Thirty-Year Trends in the Incidence of Atrial Fibrillation: The ARIC Study

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BACKGROUND: Long-term data to study recent trends in the incidence of atrial fibrillation (AF), overall and among sex and race groups, are scarce. We evaluated the 30-year trends in the incidence of AF in the ARIC (Atherosclerosis Risk in Communities) study cohort and explored race and sex differences in these trends.

METHODS AND RESULTS: We included 15,343 men and women aged 45 to 64 years in 1987 to 1989 without AF from 4 US communities in the ARIC cohort. Incident AF was identified based on study ECGs, hospital discharge codes, and death certificates through 2017. We calculated age and period-specific incidence rates (IRs) of AF. We used Poisson regression to calculate IR ratios of AF over time adjusting for age, sex, and race. A total of 3,241 AF cases were identified during a mean (SD) follow-up of 22 years (8.4 years) (599 in Black participants, 2,642 in White participants, 1,582 in women, and 1,659 in men). Overall, the IR of AF in the ARIC cohort was 9.6 per 1000 person-years (6.9 in Black participants, 10.5 in White participants, 8.1 in women, and 11.6 in men). Age-specific IR by time period did not show significant changes over time. In a model adjusted for sex, race, and age group, the rate of AF did not change significantly from 1987 to 1991 compared with 2012 to 2017 (IR ratio, 1.10 [95% CI, 0.88–1.36] comparing 2012–2017 with 1987–1991). Similarly, no evidence of changes over time in AF rates were identified in men and women or White and Black participants separately.

CONCLUSIONS: Even though IRs of AF increase as age increases, our analysis provided evidence suggesting that the overall IRs of AF have not changed over time in a multicenter cohort of Black and White individuals in the United States from 1987 to 2017.

Key Words: atrial fibrillation ■ epidemiology ■ incidence ■ trends

Atrial fibrillation (AF) is one of the most common clinically relevant cardiac arrhythmias, characterized by abnormal electrical activity of the heart that causes the atria to fibrillate. Globally, the burden of AF has increased over time and varies regionally with low-middle–income countries experiencing lower prevalence compared with high-income countries.1 The Global Burden of Disease 2010 study estimated that there are 33.5 million (20.9 million men [95% uncertainty interval, 19.5–22.2 million] and 12.6 million women [95% uncertainty interval, 12.0–13.7 million]) individuals globally with prevalent AF.2,3 Studies in the United States have reported inconsistent results. FHS (Framingham Heart Study) (1958 to 2007) and a study in Olmsted County, Minnesota, for the period 1980 to 2007, both consisting of predominantly White populations, reported an increase in the incidence of AF over time.4,5 In contrast, a study of Medicare-insured patients aged ≥65 years from 1993 to 2007, a more recent analysis in Olmsted County, Minnesota (2000 to 2010), and the UK CPRD (Clinical Practice Datalink) study from 1998 to 2010 reported incidence rates (IRs) of AF that were fairly stable over time.6–8 Questions remain on the accuracy of these contrasting results, whether these results can be generalized to other communities and other racial and ethnic groups, and whether they apply to the past decade. Current figures for trends in the incidence of
AF in diverse communities in the United States are not available. To address these gaps, we evaluated the trends in the incidence of AF among >15,000 White and Black participants from the ARIC (Atherosclerosis Risk in Communities) study, who were followed for over 30 years. The results obtained from this study provide insights into the future burden of AF in the general population.

METHODS

The data, analysis, and study materials are not available to other researchers for purposes of reproducing the results or replicating the analysis because of human participant restrictions. Interested investigators may contact the ARIC Study Center at the University of North Carolina to request access to ARIC study data.

Study Population

The ARIC study is a population-based prospective cohort study consisting of participants sampled from 4 US communities (mostly White individuals from the suburbs of Minneapolis, Minnesota, and Washington County, Maryland; Black individuals from Jackson, Mississippi; and White and Black individuals from Forsyth County, North Carolina).9 The procedures were reviewed and approved by the institutional review board at the participating centers. Written informed consent was obtained from all participants. A detailed phone interview and clinical examination were performed to check the eligibility of the participants and collect baseline information. A cohort of 15,792 participants aged 45 to 64 years were enrolled during the period 1987 to 1989 (55% women, 27% Black). After an initial assessment, the participants were reexamined roughly every 3 years for 3 additional times until 1998, with further examinations in 2011 to 2013, 2016 to 2017, and 2018 to 2019.10 Response rates for the first, second, and third follow-up examinations were 93%, 86%, and 80%, respectively. Contact with the participants was maintained yearly by phone (biannual since 2012) to ascertain their health status and obtain information about hospital admissions. For the purpose of the analysis, we included follow-up information through December 31, 2017.

Among the 15,792 participants, individuals with self-identified race American Indian, Alaskan Indian, Asian, or Pacific Islander (n=48) and Black from Minnesota and Maryland sites (n=55) were excluded, because of small numbers. Individuals with prevalent AF on ECG (n=37) and whose ECG was missing or unreadable (n=309) at baseline were excluded from the study. We included a total of 15,343 participants in the final study population for analysis purposes (Figure 1).

AF Event Ascertainment

The diagnosis of AF was obtained from 3 sources: ECGs at study examinations, recorded with MAC PC ECG machines (Marquette Electronics) in all clinical centers, hospital discharge records, and death certificates.11,12 A resting 12-lead ECG recording was performed during the first 5 examinations for all ARIC participants. ECGs were transmitted to the ARIC Central ECG Reading Center by telephone for interpretation, storage, and coding. A trained cardiologist visually rechecked all automatically coded ECG recordings for AF to confirm the diagnosis.

International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM; codes 427.31 or 427.32), and International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM; code I48.x) hospital discharge diagnoses in the absence of cardiac procedures were obtained from hospitalization records to identify AF events. AF occurring during open heart surgeries was excluded. Finally, if AF (ICD-10-CM code I48 or ICD-9-CM code 427.3) was mentioned as a cause of death in the death certificate or in vital statistics obtained from National Death Index, then ARIC participants were classified as AF cases. The sensitivity and specificity by this approach was 80% and 99%, respectively, in Black individuals and 85% and 99%, respectively, in White individuals.12 The incident date of AF was established as the date for the first ECG showing AF, the first hospital discharge
with an AF or atrial flutter, or death by AF, whichever occurred earlier.

**Ascertainment of Other Variables**

Data at baseline were collected for body mass index (BMI), education level of the participant, smoking status, hypertension, and diabetes. Hypertension was defined as the use of antihypertensive medication or a systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg. Evidence of previous myocardial infarction on ECG at baseline or a self-reported physician-diagnosed myocardial infarction was considered as having a history of myocardial infarction. Participants self-reported their smoking status and education level at baseline. Gothenburg criteria or treatment of heart failure in the past 2 weeks at baseline was identified as having prevalent heart failure.13

**Statistical Analysis**

Baseline characteristics for participants, stratified by race and sex, were summarized as percentages for categorical variables and mean (SD) for continuous variables.

We computed participants’ person-years of follow-up from the date of first examination to the earliest of diagnosis of AF, loss to follow-up, or death. Age-specific IRs were calculated by 5-year age groups and calendar time by 5-year periods. The last calendar period was defined as a 6-year period (2012–2017), in order to include the most updated data. The crude IR was reported as the total number of events divided by the person-years of follow-up.

Temporal trends were reported using age-specific IRs of AF by 5-year calendar year periods. To visually assess the existence of temporal trends, age-specific crude IRs of AF by 5-year time periods were graphically plotted. We evaluated the impact of AF misclassification on rates correcting the number of cases by age and period group using the approach recommended by Greenland.14 We calculated rate ratios (RRs) and their corresponding 95% CIs for periods using Poisson regression models with robust standard errors adjusting for age, sex, and race, using person-year as the unit of analysis. Similarly, we calculated rate differences and 95% CIs using multiple linear regression adjusting for age, sex, and race. We repeated these analyses adjusting for study site by creating a variable that combines race and site (White participants from Minnesota, White participants from Washington County, White participants from Forsyth County, Black participants from Forsyth County, and Black participants from Jackson). Analysis was performed using SAS 9.4 statistical software (SAS Institute Inc) for all of the data collected.

**RESULTS**

We analyzed 15,343 participants without AF at baseline and aged 45 to 64 years. Table 1 reports the baseline characteristics of the included participants by race and sex. The proportion of current smokers was
highest among Black men. Likewise, the proportion of participants with only a basic education was higher among Black participants. The overall prevalence of risk factors for AF was higher in Black as compared with White participants.

A total of 3241 AF cases were identified during a mean follow-up of 22 years (SD, 8.4 years) (599 in Black participants, 2642 in White participants, 1582 in women, and 1659 in men). Participants underwent a mean of 3.8 ECGs (SD, 1.2) over the study period, with 71% undergoing 4 or 5 ECGs. Table 2 shows the different sources of AF ascertainment used to identify new incidence of AF during the follow-up years. Hospital discharge code only identified 82% of all AF cases, with 16% of the cases identified from ≥2 sources. The IR of AF in the entire cohort was 9.6 per 1000 person-years. Incidence of AF increased with increasing age (per 1000 person-years: 1.1 for <55 years, 4.1 for 55–64 years, 10.2 for 65–74 years, 22.6 for 75–84 years, and 39.3 for ≥85 years) and was higher in men compared with women and White compared with Black participants (per 1000 person-years: 11.6 in men, 8.1 in women, 10.5 in White, and 6.9 in Black participants). Race/center-specific IR were 11.8 per 1000 person-years for White participants in Washington County, 9.4 per 1000 person-years for White participants in Minneapolis, 7.0 per 1000 person-years for Black participants in Jackson, 10.3 per 1000 person-years for White participants in Forsyth, and 6.0 per 1000 person-years for Black participants in Forsyth. Age-specific IR by 5-year period did not show meaningful changes over time (Table 3 and Figures 2 and 3). Similarly, there was no strong evidence of increases over time in age-specific IR when stratified by race and sex group (Figure 4). Correcting IRs assuming different values for sensitivity and specificity in AF ascertainment resulted in the same patterns over time (Figure S1.)

The rate of AF was 45% higher in men compared with women (RR, 1.45; 95% CI, 1.36–1.56) and 32% higher in White compared with Black participants (RR, 1.32; 95% CI, 1.21–1.44), adjusting for age and period, in addition to including sex and race. In a model adjusted for sex, race, and age group, the RR of AF in 2012 to 2017 compared with 1987 to 1991 was 1.10 (95% CI, 0.88–1.36) (Table 4). Interactions between age group and calendar year were not significant, suggesting that temporal trends were not different by age group. A similar pattern was observed when estimating adjusted rate differences (Table 5), with the rate difference of AF in 2012 to 2017 compared with 1987 to 1991 being 0.6 per 1000 person-years (95% CI, −1.2 to 2.4). Analyses adjusting for race and center instead of just race provided similar results (Tables S1 and S2).

DISCUSSION

In our analysis of 15 343 participants aged 45 to 64 years followed for up to 30 years, we did not find any evidence of increased IRs of AF over time. Also, and as previously described, despite the prevalence of risk factors being higher in Black individuals, the IRs of AF were higher in White individuals. Consistent with previous population-based studies in the United States, the incidence of AF increased exponentially with age and was greater in men than in women. Age-adjusted incidence in

| Table 1. Baseline Characteristics of Study Participants in the ARIC Study, 1987 to 1989 |
|--------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Overall | White men | White women | Black men | Black women |
| No. (%) | 15 343 (100) | 5332 (34.8) | 5948 (38.8) | 1539 (10.0) | 2524 (16.4) |
| Age, mean (SD), y | 54.2±5.8 | 54.8±5.7 | 54.0±5.7 | 54.0±6.0 | 53.3±5.7 |
| BMI, mean (SD), kg/m² | 27.7±6.4 | 27.4±4.0 | 26.8±5.5 | 27.7±5.0 | 30.8±6.5 |
| Education level, n (%) | | | | | |
| Less than high school | 3622 (23.6) | 960 (18.0) | 978 (16.5) | 677 (40.0) | 1007 (40.0) |
| Completed high school | 6262 (40.8) | 2093 (39.3) | 3022 (50.9) | 400 (26.1) | 747 (29.7) |
| At least some college | 5435 (35.4) | 2271 (42.7) | 1943 (32.7) | 457 (29.5) | 764 (30.3) |
| Smoking, n (%) | | | | | |
| Current | 4005 (26.1) | 1311 (24.6) | 1480 (24.9) | 589 (38.3) | 625 (24.8) |
| Former | 4950 (32.3) | 2534 (47.5) | 1454 (24.5) | 520 (33.8) | 442 (17.5) |
| Never | 6374 (41.5) | 1486 (27.9) | 3008 (50.6) | 429 (27.9) | 1451 (57.6) |
| Hypertension, n (%) | 5324 (34.7) | 1510 (26.2) | 1551 (28.5) | 839 (54.6) | 1424 (56.7) |
| Diabetes, n (%) | 1812 (11.8) | 542 (10.2) | 484 (8.2) | 277 (18.3) | 509 (20.8) |
| Prevalent heart failure, n (%) | 709 (4.6) | 148 (4.8) | 280 (2.8) | 65 (4.3) | 176 (8.6) |
| Prevalent coronary heart disease, n (%) | 735 (4.8) | 464 (8.9) | 109 (1.9) | 89 (5.8) | 73 (2.9) |
| Prevalent stroke, n (%) | 275 (1.8) | 86 (1.7) | 104 (1.8) | 30 (2.0) | 55 (2.2) |

ARIC indicates Atherosclerosis Risk in Communities; and BMI, body mass index.
White men compared with White women were higher in both FHS and the Olmsted County, Minnesota, study. Comparable to the IRs being higher in White individuals, a prior analysis in the ARIC cohort reported a lifetime risk of developing AF of 1 in 3 among White individuals and 1 in 5 among Black individuals.10

Table 2. Sources of Incident Cases of AF in the ARIC Study, 1987 to 2017

| Source | AF cases, n (%) |
|--------|----------------|
| Hospital discharge code only | 2670 (82.3) |
| Examination ECG only | 32 (1) |
| Death certificate only | 31 (1) |
| Both hospital discharge code and death certificate, no examination ECG | 247 (7.6) |
| Both hospital discharge code and examination ECG, no death certificate | 217 (6.7) |
| Both examination ECG and death certificate, no hospital discharge code | 2 (0.1) |
| All 3 sources | 42 (1.3) |
| Total | 3241 (100) |

The incident date of atrial fibrillation (AF) was established as the date of the first ECG that showed AF, the first hospital discharge with AF or atrial flutter, or death by AF, whichever occurred earlier. ARIC indicates Atherosclerosis Risk in Communities.

Table 3. Crude Rates of AF (per 1000 PY) Stratified by 5-Year Age Group and 5-Year Calendar Year

| Age group, y | Calendar year of follow-up | 1987–1991 | 1992–1996 | 1997–2001 | 2002–2006 | 2007–2011 | 2012–2017 |
|--------------|-----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| 45–49        | IR (95% CI)                 | 0.68 (0.3–1.3) | 1.5 (0.2–5.5) |           |           |           |           |
|              | Cases/PY                    | 7/10 928 | 2/1318 |           |           |           |           |
| 50–54        | IR (95% CI)                 | 1.4 (0.8–2.1) | 1.2 (0.7–1.9) | 0.8 (0.02–4.4) |           |           |           |
|              | Cases/PY                    | 21/15 467 | 19/15 260 | 1/1275 |           |           |           |
| 55–59        | IR (95% CI)                 | 2.7 (1.9–3.7) | 2.9 (2.2–3.7) | 3.8 (2.8–4.9) | 4.1 (1.5–9.1) |           |           |
|              | Cases/PY                    | 39/14 593 | 55/19 115 | 55/14 596 | 5/1206 |           |           |
| 60–64        | IR (95% CI)                 | 4.5 (3.5–5.8) | 5.3 (4.2–6.5) | 4.5 (3.5–5.6) | 5.5 (4.4–6.9) | 5.3 (1.9–11.6) |           |
|              | Cases/PY                    | 61/13 465 | 92/17 462 | 80/17 865 | 76/13 684 | 6/1123 |           |
| 65–69        | IR (95% CI)                 | 9.3 (6.5–12.8) | 8.9 (7.5–10.6) | 7.1 (5.9–8.8) | 7.1 (5.9–8.5) | 6.9 (5.5–8.5) | 15.9 (9.1–25.8) |
|              | Cases/PY                    | 37/3992 | 132/14 808 | 113/15 837 | 115/16 264 | 86/12 497 | 16/1005 |
| 70–74        | IR (95% CI)                 | 13.1 (9.6–17.6) | 14.3 (12.3–18.5) | 12.2 (10.5–14.2) | 11.6 (9.9–13.5) | 14.8 (12.4–17.5) |           |
|              | Cases/PY                    | 45/3426 | 183/12 787 | 168/13 704 | 166/14 266 | 161/11 017 |           |
| 75–79        | IR (95% CI)                 | 15.1 (10.9–20.4) | 20.3 (17.6–23.2) | 20.8 (18.2–23.6) | 19.0 (16.7–21.6) |           |           |
|              | Cases/PY                    | 42/2780 | 209/10 290 | 231/11 096 | 237/12 459 |           |           |
| 80–84        | IR (95% CI)                 | 23.3 (17.5–30.6) |            | 32.1 (28.1–36.5) | 27.3 (23.9–31.0) |           |           |
|              | Cases/PY                    | 49/2097 | 233/7251 | 235/8598 |           |           |           |
| 85–89        | IR (95% CI)                 |            |            | 47.9 (36.6–61.1) | 36.7 (31.4–42.5) |           |           |
|              | Cases/PY                    | 61/1273 | 173/4715 |           |           |           |           |
| 90–94        | IR (95% CI)                 |            |            |            |            | 41.6 (28.1–59.3) |           |
|              | Cases/PY                    |            |            |            |            | 30/721 |           |

AF indicates atrial fibrillation; IR, incidence rate; and PY, person-year.
The Olmsted County, Minnesota, study reported an increasing trend in the age- and sex-adjusted incidence of AF from 1980 to 2000 (3.04 versus 3.68 per 1000 person-years). Similar to these study results, FHS also showed an increase in the age-adjusted IR (1.83 per 1000 person-years in 1958–1967 versus 3.75 per 1000 person-years in 1998–2007) over time. In contrast, a study of the UK CPRD from 1998 to 2010...

Figure 2. Age-specific incidence rates of atrial fibrillation (AF) by period in the ARIC (Atherosclerosis Risk in Communities) cohort, 1987 to 2017. PY indicates person-years.

Figure 3. Period-specific incidence rates of atrial fibrillation (AF) by age in the ARIC (Atherosclerosis Risk in Communities) cohort, 1987 to 2017. PY indicates person-years.
showed a fairly stable IR over time (1.11 in 1998–2001, 1.33 in 2002–2006, and 1.33 in 2007–2010). Also, a more recent study of AF incidence in Olmsted County, Minnesota (2000–2010), did not report continued increases in AF incidence. Our findings are consistent with both the UK CPRD study and the recent Olmsted County, Minnesota, study. Inconsistencies among studies can be related to differences in the underlying populations and the periods under consideration, with a more diverse population and more recent periods in our analysis of the ARIC cohort compared with previous studies.

Although Black individuals have an underlying higher burden of risk factors compared with White individuals, we found lower overall rates of AF among the former racial group, after controlling for age, period, and sex. These findings are similar to those in other populations. Reasons for this paradoxical difference in AF rates by race are currently unknown. A prior analysis in the ARIC cohort indicated that these differences are unlikely to be explained by underascertainment of AF in Black participants attributable to lower socioeconomic status and poorer access to health care.

**Figure 4.** Age-specific incidence rates of atrial fibrillation (AF) by race, sex, and period in the ARIC (Atherosclerosis Risk in Communities) cohort, 1987 to 2017. PY indicates person-years.
Several studies among Europe, New Zealand, Western Australia, Japan, and the United States have demonstrated decreasing trends in stroke and coronary heart disease incidence over the past few decades. This decline in cardiovascular disease incidence has been attributed to reductions in the prevalence of risk factors for cardiovascular disease, better management of these risk factors, and improved medical care. These positive trends in stroke and coronary heart disease, however, have not been accompanied by reductions in AF incidence, as shown in our current analysis of the ARIC cohort and other studies, despite some risk factors being shared between these conditions. These discrepancies highlight the importance of developing specific strategies for the prevention of AF that go beyond current approaches for prevention and control of overall cardiovascular disease.

Strengths and Limitations
The ARIC cohort has a large sample size and a diverse population with an extended follow-up time, which allows the estimated IRs to be precise, even among race and sex groups. As this is one of the longest follow-up studies with a biracial population in 4 communities among the United States, the cohort is more diverse than other studies, thus facilitating generalizability of the results. The study also benefits from excellent follow-up, careful participant assessments, and availability of repeated ECGs and information on hospitalizations.

One major limitation of the study is the ascertainment of AF. Asymptomatic AF or those cases managed in outpatient care will be missed as the ascertainment of AF is based primarily on hospital discharge codes. In addition, we are unable to differentiate between paroxysmal AF and persistent AF based on study ECG and hospital discharge records. Participants in the ARIC study were born between 1920 and 1945. Thus, the observed trends in AF incidence may not be applicable to individuals from more recent birth cohorts. Also, the relatively narrow age range at baseline limits the ability to study trends among all age groups. Finally, since most of the black participants come from the Jackson site, it is not possible to perfectly disentangle race differences from differences in location.

CONCLUSIONS
We report that the IRs of AF in a large biracial population–based closed cohort in 4 different US...
communities did not change over time from 1987 to 2017. The increasing incidence of AF with increasing age helps to understand the burden of AF and its public health impact. A careful evaluation is needed to fully understand the risk factors and get insights into the mechanism causing racial discrepancy in the incidence of AF. Future studies should address the issue of continuous monitoring of participants for subclinical AF as well as develop strategies aimed in reducing the burden of AF in the population.

ARTICLE INFORMATION
Received August 10, 2021; accepted March 14, 2022.

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Acknowledgments
The authors thank the staff and participants of the ARIC study for their important contributions.

Sources of Funding
The ARIC study has been funded in whole or in part with federal funds from the National Heart, Lung, and Blood Institute (NHLBI), the National Institutes of Health (NIH), and the Department of Health and Human Services, under contract numbers HHSN268201700001I, HHSN268201700002I, HHSN268201700003I, HHSN268201700004I, and HHSN268201700005I. Research reported in this publication was also supported by the NHLBI of the National Heart, Lung, and Blood Institute (NHLBI), the National Institutes of Health, Baltimore, MD (S.K.).

Disclosures
None.

Supplemental Material
Tables S1–S2
Figure S1

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SUPPLEMENTAL MATERIAL
Table S1. Rate ratio for AF by sex, center - race, age and period in the Atherosclerosis Risk in Communities Study, 1987-2017.

|                        | Rate Ratio | 95% CI      | p-value  |
|------------------------|------------|-------------|----------|
| Sex (Male vs Female)   | 1.46       | 1.36, 1.56  | <0.0001  |
| Center – Race          |            |             |          |
| Minnesota White        | 1          | Ref.        |          |
| Washington Co. White   | 1.21       | 1.11, 1.33  | <0.0001  |
| Forsyth Co. White      | 1.09       | 0.99, 1.20  | <0.08    |
| Forsyth Co. Black      | 0.71       | 0.54, 0.94  | 0.02     |
| Jackson Black          | 0.85       | 0.77, 0.95  | 0.004    |
| **5-year Age category**|            |             |          |
| 45-49                  | 1          | Ref         |          |
| 50-54                  | 1.65       | 0.80, 3.40  | 0.18     |
| 55-59                  | 3.93       | 1.99, 7.76  | <0.0001  |
| 60-64                  | 6.21       | 3.17, 12.2  | <0.0001  |
| 65-69                  | 9.52       | 4.83, 18.8  | <0.0001  |
| 70-74                  | 16.0       | 8.08, 31.5  | <0.0001  |
| 75-79                  | 23.7       | 12.0, 47.0  | <0.0001  |
| 80-84                  | 34.3       | 17.3, 68.1  | <0.0001  |
| 85-89                  | 46.9       | 23.4, 93.9  | <0.0001  |
| 90-94                  | 52.7       | 24.6, 113   | <0.0001  |
| **5-year Period**      |            |             |          |
| 1987-1991              | 1          | Ref         |          |
| 1992-1996              | 1.12       | 0.92, 1.35  | 0.26     |
| 1997-2001              | 1.06       | 0.87, 1.29  | 0.57     |
| 2002-2006              | 1.06       | 0.86, 1.30  | 0.58     |
| 2007-2011              | 1.13       | 0.92, 1.39  | 0.25     |
| 2012-2017              | 1.11       | 0.89, 1.38  | 0.34     |

Results from Poisson regression model including all variables in the table.
Table S2. Rate differences for AF by sex, center - race, age and period in the Atherosclerosis Risk in Communities Study, 1987-2017.

| Rate Difference (per 1000 person-years) | 95% CI       | p-value   |
|----------------------------------------|--------------|-----------|
| Sex (Male vs Female)                   | 3.7          | 3.0, 4.4  | <0.0001   |
| Center – Race                          |              |           |           |
| Minnesota White                        | Ref          |           |           |
| Washington Co. White                   | 2.1          | 1.1, 3.0  | <0.0001   |
| Forsyth Co. White                      | 0.8          | -0.2, 1.7 | 0.11      |
| Forsyth Co. Black                      | -2.5         | -4.6, -0.4| 0.02      |
| Jackson Black                          | -1.2         | -2.1, -0.3| 0.01      |
| 5-year Age category                    |              |           |           |
| 45-49                                  | Ref          |           |           |
| 50-54                                  | 0.2          | -1.9, 2.3 | 0.85      |
| 55-59                                  | 1.9          | -0.1, 3.9 | 0.06      |
| 60-64                                  | 3.7          | 1.6, 5.7  | 0.0004    |
| 65-69                                  | 6.3          | 4.2, 8.4  | <0.0001   |
| 70-74                                  | 11.5         | 9.3, 13.7 | <0.0001   |
| 75-79                                  | 17.9         | 15.6, 20.3| <0.0001   |
| 80-84                                  | 27.0         | 24.3, 29.6| <0.0001   |
| 85-89                                  | 37.3         | 34.0, 40.7| <0.0001   |
| 90-94                                  | 40.1         | 32.7, 47.6| <0.0001   |
| 5-year Period                          |              |           |           |
| 1987-1991                              | Ref          |           |           |
| 1992-1996                              | 0.6          | -0.6, 1.7 | 0.33      |
| 1997-2001                              | 0.3          | -0.9, 1.6 | 0.58      |
| 2002-2006                              | 0.3          | -1.1, 1.7 | 0.68      |
| 2007-2011                              | 1.1          | -0.4, 2.7 | 0.16      |
| 2012-2017                              | 0.7          | -1.1, 2.5 | 0.43      |

Results from linear regression model including all variables in the table.
Figure S1. Incidence rates corrected by imperfect sensitivity and specificity

| agegroup | period     | p_star | a_star | s | ir  |
|----------|------------|--------|--------|---|-----|
| 45-49    | 1987-91    | 7   | 10928  | 0.6 | -0.4 |
| 50-54    | 1987-91    | 21  | 13467  | 1.4 | 0.4  |
| 55-59    | 1987-91    | 19  | 14593  | 2.7 | 27   |
| 60-64    | 1987-91    | 41  | 13485  | 4.3 | 53   |
| 65-69    | 1987-91    | 37  | 3992   | 9.3 | 37   |
| 45-49    | 1992-96    | 2   | 1318   | 1.5 | 1.6  |
| 50-54    | 1992-96    | 10  | 15280  | 1.2 | 6.3  |
| 55-59    | 1992-96    | 55  | 19115  | 2.9 | 60   |
| 60-64    | 1992-96    | 92  | 17462  | 5.3 | 63   |
| 65-69    | 1992-96    | 132 | 14808  | 8.9 | 130  |
| 70-74    | 1992-96    | 45  | 3426   | 13.1| 46   |
| 50-54    | 1997-01    | 1   | 1275   | 0.8 | 0.2  |
| 55-59    | 1997-01    | 55  | 14596  | 3.8 | 45   |
| 60-64    | 1997-01    | 40  | 17355  | 4.5 | 69   |
| 65-69    | 1997-01    | 113 | 15837  | 7.1 | 108  |
| 70-74    | 1997-01    | 183 | 12787  | 14.3| 189  |
| 75-79    | 1997-01    | 44  | 2780   | 13.1| 44   |
| 55-59    | 2002-06    | 6   | 1126   | 4.1 | 4.3  |
| 60-64    | 2002-06    | 76  | 13684  | 5.6 | 59   |
| 65-69    | 2002-06    | 115 | 16264  | 7.1 | 110  |
| 70-74    | 2002-06    | 168 | 13704  | 12.3| 171  |
| 75-79    | 2002-06    | 209 | 10290  | 23.4| 221  |
| 80-84    | 2002-06    | 49  | 2067   | 23.6| 52   |
| 85-89    | 2007-11    | 6   | 1113   | 5.3 | 5.6  |
| 90-94    | 2007-11    | 86  | 12497  | 6.9 | 82   |
| 70-74    | 2007-11    | 166 | 14266  | 11.6| 169  |
| 75-79    | 2007-11    | 231 | 11096  | 20.8| 244  |
| 80-84    | 2007-11    | 233 | 7251   | 32.1| 251  |
| 85-89    | 2012-17    | 16  | 1005   | 15.9| 17   |
| 75-79    | 2012-17    | 161 | 11017  | 14.6| 167  |
| 80-84    | 2012-17    | 235 | 8598   | 27.3| 252  |
| 85-89    | 2012-17    | 173 | 4715   | 38.7| 187  |

| agegroup | period     | p_star | a_star | s | ir  |
|----------|------------|--------|--------|---|-----|
| 45-49    | 1987-91    | 2   | 1328   | 1.4 | 0.8  |
| 50-54    | 1987-91    | 10  | 15280  | 1.2 | 6.3  |
| 55-59    | 1987-91    | 55  | 19115  | 2.9 | 60   |
| 60-64    | 1987-91    | 92  | 17462  | 5.3 | 63   |
| 65-69    | 1987-91    | 132 | 14808  | 8.9 | 130  |
| 70-74    | 1987-91    | 45  | 3426   | 13.1| 46   |
| 50-54    | 1992-96    | 1   | 1275   | 0.8 | 0.2  |
| 55-59    | 1992-96    | 55  | 14596  | 3.8 | 45   |
| 60-64    | 1992-96    | 40  | 17355  | 4.5 | 69   |
| 65-69    | 1992-96    | 113 | 15837  | 7.1 | 108  |
| 70-74    | 1992-96    | 183 | 12787  | 14.3| 189  |
| 75-79    | 1992-96    | 44  | 2780   | 13.1| 44   |
| 55-59    | 2002-06    | 6   | 1126   | 4.1 | 4.3  |
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| 65-69    | 2002-06    | 115 | 16264  | 7.1 | 110  |
| 70-74    | 2002-06    | 168 | 13704  | 12.3| 171  |
| 75-79    | 2002-06    | 209 | 10290  | 23.4| 221  |
| 80-84    | 2002-06    | 49  | 2067   | 23.6| 52   |
| 85-89    | 2007-11    | 6   | 1113   | 5.3 | 5.6  |
| 90-94    | 2007-11    | 86  | 12497  | 6.9 | 82   |
| 70-74    | 2007-11    | 166 | 14266  | 11.6| 169  |
| 75-79    | 2007-11    | 231 | 11096  | 20.8| 244  |
| 80-84    | 2007-11    | 233 | 7251   | 32.1| 251  |
| 85-89    | 2012-17    | 16  | 1005   | 15.9| 17   |
| 75-79    | 2012-17    | 161 | 11017  | 14.6| 167  |
| 80-84    | 2012-17    | 235 | 8598   | 27.3| 252  |
| 85-89    | 2012-17    | 173 | 4715   | 38.7| 187  |

- Sensitivity 90.0%
- Specificity 99.9%