); p<0.001	1.39 (1.22–1.58); p<0.001
Difficulty walking half a mile	2.27 (1.96–2.63); p<0.001	1.19 (1.02–1.39); p=0.027
Left ventricular hypertrophy	1.79 (1.36–2.36); p<0.001	1.33 (1.002–1.76); p=0.048
History of cancer	1.17 (1.004–1.37); p=0.044	1.19 (1.01–1.39); p=0.033
Atrial fibrillation	1.99 (1.42–2.80); p<0.001	1.55 (1.09–2.21); p=0.014
Stroke (time varying covariate)	2.71 (2.29–3.22); p<0.001	1.90 (1.58–2.28); p<0.001

* Also adjusted for race, marital status, education as multi-categorical, income as multi-categorical, social support score, depression score, hearing problem, frequent falls, dizziness, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, arthritis, left ventricular systolic dysfunction, and acute myocardial infarction as a time varying covariate.