

ORIGINAL ARTICLE

# Lifetime Risk of Atrial Fibrillation by Race and Socioeconomic Status

## ARIC Study (Atherosclerosis Risk in Communities)

See Editorial by McCauley and Darbar

**BACKGROUND:** Limited information exists on the lifetime risk of atrial fibrillation (AF) in African Americans and by socioeconomic status.

**METHODS:** We studied 15 343 participants without AF at baseline from the ARIC (Atherosclerosis Risk in Communities) cohort recruited in 1987 to 1989 from 4 communities in the United States when they were 45 to 64 years of age. Participants have been followed through 2014. Incidence rates of AF were calculated dividing the number of new cases by person-years of follow-up. Lifetime risk of AF was estimated by a modified Kaplan-Meier method considering death as a competing risk. Participants' family income and education were obtained at baseline.

**RESULTS:** We identified 2760 AF cases during a mean follow-up of 21 years. Lifetime risk of AF was 36% (95% confidence interval, 32%–38%) in white men, 30% (95% confidence interval, 26%–32%) in white women, 21% (95% confidence interval, 13%–24%) in African American men, and 22% (95% confidence interval, 16%–25%) in African American women. Regardless of race and sex, incidence rates of AF decreased from the lowest to the highest categories of income and education. In contrast, lifetime risk of AF increased in individuals with higher income and education in most sex-race groups. Cumulative incidence of AF was lower in those with higher income and education compared with their low socioeconomic status counterparts through earlier life but was reversed after age 80.

**CONCLUSIONS:** Lifetime risk of AF in the ARIC cohort was  $\approx$ 1 in 3 among whites and 1 in 5 among African Americans. Socioeconomic status was inversely associated with cumulative incidence of AF before the last decades of life.

**VISUAL OVERVIEW:** An online [visual overview](#) is available for this article.

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**Key Words:** atherosclerosis ■ atrial fibrillation ■ incidence ■ income ■ stroke

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## WHAT IS KNOWN?

- Previous community-based studies have shown that  $\approx 1$  in 3 persons will develop atrial fibrillation (AF) during their lifetime. These studies, however, have been mostly restricted to white individuals. Lifetime risk of AF among African Americans has not been reported.
- Lower socioeconomic status has been linked with higher risk of cardiovascular diseases, including AF, but the lifetime risk of AF across socioeconomic status groups is unknown.

## WHAT THE STUDY ADDS?

- In a large biracial cohort in the United States, lifetime risk of AF was  $\approx 1$  in 3 among whites and 1 in 5 among African Americans. Although African Americans had lower incidence rates and lifetime risk of AF than whites, the overall cumulative risk of AF in this group is not trivial.
- Rates of AF were lower among those with higher socioeconomic status. However, the lifetime risk of AF was higher among individuals with higher education and income across most race and sex groups.

**A**trial fibrillation (AF) is a common cardiac arrhythmia, affecting 2.7 to 6.1 million people in the United States alone. This number is expected to increase as the population ages.<sup>1</sup> AF costs the United States around \$6 billion every year, and people who have AF spend an additional \$8705 per year on medical costs compared with people without AF.<sup>1,2</sup> AF also is associated with significant morbidity, as it increases the risk of heart failure (HF), myocardial infarction (MI),<sup>3</sup> and stroke.<sup>4</sup>

Findings from the Framingham Heart Study in 2004 indicated that 1 in 4 individuals would develop AF during their lifetime,<sup>5</sup> with recent estimates in the same cohort suggesting that lifetime risk of AF is  $>1$  in 3.<sup>6</sup> Lifetime risk quantifies the absolute risk of developing a disease of interest before death. It is calculated as the adjusted cumulative incidence of the disease, taking the competing risk of death into account.<sup>5</sup> Estimates of the lifetime risk of developing AF are an easy way to communicate future risk to individuals.<sup>5</sup> However, the recent Framingham estimates, though taking into account recent upward trends in the incidence of AF,<sup>7</sup> may not be generalizable to nonwhite populations because its participants are from a predominantly white population of European origin. Because African Americans and other ethnic and racial groups have lower risk of AF compared with whites,<sup>8,9</sup> contemporary estimates of lifetime risk of AF in more diverse populations are needed.

Socioeconomic and racial health disparities exist in the United States,<sup>10</sup> which influences health outcomes, including the management and care of cardiovascular diseases.<sup>11</sup> A previous analysis of the US-based ARIC study (Atherosclerosis Risk in Communities) cohort showed that lower income in the overall population and lower education level among women was associated with increased risk of AF.<sup>12</sup> To date, however, no studies have explored the lifetime risk of AF by socioeconomic status (SES).

Therefore, to address these gaps, we used over 25 years of follow-up among 15 343 participants in the ARIC study to provide estimates of lifetime risk of AF by race and SES. These estimates can provide a more precise picture of the current and future public health burden of AF in the US population.

## METHODS

The data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure because of participant privacy issues. Investigators interested in obtaining ARIC data can do so by contacting the ARIC Coordinating Center at the University of North Carolina at Chapel Hill or via the National Heart, Lung, and Blood Institute BioLINCC repository.

## Study Population

The ARIC study is a prospective cohort study for the investigation of risk factors for cardiovascular diseases.<sup>8,13</sup> During 1987 to 1989, 15 792 participants (55% women, 27% African Americans) 45 to 64 years old were enrolled in the study. The participants were sampled from 4 US communities: Washington County, MD; the northwest suburbs of Minneapolis, MN; Jackson, MS; and Forsyth County, NC. The racial composition of the cohort reflected the underlying populations, except in Jackson, MS, where only African Americans (AAs) were sampled. Baseline information was collected by a phone interview and a clinical examination. Subsequently, participants were examined 3 $\times$  at roughly 3-year intervals until 1998, with a fifth examination taking place in 2011 to 2013. During follow-up, participants were contacted annually by phone to gather information on hospital admission and verify vital status. The response rates on the triennial exams and the annual phone interview were 93%, 86%, 80%, and  $>90\%$ , respectively. For this analysis, we included follow-up information through December 31, 2014. The ARIC study has been approved by the Institutional Review Boards at the participating institutions. All the participants signed a written informed consent.

Among the 15 792 participants, we excluded the following from the analysis: 48 with self-reported race nonwhite or non-African American and 55 AAs in the study centers of MN and MD because of the small sample sizes; 37 with AF or atrial flutter diagnosed by ECG at the baseline visit; and 309 whose ECG was missing or unreadable at the baseline visit. In total, we included 15 343 participants as the study population. For the analysis by total family income and education, we additionally excluded 893 whose income information was

missing and 24 whose education information missing, respectively, in the corresponding analysis.

## Incidence of AF Events

The ascertainment of AF has been reported previously.<sup>8,12</sup> In brief, AF was identified by 3 sources: ECGs from follow-up exams, hospital discharge records, and death certificates. ECGs during follow-up exams were done with MAC PC personal Cardiographs. All ECGs were transmitted to the ARIC ECG reading center for coding, interpretation, and storage. A trained cardiologist visually read recordings of ECGs automatically coded as AF for the certainty of the diagnosis. Also, the information of hospitalization was obtained during the annual follow-up interview and from surveillance of local hospitals. A trained abstractor accessed the hospital discharge records and recorded all the diagnoses according to *International Classification of Diseases*, Ninth Revision, Clinical Modification. AF was defined if codes 427.31 or 427.32 were present in the absence of procedure codes for open heart surgery. Finally, information on death from any cause was collected by calling participant's proxy, or from obituaries, hospital records, death certificates, or vital statistics from the National Death Index.<sup>14</sup> Cases of AF were identified from death certificates if *International Classification of Diseases*, Tenth Revision, code I48 or *International Classification of Diseases*, Ninth Revision, code 427.3 were listed as one of the causes of death. We have previously demonstrated the validity of this approach for AF event identification, with a positive predictive value of ≈90%.<sup>8</sup>

The incidence date of AF was defined as the first occurrence of AF in an ECG during follow-up examination, a hospital discharge record, or death certificate.<sup>8</sup>

## Assessment of SES and Covariates

The total family income and individual education level were self-reported during the baseline visit. For the analysis, we categorized total family income into 3 groups: <\$25 000 per year; \$25 000 to <\$50 000 per year; and ≥\$50 000 per year. In AAs, the last 2 groups were combined into one as ≥\$25 000 per year because of the small number of AA participants with reported income ≥\$50 000. Education level was also divided into 3 categories: basic—less than high school; intermediate—high school or equivalent; and high—completed at least some college education.

Risk factors for cardiovascular disease were measured at baseline. Smoking status was self-reported. Participant's height was measured without wearing shoes and weight wearing light clothing. Blood pressure was measured 3× at each visit after a 5-minute rest and in sitting position. The average of the last 2 measurements was used. Blood pressure ≥140/90 mm Hg or taking medications for hypertension was defined as hypertension. Fasting blood glucose ≥126 mg/dL, nonfasting blood glucose ≥200 mg/dL, current treatment for diabetes mellitus, or self-reported physician diagnosis of diabetes mellitus was defined as diabetes mellitus.<sup>15</sup> Self-reported history of MI or electrocardiographic evidence of prior MI was characterized as prevalent MI.<sup>16</sup> Prevalent HF was identified by the Gothenburg criteria or treatment of HF in the past 2 weeks at baseline.<sup>15,17</sup>

To have an overall summary of the risk of AF in the study population, we calculated the individual predicted 5-year risk based on the previously described CHARGE-AF score (Cohorts for Heart and Aging Research in Genomic Epidemiology–Atrial Fibrillation).<sup>18</sup> The model includes the following variables: age, race (white or African American), height, weight, systolic and diastolic blood pressure, smoking status, the presence of treatment of hypertension with medications, diabetes mellitus, HF, and history of MI.

## Statistical Analysis

Participants' characteristics at baseline are presented as percentages for the categorized variables and mean (SD) for the continuous and stratified by race.

We calculated age-specific rates of AF by 10-year group for age 45 to 54 and 5-year groups starting at age 55 through age 92 (oldest attained age). Incidence rates were calculated dividing the number of new cases in an age-specific group by the corresponding person-years of follow-up. Person-years of follow-up were defined from the date of visit 1 to the first diagnosis of AF, death, loss of follow-up, or December 31, 2014, whichever occurred first. The crude incidence rate was calculated as the total number of AF events divided by total person-years of follow-up. Rates were age standardized using the age-specific distribution of person-years in the entire cohort as the standard population. We also calculated sub-distribution hazard ratios of AF accounting for the competing risk of death using the Fine and Gray model.

We used a modified Kaplan-Meier method that accounts for the competing risk of death to calculate the lifetime risk of AF (cumulative incidence through oldest attained age in the cohort), as reported previously.<sup>19</sup> In the traditional Kaplan-Meier method, death is considered as any other type of censoring, which assumes that rates of the end point (AF in this case) are the same in censored and remaining participants. This is not reasonable among those who died because they are no longer at risk of developing AF. Survival estimates that do not consider death as a competing risk, therefore, lead to overestimates of the true cumulative and lifetime risk. In contrast, the method described in Beiser et al<sup>19</sup> estimates the cumulative risk of AF at a particular age by calculating AF-free survival probabilities conditional on being free of AF and alive up to that age. We calculated lifetime risk through age 92 (oldest age at which an AF event occurred in the cohort) starting at the index age 45, 55, 65, and 75. We performed separate calculations by race, sex, total family income, education level, and predicted 5-year AF risk according to quartiles of the CHARGE-AF score. This analysis was performed to estimate lifetime risk of AF across categories of short-term (5 years) AF risk and evaluate whether individuals with low predicted short-term risk of AF remain at low risk over their lifetime, or whether this risk increases.

SAS 9.4 (SAS Inc, Cary, NC) was used for the analysis.

## RESULTS

### Characteristics of Participants at Baseline

We analyzed 15 343 participants aged 45 to 64 years and without AF at baseline. Table 1 shows participants' characteristics by race and sex, whereas Table I in the

**Table 1. Baseline Characteristics of Participants, ARIC Study (Atherosclerosis Risk in Communities), 1987 to 1989**

	White Men	White Women	African American Men	African American Women
N (%)	5332 (35)	5948 (39)	1539 (10)	2524 (16)
Incidence AF cases	1263	1009	212	309
Age, y	55 (6)	54 (6)	54 (6)	53 (6)
Height, cm	176 (7)	162 (6)	176 (7)	163 (6)
Weight, kg	85 (14)	70 (15)	85 (17)	82 (18)
BMI, kg/m <sup>2</sup>	27 (4)	27 (6)	28 (5)	31 (7)
SBP, mmHg	120 (16)	117 (18)	130 (22)	128 (22)
DBP, mmHg	73 (10)	70 (10)	82 (13)	78 (12)
Smoking, %	25	25	38	25
Antihypertension therapy, %	20	20	34	45
Prevalence of diabetes mellitus, %	10	8	18	21
Prevalence of HF, %	3	5	5	9
Prior MI, %	7	1	5	3
CHARGE-AF score	0.02 (0.02)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
Estimated glomerular filtration rate, mL min <sup>-1</sup> 1.73 m <sup>-2</sup>	97 (13)	101 (12)	107 (19)	110 (20)

Values correspond to means (SDs) or percentages. CHARGE-AF score (Cohorts for Heart and Aging Research in Genomic Epidemiology–Atrial Fibrillation): predicted 5-year risk of atrial fibrillation (AF). BMI indicates body mass index; DBP, diastolic blood pressure; HF, heart failure; MI, myocardial infarction; and SBP, systolic blood pressure.

**Data Supplement** reports characteristics by race, family income, and education. In the entire cohort, AAs had a worse cardiovascular profile than whites, whereas white men (WM) had higher predicted 5-year risk of AF than other groups. Likewise, among both whites and AAs, the lower income groups had a higher proportion of women (63% in whites and 67% in AAs) compared with the other income groups, and those in the lowest categories of income and education had more adverse cardiovascular risk factors: higher systolic blood pressure and higher prevalence of hypertension, diabetes mellitus, HF, and MI, and smoking. Overall, higher income and education were correlated with more favorable cardiovascular profile, and across categories of income and education, whites had a lower prevalence of cardiovascular risk factors than AAs.

## AF Incidence and Lifetime Risk by Race and Sex

During a mean (SD) follow-up of 21 (7) years, we identified 2793 new cases of AF (2272 in whites and 521 in AAs). Incidence rates of AF rose dramatically with age,

with whites showing a higher rate (9.1 per 1000 person-years) than AAs (6.8 per 1000 person-years) overall. Table 2 presents the age-, race-, and sex-specific incidence rates of AF per 1000 person-years from 1987 to 2014. Age-standardized rates were highest (11.3 per 1000 person-years) among WM and lowest (6.1 per 1000 person-years) among AA women (AAW). Compared with WM, the rate ratios and 95% confidence intervals of AF in AAW, African American men (AAM), and WW were 0.54 (95% confidence interval, 0.47–0.61), 0.71 (95% confidence interval, 0.62–0.83), and 0.64 (95% confidence interval, 0.59–0.70), respectively. Similar patterns were observed in a model including death as a competing risk, with women and African Americans experiencing lower rates of AF. Rates of early-onset AF (before age 65) in 8613 participants without comorbidities (diabetes mellitus, hypertension, HF, or MI) at baseline were 3.2 per 1000 person-years among WM, 1.6 per 1000 person-years among WW, 0.9 per 1000 person-years among AAM, and 0.9 per 1,000 person-years among AAW.

The lifetime risk of AF in whites was 33% and in AAs 21%, or ≈1 in 3 and 1 in 5, respectively. Lifetime risk was 36% in WM, 30% in WW, 21% in AAM, and 22% in AAW. Table II in the **Data Supplement** displays the lifetime risk by race and sex at the index age of 45, 55, 65, and 75. The lifetime risk of AF remained almost constant from index age 45 to 65, with slightly smaller values after index age 75. Figure 1 shows the cumulative incidence of AF from age 45 to 92 by race and sex.

## AF Incidence and Lifetime Risk by Income and Education

Tables 3 and 4 show the age-, race-, income-, and education-specific AF incidence rates per 1000 person-years from 1987 to 2014. Overall, regardless of race and sex, AF incidence rates decreased from the lowest to the highest categories of income and education. Compared with those with the lowest income, individuals in the highest income category had age-standardized relative rate reduction of 24% (WM), 30% (WW), 20% (AAM), and 27% (AAW). Corresponding figure for high education versus low education was 21%, 43%, 29%, and 37% in WM, WW, AAM, and AAW, respectively. These associations, however, disappeared in men or were attenuated in women using models that considered death as a competing risk.

Table III in the **Data Supplement** provides lifetime risk of AF by race, sex, income, and education conditional on survival free of AF from index age 45 to 75. In contrast to the clear association of higher income and education with lower rates of AF, lifetime risk of AF was higher in WM, AAM, and AAW with higher income and education. Among WW, in contrast, higher income and education were associated with lower lifetime risk of AF. Figure 2 presents the cumulative incidence of AF from age 45 to 92

**Table 2.** Age-, Race-, and Sex-Specific Incidence Rates of AF per 1000 Person-Years, ARIC Study (Atherosclerosis Risk in Communities), 1987 to 2014

Age Group	White Men			White Women			African American Men			African American Women		
	No. of AF	Person-Years	IR*	No. of AF	Person-Years	IR	No. of AF	Person-Years	IR	No. of AF	Person-Years	IR
45–54	25	13 355	1.9	9	17 483	0.5	4	4681	0.7	4	8397	0.5
55–59	66	16 223	4.1	30	19 809	1.5	11	4817	2.3	13	8781	1.5
60–64	132	21 855	6.0	84	25 581	3.3	23	5983	3.8	31	10 641	2.9
65–69	220	22 324	9.9	169	26 341	6.4	42	5952	7.1	56	10 606	5.3
70–74	279	18 143	15.4	241	22 001	11.0	51	4481	11.4	74	8449	8.8
75–79	267	11 198	23.8	224	13 808	16.2	47	2378	19.8	68	4692	14.5
80–84	198	5118	38.7	178	6605	26.9	24	943	25.5	40	2107	19.0
85–89	73	1255	58.2	73	1904	38.4	10	233	42.9	21	557	37.7
Crude rate	1262	109 514	11.5	1008	133 602	7.5	212	29 478	7.2	308	54 250	5.7
Age-standardized rate			11.3			7.3			8.1			6.1
RR (95% CI)†	1 (Ref.)			0.64 (0.59–0.70)			0.71 (0.62–0.83)			0.54 (0.47–0.61)		
SHR (95% CI)‡	1 (Ref.)			0.72 (0.66–0.78)			0.57 (0.49–0.66)			0.53 (0.46–0.60)		

AF indicates atrial fibrillation; CI, confidence interval; IR, incidence rate; RR, rate ratio; and SHR, subdistribution hazard ratio.

\*Incidence rate (per 1000 person-years).

†Age-standardized rate ratio and 95% confidence interval.

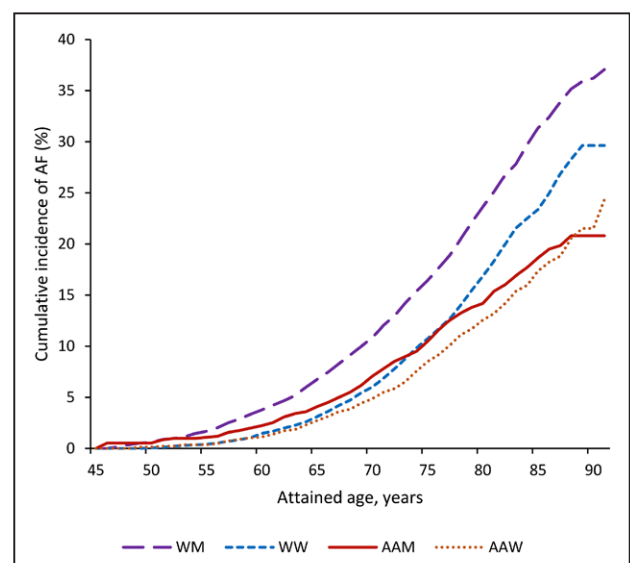
‡Subdistribution hazard ratios of AF adjusted for age considering death as a competing risk.

by income and education in WM, WW, AAM, and AAW. Figure 2 shows that in WM, AAM, and AAW, cumulative incidence of AF earlier in life is lower among those with higher income and education, but that trend is reversed later in life. WW, however, experienced lower AF cumulative incidence from the lowest to the highest categories of income and education during their entire lifetime.

### Lifetime Risk of AF by Predicted AF Risk

With the purpose of estimating long-term risk of AF across categories of short-term predicted AF risk, we estimated the lifetime risk of AF by quartiles of the predicted 5-year AF risk calculated from the CHARGE-AF model at baseline (variables included in the predictive model are given in Methods). Lifetime risk across quartiles of predicted 5-year risk at baseline was 11% for those with predicted risk  $\leq 0.4\%$ , 25% for predicted risk  $> 0.4\%$  and  $\leq 0.8\%$ , 29% for predicted risk  $> 0.8\%$  and  $\leq 1.5\%$ , and 37% for those with predicted risk  $> 1.5\%$ , as shown in Table IV in the [Data Supplement](#). Figure 3 presents the cumulative incidence of AF by quartiles of predicted 5-year risk of AF during age 45 to 92. The cumulative incidence positively increased with the predicted risk. The individuals having the highest predicted risk of AF showed more dramatic increase of cumulative incidence from age 45 to 92 compared with their counterparts who possessed lower predicted risk of AF.

risk of developing AF was  $\approx 1$  in 3 among whites and 1 in 5 among AAs. We also reported higher rates of AF with old age, among whites, and in individuals with lower SES. In contrast, the lifetime risk of AF was lower in individuals with low versus high SES in most race-sex groups, possibly because of longer survival among the socioeconomically advantaged. Even among those with the lowest short-term predicted risk of AF, lifetime risk was considerable ( $> 10\%$ ).



**Figure 1.** Race- and sex-specific adjusted cumulative incidence of atrial fibrillation (AF), ARIC study (Atherosclerosis Risk in Communities), 1987 to 2014. Lifetime risk is cumulative risk through 92 years of age.

AAM indicates African American men; AAW, African American women; WM, white men; and WW, white women.

## DISCUSSION

In this analysis of 15 343 men and women followed for an average of 21 years, we estimated that the lifetime

**Table 3. Age-, Race-, Sex-, and Income-Specific Incidence Rates of AF per 1000 Person-Years, ARIC Study (Atherosclerosis Risk in Communities), 1987 to 2014**

Age Group	White Men			White Women			African American Men			African American Women		
	<\$25 000	\$25 000–<\$50 000	≥\$50 000	<\$25 000	\$25 000–<\$50 000	≥\$50 000	<\$25 000	≥\$25 000	≥\$25 000	<\$25 000	≥\$25 000	≥\$25 000
45–54	1.3	2.1	1.6	0.9	0.7	0.2	0.9	0.8	0.6	0.3	0.3	0.3
55–59	6.9	4.2	2.6	1.5	2.1	0.8	1.3	3.3	2.1	0.3	0.3	0.3
60–64	7.1	6.0	5.7	2.7	3.4	3.4	5.1	2.5	3.8	1.1	1.1	1.1
65–69	14.8	9.5	7.2	10.0	5.9	3.7	7.1	7.0	5.2	5.5	5.5	5.5
70–74	19.3	14.6	14.8	12.4	10.4	9.7	13.4	9.1	9.1	8.1	8.1	8.1
75–79	27.3	24.1	22.2	19.3	16.0	14.2	24.1	14.3	16.7	9.0	9.0	9.0
80–84	30.6	41.5	41.0	31.8	23.6	23.4	28.1	21.4	22.4	9.1	9.1	9.1
85–89	78.9	43.3	61.2	38.3	40.3	38.4	31.5	67.1	30.6	70.7	70.7	70.7
Rate*	13.7	11.1	10.4	8.7	7.1	6.0	8.9	7.2	6.7	4.9	4.9	4.9
RR (95% CI)†	1 (Ref.)	0.81 (0.70–0.94)	0.76 (0.65–0.88)	1 (Ref.)	0.82 (0.71–0.94)	0.70 (0.59–0.83)	1 (Ref.)	0.80 (0.60–1.07)	1 (Ref.)	0.73 (0.56–0.96)	0.73 (0.56–0.96)	0.73 (0.56–0.96)
SHR (95% CI)‡	1 (Ref.)	0.94 (0.82–1.09)	0.93 (0.79–1.09)	1 (Ref.)	0.90 (0.78–1.04)	0.77 (0.65–0.93)	1 (Ref.)	1.00 (0.74–1.36)	1 (Ref.)	0.71 (0.51–1.00)	0.71 (0.51–1.00)	0.71 (0.51–1.00)

AF indicates atrial fibrillation; CI, confidence interval; and RR, rate ratio.

\*Age-standardized rate.

†Age-standardized rate ratio and 95% confidence interval.

‡Subdistribution hazard ratios of AF adjusted for age considering death as a competing risk.

**Table 4. Age-, Race-, Sex-, and Education-Specific Incidence Rates of AF per 1000 Person-Years, ARIC Study (Atherosclerosis Risk in Communities), 1987 to 2014**

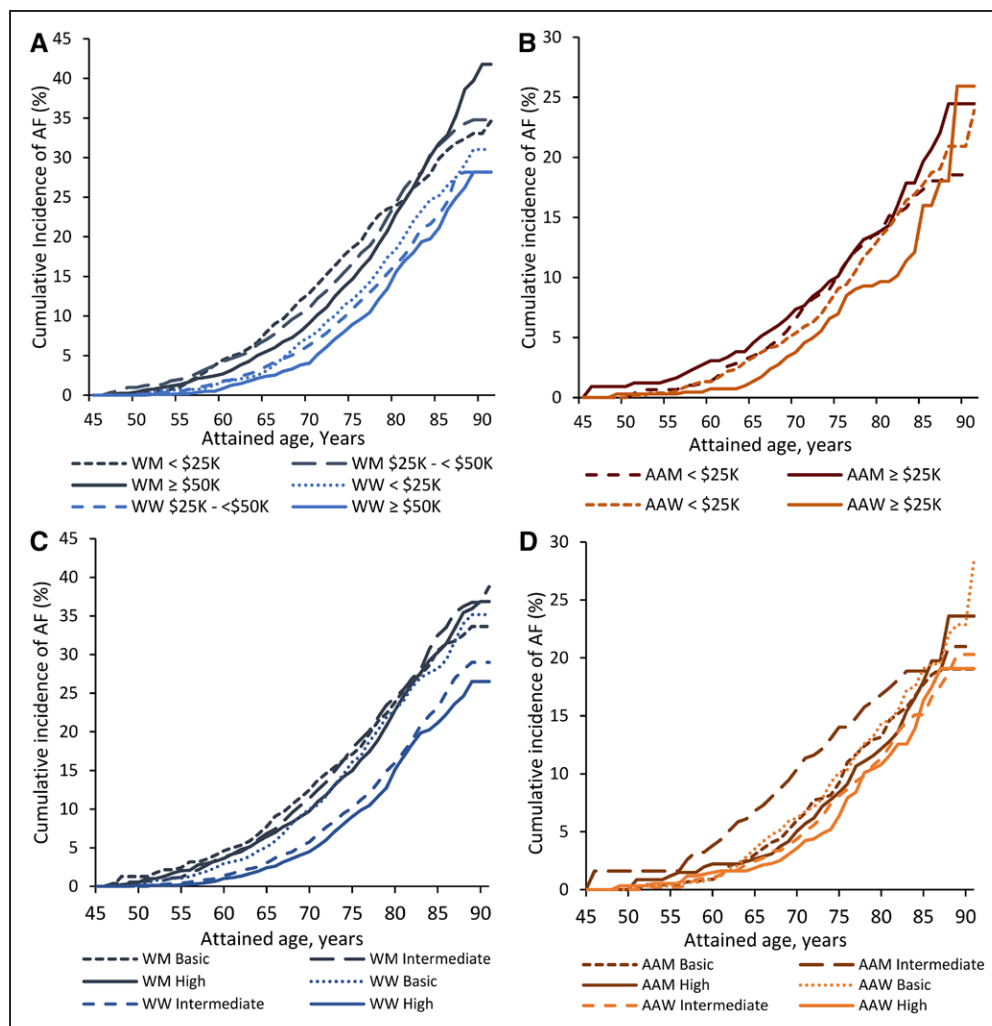
Age Group	White Men			White Women			African American Men			African American Women		
	Basic	Intermediate	High	Basic	Intermediate	High	Basic	Intermediate	High	Basic	Intermediate	High
45–54	2.2	1.2	2.4	1.6	0.6	0.1	0.7	0.7	1.1	0.4	0.4	0.6
55–59	4.1	5	3.2	3.0	1.4	1.2	1.1	3.8	2.3	1.0	1.9	1.7
60–64	6.5	6.2	5.7	4.9	3.2	2.7	4.1	7.2	1.0	4.9	2.8	0.6
65–69	12.7	11.1	7.7	11.0	6.1	4.7	7.8	9.6	4.2	7.8	4.2	3.3
70–74	15.9	16.9	13.9	15.1	10.6	9.6	11.5	13.1	10.1	10.0	10.0	5.7
75–79	25.7	26.3	20.9	25.0	15.5	12.7	25.9	15.3	13.7	15.3	11.2	16.5
80–84	41.7	35.9	38.7	27.7	26.7	27.0	30.0	18.5	23.1	22.7	19.4	12.2
85–89	65.2	62.1	51.4	51.5	39.5	28.2	45.8	19.2	60.0	41.8	29.8	39.7
Rate*	12.5	12.1	10.2	10.6	7.1	6.0	8.9	8.7	6.3	7.4	5.7	4.7
RR (95% CI)†	1 (Ref.)	0.96 (0.83–1.12)	0.81 (0.70–0.94)	1 (Ref.)	0.67 (0.57–0.78)	0.57 (0.48–0.68)	1 (Ref.)	0.97 (0.70–1.35)	0.71 (0.50–1.00)	1 (Ref.)	0.77 (0.59–1.00)	0.63 (0.48–0.84)
SHR (95% CI)‡	1 (Ref.)	1.06 (0.90–1.23)	0.95 (0.81–1.11)	1 (Ref.)	0.74 (0.63–0.87)	0.65 (0.54–0.77)	1 (Ref.)	1.07 (0.77–1.49)	0.79 (0.56–1.12)	1 (Ref.)	0.83 (0.64–1.09)	0.71 (0.53–0.95)

Basic, did not complete high school; intermediate, completed high school or equivalent; and high, completed at least some college education. AF indicates atrial fibrillation; CI, confidence interval; and RR, rate ratio.

\*Age-standardized rate.

†Age-standardized rate ratio and 95% confidence interval.

‡Subdistribution hazard ratios of AF adjusted for age considering death as a competing risk.



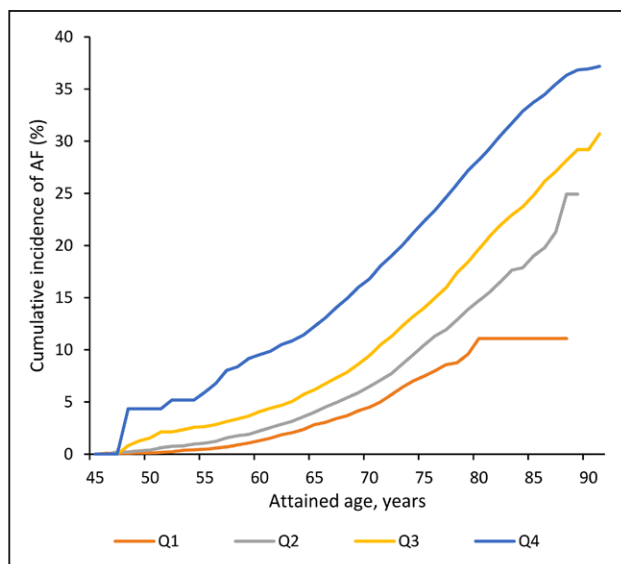
**Figure 2.** Adjusted cumulative incidence of atrial fibrillation (AF) from age 45 to 92 by income, education, race and sex, ARIC study (Atherosclerosis Risk in Communities), 1987 to 2014.

**A,** By income categories in whites. **B,** By income categories in African Americans. **C,** By education categories in whites. **D,** By education categories in African Americans. AAM indicates African American men; AAW, African American women; WM, white men; and WW, white women.

The current results complement those from an earlier analysis of the ARIC cohort with follow-up through 2004 (compared with 2014 in the present analysis).<sup>8</sup> The overall results from the 2 analyses are consistent, showing higher incidence rates of AF in whites than in AAs, in men than in women, and exponential rate increases with age. However, because of the aging of the cohort during the extended follow-up, the crude incidence rates of AF increased from 6.7 to 11.5 per 1000 person-years in WM, from 4.0 to 7.5 in WW, from 3.9 to 7.2 in AAM, and from 3.0 to 5.7 in AAW, compared with the previous ARIC report.<sup>8</sup>

AF incidence rates in WM and WW in the ARIC cohort are comparable to the rates reported in a recent analysis of the Framingham Heart Study,<sup>7</sup> reflecting the general occurrence of AF in the white population in the United States. We also found that AF lifetime risk is around 1 in 3 in whites (36% in WM and 30% in WW) after the age of 45 years, which is higher than

the lifetime risks reported in a previous analysis of the Framingham Heart Study,<sup>5</sup> the Swedish Study of Men Born in 1913,<sup>20</sup> and the Dutch Rotterdam Study,<sup>21</sup> but similar to a recent report from the Framingham Heart Study. The increased AF lifetime risk may partially be attributed to enhanced surveillance for and awareness of AF in the community.<sup>7</sup> Of note, follow-up in the older Framingham Heart Study and Rotterdam Study publications ended before the year 2000.<sup>5,21</sup> Also, differences in AF risk factors and lifestyles across cohorts might explain the differences. For example, the prevalence of diabetes mellitus and MI in the ARIC cohort was higher than that in the Rotterdam Study.<sup>21</sup> Differences in the lifetime risk of AF between the current ARIC report and the recent Framingham Heart Study<sup>6</sup> can be explained by dissimilarities in the ascertainment of AF, which rely mostly in hospitalizations in ARIC, whereas the Framingham Heart Study had access to outpatient medical records.



**Figure 3.** Adjusted cumulative incidence of atrial fibrillation (AF) from age 45 to 92 by quartiles of predicted 5-year risk of AF, ARIC study (Atherosclerosis Risk in Communities), 1987 to 2014.

Q1: predicted risk  $\leq 0.4\%$ . Q2:  $0.4\% < \text{predicted risk} \leq 0.8\%$ . Q3:  $0.8\% < \text{predicted risk} \leq 1.5\%$ . Q4: predicted risk  $> 1.5\%$ .

Multiple studies have demonstrated that AAs have lower incidence of AF than whites. In an earlier analysis of the ARIC study, we found that AF rates in AAs were 41% lower compared with whites after an average 15-year follow-up.<sup>8</sup> The same results have been found in different cohorts.<sup>22–28</sup> Complementing previous studies, we now show that AAs have lower lifetime risk of AF than whites, despite higher prevalence of AF risk factors. However, notwithstanding their lower lifetime risk, still 1 in 5 AAs in ARIC were estimated to develop AF during their lifetime, certainly not a trivial figure. We also found that unlike whites, AAW had a slightly increased lifetime risk compared with AAM. The reason might be that AAW could live longer to very old age to have more chance of developing AF than AAM. In fact, AAW have lower all-cause mortality and longer life expectancy than AAM.<sup>29</sup>

Prior research has reported higher rates of cardiovascular disease, including AF, among those with lower SES.<sup>30–34</sup> As expected, we found that age-standardized incidence rates of AF decreased in a dose-response fashion with higher income and education, regardless of race and sex. Our findings are consistent with a previous ARIC report that specifically focused on examining the association between SES and AF incidence.<sup>12</sup>

In contrast to the inverse association of SES with AF rates, we found that AF lifetime risk increased with income in WM, AAM, and AAW and with education in WM and AAM. In this analysis, we found that cumulative incidence of AF was generally lower earlier in life among those with higher income but increased substantially in the last decade of life among those with

higher SES. Consistent with our findings, a prior study showed that the association between mortality risk and SES was attenuated in older people.<sup>34</sup> One potential explanation for this observation is the impact of mortality as a competing risk disproportionately affecting the socioeconomically disadvantaged groups. As we showed in this analysis, ARIC participants in the lowest ranks of income and education had the highest prevalence of cardiovascular risk factors. Consequently, mortality would be higher in people with low income and education compared with others and, therefore, fewer people in low income and education would survive to old age to have a chance to develop AF. This may result in more AF in people with high income and education at the very late stage of life. This pattern, however, was not present in WW and, to a lesser extent, in AAW, with high SES being associated with both lower rates and lifetime risk of AF. Differences between WW and the other groups could be because of variance in mortality rates across groups, with WW having lower mortality rates and surviving to older ages in general. In summary, estimates of lifetime risk of AF across SES groups may be problematic because it could mask actual socioeconomic disparities in the incidence of the arrhythmia.

We also found that lifetime risk of AF increased with higher short-term risk of AF, as predicted by the CHARGE-AF score. However, even among participants with very low short-term risk, the lifetime risk of AF was substantial ( $>10\%$  in those with 5-year predicted risk of  $<0.4\%$ ). These findings highlight the need to maintain a life-course perspective and can assist the development of preventive messages.<sup>35</sup>

Our findings have significant implications for public health. Our observation that 1 in 3 whites and 1 in 5 AAs will develop AF during their lifetime underscores the high burden of AF in the community. The increased number of AF patients has brought about an increased demand for anticoagulation treatment for stroke prevention<sup>36</sup> and highlights the need for more randomized trials to evaluate strategies to reduce risk of ischemic events associated with AF.<sup>37</sup> The impact of AF is exacerbated by the increased risk of stroke, HF, and mortality in persons affected by AF.<sup>38–41</sup> Hence, novel prevention approaches for AF and its complications are urgently needed overall and specifically in low SES individuals and other vulnerable groups, such as AAs, who experience more AF-related adverse clinical outcomes.<sup>14</sup>

## Strengths and Limitations

Ours is the first study to report the lifetime risk of AF in AAs. It takes advantage of the data available in the ARIC cohort, one of the longest follow-up studies in a large biracial population in the United States. In addi-



tion to the diverse population, the large number of AF events, and the extended follow-up, other strengths include the excellent cohort retention and the careful methodology for ascertainment of cardiovascular events and mortality.

There are certain limitations in our study. More importantly, ascertainment of AF is likely to be incomplete because we are missing asymptomatic cases and those exclusively managed in the outpatient settings. The recognition and coding of AF could be different across different race/ethnic groups. Also, AF can be intermittent and therefore may not be detected with a standard 10-s ECG and hospitalizations. In addition, the information on education and total family income was self-reported, without any external validation, and collected only at baseline. Moreover, family income did not take into account family size because this information was not collected. Although the individual education status might not change after baseline, the total family income of some participants could change during the >20 years of follow-up. Finally, the impact of education and income in the ARIC study reflects the experience of a cohort born between the 1920s to early 1940s, which may be different from those of later cohorts.

## Conclusions

We found that lifetime risk of AF in a contemporary cohort is  $\approx 1$  in 3 among whites, higher than previously reported, and 1 in 5 among AAs. These results contribute to clarify the public health impact of AF and can be used to raise awareness of this common condition among the population. Our findings also emphasize the importance of developing programs on screening and prevention of AF in low SES populations.

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## Disclosures

None.

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**Lifetime Risk of Atrial Fibrillation by Race and Socioeconomic Status: ARIC Study  
(Atherosclerosis Risk in Communities)**

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**SUPPLEMENTAL MATERIAL**

**Supplementary Table 1. Baseline Characteristics of participants by race, family income, and education, Atherosclerosis Risk in Communities Study, 1987 - 1989**

	Whites (n=11,280)						African-Americans (n=4,063)				
	Total Family Income			Education Levels			Total Family Income		Education Levels		
	<\$25K	\$25K-<\$50K	≥\$50K	Basic	Intermediate	High	<\$25K	≥\$25K	Basic	Intermediate	High
N	2874	4569	3337	1844	4890	4046	2598	1055	1529	1035	1089
% of total	26.7	42.4	31.0	17.1	45.4	37.5	71.1	28.9	41.9	28.3	29.8
AF cases	683	917	58	491	1007	768	366	26	258	142	119
Age, years	57(6)	54(6)	53(5)	56(5)	54(6)	54(6)	54(6)	52(5)	55 (6)	53 (6)	52 (6)
% of female	62	51	46	50	59	46	67	52	60	65	63
Height (women), cm	161(6)	162(6)	163(6)	160(6)	162(6)	163(6)	163(6)	164(6)	163 (6)	163 (6)	164 (6)
Height (men), cm	174(7)	176(7)	178(6)	174 (6)	176(7)	178(6)	176(7)	177(7)	176 (7)	176 (7)	177 (7)
Weight, kg	76(16)	78 (16)	78 (16)	78 (16)	76(16)	78(16)	83(18)	83(16)	84 (18)	83 (17)	82 (17)
SBP, mmHg	122(18)	119 (17)	116 (16)	122 (18)	119(17)	117(16)	131(22)	125(19)	132 (22)	128 (23)	126 (19)
DBP, mmHg	71(10)	72(10)	72(10)	71(10)	72(10)	72(10)	80(12)	79(12)	80 (13)	79 (13)	79 (12)
Smoking, %	30	25	20	35	26	19	32	25	34	29	25
AT,%	26	20	15	26	21	16	44	34	46	38	36
Diabetes, %	14	9	6	15	9	7	23	13	25	19	15
HF, %	6	3	2	6	4	3	9	3	10	7	4
Prior MI, %	6	4	3	8	4	3	4	2	5	4	2

Values corresponding to mean (standard deviation) or percentages. AT: antihypertensive therapy. DBP: diastolic blood pressure. HF: heart failure. MI: myocardial infarction. SBP: systolic blood pressure

**Supplementary Table 2. Estimates (95% confidence intervals) of race- and sex-specific lifetime risk of AF conditional on survival free of AF to age 45, 55, 65, or 75, Atherosclerosis Risk in Communities study, 1987-2014.**

Survival free of AF	White men	White women	African American men	African American women
age 45	36 (32, 38)	30 (26, 32)	21 (13, 24)	22 (16, 25)
age 55	36 (32, 38)	30 (27, 32)	21 (13, 24)	22 (16, 25)
age 65	35 (31, 37)	30 (26, 32)	22 (14, 26)	23 (17, 26)
age 75	32 (28, 35)	26 (23, 29)	21 (12, 26)	21 (15, 26)

**Supplementary Table 3.** Estimates (95% confidence intervals) of race-, sex, income-, and education-specific lifetime risk of AF conditional on survival free of AF to age 45, 55, 65, and 75, Atherosclerosis Risk in Communities study, 1987-2014.

Survival free of AF	White men			White women			African American men			African American women		
	<\$25K	\$25K - <\$50K	≥\$50K	<\$25K	\$25K - <\$50K	≥\$50K	<\$25K	≥\$25K	<\$25K	≥\$25K	<\$25K	≥\$25K
age 45	33 (26, 37)	35 (30, 38)	40 (32, 45)	31 (26, 34)	28 (24, 31)	28 (20, 34)	19 (10, 22)	25 (6, 31)	21 (15, 24)	26 (2, 37)		
age 55	34 (27, 38)	34 (29, 37)	40 (32, 45)	31 (26, 34)	29 (24, 32)	28 (20, 35)	19 (11, 23)	25 (6, 32)	22 (16, 25)	26 (3, 38)		
age 65	33 (26, 37)	33 (28, 36)	39 (31, 45)	32 (27, 35)	28 (23, 31)	28 (19, 34)	21 (12, 25)	25 (6, 33)	22 (16, 25)	28 (4, 40)		
age 75	30 (22, 35)	30 (24, 34)	37 (28, 44)	29 (23, 33)	24 (19, 28)	25 (15, 32)	21 (11, 26)	24 (4, 34)	21 (15, 26)	26 (1, 41)		
Survival free of AF	Basic	Intermedi ate	High	Basic	Intermedi ate	High	Basic	Intermedi ate	High	Basic	Intermedi ate	High
age 45	34 (26, 38)	37 (31, 40)	36 (30, 39)	35 (28, 40)	29 (25, 32)	27 (21, 30)	19 (10, 23)	21 (3, 27)	24 (1, 33)	23 (14, 27)	20 (9, 26)	19 (10, 25)
age 55	33 (25, 37)	37 (31, 40)	35 (30, 39)	34.6 (27, 39)	29 (25, 32)	27 (21, 31)	20 (11, 24)	21 (3, 27)	24 (0, 33)	23 (14, 27)	22 (10, 28)	19 (10, 25)
age 65	33 (25, 37)	36 (30, 39)	34 (28, 38)	35 (28, 40)	29 (24, 32)	26 (21, 31)	22 (13, 27)	20 (1, 27)	25 (1, 35)	24 (15, 29)	22 (10, 28)	20 (10, 26)
age 75	32 (23, 38)	33 (26, 37)	32 (25, 36)	31 (23, 37)	26 (21, 29)	23 (17, 28)	24 (13, 30)	16 (0, 26)	24 (0, 38)	23 (13, 29)	20 (7, 28)	19 (9, 26)

**Supplementary Table 4.** Estimates (95% confidence intervals) of lifetime risk of AF conditional on survival free of AF to age 45, 55, 65, or 75 by quartiles of 5-year predicted risk, Atherosclerosis Risk in Communities Study, 1987-2014.

Survival free of AF	Q1 Predicted risk $\leq$ 0.4%	Q2 0.4% < Predicted risk $\leq$ 0.8%	Q3 0.8% < Predicted risk $\leq$ 1.5%	Q4 Predicted risk > 1.5%
age 45	11 (8, 13)	25 (12, 33)	29 (25, 32)	37 (32, 43)
age 55	11 (8, 13)	25 (12, 33)	29 (25, 31)	35 (32, 37)
age 65	10 (7, 12)	24 (11, 33)	28 (25, 31)	34 (31, 36)
age 75	5 (2, 8)	22 ( 8, 33)	25 (21, 28)	31 (28, 33)