


Association Between Neighborhood-Level Poverty and Incident Atrial Fibrillation: a Retrospective Cohort Study



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BACKGROUND: Atrial fibrillation (AF) is a leading cause of cardiovascular morbidity and mortality. While neighborhood-level factors, such as poverty, have been related to prevalence of AF risk factors, the association between neighborhood poverty and incident AF has been limited.

OBJECTIVE: Using a large cohort from a health system serving the greater Chicago area, we sought to determine the association between neighborhood-level poverty and incident AF.

DESIGN: Retrospective cohort study.

PARTICIPANTS: Adults, aged 30 to 80 years, without baseline cardiovascular disease from January 1, 2005, to December 31, 2018.

MAIN MEASURES: We geocoded and matched residential addresses of all eligible patients to census-level poverty estimates from the American Community Survey. Neighborhood-level poverty (low, intermediate, and high) was defined as the proportion of residents in the census tract living below the federal poverty threshold. We used generalized linear mixed effects models with a logit link function to examine the association between neighborhood poverty and incident AF, adjusting for patient demographic and clinical AF risk factors.

KEY RESULTS: Among 28,858 in the cohort, patients in the high poverty group were more often non-Hispanic Black or Hispanic and had higher rates of AF risk factors. Over 5 years of follow-up, 971 (3.4%) patients developed incident AF. Of these, 502 (51.7%) were in the low poverty, 327 (33.7%) in the intermediate poverty, and 142 (14.6%) in the high poverty group. The adjusted odds ratio (aOR) of AF was higher for the intermediate poverty compared with that for the low poverty group (aOR 1.23 [95% CI 1.01–1.48]). The point estimate for the aOR of AF incidence was similar, but not statistically significant, for the high poverty compared with the low poverty group (aOR 1.25 [95% CI 0.98–1.59]).

CONCLUSION: In adults without baseline cardiovascular disease managed in a large, integrated health system,

intermediate neighborhood poverty was significantly associated with incident AF. Understanding neighborhood-level drivers of AF disparities will help achieve equitable care.

KEY WORDS: atrial fibrillation; neighborhood; poverty; social determinants.

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Atrial fibrillation (AF) is the most common heart rhythm disorder in US adults and is projected to affect nearly 12 million individuals by the year 2030 [1]. Atrial fibrillation is associated with a five-fold higher risk of stroke [2] and two-fold higher risk of cardiovascular mortality [3]. In addition, atrial fibrillation contributes to rising medical costs on a population level [4] as well as poorer patient-reported quality of life on an individual level [5].

Prior evidence has identified several clinical risk factors associated with the development of atrial fibrillation, including obesity, diabetes, and hypertension [6]. However, as increasing attention is paid to the social determinants of cardiovascular disease, it is uncertain how sociodemographic factors influence the risk of developing atrial fibrillation [7]. Whereas prior studies have examined the relationship between individual-level socioeconomic status (e.g., race, ethnicity) and atrial fibrillation-related treatment and outcomes [8, 9], few have specifically assessed the association of socioeconomic factors with the onset of atrial fibrillation [10, 11]. Previous studies have demonstrated an association between neighborhood-level deprivation and multiple clinical risk factors for developing atrial fibrillation, suggesting the factors driving this deprivation may contribute to the incidence burden of atrial fibrillation [12–15]. Yet, understanding poverty as a social determinant of health and key component of neighborhood deprivation, through its influence either on the built environment or on the persistence of clinical risk factors,

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remains an important gap in the atrial fibrillation literature that requires direct examination. This is especially important in a diverse, urban patient population residing in high poverty neighborhoods.

Using data from a large integrated health system that serves the greater Chicago area, we retrospectively examined the association between neighborhood-level poverty and incidence of atrial fibrillation in a cohort of adults without baseline cardiovascular disease.

METHODS

Data Sources

The Northwestern Medicine Enterprise Data Warehouse (NMEDW) was created in 2007 and serves as an electronic health repository of data from an integrated health system with over 200 primary clinical sites in the metropolitan Chicago area [16]. The NMEDW stores observations on over 6 million patients, loading nearly 3 billion new data elements from 142 separate sources each day. The NMEDW includes individuals receiving care at any of the Northwestern Medicine–affiliated institutions, comprising tertiary and secondary hospitals and inpatient and outpatient sites throughout northeastern Illinois [16].

The data for all neighborhood-level factors in this analysis were ascertained using the 2007–2011 American Community Survey (ACS) [17, 18]. The ACS is a repeated, cross-sectional survey conducted by the US Census Bureau administered annually to a nationally representative sample of over 3 million American households [19]. The survey collects social and economic characteristics of persons and households such as age, gender, race, income, education, and employment. The additional collection of Federal Information Processing Standards codes permits the survey data to be linked with other databases at the state, county, and census tract levels [20].

Study Population

The study population consisted of patients in the NMEDW who were 30–80 years old at the time of their first outpatient visit in the health system between January 1, 2005, and December 31, 2013. Patients were included if they were free of cardiovascular disease at this index outpatient visit (i.e., baseline), and if they had at least 5 years of follow-up (through December 31, 2018). For those with historical records, a look-back period prior to January 1, 2005, was also performed to confirm no prior history of cardiovascular disease, defined by a diagnosis of atrial fibrillation, coronary artery disease, stroke/cerebrovascular disease, peripheral arterial disease, or heart failure, or presence of a pacemaker prior to the baseline visit (Appendix Table 1). Additionally, patients were excluded if missing measurements for key covariates at baseline including smoking status, body mass index (BMI), blood pressure, and glucose levels. Billing addresses from the baseline visit were geocoded using ArcGIS Pro and matched to ACS census

tract-level poverty estimates. Patients were excluded from the analysis if their addresses could not be accurately geocoded ($N = 2165$) or if their baseline address was outside of Illinois ($N = 319$) resulting in a final study population of 28,858 patients (Fig. 1).

Primary Exposure and Outcome Ascertainment

Neighborhood-level poverty is the primary exposure for this analysis. The census tract is used as a proxy for neighborhood, as previously described [21]. Neighborhood poverty is quantified as the proportion of people in a given census tract living below the US-defined poverty threshold (income to poverty ratio less than 1) [22]. Using all of the available census tract-level poverty estimates for Illinois, we calculated tertiles of this proportion to derive three categories of neighborhood poverty (Fig. 2): low poverty (proportion below poverty threshold less than 0.073, which translates to approximately 7% of the census tract living below the US-defined poverty threshold), intermediate poverty (proportion below poverty threshold from 0.073 to 0.16, or between 7 and 16% of households living below the poverty threshold), and high poverty (proportion below poverty threshold greater than 0.16, or greater than 16% of households living below the poverty threshold) [22, 23].

The primary outcome is incidence of atrial fibrillation in the follow-up period. Atrial fibrillation was defined as the first atrial fibrillation diagnosis (inpatient or outpatient) using previously established *ICD-9-CM* (427.31) and *ICD-10-CM* (I48.0, I48.1, I48.2, I48.9, I48.91) diagnosis codes for atrial fibrillation [8].

Baseline Covariates

Additional covariates of interest included baseline demographics and other known clinical risk factors for atrial fibrillation. Baseline demographics included age at baseline visit, sex, and race/ethnicity. Race/ethnicity was categorized as non-Hispanic White, non-Hispanic Black, Hispanic, and other. Clinical risk factors for atrial fibrillation included objectively assessed body mass index (calculated using height and weight measures) and systolic and diastolic blood pressure. Laboratory testing included random glucose levels. Hypertension was defined as having a systolic blood pressure of 140 mmHg or higher, anti-hypertensive medication use, or a hypertension diagnosis per *ICD-9* and *ICD-10* diagnosis codes. Diabetes was defined as having a hemoglobin A1C level of 6.5% or higher, anti-diabetic medication use, or a diabetes diagnosis per *ICD* codes. Obesity was defined by $BMI \geq 30 \text{ kg/m}^2$. Smoking status was defined as being a current smoker (every day or some days) or not a current smoker. Diagnosis codes used for clinical risk factor identification can be found in Appendix Table 1.

Statistical Analysis

We compared baseline demographic and clinical characteristics across tertiles of neighborhood poverty using chi-square

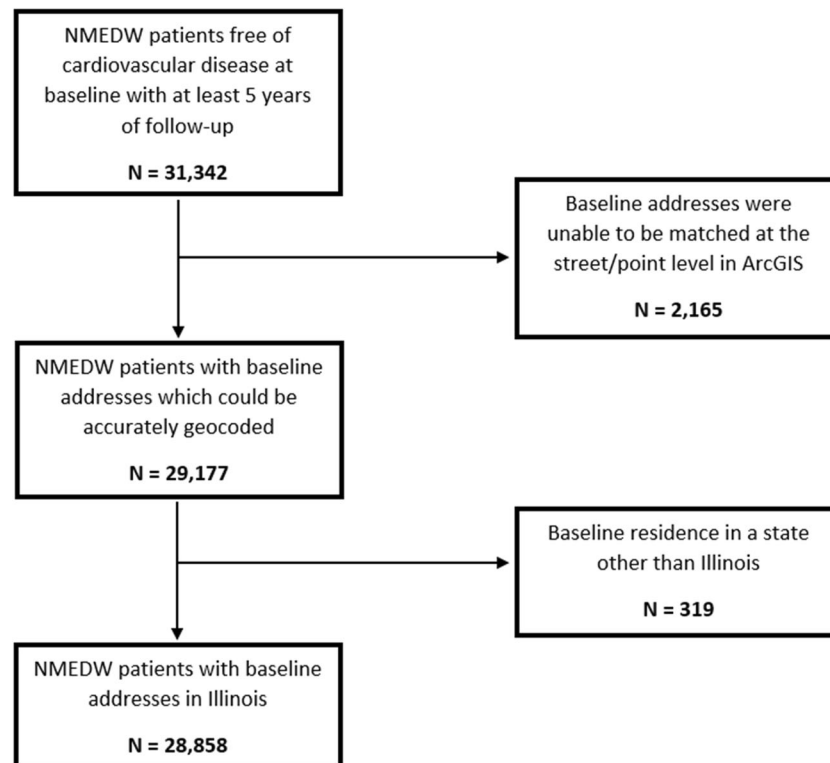


Fig. 1 Study flow diagram describing patient inclusion criteria for the retrospective cohort analysis from the Northwestern Medicine Enterprise Data Warehouse (NMEDW).

tests for categorical variables and analysis of variance or Kruskal-Wallis tests for continuous variables. Generalized linear mixed effects models with a logit link function were used to evaluate the association between neighborhood-level poverty and incident atrial fibrillation while accounting for the non-independence of patients residing within the same census tract using a random intercept for census tract. We accounted for the non-independence of patients residing within the same neighborhood through the inclusion of a random intercept for census tract. The relationship between neighborhood poverty category and atrial fibrillation was assessed using a series of sequentially adjusted models: unadjusted (Model 1), adjusted for demographics including continuous age, sex, and race/ethnicity (Model 2), and additionally adjusted for clinical risk factors, including smoking, continuous BMI, hypertension, and diabetes (Model 3). We examined whether the relationship between neighborhood-level poverty and atrial fibrillation differed by race/ethnicity by testing an interaction term in the fully adjusted model and observed that this interaction was not statistically significant ($p > 0.05$); thus, these findings are not included in the results below.

We used a two-tailed p value of < 0.05 to define statistical significance. All statistical analyses were performed using R version 3.6.1 or SAS version 9.4. This study was approved by the Northwestern University Feinberg School of Medicine Institutional Review Board.

RESULTS

Baseline Characteristics

The final cohort comprised 28,858 patients, including 15,952 (55.3%) that resided in a neighborhood characterized as having a low proportion of residents living below the poverty threshold (i.e., low poverty tertile), 8474 (29.4%) that resided in an intermediate poverty neighborhood, and 4432 (15.4%) that resided in a neighborhood with a high proportion of residents living below the federal poverty level (i.e., high poverty tertile) (Table 1). The mean age (standard deviation) of individuals in the cohort was 51.4 (± 11.3) years and included 2994 (10.4%) non-Hispanic Black and 1397 (4.8%) Hispanic patients as well as 16,578 (57.4%) women. Patients living in high poverty neighborhoods were more often non-Hispanic Black or Hispanic and current smokers, and had higher rates of obesity, hypertension, and diabetes.

Incidence of Atrial Fibrillation

At the 5-year follow-up, 971 (3.4%) patients developed atrial fibrillation. Of those who developed atrial fibrillation, 502 (51.7%) were in the low poverty, 327 (33.7%) in the intermediate poverty, and 142 (14.6%) in the high poverty group (Table 1). Women, non-Hispanic Black individuals, and those who identified their race as other had lower odds of developing atrial fibrillation in adjusted analyses. Atrial fibrillation risk factors, including BMI and hypertension, were associated with greater incidence of atrial fibrillation. The unadjusted odds of

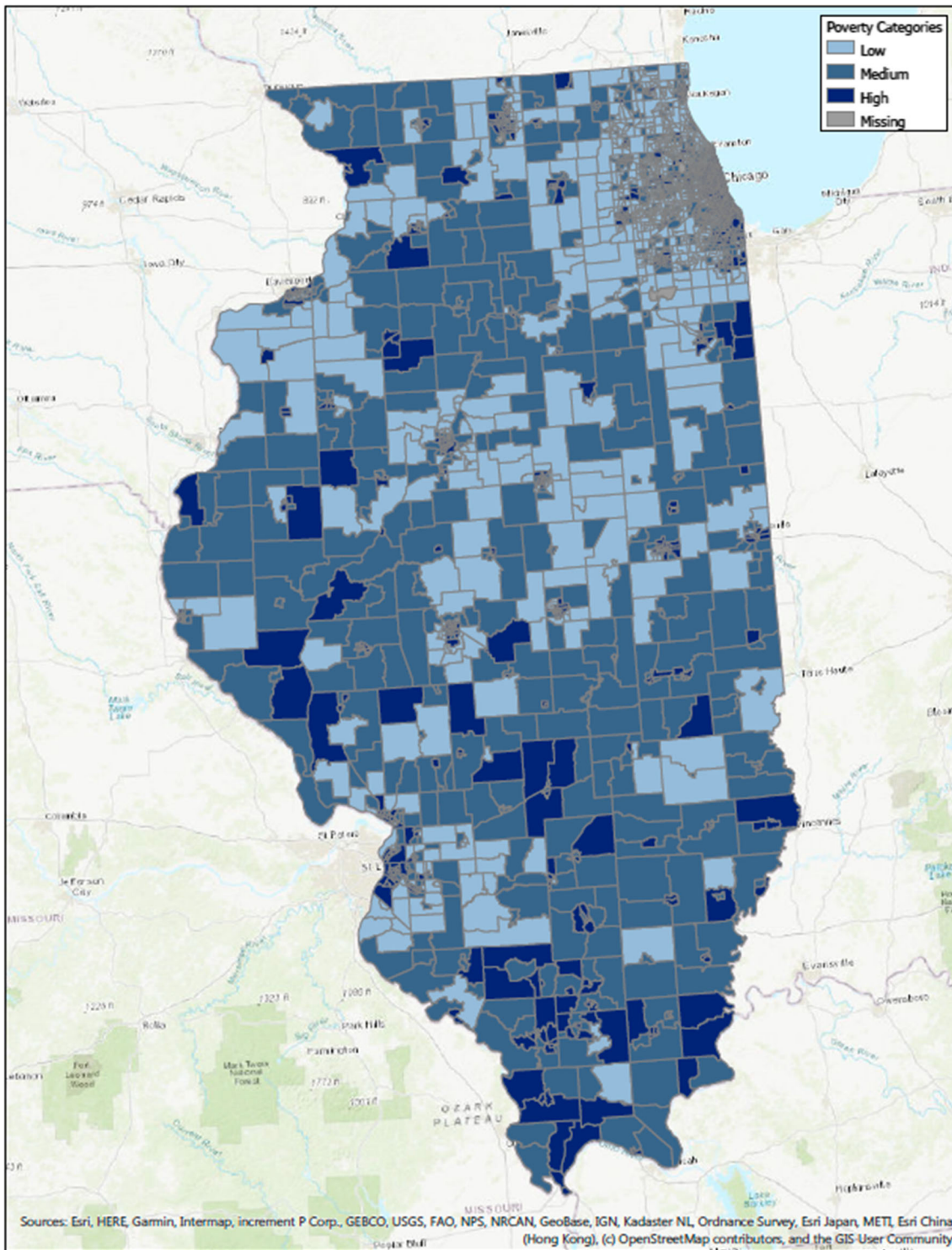


Fig. 2 Map of poverty categories for the greater Chicago area. Shading of census tracts corresponds to poverty category with the lightest blue representing neighborhoods with the lowest proportion of residents below the US-defined poverty level and the darkest blue representing neighborhoods with the highest proportion of residents above the US-defined poverty level.

developing atrial fibrillation in the intermediate poverty group (odds ratio, OR 1.13 [95% CI 0.94–1.35]) and high poverty group (OR 0.96 [95% CI 0.78–1.20]) were not significantly different compared to the low poverty group (Table 2). When adjusting for sociodemographic factors, patients in the intermediate poverty group had a higher incidence of atrial

fibrillation compared with the low poverty group (OR 1.21 [95% CI 1.00–1.46]). The point estimate for the odds ratio was similar between the high versus low poverty groups but was not statistically significant (OR 1.23 [95% CI 0.96, 1.57]). When adjusting further for clinical risk factors, patients in the intermediate poverty group still had a higher incidence of atrial

Table 1 Baseline Characteristics of Patients Overall and Stratified by Neighborhood-Level Poverty

	Overall	Neighborhood poverty category ^{*†‡}		
		Low	Intermediate	High
Sample size, N (%)	28,858	15,952 (55.3)	8474 (29.4)	4432 (15.4)
Age at baseline (years)	51.39 (11.3)	51.68 (10.9)	51.34 (11.8)	50.48 (11.7)
Male, N (%)	12,280 (42.6)	7296 (45.7)	3460 (40.8)	1524 (34.4)
Race/ethnicity, N (%)				
Non-Hispanic	21,526 (74.6)	13,600 (85.3)	6093 (71.9)	1833 (41.4)
White	2994 (10.4)	528 (3.3)	836 (9.9)	1630 (36.8)
Black	1397 (4.8)	510 (3.2)	510 (6.0)	377 (8.5)
Hispanic/Latino	2941 (10.2)	1314 (8.2)	1035 (12.2)	592 (13.4)
Other	2865 (9.9)	1461 (9.2)	888 (10.5)	516 (11.6)
Current smoking, N (%)	13,802 (47.8)	7438 (46.6)	3989 (47.1)	2375 (53.6)
Hypertension, N (%)	125.8 (16.7)	125.66 (16.4)	125.52 (17.0)	126.69 (17.1)
Systolic blood pressure (mm Hg)	10,408 (36.1)	5623 (35.2)	2916 (34.4)	1869 (42.2)
Obesity, N (%)	28.83 (6.0)	28.69 (5.8)	28.66 (6.1)	29.63 (6.5)
Body mass index (kg/m ²)	5188 (18.0)	2580 (16.2)	1529 (18.0)	1079 (24.3)
Diabetes, N (%)	6.19 (1.4)	6.21 (1.4)	6.14 (1.4)	6.21 (1.4)
Hemoglobin A1C, %	971 (3.4%)	502 (51.7%)	327 (33.7%)	142 (14.6%)
Developed incident atrial fibrillation, N (%)				

*For continuous characteristics, the mean (standard deviation) is reported, and for categorical characteristics the frequency (percent) is reported

†Neighborhood poverty categories were defined based on tertiles of the proportion living below the poverty threshold in a census tract. Low poverty corresponds to a proportion less than 0.073. Intermediate poverty corresponds to a proportion from 0.073 to 0.160. High poverty corresponds to a proportion greater than 0.160

‡All baseline characteristics differed significantly ($p < 0.05$) across neighborhood poverty categories

fibrillation compared with the low poverty group (OR 1.23 [95% CI 1.01–1.48]). The point estimate for the fully adjusted odds ratio was similar when comparing the high and low poverty groups (OR 1.25 [95% CI 0.98, 1.59]), but was not significantly different (Table 2).

DISCUSSION

Atrial fibrillation is an increasingly common and morbid heart rhythm disorder with substantial medical and societal costs [24]. In this study, we examined a real-world, retrospective cohort of adults free of cardiovascular disease at baseline and observed an association between intermediate neighborhood-level poverty and incident atrial fibrillation after adjusting for demographic and clinical risk factors, with a trend toward significance for high neighborhood-level poverty, though limited by the relatively small size of the high poverty group. Identifying factors, such as neighborhood-level poverty,

Table 2 Odds Ratios (95% Confidence Intervals) Describing the Association Between Neighborhood-Level Poverty and Atrial Fibrillation with Sequential Models Adjusting for Demographics and Known Atrial Fibrillation Risk Factors

	Model 1 Unadjusted	Model 2 Adjusted for demographics	Model 3 Model 2 plus risk factors
Neighborhood-level poverty [*]			
Low	Ref.	Ref.	Ref.
Intermediate	1.13 (0.94–1.35)	1.21 (1.00–1.46) [‡]	1.23 (1.01–1.48) [‡]
High	0.96 (0.78–1.20)	1.23 (0.96–1.57)	1.25 (0.98–1.59)
Demographics			
Age at baseline (per 1 year) [†]	-	1.09 (1.08–1.10) [‡]	1.09 (1.08–1.09) [‡]
Female (vs. male)	-	0.46 (0.41–0.53) [‡]	0.46 (0.40–0.53) [‡]
Race/ethnicity			
Non-Hispanic White [†]	Ref.	Ref.	Ref.
Non-Hispanic Black [†]	-	0.81 (0.62–1.06)	0.75 (0.57–0.97) [‡]
Hispanic/Latino	-	0.75 (0.51–1.10)	0.75 (0.51–1.09)
Other	-	0.65 (0.50–0.85) [‡]	0.70 (0.54–0.92) [‡]
Atrial fibrillation risk factors			
Body mass index (per 1 kg/m ²) [†]	-	-	1.03 (1.01–1.04) [‡]
Hypertension [*]	-	-	1.42 (1.21–1.66) [‡]
Diabetes [*]	-	-	0.94 (0.79–1.10) [‡]
Current smoker [*]	-	-	0.71 (0.55–0.92) [‡]

*Neighborhood poverty, hypertension, diabetes, and current smoker as defined in the “METHODS” section

†Odds ratios for continuous variables (age at baseline and body mass index) represent the difference in odds of atrial fibrillation for a 1 unit increase in the metric

‡Represents a statistically significant adjusted odds ratio at p value < 0.05

beyond the traditional clinical risk factors associated with atrial fibrillation may be useful to ensuring equitable prevention of this condition.

Results in Context of Individual Versus Neighborhood Socioeconomic Status

Prior studies have examined the association between individual- or household-level socioeconomic status (SES) and incidence of atrial fibrillation [8, 9]. Two analyses of the Atherosclerosis Risk in Communities (ARIC) study in 2014 and 2018 reported inverse relationships between individual-level SES and atrial fibrillation. The cumulative incidence of atrial fibrillation was lower among those with higher SES (i.e., self-reported family income and education level) independent of traditional atrial fibrillation risk factors in a prospective cohort of over 14,000 patients recruited from 1987 to 1989 [10, 25]. Examining broader neighborhood-level SES and utilizing a contemporary, more racially and ethnically diverse patient cohort, the current analysis also observed an inverse relationship, although the association between neighborhoods

with the highest proportion of residents living below the US-defined poverty level and incident atrial fibrillation was not statistically significant.

Two additional reports out of Sweden [26] and New York City [27] examined the association between combined measures of neighborhood-level SES (e.g., factors such as neighborhood-level median household income, education level, employment status, and receipt of social services) and incident atrial fibrillation. Respectively, the Swedish study found an inverse association between SES and hospitalization for atrial fibrillation (in women, but not in men), while the New York City study did not observe a statistically significant relationship between a composite SES score and incident atrial fibrillation. These contradictory findings reveal the complex interplay between neighborhood SES and incidence of atrial fibrillation. The disparate findings, compared with the current analysis, may reflect patient-level demographic and clinical differences in the two cohorts, time lapse between SES measurement and the diagnosis of atrial fibrillation, and limitations in atrial fibrillation ascertainment in the previous analyses, including the use of electrocardiograms only without atrial fibrillation diagnosis code assessment in the New York City study.

Determinants of Neighborhood-Level Poverty and Atrial Fibrillation Incidence

The relationship between neighborhood-level poverty and atrial fibrillation incidence is complex and is likely confounded by the relationship between race/ethnicity and the structural environment. As observed in our analysis, individuals residing in higher poverty neighborhoods are more likely to be non-Hispanic Black or Hispanic [28] and have a higher rate of clinical risk factors for atrial fibrillation including smoking, obesity, hypertension, and diabetes. Factors present in poorer neighborhoods such as decreased access to healthy foods, limited green space, and scarce public safety resources to support physical activity likely exacerbate these clinical risk factors [13]. Other determinants of our findings may include the fact that neighborhoods with a greater proportion of residents living below the US-defined poverty level tend to have higher rates of air pollution [29]. Air pollution is a known risk factor broadly associated with cardiovascular disease [29], and an increasingly recognized risk factor for atrial fibrillation, which may influence atrial fibrillation incidence in high poverty communities [30, 31]. Additionally, increased allostatic load, a concept related to physiologic stress, has been reported in individuals residing in high poverty compared with low poverty neighborhoods and has also been connected with the development of cardiovascular disease [32]. These factors may explain higher incidence of atrial fibrillation in higher poverty groups though they were not directly examined in our analysis and would further not explain why the association between high poverty and incident atrial fibrillation was not statistically significant.

In contrast, there are characteristics of individuals residing in high poverty neighborhoods that have been associated with lower incidence of atrial fibrillation. First, racial/ethnic differences in atrial fibrillation incidence have been previously described, with Black and Hispanic individuals demonstrating a lower risk of atrial fibrillation compared with their White counterparts [33]. These racial/ethnic differences have been largely attributed to genetic factors, with a greater incidence of atrial fibrillation reported in individuals of European ancestry [34, 35]. However, decreased geographic or insurance-related access to or limited engagement in health care, decreased access to cardiovascular specialist care, and provider bias for individuals residing in high poverty neighborhoods may result in lower ascertainment of atrial fibrillation in these communities [36]. Finally, it is well-established that life expectancy is reduced among lower income adults on the individual and population level [37, 38]. Thus, a higher rate of competing risk of premature death in high compared with low poverty neighborhoods [39] may result in fewer individuals in the highest poverty neighborhoods developing atrial fibrillation over time, given the significant association between aging and atrial fibrillation incidence [2]. This observation represents an important area of future exploration in the study of the relationship between poverty and incident atrial fibrillation.

Strengths and Limitations

This study has several strengths. The data were obtained from a large retrospective cohort with detailed sociodemographic and comprehensive clinical risk factor data. The analysis used robust geocoding methodology along with census tract-level data to assess neighborhood poverty in a representative, diverse population.

There are also certain limitations. First, because this was an observational study, we cannot exclude the possibility of residual or unmeasured confounding, particularly in our assessment of individual-level social risk factors for atrial fibrillation, including education, insurance, and employment status or other neighborhood-level factors such as environment exposures, racial composition, or community-level access to care. Second, while we adjusted for clinical risk factor burden at baseline, we were not able to capture cumulative burden over time, which has been associated with adverse cardiovascular remodeling and events that may predispose to atrial fibrillation. Third, as cohort entry required individuals to have at least 5 years of follow-up data as well as to have a matchable address, we cannot exclude the possibility of selection bias due to loss to follow-up. Fourth, our ascertainment of atrial fibrillation comprised using ICD codes alone and did not include electrocardiographic or Holter monitoring data, nor whether an atrial fibrillation diagnosis was paroxysmal or asymptomatic, which may have resulted in underascertainment of atrial fibrillation cases. While this method makes it difficult to capture the true burden of atrial fibrillation, it is likely we were able to adequately capture a large

proportion of symptomatic atrial fibrillation that required interaction with the healthcare system. Furthermore, our rates of incident atrial fibrillation were similar to prior population-based cohort studies (e.g., the Multi-Ethnic Study of Atherosclerosis) that incorporated independent physician-based event adjudication and electrocardiographic data [40]. Finally, our analysis did not include an examination of possible clustering of potential neighborhood-specific atrial fibrillation-related exposures, an important area of future study.

CONCLUSION

In a large, diverse, real-world cohort of patients without baseline cardiovascular disease, we found that individuals living in the neighborhoods at the intermediate poverty level had a higher incidence of atrial fibrillation over time with a trend toward a higher incidence in individuals residing in neighborhoods at the highest poverty level. Understanding how neighborhood- and individual-level clinical and sociodemographic factors interact to increase the risk of atrial fibrillation is critical to developing equitable prevention strategies in this increasingly common and morbid cardiovascular condition.

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Declarations:

Ethics Approval: This study was approved by the Northwestern University Feinberg School of Medicine Institutional Review Board.

Conflict of Interest: The authors declare that they do not have a conflict of interest.

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