

Trends in Stroke Incidence Rates in Older US Adults

An Update From the Atherosclerosis Risk in Communities (ARIC) Cohort Study

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IMPORTANCE Determining whether the previously reported decreased stroke incidence rates from 1987 to 2011 among US adults 65 years and older in the Atherosclerosis Risk in Communities (ARIC) study continued to decrease subsequently can help guide policy and planning efforts.

OBJECTIVE To evaluate whether stroke incidence declines among older adults in the ARIC study continued after 2011.

DESIGN, SETTING, AND PARTICIPANTS ARIC is a community-based prospective cohort study including 15 792 individuals aged 45 to 64 years at baseline (1987-1989), selected by probability sampling from residents of Forsyth County, North Carolina; Jackson, Mississippi (black individuals only); the northwestern suburbs of Minneapolis, Minneapolis; and Washington County, Maryland (ie, center). The present study included ARIC participants free of stroke at baseline, followed up through December 31, 2017. Data were collected through personal interviews and physical examinations during study visits, annual/semiannual telephone interviews, and active surveillance of discharges from local hospitals. Stroke events were adjudicated by study-physicians reviewers. Analysis began September 2018.

MAIN OUTCOMES AND MEASURES The main outcome was stroke incidence rates, which were computed with 95% CIs stratifying the analysis by age and calendar time. Trends in adjusted incidence rates were assessed using Poisson regression incidence rate ratios. Models included calendar time, age, sex, race/center, and time-varying risk factors (hypertension, diabetes, coronary heart disease, cholesterol-lowering medication use, and smoking).

RESULTS Of 14 357 ARIC participants with 326 654 person-years of follow-up, the mean (SD) age at baseline was 54.1 (5.8) years and 7955 (55.4%) were women. From 1987 to 2017, a total of 1340 incident strokes occurred among ARIC participants, and among them, 1028 (76.7%) occurred in participants 65 years and older. Crude incidence rates of stroke for participants 65 years and older decreased progressively from 1987 to 2017. Incidence rates, adjusted for age, sex, race/center, and time-varying risk factors, decreased by 32% (95% CI, 23%-40%) per 10 years in participants 65 years and older. Findings were consistent across decades, sex, and race.

CONCLUSIONS AND RELEVANCE Validated total stroke incidence rates in adults 65 years and older decreased over the last 30 years in the ARIC cohort. The decrease in rates previously reported for 1987 to 2011 extends for the subsequent 6 years in men and women as well as in white and black individuals.

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Global data show that stroke incidence rates in high-income countries decreased from 1990 to 2010 by 13% (95% CI, 6%-18%) for ischemic stroke and by 19% (95% CI, 5%-30%) for hemorrhagic stroke.¹ In the United States, declines in stroke incidence have been reported in participants of the Framingham Heart Study up to 2004,² the Greater Cincinnati/Northern Kentucky Stroke Study^{3,4} up to 2010, and the BASIC Project⁵ also up to 2010; however, these studies did not include data from 2010 to the present. Using validated stroke data in the Atherosclerosis Risk in Communities (ARIC) cohort study, we have shown decreasing stroke incidence rates from 1987 to 2011 among people 65 years and older, while no significant changes were evident in younger ARIC participants.⁶ In the present study, we evaluated whether the decline in stroke incidence rates in older adults continued in the subsequent 6 years, from 2011 to 2017.

Methods

Study Population

The ARIC cohort study has been previously described.⁷ Briefly, at baseline (1987-1989), ARIC included 15 792 individuals aged 45 to 64 years, selected by probability sampling from residents of 4 communities in the United States (Forsyth County, North Carolina; Jackson, Mississippi [black individuals only]; the northwestern suburbs of Minneapolis, Minneapolis; and Washington County, Maryland). All ARIC participants provided written informed consent, and the study was approved by institutional review boards of all collaborating centers. At ARIC visits (baseline and follow-up in 1990-1992, 1993-1995, 1996-1998, 2011-2013, and 2016-2017), data were collected through personal interviews and physical examinations. In addition, annual/semiannual telephone interviews and active surveillance of discharges from local hospitals were conducted. For the present study, we included black and white individuals with no prevalent stroke at baseline and with complete data on covariates.

Ascertainment of Stroke Events

All stroke hospitalizations and deaths from January 1, 1987, to December 31, 2017, were identified. Methods for ascertainment of stroke events were detailed elsewhere.^{7,8} Hospital records for possible stroke-related hospitalizations were obtained (*International Classification of Diseases, Ninth Revision [ICD-9]* codes: 430-438 until 1997; *ICD-9* codes 430-436 and *ICD-10* codes G45.X, I60.X, I61.X, I62.X, I63.X, I65.X, I66.X, and I67.X afterward) and information on fatal stroke was collected through linkage with the National Death Index. Strokes were identified by a computer algorithm and adjudicated by physician reviewers.^{6,8} The present study includes 1340 incident strokes occurring from baseline to December 31, 2017, defined as a first definite or probable stroke in a participant with no self-report of physician-diagnosed stroke at baseline.

Key Points

Question Have stroke incidence rates among adults aged 65 years and older continued to decline in recent years?

Findings In this study of the Atherosclerosis Risk in Communities cohort study data including 1340 incident strokes occurring from 1987 to 2017, adjusted stroke incidence rates decreased by 32% per 10 years in participants 65 years and older. Findings were consistent in men and women as well as in white and black individuals.

Meaning Validated stroke incidence rates in adults 65 years and older decreased over the last 30 years in the Atherosclerosis Risk in Communities cohort; the decrease in rates previously reported for 1987 to 2011 has extended to 2017.

Statistical Analysis

We studied the characteristics of participants at baseline (ARIC visit 1, 1987-1989) for all 14 357 participants included in the present study and at 2 follow-up visits (visit 4, 1996-1998 and visit 5, 2011-2013) for participants 65 years and older, as the study focuses on this age group. Incidence rates and 95% confidence intervals of definite or probable stroke per 1000 person-years (PY) were calculated and modeled with Poisson regression, stratifying age by 5-year groups and calendar time by 3-year groups (4-year for the most recent period, 2014-2017). Temporal trends were estimated using Poisson regression incidence rate ratios.

Crude incidence rates per 1000 PY and adjusted incidence rate ratios per 10-year calendar time and age are presented. Incidence rate ratios were adjusted for age and calendar time (model 1) and additionally adjusted for sex, race/center, and time-varying risk factors (hypertension, diabetes, coronary heart disease, cholesterol-lowering medications use, and smoking) (model 2). Interactions between calendar time and race, sex, and age group were assessed. Analysis by race, sex, and age group was also performed. Stata version 14 (Stata Corp) was used for data analysis. All tests were 2 sided, and *P* less than .05 was considered statistically significant. Analysis began in September 2018.

Results

At baseline, 7955 of 14 357 participants (55.4%) were women, and the mean (SD) age of all participants was 54.1 (5.8) years. Participants were followed up for 326 654 PY. Among ARIC participants aged 65 to 74 years, the distribution of risk factors changed from 1996-1998 (visit 4) to 2011-2013 (visit 5) (**Table 1**). Adjusted for age, sex, and race/center, the prevalence of diabetes and hypertension increased, while the use of antihypertensive and cholesterol-lowering medications increased, and blood pressure, lipids levels, and current smoking decreased.

Overall, 1028 incident strokes occurred among individuals 65 years and older during 184 343 PY in this age group. Crude incidence rates of stroke for individuals 65 years and older decreased from 1987 to 2017, while no signifi-

cant changes in rates were observed among those younger than 65 years (eTable in the Supplement). Incidence rates adjusted for age, sex, race/center, time-varying hypertension, diabetes, coronary heart disease, smoking, and use of cholesterol-lowering medications decreased by 28% per 10 years (95% CI, 20%-36%) overall. Decreases were similar in men and women as well as in white and black individuals (Table 2), and there was no significant interaction by these demographics or follow-up decade, although power is limited. Analysis by age group showed a 32% (95% CI, 23%-40%) decrease in adjusted rates among individuals 65 years and older from 1987 to 2017 (Table 2). A significant decreasing linear trend with continuous calendar time over the last 30 years was observed in stroke incidence rates for older adults in ARIC (Figure).

Discussion

We found that the decrease in stroke incidence rates previously observed in the ARIC cohort participants⁶ continued into the recent years. The decrease in rates over the last 30 years was observed in men and women as well as in black and white individuals 65 years and older. After 2011, all ARIC participants were 65 years and older; therefore,

the present update does not show new data for the younger group.

Limited data are available on stroke incidence rates for the most recent years. Declines in stroke incidence in older adults during recent years have been reported in 3 recent studies. A Canadian study⁹ reported declining incidence of stroke from 2002-2003 to 2013-2014 among individuals 80 years and older. Similar to our findings, rates of first-ever stroke in Sweden decreased by 33% from 2001-2002 to 2015-2016 in older adults, while no change was found in those younger than 65 years.¹⁰ In the United Kingdom, age-adjusted incidence of ischemic stroke decreased by 43% from 2000-2003 to 2012-2015. Yet, different from ours and other studies findings, the decreasing trends in the United Kingdom were observed both in younger (age <55 years) and older (age ≥55 years) groups.¹¹ We are now reporting updated rates and trends in stroke incidence in the United States using data on validated stroke events in the ARIC cohort study. Availability of detailed information collected in the ARIC biracial cohort during the last 3 decades, including time-varying data on important risk factors for stroke, and complete adjudication of all stroke events in ARIC, are the main strengths in our study. Although smoking, systolic blood pressure, and cholesterol levels have decreased over time in ARIC

Table 1. Characteristics of ARIC Participants at Baseline and Aged 65-74 Years at Visits 4 and 5

Characteristic	No. (%) ^a		
	Overall 1987-1989 (Visit 1)	Age 65-74 y ^b 1996-1998 (Visit 4)	2011-2013 (Visit 5)
Total No.	14 357	4218	2843
Age, mean (SD), y	54.1 (5.8)	68.8 (2.6)	71.1 (1.9)
Female	7955 (55.4)	2204 (52.3)	1716 (60.4)
Race/center			
White/Minneapolis, MN	3844 (26.8)	1190 (28.2)	848 (29.8)
White/Washington County, MD Forsyth County, NC	3382 (23.6)	1172 (27.8)	651 (22.9)
White	3331 (23.2)	1079 (25.6)	596 (21.0)
Black	442 (3.1)	105 (2.5)	54 (1.9)
Black/Jackson, MS	3358 (23.4)	672 (15.9)	694 (24.4)
Smoking status ^c			
Current	3711 (25.9)	485 (11.6)	210 (7.7)
Former	4651 (32.4)	1946 (46.6)	1316 (48.0)
Never	5995 (41.8)	1747 (41.8)	1214 (44.3)
Hypertension ^c	4886 (34.0)	2327 (55.5)	2000 (70.9)
Blood pressure, median (range), mm Hg ^c			
Systolic	119 (108-131)	130 (118-144)	127 (117-139)
Diastolic	73 (66-80)	69 (62-76)	68 (61-75)
Hypertension medication ^c	4241 (29.5)	2129 (50.5)	2.030 (71.6)
Diabetes ^c	1662 (11.6)	782 (18.7)	1066 (38.1)
Coronary heart disease	649 (4.5)	476 (11.3)	322 (11.3)
Total cholesterol, median (range), mg/dL ^c	212 (186-239)	198 (176-222)	182 (156-211)
Cholesterol-lowering medication ^c	404 (2.8)	742 (17.7)	1526 (54.0)

Abbreviation: ARIC, Atherosclerosis Risk in Communities.

SI conversion factor: To convert cholesterol to mmol/L, multiply by 0.0259.

^a Missing data rate was <2.5% for all variables.

^b Rates among participants aged 65 to 74 years in 1996-1998 (visit 4) and 2011-2013 (visit 5) were adjusted for age, sex, and race/center.

^c $P < .001$ for the comparison between participants aged 65 to 74 years in 1996-1998 (visit 4) and in 2011-2013 (visit 5).

Table 2. Total Stroke Incidence Rates and Incidence Rate Ratios per 10-Year Calendar Time and Age, Overall and Stratified by Race, Sex, and Age Group, 1987-2017

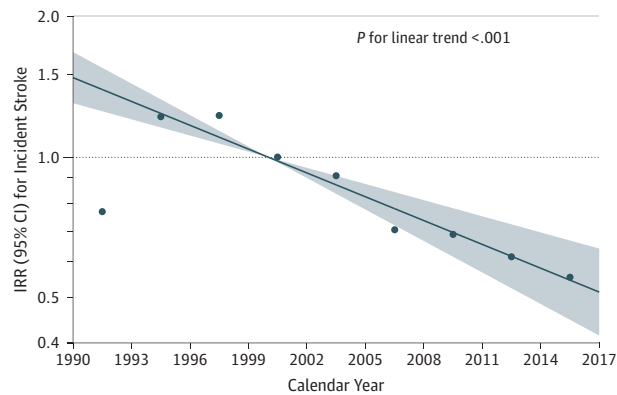
Variable	Overall	Race			Sex		Age Group	
		White	Black	Men	Women	<65 y	≥65 y	
No. of events/No. of person-years	1340/326 654	834/245 931	506/80 823	635/138 336	705/188 318	312/142 312	1028/184 343	
Total crude IRRs (95% CI) per 1000 person-years	4.10 (3.89-4.33)	3.39 (3.17-3.63)	6.26 (5.74-6.83)	4.59 (4.25-4.96)	3.74 (3.48-4.03)	2.19 (1.96-2.45)	5.58 (5.25-5.93)	
Model 1: Calendar Year and Age, IRR (95% CI)								
Calendar time per 10 y	0.77 (0.69-0.85)	0.75 (0.65-0.86)	0.73 (0.61-0.87)	0.75 (0.64-0.87)	0.80 (0.69-0.93)	0.98 (0.76-1.26)	0.73 (0.64-0.82) ^a	
Age per 10 y	2.10 (1.91-2.31)	2.51 (2.21-2.84)	1.81 (1.56-2.10) ^a	2.02 (1.76-2.32)	2.14 (1.88-2.44)	1.98 (1.48-2.64)	2.05 (1.80-2.33)	
Model 2: Calendar Year, Age, Sex, Time-Varying Risk Factors, and Race/Center, IRR (95% CI)								
Calendar time per 10 y	0.72 (0.64-0.80)	0.71 (0.62-0.82)	0.74 (0.62-0.88)	0.70 (0.60-0.82)	0.74 (0.63-0.86)	0.94 (0.73-1.21)	0.68 (0.60-0.77) ^a	
Age per 10 y	2.03 (1.84-2.24)	2.36 (2.08-2.68)	1.61 (1.38-1.88) ^a	1.98 (1.72-2.28)	2.07 (1.81-2.37)	1.63 (1.21-2.18)	2.04 (1.79-2.33)	
Sex								
Women	1 [Reference]	1 [Reference]	1 [Reference]	NA	NA	1 [Reference]	1 [Reference]	
Men	1.18 (1.05-1.32)	1.20 (1.04-1.39)	1.18 (0.98-1.43)	NA	NA	1.29 (1.02-1.64)	1.14 (1.00-1.30)	
Time-varying risk factors^b								
Hypertension	1.80 (1.58-2.05)	1.59 (1.36-1.85)	2.38 (1.85-3.07) ^a	1.89 (1.57-2.27)	1.72 (1.43-2.07)	2.36 (1.83-3.05)	1.59 (1.37-1.85) ^a	
Diabetes	1.62 (1.44-1.83)	1.44 (1.23-1.68)	1.96 (1.63-2.35) ^a	1.46 (1.22-1.73)	1.77 (1.51-2.08)	2.77 (2.18-3.52)	1.40 (1.22-1.60) ^a	
Coronary heart disease	1.69 (1.48-1.94)	1.61 (1.36-1.91)	1.84 (1.46-2.33)	1.49 (1.24-1.78)	2.07 (1.69-2.53) ^a	2.72 (2.03-3.65)	1.53 (1.31-1.78) ^a	
Smoking status								
Never smoker	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]	
Former smoker	1.05 (0.93-1.19)	1.02 (0.88-1.20)	1.14 (0.92-1.40)	0.97 (0.81-1.17)	1.12 (0.95-1.34)	1.20 (0.90-1.60)	1.01 (0.88-1.17)	
Current smoker	1.81 (1.56-2.10)	1.90 (1.56-2.32)	1.69 (1.34-2.12)	1.70 (1.35-2.13)	1.86 (1.52-2.28)	2.07 (1.57-2.73)	1.73 (1.44-2.07)	
Cholesterol-lowering medication	1.00 (0.87-1.15)	1.06 (0.90-1.25)	0.89 (0.68-1.16)	0.95 (0.77-1.16)	1.05 (0.87-1.26)	0.83 (0.56-1.25)	1.05 (0.90-1.22)	

Abbreviations: IRR, incidence rate; IRRs, incidence rate ratio; NA, not applicable.

^a P < .05 for interaction in a model containing both groups and interaction terms for all variables.

^b Prevalence at baseline as reference.

Figure. Adjusted Stroke Incidence Rate Ratios vs Calendar Time in Atherosclerosis Risk in Communities Participants 65 Years and Older



Dots represent adjusted incidence rate ratio point estimates from a model run using a categorical calendar time variable, plotted at midpoint of each 3-year calendar time category (4 years for the last period 2014-2017), with 1999-2001 as the reference category. The solid line represents the linear trend in adjusted incidence rate ratios (IRRs), and the shaded area represents the 95% CI with 2000 as the reference point. Rates were adjusted for age, sex, race/center, and time-varying risk factors (hypertension, diabetes, coronary heart disease, cholesterol-lowering medications use, and smoking status).

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participants, measured risk factors did not explain the decline in stroke incidence.

Limitations

A limitation of the present study is the small number of hemorrhagic strokes, which does not allow for analysis by stroke type. In addition, the ARIC population includes only white and black individuals and the cohort ages with time; therefore, no new information for individuals younger than 65 years is available on this age group for the most recent years. The decline observed in rates of incident stroke among individuals 65 years and older is reassuring; nevertheless, as result of the aging of the population, stroke continues to pose an important global burden.

Conclusions

Validated total stroke incidence rates among individuals 65 years and older decreased over the last 30 years in the ARIC cohort. The decrease in rates previously reported for 1987-2011 extends for the subsequent 6 years (2011-2017) in men and women as well as in white and black individuals.

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