ORIGINAL RESEARCH

Association of household income and adverse outcomes in patients with atrial fibrillation

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ABSTRACT

Background Social determinants of health are relevant to cardiovascular outcomes but have had limited examination in atrial fibrillation (AF).
Objectives The purpose of this study was to examine the association of annual household income and cardiovascular outcomes in individuals with AF.
Methods We analysed administrative claims for individuals with AF from 2009 to 2015 captured by a health claims database. We categorised estimates of annual household income as <\$40 000; \$40–\$59 999; \$60–\$74 999; \$75–\$99 999; and ≥\$100 000. Covariates included demographics, education, cardiovascular disease risk factors, comorbid conditions and anticoagulation. We examined event rates by income category and in multivariable-adjusted models in reference to the highest income category (≥\$100 000).
Results Our analysis included 336 736 individuals (age 72.7±11.9 years; 44.5% women; 82.6% white, 8.4% black, 7.0% Hispanic and 2.1% Asian) with AF followed for median (25th and 75th percentile) of 1.5 (95% CI 0.6 to 3.0) years. We observed an inverse association between income and heart failure and myocardial infarction (MI) with evidence of progressive risk across decreased income categories. Individuals with household income <\$40 000 had the greatest risk for heart failure (HR 1.17; 95% CI 1.05 to 1.30) and MI (HR 1.18; 95% CI 0.98 to 1.41) compared with those with income ≥\$100 000.
Conclusions We identified an association between lower household income and adverse outcomes in a large cohort of individuals with AF. Our findings support consideration of income in the evaluation of cardiovascular risk in individuals with AF.

INTRODUCTION

Atrial fibrillation (AF) is a common, highly morbid cardiac arrhythmia that is associated with multiple cardiovascular and non-cardiovascular complications. AF results in significant social and medical burdens and accounts for \$6 billion in annual US healthcare spending.[1] Care for AF is complex and requires adequate social resources and health literacy to monitor for symptoms, navigate and adhere to complicated medication regimens (such as anticoagulation) and coordinate primary and specialty care services.[2]

Social determinants of health are relevant to AF given their potential to affect treatment and associated outcomes. To date, the foremost focus of social determinants in AF has been on race. Studies have underscored racial differences in treatment, awareness of the condition and risk for adverse outcomes.[3 4] In a community-based study, income has likewise been related to increased risk of developing AF.[5] Median neighbourhood income has also been positively associated with access to direct oral anticoagulants (as opposed to warfarin).[6] Additional social determinants of health, such as neighborhood-level and community-level factors and healthcare access, likewise have relevance to health outcomes[7] and may mediate associations between income and health outcomes in AF. Examination of the interaction of race and income in AF remains limited and may demonstrate how interrelated social factors contribute towards adverse outcomes and thereby direct treatment efforts.

We investigated the association of household income and cardiovascular outcomes in individuals with AF. We used a database of deidentified, aggregated commercial and Medicare Advantage health claims, thereby enabling us to conduct our analysis in a large, socially diverse cohort with enhanced generalisability. Our primary hypothesis was that lower income would be associated with increased risks of heart failure, myocardial infarction and stroke in this large cohort of individuals with AF. Our secondary hypothesis was that lower income would be a stronger risk factor for adverse outcomes in racial and ethnic minorities compared with white referents.

METHODS

Cohort selection

We obtained data from Optum Clinformatics Data Mart (Eden Prairie, Minnesota, www.optum.com), a large US database composed of inpatient, outpatient, emergency department, pharmacy and laboratory health claims. Data are deidentified, and informed consent is thereby waived. Medical claims include International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes; Current Procedural Terminology, Version 4 procedure codes; Healthcare Common Procedure Coding System procedure codes; and site of service codes. The database includes commercial and Medicare Advantage enrollees and is geographically diverse across the USA and similar to the insured population.[8] Patients or the public were not involved in the design, or conduct, or reporting, or dissemination of our research.

We selected individuals having a diagnosis of AF during the period of 1 January 2009–30 September 2015. AF was defined by the presence of at least one inpatient or two outpatient claims for AF (ICD-9-CM 427.31 or 427.32 in any diagnostic position). We required two outpatient claims in order to minimise the impact of rule-out diagnoses and improve the specificity of our definition of AF; this restriction is not applied to inpatient claims, which have greater specificity for the diagnosis of AF. This approach has been validated elsewhere.[9] Outpatient AF diagnostic codes were temporally separated by a minimum of 1 week to a maximum of 1 year. Date of diagnosis (first in-patient claim or second out-patient claim) was defined as the date of study entry for time-dependent analyses. We used the second outpatient claim of AF to preclude the immortal time bias inherent to initiating analysis at the first date of AF diagnosis. We identified 727 935 individuals with a diagnosis of AF.

Household income

Household income was derived by AmeriLINK Consumer Marketing Database, which provides estimates of annual household income. Income data are collected by monthly survey from a representative cross section of the US population of >30 000 households and are informed by 130 variables that encompass ZIP +4 (a highly specific geographic locator), Internal Revenue Service data, address-level home value, aggregated credit and short-term loans. Derived estimates of household income are validated by comparison to self-reported income collected by household surveys.[10] The claims database divides household income into six categories: <$40 000, $40–$49 999, $50–$59 999, $60–$74 999, $75–$99 999 and ≥$100 000. For this analysis, we categorised income as <$40 000; $40–$59 999; $60–$74 999; $75–$99 999; and ≥$100 000. We combined the $40–$49 999 and $50–$59 999 categories due to the limited numbers cohort participants in these two categories of estimated annual household income.

Outcome ascertainment

We identified incident cardiovascular events that occurred within the enrolment period after the date of AF diagnosis. The outcomes of interest were obtained from inpatient claims and included heart failure,[11] myocardial infarction[12 13] and ischaemic stroke.[14] Each outcome was defined using the primary discharge diagnosis in an inpatient claim as follows: heart failure was defined by the presence of ICD-9-CM codes 402.x1, 404.x1, 404.x3 and 428; myocardial infarction was defined by the presence of ICD-9-CM discharge diagnosis code of 410.xx; ischaemic stroke was defined by the presence of ICD-9-CM codes 434.xx and 436.xx. online supplementary table 1 provides a comprehensive list of ICD codes used to identify the outcomes of heart failure, myocardial infarction and stroke.

Covariates

Age, sex and race are included in the claims data. The database collects race and ethnicity from public records (eg, driver's licence) and by imputation with commercially available software (E-Tech, Ethnic Technologies, South Hackensack, New Jersey) that employs validated algorithms incorporating racial and ethnic neighbourhood composition as ascertained by the US Census, residential zip code and first and last name.[15] Race and ethnicity were subsequently categorised as white, black, Asian or Hispanic. Education level was derived from Census data at the ZIP +4 level and categorised as less than high school diploma, high school diploma, less than bachelor degree, bachelor degree or higher or unknown. For this analysis, we categorised education as less than high school diploma and high school diploma; less than bachelor degree; or bachelor degree or higher. Additional clinical covariates were selected from prior analyses of AF with recognised contributions to the outcomes studied here and relevance to AF.[16] These covariates included hypertension, diabetes, prior coronary heart disease, prior heart failure, prior stroke, chronic obstructive pulmonary disease and chronic kidney disease. All covariates were defined by ICD-9-CM codes in inpatient and outpatient claims prior to or at the time of AF diagnosis, as listed in online supplementary table 1.

Oral anticoagulation

We identified oral anticoagulants including warfarin, dabigatran, rivaroxaban and apixaban prescribed within 3 months prior to 6 months after the date of AF diagnosis. Data were obtained from outpatient pharmaceutical claims, which provide the National Drug Code, the prescription fill date and the number of days supplied.

Statistical analysis

We summarised the distributions of continuous and categorical variables. Our primary analysis was the association of income with incident heart failure, myocardial infarction and ischaemic stroke in individuals with AF. Date of AF diagnosis was defined as time 0, and time of study entry for each individual was included in our cohort. We calculated the rates of incident events during follow-up through database disenrolment or 30 September 2015, whichever came first. We then examined associations of income with myocardial infarction, heart failure and ischaemic stroke in multivariable-adjusted Cox proportional hazards models that compared risk by income category using income ≥$100 000 as the referent. For each outcome assessed, we excluded the respective prevalent disease. We then examined for interactions by race and income as well as for income and education. All analyses were adjusted initially for age, sex and race (model 1); then for age, sex, race, education, hypertension, diabetes, ischaemic stroke, coronary heart disease and heart failure (model 2); and then adjusted for all covariates including age, sex, race, education, hypertension, diabetes, ischaemic stroke, coronary heart disease, heart failure, chronic obstructive pulmonary disease and chronic kidney disease as well as oral anticoagulant use (model 3). We stratified individuals by race and ethnicity to assess for differences in risk by income level to investigate differences by race and ethnicity strata.

We verified the assumption of proportional hazards with Schoenfeld residuals. All statistical analyses were performed using SAS V.9.4. Given the potential for residual confounding in our analysis, we conducted a bias analysis using the methods articulated by VanderWeele and Ding.[17] Specifically, we calculated the E-value for the HRs obtained comparing the lowest to the highest income category for those endpoints in which we found associations. The E-value can be interpreted as the minimum strength of association that an unmeasured confounder would need to have with both the exposure and the outcome, after adjusting for the measured covariates, to explain away an observed association.[17]

RESULTS

After excluding individuals with <180 days of enrolment before a diagnosis of AF (n=3 12 958), and those missing income (n=66

Table 1 Characteristics of AF cohort, 2009–2015

	Entire cohort	<$40 000	$40–$59 000	$60–$74 000	$75–$99 000	≥$100 000
No. of individuals	336 736	129 845	62 833	34 685	41 246	68 127
Demographics						
Age, years (mean (SD))	72.7 (11.9)	77.2 (9.3)	73.5 (11.1)	71.4 (11.8)	69.6 (12.3)	66 (12.8)
Women	149 865 (44.5)	73 896 (56.9)	26 426 (42.1)	13 421 (38.7)	14 963 (36.3)	21 159 (31.1)
Race						
White	277 964 (82.6)	101 939 (78.5)	51 418 (81.8)	28 913 (83.4)	35 210 (85.4)	60 484 (88.8)
Black	28 286 (8.4)	15 262 (11.8)	5532 (8.8)	2617 (7.6)	2414 (5.9)	2461 (3.6)
Asian	6976 (2.1)	1954 (1.5)	1155 (1.8)	780 (2.3)	1015 (2.5)	2072 (3)
Hispanic	23 510 (7.0)	10 690 (8.2)	4728 (7.5)	2375 (6.9)	2607 (6.3)	3110 (4.6)
Education						
<High School	103 579 (30.8)	61 581 (47.4)	20 952 (33.4)	8894 (25.6)	7648 (18.5)	4504 (6.6)
<Bachelor's degree	188 007 (55.8)	64 051 (49.3)	37 173 (59.2)	22 184 (64)	27 102 (65.7)	37 497 (55.0)
≥Bachelor's degree	45 150 (13.4)	4213 (3.2)	4708 (7.5)	3607 (10.4)	6496 (15.8)	26 126 (38.4)
Comorbidities						
CHA_2DS_2-VASc (mean (SD))	4.1 (2.0)	4.7 (1.8)	4.2 (1.9)	3.8 (2.0)	3.6 (2.0)	3.0 (2.0)
Hypertension	275 630 (82.8)	113 145 (87.9)	52 605 (84.6)	28 262 (82.5)	32 538 (80.0)	49 080 (73.3)
Diabetes	176 929 (34.9)	75 342 (38.6)	34 336 (36.9)	18 176 (35.4)	20 502 (33.0)	28 573 (27.1)
Prior CHD	148 841 (44.2)	62 204 (47.9)	29 159 (46.4)	15 446 (44.5)	17 346 (42.1)	24 686 (36.2)
Prior HF	110 242 (32.7)	50 549 (38.9)	21 176 (33.7)	10 746 (31)	11 773 (28.5)	15 998 (23.5)
Prior stroke	88 607 (26.3)	39 746 (30.6)	17 273 (27.5)	8717 (25.1)	9763 (23.7)	13 108 (19.2)
COPD	116 482 (34.6)	52 986 (40.8)	22 572 (35.9)	11 416 (32.9)	12 573 (30.5)	16 935 (24.9)
CKD	70 388 (20.9)	33 176 (25.6)	13 862 (22.1)	6867 (19.8)	7326 (17.8)	9157 (13.4)
Oral anticoagulant use	86 702 (25.8)	31 182 (24.0)	16 210 (25.8)	9274 (26.8)	11 277 (27.3)	18 759 (27.5)

Values correspond to N (percentage) unless otherwise stated.

AF, atrial fibrillation; CHA2DS2-VASc, congestive heart failure, hypertension, age ≥75 years, diabetes mellitus, stroke/transient ischaemic attack, vascular disease, age 65–75 years and sex category.; CHD, coronary heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; HF, heart failure.

822), race or ethnicity (n=11 130), or education (n=289), there were 336 736 individuals included in the analysis (mean age 72.7±11.9 years; 44.5% women), as summarised in table 1.

The majority were white race (82.6%) with 28 286 (8.4%) black, 23 510 (7.0%) Hispanic and 6976 (2.1%) Asian. A greater proportion of black (54%) and Hispanic (45%) individuals belonged to the lowest income category compared with whites (37%) or Asians (28%). Education was likewise distributed by income, with a greater proportion of individuals with lower education belonging to lower income categories. In contrast, 58% of individuals with a bachelor's degree or higher were in the highest income category.

During a median (25th and 75th percentile) follow-up of 1.5 (95% CI 0.6 to 3.0) years, there were 4736 cases of heart failure; 1444 cases of myocardial infarction; and 3435 cases of stroke. table 2 summarises the incidence rates for each of the outcomes by income category. With increasing income category, event rates decreased with respect to myocardial infarction, heart failure and stroke.

Table 3 summarises the HRs with p values for the trend of the associations of income with each of the cardiovascular outcomes, while figure 1 presents them graphically.

We observed a graded, inverse association between income and the risks for heart failure and myocardial infarction. Individuals in the lowest income category had the greatest risk for heart failure with a HR of 1.17 (95% CI 1.05 to 1.30) and myocardial infarction with an HR of 1.18 (95% CI 0.98 to 1.41) relative to the highest income category. The association between income and heart failure remained significant in the lowest income category after multivariable adjustment with the clinical covariates, oral anticoagulant use and education. We did not observe an association between income and ischaemic stroke.

Interactions for race/ethnicity and income and for income and education were not statistically significant in multivariable-adjusted models. The results of analyses stratified by race and ethnicity are presented in online supplementary table 2A and 2D. Our bias assessment identified an E-value of 2.17 (CI, lower limit, 1.88) for the association between extreme income categories

Table 2 Age-standardised, sex-standardised and race-standardised incidence rates and 95% CIs (per 1000 person-years) of cardiovascular disease (heart failure, myocardial infarction and ischaemic stroke) by income categories

	Income				
Event	**<$40 000**	**$40–$59 000**	**$60–$74 000**	**$75–$99 000**	**≥$100 000**
Heart failure*	5.4 (4.2 to 6.6)	4.1 (3.5 to 4.6)	3.4 (2.7 to 4.0)	3.1 (2.7 to 3.6)	3.0 (2.4 to 3.5)
Myocardial infarction†	2.1 (1.6 to 2.7)	1.9 (1.5 to 2.4)	1.4 (0.9 to 1.9)	1.4 (1.0 to 1.7)	1.6 (1.0 to 1.5)
Stroke‡	3.2 (2.2 to 4.2)	2.5 (2.0 to 3.0)	2.3 (1.9 to 2.7)	2.1 (1.8 to 2.4)	2.3 (2.0 to 2.6)

*Prevalent heart failure was excluded from model 3 when calculating incident heart failure.
†Prevalent coronary heart disease was excluded from model 3 when calculating incident myocardial infarction.
‡Prevalent ischaemic stroke was excluded from model 3 when calculating incident ischaemic stroke.

Table 3 HRs and 95% CIs of cardiovascular outcomes by income category and adjusted for covariates in cohort with AF

	Income					
	<$40 000	$40–$59 000	$60–$74 000	$75–$99 000	≥$100 000	P value for trend
Heart failure*						
Model 1	1.41 (1.28 to 1.55)	1.30 (1.17 to 1.44)	1.22 (1.08 to 1.38)	1.18 (1.05 to 1.33)	1 (ref)	<0.0001
Model 2	1.19 (1.07 to 1.32)	1.14 (1.02 to 1.28)	1.11 (0.98 to 1.26)	1.10 (0.97 to 1.24)	1 (ref)	0.03
Model 3	1.17 (1.05 to 1.30)	1.13 (1.01 to 1.26)	1.10 (0.97 to 1.25)	1.09 (0.97 to 1.23)	1 (ref)	0.05
Myocardial infarction†						
Model 1	1.35 (1.14 to 1.60)	1.28 (1.07 to 1.54)	1.18 (0.95 to 1.46)	1.10 (0.89 to 1.36)	1 (ref)	0.005
Model 2	1.18 (0.98 to 1.42)	1.16 (0.96 to 1.41)	1.09 (0.87 to 1.36)	1.05 (0.85 to 1.30)	1 (ref)	0.42
Model 3	1.18 (0.98 to 1.41)	1.15 (0.95 to 1.40)	1.09 (0.87 to 1.36)	1.05 (0.84 to 1.30)	1 (ref)	0.46
Ischaemic stroke‡						
Model 1	1.06 (0.95 to 1.18)	0.97 (0.86 to 1.1)	0.99 (0.86 to 1.14)	1.00 (0.87 to 1.15)	1 (ref)	0.36
Model 2	0.98 (0.87 to 1.11)	0.92 (0.81 to 1.04)	0.95 (0.82 to 1.09)	0.97 (0.84 to 1.11)	1 (ref)	0.62
Model 3	0.99 (0.88 to 1.12)	0.92 (0.81 to 1.05)	0.95 (0.82 to 1.1)	0.97 (0.84 to 1.12)	1 (ref)	0.61

Model 1 adjusted for baseline age, sex and race.
Model 2 adjusted for baseline age, sex, race, education, hypertension, diabetes and prevalent ischaemic stroke, prevalent coronary heart disease, and prevalent heart failure.
Model 3 adjusted for baseline age, sex, race, education, hypertension, diabetes, prevalent ischaemic stroke, prevalent coronary heart disease, prevalent heart failure, chronic obstructive pulmonary disease, chronic kidney disease, and oral anticoagulant use.
*Prevalent heart failure was excluded from model 3 when calculating incident heart failure.
†Prevalent coronary heart disease was excluded from model 3 when calculating incident myocardial infarction.
‡Prevalent ischaemic stroke was excluded from model 3 when calculating incident ischaemic stroke.
AF, atrial fibrillation.

and heart failure in model 1, and an E-value of 2.04 (CI, lower limit, 1.54) for the association between extreme income categories and myocardial infarction in Model 1. We concluded from these calculations that potential unmeasured confounders, such as neighbourhood SES or racial segregation, have weaker associations with the endpoints of interest and therefore are unlikely to be responsible for the observed associations.[18 19]

DISCUSSION

In a large, geographically diverse health claims database, we observed associations between annual income and increased risk of heart failure and myocardial infarction in individuals with incident AF. Specifically, we observed progressively increased risk for these adverse cardiovascular outcomes, such that individuals with income categorised as <$40 000/year had the greatest risk. The association of lower household income and the increased risk of heart failure remained significant even after multivariable adjustment. These findings were observed over a relatively limited follow-up duration (median 1.5 years).

There was no association between income and risk of ischaemic stroke in the cohort as a whole. Lack of an association may be due to the relatively limited follow-up duration in this study and/or the similar prevalence of anticoagulant prescriptions across income categories.

Prior study of income in relation to AF and cardiovascular disease

The examination of income and AF has had limited study with one community-based study identifying a graded, inverse, dose-response association between total family income and risk of incident AF.[6] In contrast, the association of income with cardiovascular outcomes and mortality has been well established. Total family income has been inversely associated with cardiovascular disease and cardiovascular death in multiple studies and was deemed a 'neglected' metric for cardiovascular disease.[20–22] An analysis of the National Longitudinal Mortality Study identified a strong association between income and mortality that was most pronounced at incomes below $22 500.[23] Income has further relevance to longevity. Robust data indicate a strong linear association between income and length of life in US adults.[24] The aforementioned studies indicate the relevance of income to health outcomes including cardiovascular disease and mortality. Our study now contributes further data on the importance of income, specifically towards the associations of income and health outcomes directly relevant to the increasing number of people with AF.

Rationale for the association of income and health outcomes

Multiple potential pathways have been proposed to relate income and health. The socioecological theory asserts that health is shaped by multiple factors: social, family and community networks; living and working conditions; and broad social, economic, cultural and environmental conditions and policies.[25] Low income as determined by socioeconomic status has been associated in general with diminished access to preventative care,[26] specialty care[27] and poorer clinical outcomes.[28] Low socioeconomic status yields decreased access to prescription medications[29] and may contribute towards competing priorities for using health services, medications and diverse other needs. Low income may complicate adherence to medications or appointments, as individuals struggle to choose between material necessities and medical care. Furthermore, limited health literacy is more prevalent in lower income individuals and likewise may add to the heterogenous contributions of social determinants on complicated chronic disease such as AF.[2] This study demonstrates an important association between income and cardiovascular disease in AF and we recognise that further research is needed to understand the complex pathways by which patients with low income and AF develop adverse outcomes.

Relevance of social determinants to clinical care and practice

Recognising that social determinants are associated with health outcomes, there has been increased focus on their incorporation into routine clinical care. The National Academy of Medicine has recommended inclusion of social and behavioural determinants in electronic health records due to the 'substantial

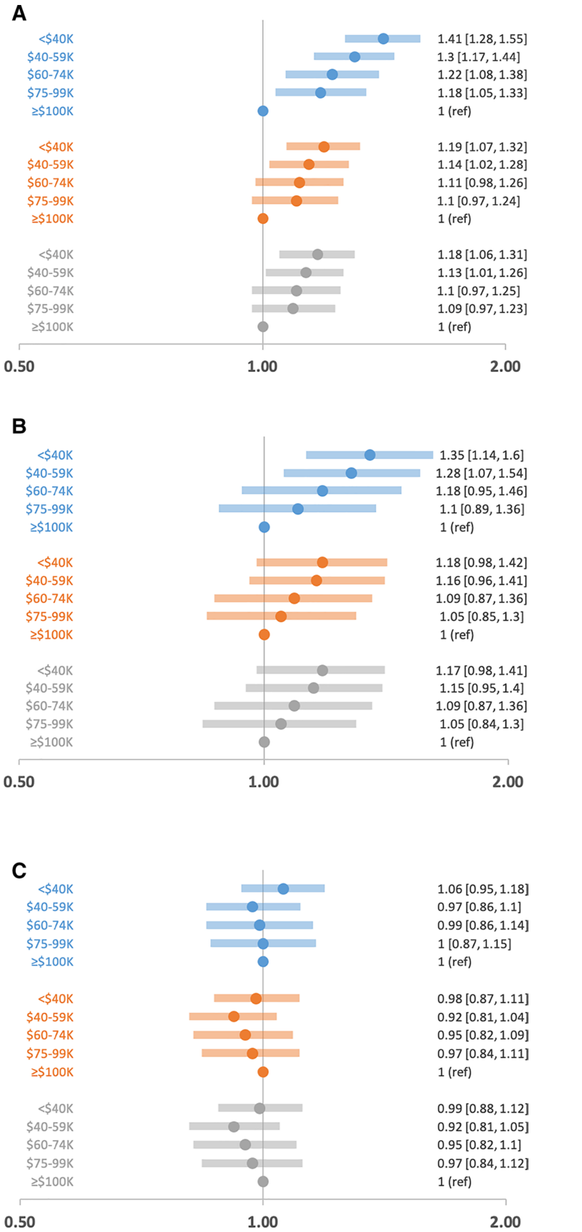

Figure 1 A–C: HRs with 95% CIs of incident heart failure, myocardial infarction and ischaemic stroke by income category and adjusted for covariates in cohort with AF. Figure parts A–C are forest plots of multivariable-adjusted HRs with 95% CIs of incident cardiovascular outcomes heart failure, myocardial infarction and ischaemic stroke by income category. Incident event rates were calculated and related to income in multivariable-adjusted Cox proportional hazard models that compared risk by income category with income >$100 000 as referent. Model 1: adjusted for age, sex and race; model 2: adjusted for age, sex, race, education, hypertension, diabetes, prevalent coronary heart disease and prevalent heart failure; model 3: adjusted for age, sex, race, education, hypertension, diabetes, prevalent coronary heart disease, prevalent heart failure, chronic obstructive coronary disease, chronic kidney disease and oral anticoagulant use. (A) Heart failure by income category; (B) myocardial infarction by income category; (C) ischaemic stroke by income category adjusted for the three models. AF, atrial fibrillation.

empirical evidence of the contribution of social and behavioural factors to function status and the onset, progression, and effective treatment of disease'.[30] Our analysis indicates the substantive contribution of income towards adversity and its prominent role as a social determinant of health. Our study is unable to distinguish the multiple mechanisms and pathways that may relate income and adverse cardiovascular outcomes; however, our findings underscore the importance of further studies to examine the practical implications of using income in routine clinical assessment with the goal of identifying and effectively intervening on high-risk patient populations. Collecting and using income data as one component of a risk stratification tool that incorporates a suite of social determinants of health in the clinical setting may be of interest to clinicians seeking to identify and intervene on vulnerable patients, health systems attempting to improve the outcomes of populations and health plans seeking to provide high value, cost conscious care.

Strengths and limitations

Our analysis had several strengths, most particularly the availability of nationwide health claims data from over 300 000 individuals diagnosed with AF. The generalisability of our analysis to insured persons with AF is strengthened by the utilisation of a database that is geographically diverse and racially representative as well as inclusive of enrollees of both private and Medicare advantage plans.

We would also like to summarise the important limitations of our study. First, inclusion in this cohort required that individuals have health insurance, thereby allowing health claims data to be captured. Consequently, the exclusion of a highly vulnerable patient population may underestimate the effect of income on adverse cardiovascular outcomes in individuals with AF and may not be generalisable to the uninsured population. Second, using claims data selects for individuals with AF who are more often in need of medical care, thereby limiting the generalisability to individuals with AF who do not seek care and do not generate health claims. Third, requiring two outpatient claims for AF was intended to increase specificity of the diagnostic algorithm but excluding individuals with only one outpatient claim may have selected for individuals with more symptomatic AF, again limiting the generalisability of our results to patients with asymptomatic paroxysmal AF. Fourth, we relied exclusively on health claims for ascertainment of AF, covariates and the cardiovascular outcomes; we are not able to correlate administrative claims with clinical data by individual review of health records. Fifth, several variables including income, race and education were derived using varied algorithms, thereby subject to misrepresentation. Sixth, we expect that there is residual confounding by omission of informative, socially relevant variables (neighbourhood-level determinants, treatment adherence and health literacy) that may be part of a causal pathway to relate income and adverse clinical outcomes associated with AF. However, our assessment for uncontrolled confounding suggested that only a strong unmeasured confounder (E-value >2) would be able to explain the observed associations. Seventh, our follow-up time for this study was limited to a median of 1.5 years. We expect that a longer study interval would have yielded more events to include in the analysis. The limited follow-up time also allows for the potential of reverse causation. Eighth, our analyses do not account for the effect of AF treatment during the observation period. However, we included prescription of oral anticoagulation for stroke prevention as a fundamental metric of routine clinical care for AF. Finally, we recognise our categorisation of income as limited. The measurement of income is complex and may be adjusted for family size, the addition of non-cash benefits such as food stamps or Medicare or broadened to include wealth and assets that are separate from income.[25]

Key messages

What is already known on this subject?

- Income is strongly associated with cardiovascular disease risk and mortality. There has been limited knowledge of the association between income and adverse cardiovascular outcomes in individuals with atrial fibrillation.

What might this study add?

- This study identified significant associations between household income and risks for myocardial infarction and heart failure in individuals with prevalent atrial fibrillation. Individuals in the lowest income quartile had 1.3-fold to 1.4-fold greater risk for myocardial infarction and heart failure relative to the highest income quartile. These results support prior evidence demonstrating the relevance of social resources to health outcomes.

How might this impact on clinical practice?

- Household income is a social determinant of health that mediates access to care and health outcomes. Incorporating social factors in health systems and the provision of care provide opportunities to promote equity, address disparities and improve outcomes in vulnerable patient populations.

CONCLUSION

In conclusion, in a retrospective analysis of a large US healthcare utilisation database, we observed a significant association between income and risk of cardiovascular outcomes relevant to AF, specifically heart failure and myocardial infarction. Our results are consistent with prior evidence that underscores the relevance of income to increased risk for cardiovascular and health outcomes. Further study must now address how to incorporate data regarding income into the treatment of patients with AF to improve cardiovascular outcomes and mitigate adverse outcomes in vulnerable patient populations.

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Contributors AA and JWM conceived and designed the primary aim and method of this study. JC, LB, WTO, PLL, LYC and AMC designed and implemented data collection. AA, JWM, JC and ARL analysed the data. JWM and ARL drafted the manuscript. JWM and AA supervised the project. AA and PLL obtained funding. All authors critically reviewed and developed the final manuscript.

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Patient consent for publication Not required.

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REFERENCES

1 Benjamin EJ, Virani SS, Callaway CW, *et al*. Heart disease and stroke Statistics-2018 update: a report from the American heart association. *Circulation* 2018;137:e67–492.
2 Magnani JW, Mujahid MS, Aronow HD, *et al*. Health literacy and cardiovascular disease: fundamental relevance to primary and secondary prevention: a scientific statement from the American heart association. *Circulation* 2018;138:e48–74.
3 Magnani JW, Norby FL, Agarwal SK, *et al*. Racial differences in atrial Fibrillation-Related cardiovascular disease and mortality: the Atherosclerosis risk in communities (ARIC) study. *JAMA Cardiol* 2016;1:433–41.
4 Essien UR, Holmes DN, Jackson LR, *et al*. Association of Race/Ethnicity with oral anticoagulant use in patients with atrial fibrillation: findings from the outcomes Registry for better informed treatment of atrial fibrillation II. *JAMA Cardiol* 2018;3:1174–82.
5 Misialek JR, Rose KM, Everson-Rose SA, *et al*. Socioeconomic status and the incidence of atrial fibrillation in whites and blacks: the Atherosclerosis risk in communities (ARIC) study. *J Am Heart Assoc* 2014;3:e001159.
6 Sholzberg M, Gomes T, Juurlink DN, *et al*. The influence of socioeconomic status on selection of anticoagulation for atrial fibrillation. *PLoS One* 2016;11:e0149142.
7 Havranek EP, Mujahid MS, Barr DA. Social determinants of risk and outcomes for cardiovascular disease: a scientific statement from the American heart association. *Circulation* 2015;132:873–98.
8 Wallace PJ, Shah ND, Dennen T, *et al*. Optum Labs: building a novel node in the learning health care system. *Health Aff* 2014;33:1187–94.
9 Piccini JP, Hammill BG, Sinner MF, *et al*. Incidence and prevalence of atrial fibrillation and associated mortality among Medicare beneficiaries, 1993-2007. *Circ Cardiovasc Qual Outcomes* 2012;5:85–93.
10 KDM Group. AmeriLINK Income Products [Internet], 2014. Available: https://www.kbmg.com/products/amerilink/ [Accessed 6 Aug 2019].
11 Saczynski JS, Andrade SE, Harrold LR. Mini-Sentinel systematic evaluation of health outcome of interest definitions for studies using administrative and claims data. *Pharmacoepidemiol Drug Saf* 2012;21.
12 Kiyota Y, Schneeweiss S, Glynn RJ, *et al*. Accuracy of Medicare claims-based diagnosis of acute myocardial infarction: estimating positive predictive value on the basis of review of hospital records. *Am Heart J* 2004;148:99–104.
13 Wahl PM, Rodgers K, Schneeweiss S, *et al*. Validation of claims-based diagnostic and procedure codes for cardiovascular and gastrointestinal serious adverse events in a commercially-insured population. *Pharmacoepidemiol Drug Saf* 2010;19:596–603.
14 Andrade SE, Harrold LR, Tjia J, *et al*. A systematic review of validated methods for identifying cerebrovascular accident or transient ischemic attack using administrative data. *Pharmacoepidemiol Drug Saf* 2012;21:100–28.
15 DeFrank JT, Bowling JM, Rimer BK, *et al*. Triangulating differential nonresponse by race in a telephone survey. *Prev Chronic Dis* 2007;4:A60.
16 Huxley RR, Lopez FL, Folsom AR, *et al*. Absolute and attributable risks of atrial fibrillation in relation to optimal and borderline risk factors: the Atherosclerosis risk in communities (ARIC) study. *Circulation* 2011;123:1501–8.
17 VanderWeele TJ, Ding P. Sensitivity analysis in observational research: introducing the E-Value. *Ann Intern Med* 2017;167:268.

18 Akwo EA, Kabagambe EK, Harrell FE, *et al*. Neighborhood deprivation predicts heart failure risk in a low-income population of blacks and whites in the southeastern United States. *Circ Cardiovasc Qual Outcomes* 2018;11:e004052.
19 Kershaw KN, Osypuk TL, Do DP, *et al*. Neighborhood-level racial/ethnic residential segregation and incident cardiovascular disease: the multi-ethnic study of atherosclerosis. *Circulation* 2015;131:141–8.
20 Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: a review of the literature. *Circulation* 1993;88:1973–98.
21 Lemstra M, Rogers M, Moraros J. Income and heart disease: neglected risk factor. *Can Fam Physician* 2015;61:698–704.
22 Khaing W, Vallibhakara SA, Attia J, *et al*. Effects of education and income on cardiovascular outcomes: a systematic review and meta-analysis. *Eur J Prev Cardiol* 2017;24:1032–42.
23 Backlund E, Sorlie PD, Johnson NJ. A comparison of the relationships of education and income with mortality: the National longitudinal mortality study. *Soc Sci Med* 1999;49:1373–84.
24 Chetty R, Stepner M, Abraham S, *et al*. The association between income and life expectancy in the United States, 2001-2014. *JAMA* 2016;315:1750–66.
25 McLeroy KR, Bibeau D, Steckler A, *et al*. An ecological perspective on health promotion programs. *Health Educ Q* 1988;15:351–77.
26 Katz SJ, Hofer TP. Socioeconomic disparities in preventive care persist despite universal coverage. breast and cervical cancer screening in Ontario and the United States. *JAMA* 1994;272:530–4.
27 Alter DA, Iron K, Austin PC, *et al*. Socioeconomic status, service patterns, and perceptions of care among survivors of acute myocardial infarction in Canada. *JAMA* 2004;291:1100–7.
28 Clark AM, DesMeules M, Luo W, *et al*. Socioeconomic status and cardiovascular disease: risks and implications for care. *Nat Rev Cardiol* 2009;6:712–22.
29 Hyun KK, Brieger D, Woodward M, *et al*. The effect of socioeconomic disadvantage on prescription of guideline-recommended medications for patients with acute coronary syndrome: systematic review and meta-analysis. *Int J Equity Health* 2017;16:162.
30 Committee on the Recommended Social and Behavioral Domains and Measures for Electronic Health Records, Board on Population Health and Public Health Practice, Institute of Medicine. *Capturing social and behavioral domains and measures in electronic health records: phase 2*. Washington (DC): National Academies Press (US), 2015. http://www.ncbi.nlm.nih.gov/books/NBK268995/