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ORIGINAL RESEARCH

Ambulatory Care Fragmentation and Incident Stroke

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BACKGROUND: More fragmented ambulatory care (ie, care spread across many providers without a dominant provider) has been associated with excess emergency department and inpatient care. We sought to determine whether more fragmented ambulatory care is associated with an increase in the hazard of incident stroke, overall and stratified by health status and by race.

METHODS AND RESULTS: We conducted a secondary analysis of data from the REGARDS (Reasons for Geographic and Racial Differences in Stroke) study (2003–2016), including participants aged ≥65 years who had linked Medicare fee-for-service claims and no history of stroke (N=12 510). We measured fragmentation of care with the reversed Bice-Boxerman index. We used Poisson models to determine the association between fragmentation and adjudicated incident stroke. The average age of participants was 70.5 years; 53% were women, 32% were Black participants, and 16% were participants with fair or poor health. Overall, the adjusted rate of incident stroke was similar for high versus low fragmentation (8.2 versus 8.1 per 1000 person-years, respectively; *P*=0.89). Among participants with fair or poor self-rated health, having high versus low fragmentation was associated with a trend toward a higher adjusted rate of incident strokes (14.8 versus 10.4 per 1000 person-years, respectively; *P*=0.067). Among Black participants with fair or poor self-rated health, having high versus low fragmentation was associated with a higher adjusted rate of strokes (19.3 versus 10.3 per 1000 person-years, respectively; *P*=0.02).

CONCLUSIONS: Highly fragmented ambulatory care is independently associated with incident stroke among Black individuals with fair or poor health.

Key Words: ambulatory care ■ medicare ■ stroke

Patients who are at risk for incident stroke often see multiple ambulatory providers to manage their chronic conditions, such as diabetes mellitus, hypertension, heart disease, and atrial fibrillation.[1–3] For example, patients at risk for incident stroke may have a primary care provider, cardiologist, endocrinologist, and other subspecialists who they see regularly. Patients with either diabetes mellitus or heart disease see more ambulatory providers than the median Medicare beneficiary nationally.[2] Indeed, the more chronic conditions a patient has, the more providers he or she tends to see.[2]

Unfortunately, providers do not consistently communicate with each other about their common patients.[4] In a national survey of nearly 5000 providers, 30% of primary care providers reported that they do not "always or most of the time" send information about a patient's medical history or the reason for requesting a consultation at the time of referral.[4] Similarly, 20% of specialists reported that they do not "always or most of the time" send the results of the consultation back to the referring provider.[4] Thus, clinically relevant information is frequently missing at the point of care.[5]

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CLINICAL PERSPECTIVE

What Is New?

- Highly fragmented ambulatory care was associated with an increased hazard of incident stroke among Black individuals with fair or poor health, even after adjusting for clinically detailed potential confounders.

What Are the Clinical Implications?

- Excess strokes attributable to highly fragmented ambulatory care may be preventable.

Nonstandard Abbreviations and Acronyms

NCQA	National Committee for Quality Assurance
REGARDS	Reasons for Geographic and Racial Differences in Stroke
SF-1	self-rated general health (the first question in the Short-Form-12 [SF-12] survey)
WHO	World Health Organization

As a result, more fragmented ambulatory care (ie, care spread across many providers without a dominant provider) has been associated with more drug-drug interactions,[6] testing,[7] procedures,[8] emergency department visits,[9–11] and hospitalizations,[9,12] compared with less fragmented care. However, the relationship between fragmented ambulatory care and health outcomes is not well understood.[13] To our knowledge, no study has explored whether fragmented ambulatory care is associated with more incident strokes.

We previously found that the association between fragmented ambulatory care and subsequent healthcare utilization varies with patients' health status.[7,14] We hypothesized that the association between fragmented ambulatory care and stroke might also vary with health status. Healthy people might be able to see multiple providers without experiencing harm from gaps in communication, whereas sicker individuals might be more vulnerable to harm.

We sought to determine the association between fragmented ambulatory care and incident stroke using data from the nationwide prospective REGARDS (Reasons for Geographic and Racial Differences in Stroke) cohort study. As the name of the investigation conveys, the purpose of the REGARDS study is to explain geographic and racial disparities in stroke mortality.[15] Thus, we sought to measure the association between fragmentation and incident stroke overall and to determine whether any association varied with health status, geographic region, or race.

METHODS

Study Design, Population, and Data Sources

We conducted an ancillary study to the nationwide, prospective REGARDS cohort study, using data from 2003 to 2016.[15] The institutional review boards of the participating institutions approved the protocol. All participants provided written informed consent. Because of the restrictions of our data use agreement with the Centers for Medicare and Medicaid Services, the data used for this study cannot be made publicly available to other researchers for the purpose of replicating the results. However, access to REGARDS Medicare-linked data can be requested first through the REGARDS study (www.uab.edu/soph/regardsstudy/researchers) and then through Medicare's Research Data Assistance Center (www.resdac.org).

Between 2003 and 2007, 30 239 community-dwelling Black and White adults aged ≥45 years were enrolled in the REGARDS study, with oversampling of Black adults and individuals living in the Southeastern United States.[15] Baseline data collection involved computer-assisted telephone interviews and in-home visits with a physical examination, blood test, urine test, ECG, and medication inventory. Participants or their proxies are contacted by telephone every 6 months to detect study end points. The report of a potential event triggers adjudication, which involves expert review of medical records, death certificates, proxy interviews, autopsy reports, Social Security Death Index, and National Death Index.[16]

For this study, we used REGARDS study baseline data, REGARDS-adjudicated events, and REGARDS Medicare-linked claims.[17]

Variables

Exposure

We used Medicare claims to identify ambulatory visits, which were defined using a modified National Committee for Quality Assurance (NCQA) definition[18] that was restricted to Clinical Procedure Terminology codes for in-person, evaluation-and-management visits for adults in an office setting.[7] The NCQA definition of ambulatory visits does not include emergency department visits. We calculated fragmentation scores for each participant using the previously validated Bice-Boxerman index, which ranges from 0 to 1 and captures both the spread of ambulatory visits across providers and the relative share of visits by each provider (Data S1).[9,12,19,20] We reverse-coded scores, calculating 1 minus Bice-Boxerman index, so that higher scores reflected more fragmentation.[7,11,14]

Outcome

Stroke events were adjudicated by the REGARDS study according to study protocols.[21] Briefly, stroke events were defined in part using the World Health Organization (WHO) definition as "rapidly developing clinical signs of focal, at times global, disturbance of cerebral function, lasting more than 24 hours or leading to death with no apparent cause other than that of vascular origin."[21,22] Events not meeting this definition but characterized by symptoms lasting <24 hours and with neuroimaging consistent with acute ischemia or hemorrhage were also classified as "clinical strokes."[21] We used strokes based on WHO or clinical classification, adjudicated through December 31, 2016.

Baseline Covariates

Demographics included self-reported age, sex, race, marital status, educational attainment, and annual household income; as well as geographic region and rural/urban setting using Rural/Urban Commuting Area codes[23] based on baseline contact information. Medical conditions included hypertension (self-reported use of antihypertensive medication, systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg from the in-home visit), dyslipidemia (use of lipid-lowering medication, total cholesterol≥240 mg/dL, low-density lipoprotein cholesterol ≥160 mg/dL, or high-density lipoprotein cholesterol≤40 mg/dL from the in-home visit), diabetes mellitus (fasting glucose ≥126 mg/dL or nonfasting glucose ≥200 mg/dL from the in-home visit, or self-reported use of oral glucose-lowering medication or insulin), history of coronary heart disease (self-reported history of myocardial infarction, coronary artery bypass graft, angioplasty, or coronary stents; or evidence of myocardial infarction on ECG at baseline), and atrial fibrillation (self-reported or present on the study ECG at baseline). Medication variables included a validated measure of self-reported medication adherence[24]; the total number of medications taken in the past 2 weeks by medication inventory; self-reported use of antihypertensive medication, insulin, and aspirin from the computer-assisted telephone interview; and statin and warfarin use from the medication inventory. Health behaviors were self-reported and included smoking status, alcohol consumption,[25] and exercise frequency. Psychosocial variables included whether a participant reported being the primary caretaker for another individual and whether he or she saw any close friends or relatives in the past month. Depressive symptoms were defined as Center for Epidemiologic Studies Depression Scale scores ≥4.[26] Physiological variables included body mass index, heart rate, systolic blood pressure, left ventricular hypertrophy (on ECG); total, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol; glucose; estimated glomerular filtration rate;[27] urinary albumin to creatinine ratio;[28] and high-sensitivity C-reactive protein. Self-rated health was assessed using self-rated general health (SF-1) from the Short-Form-12 (SF-12) survey.[29–32] Hospitalization during the first year of observation was measured in Medicare claims.

Statistical Analysis

We included participants aged ≥65 years whose REGARDS study data were linked to Medicare claims at any time during the study period, allowing for staggered entry as participants aged into Medicare. We excluded participants who: (1) were eligible for Medicare on the basis of end-stage renal disease; (2) had fewer than 12 months of continuous Medicare fee-for-service coverage or had Medicare managed care; (3) were lost to follow-up before entry into this ancillary study; (4) had ≤3 ambulatory visits in the first year of observation, because calculating fragmentation based on ≤3 visits can lead to unreliable estimates[12]; (5) had a history of stroke; or (6) had a missing value for self-rated health.

We used descriptive statistics to characterize the sample at baseline and summarize ambulatory care utilization in the first year of observation. We used the 75th percentile fragmentation score rounded to the nearest 0.05 from the first year of observation (0.85) to dichotomize fragmentation into high (≥0.85) and low (<0.85). This approach was informed by our previous studies[7,14] and by the goal of identifying individuals who have such high scores that they might benefit from future interventions if high fragmentation is found to be associated with increased stroke risk. To compare differences between participants with high versus low fragmentation, we used Wilcoxon rank sum, Student *t*, and chi-square tests. We conducted sensitivity analyses changing the cutoff for high fragmentation to ≥0.80 and, separately, ≥0.90. We also conducted a sensitivity analysis treating fragmentation as a 4-level variable.

Observation for each participant began after the in-home visit with the first 12-month period for which there was continuous Medicare fee-for-service coverage, starting with calendar year 2004. Because fragmentation can change over time, we treated fragmentation as a time-dependent exposure.[12,14,33] Because the effects of fragmentation are hypothesized to occur relatively quickly (eg, drug-drug interactions in the context of multiple prescribers),[14,33] we measured outcomes in the 3 months following each 12-month exposure period. Specifically, for each participant, we calculated a fragmentation score for the first 12 months of his or her observation period and then determined whether a stroke occurred in the 3 months immediately following the exposure period (months 13–15). If no event occurred, we moved the window of observation forward by 3 months, measuring fragmentation in months 4 to 15 and any event in months 16 to 18, and so on (Data S2). If the number of visits in any 12-month exposure period fell below 4, we carried forward the last fragmentation score based on ≥4 visits.[12] Observation continued until an outcome or censoring occurred; censoring occurred when a participant died of nonstroke causes, no longer had Medicare fee-for-service coverage, dropped out of the REGARDS study, or reached December 31, 2016.

We used Poisson regression to estimate absolute unadjusted and adjusted rates of strokes. We used Cox proportional hazards models to estimate unadjusted and adjusted hazards ratios.[34–36] Using Schoenfeld residuals, we determined that the assumption of proportional hazards was met. We included in the fully adjusted multivariate models covariates that had a bivariate association with fragmentation (P<0.10), were used in the sampling frame, or were retained because of high clinical importance (sex, coronary heart disease, atrial fibrillation, statin, aspirin, warfarin, heart rate). If 2 variables had bivariate P values <0.10, but 1 was embedded in the definition of another (eg, use of antihypertensive medication was embedded in the definition of hypertension), we adjusted only for the broader variable to avoid collinearity. To maximize power, given that some subgroups had relatively few stroke events, we also generated a more parsimonious model, which included covariates that had multivariate P values <0.10 in the fully adjusted model, were used in the sampling frame, or were retained because of high clinical importance (dyslipidemia, atrial fibrillation, aspirin).

We conducted all model analyses using stochastic regression imputation to handle missing covariates. Stochastic regression is a method that adds a residual error term to each imputed predicted value, thereby preserving uncertainty while reducing bias.[37] The most frequently missing variable was income (missing for 12% of the sample).

We used self-rated health as a measure of health status.[29,30] We used 3 groupings of self-rated health (excellent, very good or good, fair or poor) to detect any differences among subgroups, while maximizing statistical power. We used Wald tests to determine interactions between fragmentation and self-rated health in the overall sample, by race, and by geographic region. The Wald tests were significant for self-rated health in the overall sample (P=0.04) and by race (P=0.02) but not by geographic region (P=0.94). Thus, we conducted analyses overall and stratified by self-rated health and by race.

Analyses were conducted with SAS version 9.4 (SAS Institute Inc) and Stata version 14 (StataCorp). Multivariate P values<0.05 were considered statistically significant.

RESULTS

Study Sample

Of the 30 239 REGARDS study participants, 20 403 had linked Medicare claims and were aged ≥65 years during the study period. Of those, 12 510 met our inclusion criteria (Figure S1).

Sample Characteristics

Participants in our sample were aged 70.5 years on average; 53% were women and 68% were of White race (Table 1). More than half (60%) lived in the Southeastern United States. Chronic conditions were common, with 62% having hypertension, 62% having dyslipidemia, 22% having diabetes mellitus, 21% having coronary heart disease, and 9% having atrial fibrillation. In terms of self-rated health, 17% reported excellent health, 67% reported very good or good health, and 13% reported fair or poor health. Additional characteristics are shown in Table 1. Appendices show participant characteristics stratified by self-rated health (Table S1), by race (Table S2), by self-rated health among Black participants (Table S3), and by self-rated health among White participants (Table S4).

Ambulatory Utilization

Participants with high fragmentation (fragmentation score ≥0.85) in the first year of observation were younger, more likely to be of White race, and less likely to have hypertension, dyslipidemia, and diabetes mellitus than those with low fragmentation (fragmentation score <0.85). Additional differences are shown in Table 1.

Participants with high fragmentation had on average 11.1 ambulatory visits with 6.4 providers in the first year of observation, with the most frequently seen provider accounting for 29.1% of visits (Table 2). By contrast, participants with low fragmentation had on average 9.2 ambulatory visits with 3.6 providers,

Table 1. Baseline Characteristics, Overall and Stratified by Fragmentation Score in the First Year of Observation*

Characteristic	Overall (N=12 510)	Low Fragmentation During First Year of Observation (n=9301)	High Fragmentation During First Year of Observation (n=3209)	*P* Value
Demographic characteristics				
Age, mean (SD), y	70.5 (6.0)	70.7 (6.0)	70.2 (5.9)	<0.001
Women, n (%)	6623 (52.9)	4896 (52.6)	1727 (53.8)	0.25
White race, n (%)	8513 (68.0)	6108 (65.7)	2405 (74.9)	<0.001
Marital status, married, n (%)	7487 (59.8)	5475 (58.9)	2012 (62.7)	<0.001
Education, less than high school diploma, n (%)	1545 (12.4)	1237 (13.3)	308 (9.6)	<0.001
Annual household income, <$35 000, n (%)	5422 (49.5)	4199 (51.5)	1223 (43.7)	<0.001
Geographic region, n (%)				
Stroke belt†	4551 (36.4)	3334 (35.8)	1217 (37.9)	0.010
Stroke buckle‡	2899 (23.2)	2214 (23.8)	685 (21.3)	
Neither stroke belt nor stroke buckle	5060 (40.4)	3753 (40.4)	1307 (40.7)	
Residence in urban area, n (%)	8467 (75.3)	6307 (75.2)	2160 (75.4)	0.89
Medical conditions§				
Hypertension, n (%)	7663 (61.5)	5857 (63.2)	1806 (56.4)	<0.001
Dyslipidemia, n (%)	7538 (62.3)	5668 (62.9)	1870 (60.6)	0.019
Diabetes mellitus, n (%)	2623 (21.7)	2016 (22.4)	607 (19.6)	<0.001
History of coronary heart disease, n (%)	2521 (20.5)	1852 (20.2)	669 (21.2)	0.25
Atrial fibrillation, n (%)	1149 (9.4)	840 (9.2)	309 (9.8)	0.33
Medications				
Medication adherence, n (%)	8302 (71.1)	6205 (71.4)	2097 (70.3)	0.23
No. of medications, median (25th, 75th percentiles)	6.0 (3.0, 9.0)	6.0 (3.0, 8.0)	6.0 (3.0, 9.0)	<0.001
Antihypertensive medication, n (%)	6693 (55.4)	5126 (57.1)	1567 (50.3)	<0.001
Insulin use, n (%)	657 (5.5)	483 (5.4)	174 (5.7)	0.62
Statin use, n (%)	4439 (35.5)	3297 (35.4)	1142 (35.6)	0.89
Aspirin use, n (%)	6084 (48.6)	4509 (48.5)	1575 (49.1)	0.55
Warfarin use, n (%)	522 (4.2)	402 (4.3)	120 (3.7)	0.16
Health behaviors				
Current smoker, n (%)	1344 (10.8)	1031 (11.1)	313 (9.8)	0.035
Alcohol use, n (%)				
Heavy	464 (3.8)	339 (3.7)	125 (4.0)	<0.001
Moderate	4049 (33.0)	2924 (32.0)	1125 (35.7)	
None	7775 (63.3)	5874 (64.3)	1901 (60.3)	
Exercise frequency, 0 times per week, n (%)	4192 (34.1)	3121 (34.1)	1071 (33.9)	0.84
Psychosocial variables				
Cares for a family member with a chronic illness or disability, n (%)	1493 (11.9)	1102 (11.9)	391 (12.2)	0.62
Lack of social support, n (%)	485 (4.0)	343 (3.8)	142 (4.5)	0.073
Depressive symptoms, n (%)	710 (5.7)	528 (5.7)	182 (5.7)	0.99
Physiological variables				
Body mass index, mean (SD), kg/m^2	28.9 (5.8)	29.0 (5.8)	28.6 (5.7)	<0.001
Heart rate, beats per min, mean (SD)	66.6 (24.8)	66.5 (22.4)	66.7 (30.8)	0.76
Systolic blood pressure, mean (SD), mm Hg	128.6 (16.3)	129.1 (16.3)	127.2 (16.0)	<0.001
Left ventricular hypertrophy, n (%)	1247 (10.1)	959 (10.4)	288 (9.1)	0.032
Total cholesterol, mean (SD), mg/dL	189.9 (39.4)	190.5 (39.7)	188.4 (38.3)	0.011
Low-density lipoprotein cholesterol, mean (SD), mg/dL	111.5 (33.9)	112.1 (34.2)	109.6 (32.8)	<0.001

(*Continued*)

Table 1. Continued

Characteristic	Overall (N=12 510)	Low Fragmentation During First Year of Observation (n=9301)	High Fragmentation During First Year of Observation (n=3209)	*P* Value
High-density lipoprotein cholesterol, mean (SD), mg/dL	51.6 (16.3)	51.4 (16.1)	52.3 (16.6)	0.009
Glucose, mean (SD), mg/dL	103.8 (33.7)	104.3 (34.2)	102.4 (32.2)	0.008
Estimated glomerular filtration rate, mean (SD), mL/min per 1.73 m^2	80.6 (18.9)	80.5 (19.1)	80.8 (18.3)	0.44
Urinary albumin to creatinine ratio, median (25th, 75th percentiles), mg/g	2.1 (0.9, 4.8)	2.2 (1.0, 4.8)	2.0 (0.9, 4.5)	0.010
C-reactive protein, median (25th, 75th percentiles), mg/L	7.8 (4.9, 16.7)	7.9 (4.9, 17.0)	7.6 (4.8, 15.7)	0.010
Self-rated health				
Self-rated general health (SF-1), n (%)				
Excellent	2145 (17.1)	1544 (16.6)	601 (18.7)	0.049
Very good	3940 (31.5)	2926 (31.5)	1014 (31.6)	
Good	4423 (35.4)	3336 (35.9)	1087 (33.9)	
Fair	1669 (13.3)	1251 (13.5)	418 (13.0)	
Poor	333 (2.7)	244 (2.6)	89 (2.8)	
Mental component summary score, mean (SD)	55.1 (7.6)	55.1 (7.6)	54.9 (7.6)	0.24
Physical component summary score, mean (SD)	46.6 (10.3)	46.6 (10.2)	46.5 (10.5)	0.51
Healthcare utilization				
Hospitalization in the first y of observation, n (%)	1245 (10.0)	880 (9.5)	365 (11.4)	0.002

SF indicates short-form survey.[19] Percentages may not sum to 100 because of rounding.

*Missing data: education (n=4), income (n=1554), residence in urban area (n=1261), medication count (n=12), smoking (n=48), exercise (n=207), caregiver status (n=12), lack of social support (n=308), depressive symptoms (n=72), body mass index (n=65), heart rate (n=111), systolic blood pressure (n=34), total cholesterol (n=454), low-density lipoprotein cholesterol (n=680), high-density lipoprotein cholesterol (n=529), glucose (n=456), estimated glomerular filtration rate (n=454), urinary albumin to creatinine ratio (n=505), C-reactive protein (n=724), mental component summary score (n=591), and physical component summary score (n=591).

†Stroke Belt consists of North Carolina, South Carolina, Georgia, Tennessee, Mississippi, Alabama, Louisiana, and Arkansas (except for 153 coastal counties that constitute the Stroke Buckle).[15]

‡Stroke Buckle consists of 153 coastal counties in North Carolina, South Carolina, and Georgia.[15,21]

§See Methods section for detailed definitions of variables.

with the most frequently seen provider accounting for 57.5% of visits (*P*<0.001 for each pairwise comparison). The average fragmentation score for participants with high fragmentation was 0.91, compared with 0.63 for participants with low fragmentation (*P*<0.001).

Participants with fair or poor self-rated health had more visits and more providers, compared with participants with very good/good self-rated health and compared with those with excellent self-rated health (*P*<0.001 for each comparison). However, highly fragmented care (score≥0.85) was observed in all 3 subgroups by self-rated health, affecting 25% to 28% participants in each subgroup.

Black participants had on average more visits than White participants (10.0 visits versus 9.5 visits, *P*<0.001) but fewer providers (4.1 providers versus 4.4 providers, *P*<0.001). Highly fragmented care was less common among Black participants than White participants, affecting 20% of Black participants and 28% of White participants.

Rates of Incident Strokes

Participants were observed for a median of 5.6 years (range, 1 day to 11.8 years). We observed 611 incident strokes over 75 106 person-years, for an adjusted rate of 8.1 strokes per 1000 person-years (Table 3). The majority of strokes observed were ischemic (85%), rather than hemorrhagic (11%); stroke type was unclassifiable for 4%. Overall, the adjusted rates for incident strokes was similar for high versus low fragmentation (8.2 versus 8.1 per 1000 person-years, *P*=0.89). However, there were significant differences among subgroups. The subgroup with the highest adjusted rate of incident strokes was Black participants with high fragmentation and fair or poor self-rated health who had an adjusted rate of 19.3 strokes per 1000 person-years (95% CI, 11.5 per 1000 person-years; 27.2 per 1000 person-years) (Figure 1).

Hazard of Incident Stroke

Overall, there was no association between high fragmentation and the hazard of incident stroke (adjusted

Table 2. Ambulatory Utilization During the First Year of Observation, Overall and Stratified By Fragmentation Score, Self-Rated Health, and Race*

	Overall			Self-Rated Health								
				Excellent			Very Good or Good			Fair or Poor		
	Total	Low rBBI (<0.85)	High rBBI (≥0.85)	Total	Low rBBI (<0.85)	High rBBI (≥0.85)	Total	Low rBBI (<0.85)	High rBBI (≥0.85)	Total	Low rBBI (<0.85)	High rBBI (≥0.85)
All participants												
No. (%)	12 510 (100)	9301 (74.4)	3209 (25.7)	2145 (100)	1544 (72.0)	601 (28.0)	8363 (100)	6262 (74.9)	2101 (25.1)	2002 (100)	1495 (74.9)	507 (25.1)
Visits, mean (SD)	9.68 (6.57)	9.21 (6.28)	11.05 (7.18)	7.59 (4.56)	7.36 (4.49)	8.18 (4.70)	9.56 (6.36)	9.06 (6.00)	11.06 (7.11)	12.45 (8.13)	11.78 (7.94)	14.41 (8.36)
Providers, mean (SD)	4.30 (2.30)	3.58 (1.73)	6.40 (2.46)	3.88 (1.85)	3.23 (1.39)	5.56 (1.83)	4.25 (2.26)	3.54 (1.68)	6.38 (2.44)	4.94 (2.73)	4.07 (2.11)	7.48 (2.76)
Percent of visits with the most frequently seen provider, mean (SD)	50.18 (19.96)	57.45 (17.74)	29.13 (6.74)	49.96 (19.50)	57.88 (16.92)	29.62 (6.85)	50.38 (19.89)	57.45 (17.73)	29.31 (6.73)	49.59 (20.72)	56.98 (18.57)	27.79 (6.46)
Fragmentation score, rBBI, mean (SD)	0.70 (0.22)	0.63 (0.22)	0.91 (0.04)	0.72 (0.22)	0.64 (0.21)	0.92 (0.05)	0.70 (0.22)	0.63 (0.22)	0.91 (0.04)	0.69 (0.23)	0.62 (0.22)	0.90 (0.04)
White participants												
No. (%)	8513 (100)	6108 (71.6)	2405 (28.3)	1760 (100)	1230 (69.9)	530 (30.1)	5739 (100)	4147 (72.3)	1592 (27.7)	1014 (100)	731 (72.3)	283 (27.7)
Visits, mean (SD)	9.52 (6.57)	9.07 (6.37)	10.66 (6.93)	7.50 (4.50)	7.27 (4.44)	8.05 (4.62)	9.53 (6.44)	9.03 (6.18)	10.82 (6.90)	13.00 (8.60)	12.36 (8.57)	14.65 (8.47)
Providers, mean (SD)	4.38 (2.27)	3.63 (1.72)	6.28 (2.38)	3.95 (1.82)	3.28 (1.36)	5.51 (1.79)	4.37 (2.26)	3.62 (1.70)	6.32 (2.38)	5.19 (2.73)	4.28 (2.11)	7.55 (2.74)
Percent of visits with the most frequently seen provider, mean, (SD)	48.87 (19.25)	56.59 (16.96)	29.28 (6.75)	48.80 (18.70)	57.03 (16.00)	29.72 (6.76)	49.09 (19.35)	56.64 (17.18)	29.42 (6.75)	47.81 (19.62)	55.61 (17.29)	27.65 (6.53)
Fragmentation score, rBBI, mean (SD)	0.72 (0.21)	0.65 (0.20)	0.91 (0.04)	0.74 (0.20)	0.66 (0.19)	0.92 (0.05)	0.72 (0.21)	0.65 (0.21)	0.91 (0.04)	0.72 (0.20)	0.64 (0.20)	0.90 (0.04)
Black participants												
No. (%)	3997 (100)	3193 (79.9)	804 (20.1)	385 (100)	314 (81.6)	71 (18.4)	2624 (100)	2115 (80.6)	509 (19.4)	988 (100)	764 (80.6)	224 (19.4)
Visits, mean (SD)	10.03 (6.55)	9.48 (6.08)	12.22 (7.77)	7.97 (4.82)	7.70 (4.71)	9.15 (5.15)	9.63 (6.19)	9.11 (5.65)	11.81 (7.69)	11.88 (7.57)	11.23 (7.25)	14.10 (8.21)
Providers, mean (SD)	4.13 (2.36)	3.48 (1.75)	6.75 (2.66)	3.56 (1.94)	3.02 (1.45)	5.93 (2.07)	4.01 (2.24)	3.40 (1.63)	6.57 (2.61)	4.67 (2.71)	3.88 (2.10)	7.39 (2.79)
Percent of visits with the most frequently seen provider, mean, (SD)	52.97 (21.14)	59.08 (19.03)	28.69 (6.69)	55.25 (22.08)	61.21 (19.82)	28.92 (7.51)	53.21 (20.76)	59.05 (18.67)	28.98 (6.70)	51.42 (21.66)	58.29 (19.65)	27.97 (6.38)
Fragmentation score, rBBI, mean (SD)	0.66 (0.24)	0.60 (0.24)	0.90 (0.04)	0.64 (0.26)	0.58 (0.25)	0.92 (0.05)	0.66 (0.24)	0.61 (0.23)	0.90 (0.04)	0.67 (0.25)	0.60 (0.24)	0.90 (0.04)

The reversed Bice-Boxerman index (rBBI) is equivalent to 1–Bice-Boxerman index, such that higher scores indicate more fragmentation.[19]
All comparisons of low vs high rBBI, overall and within self-rated health subgroup, are statistically significant (*P*<0.001).
*To be included in the analysis, a participant had to have ≥4 ambulatory visits in his or her first year of observation.

Table 3. Incident Rates of Stroke, Stratified by Self-Rated General Health, Fragmentation Status, and Race*

		Self-Rated General Health		
	Overall	Excellent	Very Good or Good	Fair or Poor
Sample sizes and observation time				
No. (%)	12 510	2145 (17)	8363 (67)	2002 (16)
Range of observation time	1 d to 11.8 y	11 d to 11.8 y	2 d to 11.8 y	1 d to 11.8 y
Median observation time (IQR), y	5.6 (2.9–9.1)	6.4 (3.2–9.9)	5.8 (3.0–9.4)	4.1 (2.0–7.5)
Event counts and rates				
All participants				
Total				
Observed no. of events (% participants)	611 (4.9)	96 (4.5)	399 (4.8)	116 (5.8)
Observed no. of person-years	75 106	13 836	51 367	9903
Unadjusted rate per 1000 person-years	8.1	6.9	7.8	11.7
Adjusted rate per 1000 person-years	8.1	6.9	7.8	11.7
Low fragmentation				
Observed no. of events (% participants)	423 (5.2)	73 (5.4)	277 (5.1)	73 (5.7)
Observed no. of person-years	51 053	9113	35 127	6813
Unadjusted rate per 1000 person-years	8.3	8.0	7.9	10.7
Adjusted rate per 1000 person-years	8.1	7.8	7.9	10.4
High fragmentation				
Observed no. of events (% participants)	188 (4.2)	23 (2.9)	122 (4.2)	43 (5.9)
Observed no. of person-years	24 052	4723	16 239	3090
Unadjusted rate per 1000 person-years	7.8	4.9	7.5	13.9
Adjusted rate per 1000 person-years	8.2	5.1	7.5	14.8
White participants				
Total				
Observed no. of events (% participants)	431 (5.1)	84 (4.8)	289 (5.0)	58 (5.7)
Observed no. of person-years	54 516	11 791	37 303	5422
Unadjusted rate per 1000 person-years	7.9	7.1	7.7	10.7
Adjusted rate per 1000 person-years	7.9	7.1	7.7	10.8
Low fragmentation				
Observed no. of events (% participantss)	289 (5.5)	63 (5.9)	187 (5.3)	39 (6.3)
Observed no. of person-years	35 641	7552	24 511	3577
Unadjusted rate per 1000 person-years	8.1	8.3	7.6	10.9
Adjusted rate per 1000 person-years	7.9	8.0	7.5	10.6
High fragmentation				
Observed no. of events (% participants)	142 (4.3)	21 (3.1)	102 (4.6)	19 (4.8)
Observed no. of person-years	18 875	4239	12 792	1844
Unadjusted rate per 1000 person-years	7.5	5.0	8.0	10.3
Adjusted rate per 1000 person-years	7.9	5.3	8.3	11.1
Black participants				
Total				
Observed no. of events (% participants)	180 (4.5)	12 (3.1)	110 (4.2)	58 (5.9)
Observed no. of person-years	20 590	2045	14 063	4481
Unadjusted rate per 1000 person-years	8.7	5.9	7.8	12.9
Adjusted rate per 1000 person-years	8.8	6.0	7.9	12.8
Low fragmentation				
Observed no. of events (% participants)	134 (4.7)	10 (3.7)	90 (4.6)	34 (5.2)
Observed no. of person-years	15 413	1562	10 616	3235

(Continued)

Table 3. Continued

	Overall	Self-Rated General Health		
		Excellent	Very Good or Good	Fair or Poor
Unadjusted rate per 1000 person-years	8.7	6.4	8.5	10.5
Adjusted rate per 1000 person-years	8.7	7.2	8.5	10.3
High fragmentation				
Observed no. of events (% participants)	46 (4.1)	2 (1.8)	20 (2.9)	24 (7.2)
Observed no. of person-years	5177	484	3447	1246
Unadjusted rate per 1000 person-years	8.9	4.1	5.8	19.3
Adjusted rate per 1000 person-years	8.9	3.4	6.0	19.3

*Adjusted rates were derived from Poisson models that adjusted for demographics (sex, age, race, income, region), medical conditions (hyperlipidemia, myocardial infarction, atrial fibrillation), medications (aspirin use, warfarin use), health behaviors (smoking), psychosocial variables (social support), physiological variables (body mass index, systolic blood pressure, albumin to creatinine ratio, C-reactive protein), self-rated health, and hospitalization. Fragmentation status is a time-varying exposure based on the reversed Bice-Boxerman index (low <0.85, high ≥0.85). See Methods section for more details.

hazard ratio [HR], 1.01; 95% CI, 0.85, 1.21) (Table 4). There was a trend suggesting that high fragmentation was associated with a higher hazard of stroke, compared with low fragmentation, among participants with fair or poor self-rated health (adjusted HR, 1.39; 95% CI, 0.95–2.04). There was no association among participants with very good or good self-rated health (adjusted HR, 1.01; 95% CI, 0.82–1.26) or excellent self-rated health (adjusted HR, 0.66; 95% CI, 0.41–1.07).

Among Black participants with fair or poor self-rated health, high fragmentation was associated with a significantly higher hazard of stroke, compared with low fragmentation (adjusted HR, 1.83; 95% CI, 1.06–3.14). Among Black participants, there was no association between fragmentation and stroke among participants

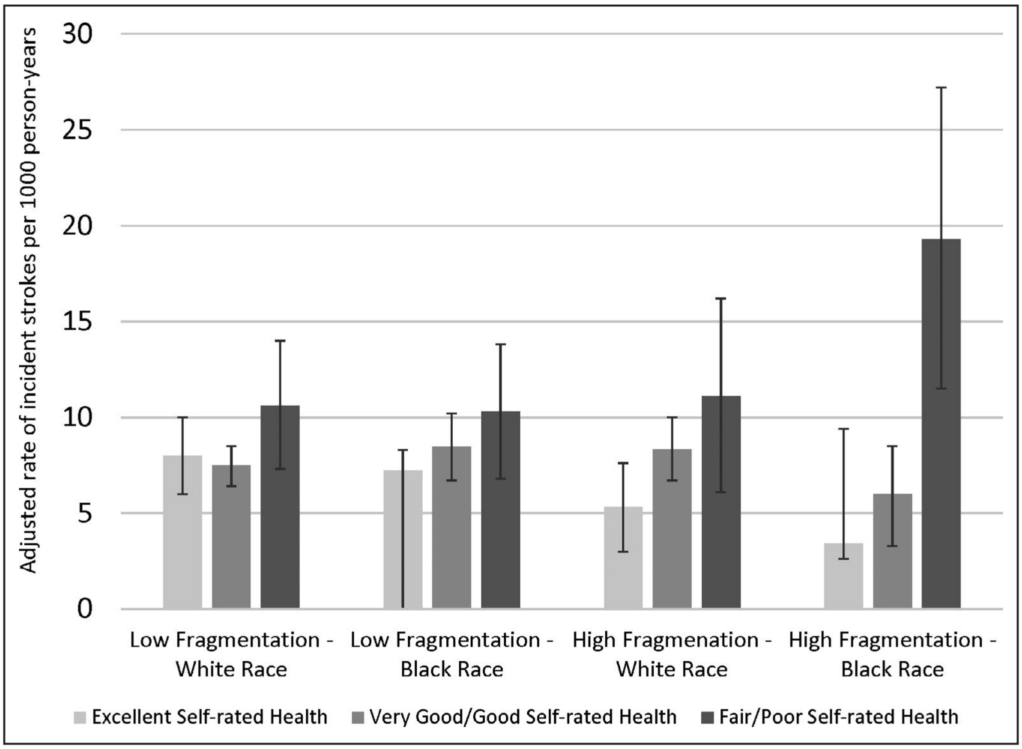

Figure. Adjusted rates of incident strokes per 1000 person-years with 95% CIs, stratified by healthcare fragmentation, self-rated health, and race.*

*Fragmentation is defined using the reversed Bice-Boxerman index (high ≥0.85, low <0.85) and modeled as a time-varying exposure. Adjusted rates were derived from multivariable Poisson models; see Table 3 for more details. The lower bound of the CI for low fragmentation—Black race—excellent self-rated health was equal to −1.6

Table 4. Hazard of Incident Stroke, Comparing High With Low Fragmentation, Overall and Stratified by Self-Rated General Health and Race (N=12 510)*

	Overall	Self-Rated General Health		
		Excellent	Very Good or Good	Fair or Poor
HRs (95% CIs)				
All participants				
Unadjusted	0.92 (0.78–1.10)	0.60 (0.37–0.96)	0.93 (0.75–1.15)	1.25 (0.86–1.82)
Model 1†	1.01 (0.84–1.21)	0.67 (0.42–1.08)	1.01 (0.82–1.26)	1.41 (0.96–2.07)
Model 2‡	1.01 (0.85–1.21)	0.66 (0.41–1.07)	1.01 (0.82–1.26)	1.39 (0.95–2.04)
White participants				
Unadjusted	0.90 (0.73–1.10)	0.58 (0.35–0.95)	1.01 (0.80–1.29)	0.89 (0.51–1.54)
Model 3§	0.98 (0.80–1.21)	0.68 (0.41–1.12)	1.10 (0.86–1.41)	0.99 (0.57–1.72)
Model 4‡	0.99 (0.81–1.21)	0.67 (0.40–1.10)	1.11 (0.87–1.42)	1.01 (0.58–1.76)
Black participants				
Unadjusted	1.04 (0.75–1.45)	…	0.69 (0.43–1.13)	1.82 (1.08–3.07)
Model 3§	1.06 (0.75–1.48)	…	0.72 (0.44–1.17)	1.87 (1.09–3.20)
Model 4‡	1.05 (0.74–1.46)	…	0.73 (0.45–1.19)	1.83 (1.06–3.14)

*HR indicates hazard ratio. Results were derived from Cox proportional hazards models that treat fragmentation as a time-varying exposure (considering 12 months of the exposure at a time and outcomes that occur in the 3 months immediately following the exposure period), with a total of up to 11.8 years of follow-up. High fragmentation is defined as a score of ≥0.85 on a reversed Bice-Boxerman index. We were not able to calculate results for Black participants with excellent self-rated health because they had too few events. Wald tests for interaction were significant for self-rated health in the overall sample (*P*=0.04) and by race (*P*=0.02).

†Model 1 is a fully adjusted model, which adjusts for 26 baseline covariates that were associated with fragmentation in the first year of observation in bivariate models (*P*<0.10), were used in the sampling frame, or were retained because of high clinical importance: demographics (age, sex, race, marital status, education, income, region), medical conditions (dyslipidemia, diabetes mellitus, coronary artery disease, atrial fibrillation), medications (medication count, statin use, aspirin use, warfarin use), heath behaviors (smoking, alcohol use), psychosocial variables (social support), physiological variables (body mass index, heart rate, systolic blood pressure, left ventricular hypertrophy, albumin to creatinine ratio, and C-reactive protein), self-rated health, and hospitalization.

‡Model 2 is a more parsimonious model that includes 18 covariates that were significant (*P*<0.10) in model 1, were used in the sampling frame, or were retained because of high clinical importance: demographics (sex, age, race, income, region), medical conditions (dyslipidemia, myocardial infarction, atrial fibrillation), medications (aspirin use, warfarin use), health behaviors (smoking), psychosocial variables (social support), physiological variables (body mass index, systolic blood pressure, albumin to creatinine ratio, C-reactive protein), self-rated health, and hospitalization.

§Model 3 is the same as model 1, except stratified by race, instead of including adjustment for race.

‡Model 4 is the same as model 2, except stratified by race, instead of including adjustment for race.

with very good or good self-rated health (adjusted HR, 0.73; 95% CI, 0.45–1.19). There were too few stroke events among Black participants with excellent self-rated health to calculate a model for that subgroup. There was no association between fragmentation and stroke among White participants, overall or by self-rated health subgroup.

Sensitivity Analyses

When we changed the cutoff for "high" fragmentation to ≥0.80 instead of ≥0.85, 46.7% of the cohort was classified as having high fragmentation (rather than 25.7%). With this alternate cutoff of ≥0.80, we did not find any association between high fragmentation and incident stroke (Table S5). When we changed the cutoff for "high" fragmentation to ≥0.90, 13.7% of the cohort was classified as having high fragmentation. With this alternate cutoff of ≥0.90, we found that the association between high fragmentation and incident stroke persisted among the subset of Black participants with fair or poor self-rated health (adjusted HR, 2.13; 95% CI, 1.15–3.95). When we modeled fragmentation as a 4-level variable, CIs widened, but the association between fragmentation and incident stroke persisted among Black participants with fair of poor self-rated health and fragmentation scores ≥0.90, compared with the reference category (adjusted HR, 2.18; 95% CI, 1.11–4.28) (Table S6).

DISCUSSION

In this nationwide, 11-year cohort study of 12 510 Medicare beneficiaries, we found that the association between highly fragmented ambulatory care and incident stroke varied with self-rated health and race. Overall, the adjusted rate of incident stroke was similar between participants with high versus low fragmentation (8.2 versus 8.1 per 1000 person-years, *P*=0.89). Among participants with fair or poor self-rated health at baseline, having high versus low fragmentation was associated with a trend toward a higher adjusted rate of incident strokes (14.8 versus 10.4 per 1000 person-years, *P*=0.067). Among Black participants with fair or poor self-rated health, having high versus low fragmentation was associated with a significantly higher adjusted rate of strokes (19.3 versus 10.3 per 1000 person-years, respectively; *P*=0.02), which was equivalent to a significantly increased adjusted hazard of stroke (HR, 1.83; 95% CI, 1.06–3.14).

This study creates a novel bridge across several existing bodies of work. There is one body of work documenting physiologic risk factors for stroke, such as age, hypertension, diabetes mellitus, atrial fibrillation, coronary heart disease, and left ventricular hypertrophy, which our analysis includes.[3] There is a second body of work linking self-rated health with stroke incidence[38] and all-cause mortality.[29,30] There is a third body of work documenting racial disparities in stroke incidence, with Black individuals experiencing a disproportionate number of strokes.[21] There is a fourth body of work documenting racial disparities in the delivery of health care.[39] This study is a novel addition, contributing new data on how fragmented ambulatory care relates to incident strokes, by self-rated health and by race, after accounting for physiologic risk factors.

The exact mechanism by which fragmentation increases the hazard of stroke among Black individuals with fair or poor self-rated health cannot be fully elucidated by the data in this study. Previous work has shown that fragmented care can lead to gaps in communication across providers caring for the same patient.[40] Such gaps in communication have been shown to be associated with an increased risk of drug-drug interactions,[6] including drug-drug interactions that could inadvertently worsen blood pressure control or worsen anticoagulation control among individuals at risk for stroke. Additional factors to be considered include that Black adults may be cared for by less well-trained physicians than White adults,[41] Black adults may have less access to specialist providers than White adults (even with similar Medicare insurance),[42,43] Black adults have reason to distrust the healthcare system,[44] and Black adults may face explicit and/or implicit bias in the care they receive.[45] In this context, Black adults with fair or poor health may be particularly vulnerable to any adverse consequences of fragmented care.

If future interventions were to try to reduce fragmentation, by how much would care patterns need to change in order to reduce fragmentation scores? To illustrate this, we provide a nomogram (Figure S2), which shows all possible patterns of providers for individuals with 12 visits (the average number of visits for Black participants with fair or poor health).[33] The nomogram shows all possible patterns of providers (1 to 12 providers) and all possible distributions of visits across those providers. The nomogram illustrates how fragmentation scores decrease as the proportion of visits with the most frequently seen provider increases. Although the nomogram illustrates only patterns of care for individuals with 12 visits, this negative correlation holds for any visit count. In our study, participants with high fragmentation often had average fragmentation scores of ≈0.90, whereas participants with low fragmentation often had fragmentation scores of ≈0.60. Using the nomogram, we can see that, for individuals with 12 visits, changing a fragmentation score from 0.90 to 0.60 would involve increasing the proportion of visits with the most frequently seen provider from ≈25% to 58%. The nomogram also shows how fragmentation scores vary with the distribution of visits to the other providers, not just the most frequently seen provider.

This study has several strengths, including the national sampling frame and large sample size, with oversampling of Black individuals to ensure robust subgroup analysis, the long follow-up period, the uniform insurance coverage through Medicare fee-for-service, the previously validated measure of fragmentation, the treatment of fragmentation as a time-varying exposure, adjudicated stroke events, and clinically detailed potential confounders that were collected through standardized protocols.

This study has several limitations. First, this is an observational study, so we cannot infer causation or rule out unmeasured confounding. There were differences in the characteristics for participants with high versus low fragmentation; the reasons for these differences are not known. However, the direction of many of these differences (such as lower rates of cardiovascular risk factors in the high fragmentation group) would bias our study toward the null. Second, we do not have data on communication among providers, so fragmentation cannot be interpreted as the definite absence of communication. Third, we cannot determine the clinical appropriateness of the ambulatory visit patterns that we observed. Fourth, we measured self-rated health and clinical covariates at baseline, and it is possible that they change over time. However, self-rated health at baseline was a significant predictor of incident stroke.

CONCLUSIONS

High fragmentation of ambulatory care was associated with an increase in the hazard of incident stroke for Black individuals with fair or poor self-rated health, compared with low fragmentation (adjusted HR, 1.83; 95% CI, 1.06–3.14). Future research is needed to better understand how fragmentation affects Black adults with fair or poor health, in order to inform the design of future interventions to prevent unnecessary fragmentation and prevent excess strokes.

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Supplementary Material

Data S1-S2
Supplemental Methods
Figures S1-S2
Tables S1-S6

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SUPPLEMENTAL MATERIAL

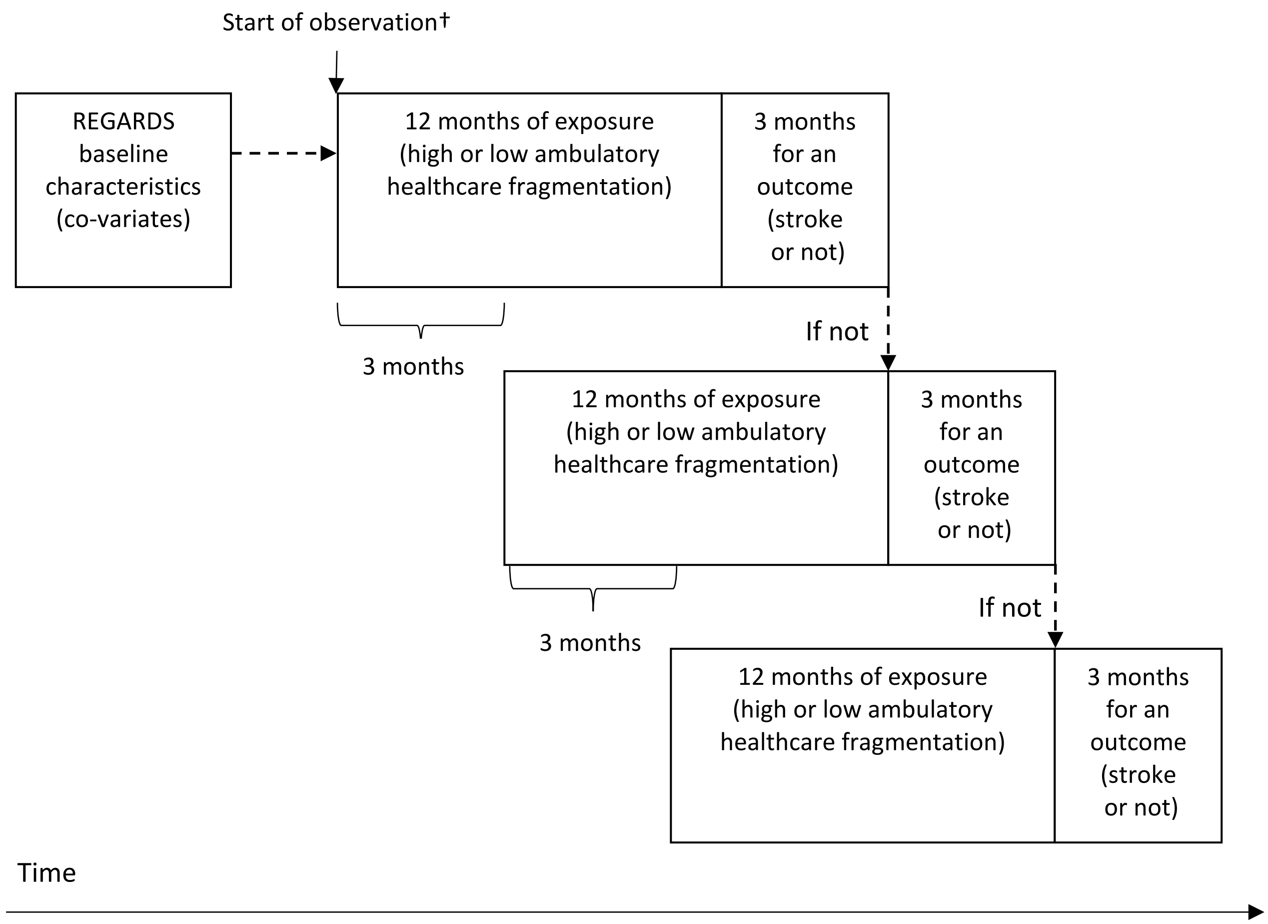
Data S1. Supplemental Methods. Formula for the Bice-Boxerman Index (BBI)*[19]

$$BBI = \frac{\left(\sum_{i=1}^{p} n_i^2\right) - n}{n\,(n-1)}$$

where n = total number of visits in the 12-month period
n_i = number of visits to provider i
p = total number of providers

* The BBI is a continuous index that ranges from 0 to 1. We have reversed the direction of the Index, calculating 1 minus BBI, so that higher scores reflect more fragmentation.

Data S2. Supplemental Methods. Schematic diagram of analytic approach*

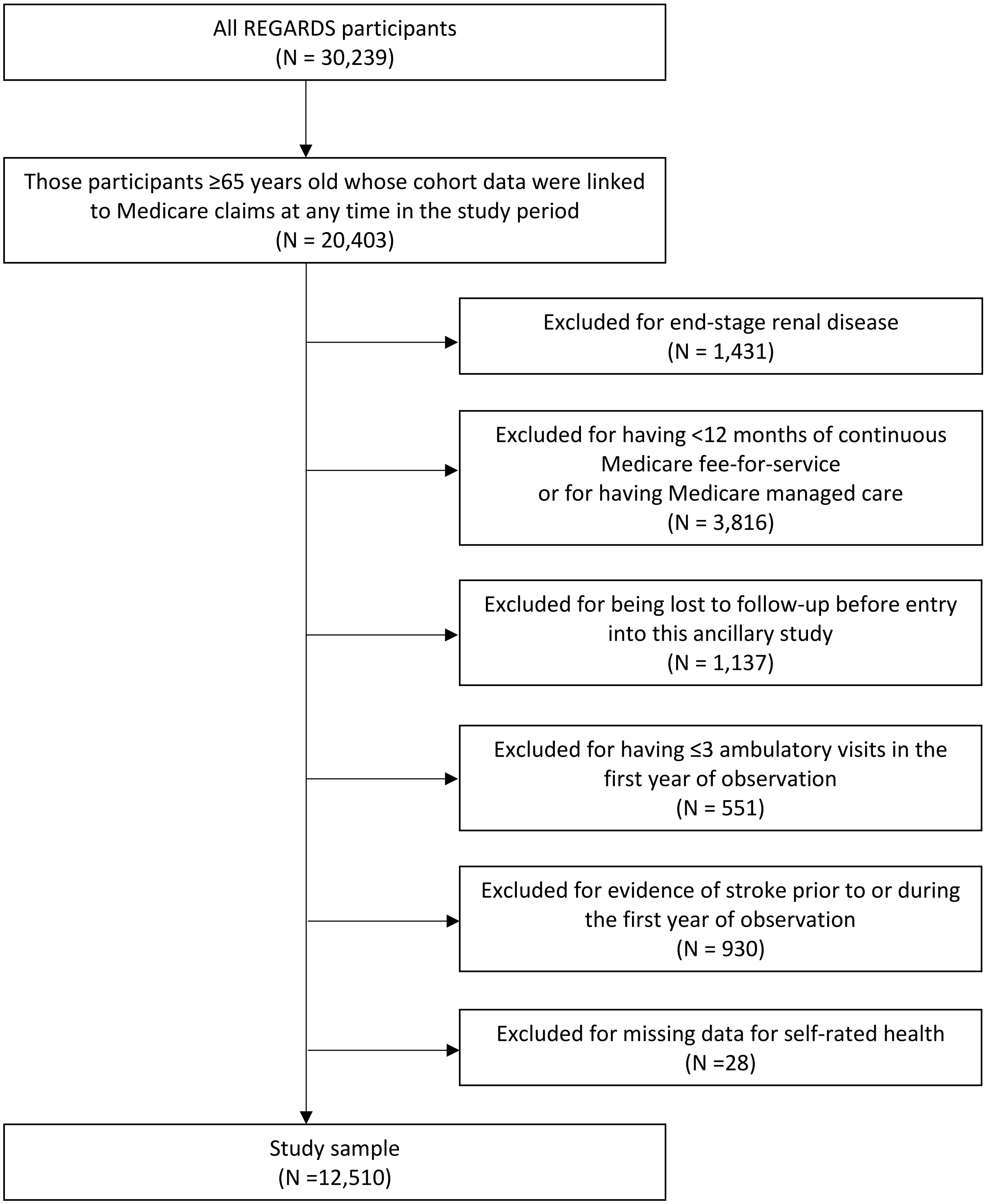


REGARDS = Reasons for Geographic and Racial Differences in Stroke.

*This schematic diagram illustrates a longitudinal design that treats the exposure (healthcare fragmentation) as time-varying. Observation continues until a stroke occurs, censoring occurs, or the end of the study period is reached. Note that the periods of time for the outcome do not overlap with each other, but they are contiguous (with the next one starting where the previous one left off).

†Observation began after the in-home visit with the first 12-month period for which there was continuous Medicare fee-for-service coverage, starting as early as January 1, 2004. The study continued (as shown in the schematic diagram) until the end of the study period, which was December 31, 2016.

Figure S1. Derivation of the study sample



Key: REGARDS = Reasons for Geographic and Racial Differences in Stroke

Table S1. Baseline characteristics, overall and stratified by self-rated health*

Characteristic	Overall (N = 12,510)	Excellent (N = 2,145)	Very good or good (N= 8,363)	Fair or poor (N = 2,002)	p-value
Demographic characteristics					
Age, years, mean (SD)	70.5 (6.0)	70.4 (5.9)	70.6 (5.9)	70.5 (6.2)	0.38
Gender, female, N (%)	6623 (52.9%)	994 (46.3%)	4425 (52.9%)	1204 (60.1%)	<0.001
Race, white, N (%)	8513 (68.0%)	1760 (82.1%)	5739 (68.6%)	1014 (50.6%)	<0.001
Marital status, married, N (%)	7487 (59.8%)	1432 (66.8%)	5049 (60.4%)	1006 (50.2%)	<0.001
Education, less than high school diploma, N (%)	1545 (12.4%)	127 (5.9%)	889 (10.6%)	529 (26.4%)	<0.001
Annual household income, <$35,000, N (%)	5422 (49.5%)	652 (33.9%)	3568 (48.8%)	1202 (69.8%)	<0.001
Geographic region, N (%)					
Stroke Belt†	4551 (36.4%)	783 (36.5%)	2980 (35.6%)	788 (39.4%)	0.015
Stroke Buckle‡	2899 (23.2%)	490 (22.8%)	1941 (23.2%)	468 (23.4%)	
Neither Stroke Belt nor Stroke Buckle	5060 (40.4%)	872 (40.7%)	3442 (41.2%)	746 (37.3%)	
Residence in urban area, N (%)	8467 (75.3%)	1412 (73.5%)	5711 (75.8%)	1344 (75.0%)	0.003
Medical conditions§					
Hypertension, N (%)	7663 (61.5%)	874 (40.8%)	5256 (63.1%)	1533 (76.8%)	<0.001
Dyslipidemia, N (%)	7538 (62.3%)	1109 (53.6%)	5082 (62.9%)	1347 (69.4%)	<0.001
Diabetes, N (%)	2623 (21.7%)	166 (8.1%)	1665 (20.6%)	792 (40.8%)	<0.001
History of coronary heart disease, N (%)	2521 (20.5%)	227 (10.7%)	1642 (20.0%)	652 (33.1%)	<0.001
Atrial fibrillation, N (%)	1149 (9.4%)	94 (4.4%)	723 (8.8%)	332 (17.0%)	<0.001
Medications					
Medication adherence, N (%)	8302 (71.1%)	1437 (75.2%)	5591 (71.2%)	1274 (66.8%)	<0.001
Number of medications, median (IQR)	6.0 (3.0, 9.0)	4.0 (2.0, 7.0)	6.0 (3.0, 8.0)	8.0 (5.0, 11.0)	<0.001
Anti-hypertensive medication, N (%)	6693 (55.4%)	671 (32.4%)	4602 (56.9%)	1420 (73.5%)	<0.001
Insulin use, N (%)	657 (5.5%)	23 (1.1%)	355 (4.4%)	279 (14.9%)	<0.001
Statin use, N (%)	4439 (35.5%)	547 (25.5%)	3074 (36.8%)	818 (40.9%)	<0.001
Aspirin use, N (%)	6084 (48.6%)	967 (45.1%)	4112 (49.2%)	1005 (50.2%)	<0.001
Warfarin use, N (%)	522 (4.2%)	40 (1.9%)	339 (4.1%)	143 (7.1%)	<0.001
Health behaviors					
Current smoker, N (%)	1344 (10.8%)	144 (6.8%)	877 (10.5%)	323 (16.2%)	<0.001
Alcohol use, N (%)					
Heavy	464 (3.8%)	113 (5.3%)	314 (3.8%)	37 (1.9%)	<0.001
Moderate	4049 (33.0%)	851 (40.2%)	2791 (34.0%)	407 (20.7%)	
None	7775 (63.3%)	1152 (54.4%)	5103 (62.2%)	1520 (77.4%)	
Exercise, 0 times per week, N (%)	4192 (34.1%)	419 (19.8%)	2740 (33.3%)	1033 (52.4%)	<0.001
Psychosocial variables					
Cares for a family member with a chronic illness or disability, N (%)	1493 (11.9%)	242 (11.3%)	990 (11.9%)	261 (13.0%)	0.20
Lack of social support, N (%)	485 (4.0%)	73 (3.5%)	320 (3.9%)	92 (4.7%)	0.13
Depressive symptoms, N (%)	710 (5.7%)	54 (2.5%)	368 (4.4%)	288 (14.4%)	<0.001
Physiological variables					
Body mass index, kg/m^2, mean (SD)	28.9 (5.8)	26.8 (4.5)	28.9 (5.6)	31.2 (6.8)	<0.001

Heart rate, beats per min, mean (SD)	66.6 (24.8)	65.4 (36.6)	66.1 (18.2)	70.0 (31.9)	<0.001
Systolic blood pressure, mm Hg, mean (SD)	128.6 (16.3)	125.7 (15.0)	128.8 (16.1)	130.9 (17.6)	<0.001
Left ventricular hypertrophy, N (%)	1247 (10.1%)	136 (6.4%)	846 (10.3%)	265 (13.4%)	<0.001
Total cholesterol, mg/dL, mean (SD)	189.9 (39.4)	193.3 (36.9)	189.5 (39.4)	188.0 (41.6)	<0.001
Low-density lipoprotein cholesterol, mg/dL, mean (SD)	111.5 (33.9)	114.5 (31.8)	111.2 (34.0)	109.5 (35.4)	<0.001
High-density lipoprotein cholesterol, mg/dL, mean (SD)	51.6 (16.3)	53.9 (17.0)	51.5 (16.2)	49.6 (15.6)	<0.001
Glucose, mg/dL, mean (SD)	103.8 (33.7)	96.5 (22.6)	103.2 (32.6)	114.0 (44.3)	<0.001
Estimated glomerular filtration rate, mL/min/1.73 m^2, mean (SD)	80.6 (18.9)	82.3 (15.3)	80.8 (18.5)	77.9 (23.2)	<0.001
Urinary albumin-to-creatinine ratio, mg/g, median (IQR)	2.1 (0.9, 4.8)	1.4 (0.7, 3.2)	2.1 (1.0, 4.6)	3.4 (1.4, 7.7)	<0.001
C-reactive protein, mg/L, median (IQR)	7.8 (4.9, 16.7)	6.4 (4.3, 11.3)	7.9 (4.9, 16.8)	10.2 (5.7, 30.2)	<0.001
Self-rated health					
Mental component summary score, mean (SD)	55.1 (7.6)	56.9 (5.5)	55.6 (6.9)	50.9 (10.4)	<0.001
Physical component summary score, mean (SD)	46.6 (10.3)	54.1 (5.4)	47.6 (8.5)	34.0 (10.3)	<0.001
Healthcare utilization					
Hospitalization in the first year of observation, N (%)	1245 (10.0%)	153 (7.1%)	803 (9.6%)	289 (14.4%)	<0.001

* Missing data: education (N=4), income (1,554), residence in urban area (N=1,261), medication count (N=12), smoking (N=48), exercise (N= 207), caregiver status (N= 12), lack of social support (N= 308), depressive symptoms (N= 72), body mass index (N=65), heart rate (111), systolic blood pressure (N=34), total cholesterol (N=454), low density lipoprotein (N=680), high-density lipoprotein (N=529), glucose (N=456), estimated glomerular filtration rate (N=454), urinary albumin-to-creatinine ratio (N=505), C-reactive protein (N=724), mental component summary score (N=591), and physical component summary score (N=591).
† Stroke Belt = North Carolina, South Carolina, Georgia, Tennessee, Mississippi, Alabama, Louisiana, and Arkansas (except for 153 coastal counties that constitute the Stroke Buckle).[15]
‡ Stroke Buckle = 153 coastal counties in North Carolina, South Carolina, and Georgia.[15,21]
§ See methods section for detailed definitions of variables.
Key: rBBI = reversed Bice-Boxerman Index (BBI), equivalent to 1 – BBI, such that higher scores indicate more fragmentation.[19] IQR = interquartile range. SF = short-form survey.[32] Percentages may not sum to 100 due to rounding.

Table S2. Baseline characteristics, overall and stratified by race*

Characteristic	Overall (N = 12,510)	Black (N = 3,997)	White (N = 8,513)	p-value
Demographic characteristics				
Age, years, mean (SD)	70.5 (6.0)	70.2 (5.8)	70.7 (6.0)	<0.001
Gender, female, N (%)	6623 (52.9%)	2531 (63.3%)	4092 (48.1%)	<0.001
Marital status, married, N (%)	7487 (59.8%)	1767 (44.2%)	5720 (67.2%)	<0.001
Education, less than high school diploma, N (%)	1545 (12.4%)	912 (22.8%)	633 (7.4%)	<0.001
Annual household income, <$35,000, N (%)	5422 (49.5%)	2269 (64.6%)	3153 (42.4%)	<0.001
Geographic region, N (%)				
Stroke Belt†	4551 (36.4%)	1345 (33.7%)	3206 (37.7%)	<0.001
Stroke Buckle‡	2899 (23.2%)	809 (20.2%)	2090 (24.6%)	
Neither Stroke Belt nor Stroke Buckle	5060 (40.4%)	1843 (46.1%)	3217 (37.8%)	
Residence in urban area, N (%)	8467 (75.3%)	3299 (89.5%)	5168 (68.3%)	<0.001
Medical conditions§				
Hypertension, N (%)	7663 (61.5%)	2990 (75.0%)	4673 (55.1%)	<0.001
Dyslipidemia, N (%)	7538 (62.3%)	2250 (58.9%)	5288 (63.9%)	<0.001
Diabetes, N (%)	2623 (21.7%)	1270 (33.1%)	1353 (16.4%)	<0.001
History of coronary heart disease, N (%)	2521 (20.5%)	693 (17.6%)	1828 (21.8%)	<0.001
Atrial fibrillation, N (%)	1149 (9.4%)	312 (8.0%)	837 (10.0%)	<0.001
Medications				
Medication adherence, N (%)	8302 (71.1%)	2620 (70.7%)	5682 (71.3%)	0.53
Number of medications, median (IQR)	6.0 (3.0, 9.0)	5.0 (3.0, 8.0)	6.0 (3.0, 9.0)	<0.001
Anti-hypertensive medication, N (%)	6693 (55.4%)	2699 (69.8%)	3994 (48.6%)	<0.001
Insulin use, N (%)	657 (5.5%)	374 (9.9%)	283 (3.5%)	<0.001
Statin use, N (%)	4439 (35.5%)	1304 (32.6%)	3135 (36.8%)	<0.001
Aspirin use, N (%)	6084 (48.6%)	1749 (43.8%)	4335 (50.9%)	
Warfarin use, N (%)	522 (4.2%)	101 (2.5%)	421 (5.0%)	<0.001
Health behaviors				
Current smoker, N (%)	1344 (10.8%)	510 (12.8%)	834 (9.8%)	<0.001
Alcohol use, N (%)				<0.001
Heavy	464 (3.8%)	79 (2.0%)	385 (4.6%)	
Moderate	4049 (33.0%)	906 (23.2%)	3143 (37.5%)	
None	7775 (63.3%)	2920 (74.8%)	4855 (57.9%)	
Exercise frequency, 0 times per week, N (%)	4192 (34.1%)	1515 (38.6%)	2677 (32.0%)	<0.001
Psychosocial variables				
Cares for a family member with a chronic illness or disability, N (%)	1493 (11.9%)	531 (13.3%)	962 (11.3%)	0.001
Lack of social support, N (%)	485 (4.0%)	154 (4.0%)	331 (4.0%)	0.99
Depressive symptoms, N (%)	710 (5.7%)	306 (7.7%)	404 (4.8%)	<0.001
Physiological variables				
Body mass index, kg/m^2, mean (SD)	28.9 (5.8)	30.6 (6.3)	28.1 (5.4)	<0.001
Heart rate, beats per minute, mean (SD)	66.6 (24.8)	68.0 (23.8)	65.9 (25.3)	<0.001
Systolic blood pressure, mm Hg, mean (SD)	128.6 (16.3)	131.8 (17.0)	127.1 (15.7)	<0.001
Left ventricular hypertrophy, N (%)	1247 (10.1%)	643 (16.3%)	604 (7.2%)	<0.001
Total cholesterol, mg/dL, mean (SD)	189.9 (39.4)	192.9 (40.9)	188.5 (38.6)	<0.001
Low-density lipoprotein cholesterol, mg/dL, mean (SD)	111.5 (33.9)	116.4 (36.1)	109.2 (32.5)	<0.001

High-density lipoprotein cholesterol, mg/dL, mean (SD)	51.6 (16.3)	53.9 (15.8)	50.6 (16.4)	<0.001
Glucose, mg/dL, mean (SD)	103.8 (33.7)	109.7 (41.9)	101.1 (28.8)	<0.001
Estimated glomerular filtration rate, mL/min/1.73 m^2, mean (SD)	80.6 (18.9)	83.9 (22.4)	79.1 (16.8)	<0.001
Urinary albumin-to-creatinine ratio, mg/g, median (IQR)	2.1 (0.9, 4.8)	2.9 (1.2, 6.4)	1.9 (0.9, 4.1)	<0.001
C-reactive protein, mg/L, median (IQR)	7.8 (4.9, 16.7)	8.3 (4.9, 20.2)	7.6 (4.9, 15.4)	<0.001
Self-rated health				
Self-rated general health (SF-1), N (%)				
Excellent	2145 (17.1%)	385 (9.6%)	1760 (20.7%)	<0.001
Very good	3940 (31.5%)	943 (23.6%)	2997 (35.2%)	
Good	4423 (35.4%)	1681 (42.1%)	2742 (32.2%)	
Fair	1669 (13.3%)	843 (21.1%)	826 (9.7%)	
Poor	333 (2.7%)	145 (3.6%)	188 (2.2%)	
Mental component summary score, mean (sd)	55.1 (7.6)	54.2 (8.4)	55.5 (7.2)	<0.001
Physical component summary score, mean (sd)	46.6 (10.3)	45.1 (10.4)	47.2 (10.1)	<0.001
Healthcare utilization				
Hospitalization in the first year of observation, N (%)	1245 (10.0%)	454 (11.4%)	791 (9.3%)	<0.001

Table S3. Baseline characteristics among black participants, overall and stratified by self-rated health

Characteristic	Overall (N = 3,997)	Excellent (N = 385)	Very good or good (N = 2624)	Fair or poor (N = 988)	p-value
Demographic characteristics					
Age, years, mean (SD)	70.2 (5.8)	70.0 (5.5)	70.2 (5.7)	70.3 (6.2)	0.7
Gender, female, N (%)	2531 (63.3%)	207 (53.8%)	1644 (62.7%)	680 (68.8%)	<0.001
Marital status, married, N (%)	1767 (44.2%)	174 (45.2%)	1207 (46.0%)	386 (39.1%)	<0.001
Education, less than high school diploma, N (%)	912 (22.8%)	59 (15.3%)	499 (19.0%)	354 (35.8%)	<0.001
Annual household income, <$35,000, N (%)	2269 (64.6%)	175 (51.0%)	1434 (61.7%)	660 (78.0%)	<0.001
Geographic region, N (%)					
Stroke Belt†	1345 (33.7%)	125 (32.5%)	869 (33.1%)	351 (35.5%)	
Stroke Buckle‡	809 (20.2%)	81 (21.0%)	522 (19.9%)	206 (20.9%)	
Neither Stroke Belt nor Stroke Buckle	1843 (46.1%)	179 (46.5%)	1233 (47.0%)	431 (43.6%)	0.46
Residence in urban area, N (%)	3299 (89.5%)	322 (90.7%)	2199 (90.8%)	778 (85.6%)	<0.001
Medical conditions§					
Hypertension, N (%)	2990 (75.0%)	216 (56.1%)	1937 (74.1%)	837 (84.8%)	<0.001
Dyslipidemia, N (%)	2250 (58.9%)	177 (48.6%)	1440 (57.6%)	633 (66.1%)	<0.001
Diabetes, N (%)	1270 (33.1%)	69 (18.8%)	759 (30.2%)	442 (46.1%)	<0.001
History of coronary heart disease, N (%)	693 (17.6%)	34 (9.1%)	384 (14.9%)	275 (28.3%)	<0.001
Atrial fibrillation, N (%)	312 (8.0%)	9 (2.4%)	162 (6.3%)	141 (14.8%)	<0.001
Medications					
Medication adherence, N (%)	2620 (70.7%)	247 (75.1%)	1742 (71.4%)	631 (67.5%)	0.016
Number of medications, median (IQR)	5.0 (3.0, 8.0)	3.0 (1.0, 5.0)	5.0 (3.0, 7.0)	7.0 (5.0, 10.0)	<0.001
Anti-hypertensive medication, N (%)	2699 (69.8%)	173 (45.6%)	1743 (68.9%)	783 (81.6%)	<0.001
Insulin use, N (%)	374 (9.9%)	14 (3.8%)	196 (7.9%)	164 (17.7%)	<0.001
Statin use, N (%)	1304 (32.6%)	73 (19.0%)	842 (32.1%)	389 (39.4%)	<0.001
Aspirin use, N (%)	1749 (43.8%)	135 (35.1%)	1141 (43.5%)	473 (47.9%)	<0.001
Warfarin use, N (%)	101 (2.5%)	4 (1.0%)	54 (2.1%)	43 (4.4%)	<0.001
Health behaviors					
Current smoker, N (%)	510 (12.8%)	46 (12.1%)	306 (11.7%)	158 (16.0%)	0.002
Alcohol use, N (%)					
Heavy	79 (2.0%)	10 (2.7%)	50 (2.0%)	19 (2.0%)	
Moderate	906 (23.2%)	88 (23.4%)	667 (26.0%)	151 (15.6%)	
None	2920 (74.8%)	278 (73.9%)	1845 (72.0%)	797 (82.4%)	<0.001
Exercise, 0 times per week, N (%)	1515 (38.6%)	89 (23.7%)	917 (35.6%)	509 (52.3%)	<0.001
Psychosocial variables					
Cares for a family member with a chronic illness or disability, N (%)	531 (13.3%)	39 (10.1%)	362 (13.8%)	130 (13.2%)	0.14
Lack of social support, N (%)	154 (4.0%)	12 (3.2%)	103 (4.1%)	39 (4.1%)	0.72
Depressive symptoms, N (%)	306 (7.7%)	15 (3.9%)	145 (5.6%)	146 (14.8%)	<0.001
Physiological variables					
Body mass index, kg/m^2, mean (SD)	30.6 (6.3)	28.5 (5.1)	30.3 (6.0)	32.3 (6.9)	<0.001

Heart rate, beats per min, mean (SD)	68.0 (23.8)	68.5 (48.8)	67.3 (21.4)	69.5 (12.4)	0.041
Systolic blood pressure, mm Hg, mean (SD)	131.8 (17.0)	129.2 (16.1)	131.7 (16.8)	133.1 (17.8)	<0.001
Left ventricular hypertrophy, N (%)	643 (16.3%)	50 (13.2%)	406 (15.7%)	187 (19.1%)	0.01
Total cholesterol, mg/dL, mean (SD)	192.9 (40.9)	198.9 (39.2)	192.9 (40.9)	190.7 (41.4)	0.005
Low-density lipoprotein cholesterol, mg/dL, mean (SD)	116.4 (36.1)	122.3 (34.6)	116.3 (36.1)	114.5 (36.7)	0.002
High-density lipoprotein cholesterol, mg/dL, mean (SD)	53.9 (15.8)	55.4 (16.4)	54.2 (15.8)	52.4 (15.6)	0.002
Glucose, mg/dL, mean (SD)	109.7 (41.9)	102.0 (31.4)	108.2 (39.8)	116.6 (49.4)	<0.001
Estimated glomerular filtration rate, mL/min/1.73 m^2, mean (SD)	83.9 (22.4)	88.0 (18.9)	84.5 (21.6)	80.6 (25.2)	<0.001
Urinary albumin-to-creatinine ratio, mg/g, median (IQR)	2.9 (1.2, 6.4)	6.5 (4.3, 11.7)	8.1 (4.8, 18.6)	10.9 (5.5, 36.8)	<0.001
C-reactive protein, mg/L, median (IQR)	8.3 (4.9, 20.2)	2.0 (0.8, 4.3)	2.8 (1.3, 6.0)	3.9 (1.5, 8.2)	<0.001
Self-rated health					
Mental component summary score, mean (SD)	54.2 (8.4)	56.7 (6.0)	55.4 (7.2)	50.2 (10.6)	<0.001
Physical component summary score, mean (SD)	45.1 (10.4)	54.1 (5.4)	47.3 (8.5)	35.7 (10.2)	<0.001
Healthcare utilization					
Hospitalization in the first year of observation, N (%)	454 (11.4%)	39 (10.1%)	280 (10.7%)	135 (13.7%)	0.03

Table S4. Baseline characteristics among white participants, overall and stratified by self-rated health

Characteristic	Overall (N = 8,513)	Excellent (N = 1,760)	Very good or good (N = 5,739)	Fair or poor (N = 1,014)	p-value
Demographic characteristics					
Age, years, mean (SD)	70.7 (6.0)	70.5 (6.0)	70.8 (6.0)	70.7 (6.2)	0.22
Gender, female, N (%)	4092 (48.1%)	787 (44.7%)	2781 (48.5%)	524 (51.7%)	0.001
Marital status, married, N (%)	5720 (67.2%)	1258 (71.5%)	3842 (66.9%)	620 (61.1%)	<0.001
Education, less than high school diploma, N (%)	633 (7.4%)	68 (3.9%)	390 (6.8%)	175 (17.3%)	<0.001
Annual household income, <$35,000, N (%)	3153 (42.4%)	477 (30.2%)	2134 (42.8%)	542 (61.9%)	<0.001
Geographic region, N (%)					
Stroke Belt†	3206 (37.7%)	658 (37.4%)	2111 (36.8%)	437 (43.1%)	<0.001
Stroke Buckle‡	2090 (24.6%)	409 (23.2%)	1419 (24.7%)	262 (25.8%)	
Neither Stroke Belt nor Stroke Buckle	3217 (37.8%)	693 (39.4%)	2209 (38.5%)	315 (31.1%)	
Residence in urban area, N (%)	5168 (68.3%)	1090 (69.6%)	3512 (68.7%)	566 (64.1%)	0.003
Medical conditions§					
Hypertension, N (%)	4673 (55.1%)	658 (37.5%)	3319 (58.0%)	696 (69.0%)	<0.001
Dyslipidemia, N (%)	5288 (63.9%)	932 (54.7%)	3642 (65.2%)	714 (72.6%)	<0.001
Diabetes, N (%)	1353 (16.4%)	97 (5.7%)	906 (16.3%)	350 (35.6%)	<0.001
History of coronary heart disease, N (%)	1828 (21.8%)	193 (11.1%)	1258 (22.3%)	377 (37.9%)	<0.001
Atrial fibrillation, N (%)	837 (10.0%)	85 (4.9%)	561 (10.0%)	191 (19.2%)	<0.001
Medications					
Ideal medication adherence	5682 (71.3%)	1190 (75.2%)	3849 (71.1%)	643 (66.1%)	<0.001
Number of medications, median (IQR)	6.0 (3.0, 9.0)	4.0 (2.0, 7.0)	6.0 (4.0, 9.0)	9.0 (6.0, 12.0)	<0.001
Anti-hypertensive medication, N (%)	3994 (48.6%)	498 (29.5%)	2859 (51.4%)	637 (65.5%)	<0.001
Insulin use, N (%)	283 (3.5%)	9 (0.5%)	159 (2.9%)	115 (12.2%)	<0.001
Statin use, N (%)	3135 (36.8%)	474 (26.9%)	2232 (38.9%)	429 (42.3%)	<0.001
Aspirin use, N (%)	4335 (50.9%)	832 (47.3%)	2971 (51.8%)	532 (52.5%)	0.002
Warfarin use, N (%)	421 (5.0%)	36 (2.1%)	285 (5.0%)	100 (9.9%)	<0.001
Health behaviors					
Current smoker, N (%)	834 (9.8%)	98 (5.6%)	571 (10.0%)	165 (16.3%)	<0.001
Alcohol use, N (%)					
Heavy	385 (4.6%)	103 (5.9%)	264 (4.7%)	18 (1.8%)	<0.001
Moderate	3143 (37.5%)	763 (43.9%)	2124 (37.6%)	256 (25.7%)	
None	4855 (57.9%)	874 (50.2%)	3258 (57.7%)	723 (72.5%)	
Exercise, 0 times per week, N (%)	2677 (32.0%)	330 (19.0%)	1823 (32.3%)	524 (52.6%)	<0.001
Psychosocial variables					
Cares for a family member with a chronic illness or disability, N (%)	962 (11.3%)	203 (11.5%)	628 (11.0%)	131 (12.9%)	0.18
Lack of social support, N (%)	331 (4.0%)	61 (3.6%)	217 (3.9%)	53 (5.3%)	0.061
Depressive symptoms, N (%)	404 (4.8%)	39 (2.2%)	223 (3.9%)	142 (14.1%)	<0.001
Physiological variables					
Body mass index, kg/m^2, mean (SD)	28.1 (5.4)	26.4 (4.2)	28.2 (5.3)	30.1 (6.5)	<0.001

Heart rate, beats per min, mean (SD)	65.9 (25.3)	64.7 (33.3)	65.5 (16.5)	70.4 (43.1)	<0.001
Systolic blood pressure, mm Hg, mean (SD)	127.1 (15.7)	124.9 (14.6)	127.5 (15.7)	128.8 (17.1)	<0.001
Left ventricular hypertrophy, N (%)	604 (7.2%)	86 (4.9%)	440 (7.8%)	78 (7.8%)	<0.001
Total cholesterol, mg/dL, mean (SD)	188.5 (38.6)	192.1 (36.3)	188.0 (38.6)	185.4 (41.7)	<0.001
Low-density lipoprotein cholesterol, mg/dL, mean (SD)	109.2 (32.5)	112.8 (30.9)	108.9 (32.7)	104.6 (33.3)	<0.001
High-density lipoprotein cholesterol, mg/dL, mean (SD)	50.6 (16.4)	53.6 (17.1)	50.3 (16.2)	46.9 (15.0)	<0.001
Glucose, mg/dL, mean (SD)	101.1 (28.8)	95.3 (20.0)	101.0 (28.6)	111.4 (38.7)	<0.001
Estimated glomerular filtration rate, mL/min/1.73 m^2, mean (SD)	79.1 (16.8)	81.1 (14.1)	79.2 (16.7)	75.2 (20.7)	<0.001
Urinary albumin-to-creatinine ratio, mg/g, median (IQR)	1.9 (0.9, 4.1)	6.3 (4.4, 11.1)	7.8 (4.9, 16.2)	9.9 (5.8, 25.0)	<0.001
C-reactive protein, mg/L, median (IQR)	7.6 (4.9, 15.4)	1.3 (0.7, 3.0)	1.9 (0.9, 4.1)	3.0 (1.3, 7.0)	<0.001
Self-rated health					
Mental component summary score, mean (SD)	55.5 (7.2)	56.9 (5.4)	55.7 (6.8)	51.6 (10.1)	<0.001
Physical component summary score, mean (SD)	47.2 (10.1)	54.0 (5.4)	47.7 (8.4)	32.4 (10.2)	<0.001
Healthcare utilization					
Hospitalization in the first year of observation, N (%)	791 (9.3%)	114 (6.5%)	523 (9.1%)	154 (15.2%)	<0.001

Table S5. Fully adjusted hazard of incident stroke, comparing high to low fragmentation, overall and stratified by self-rated general health and race, with sensitivity analyses varying the cut-off for high fragmentation*

Cut-off for high fragmentation	N (%) classified as high fragmentation	Overall	Self-rated general health: Excellent	Self-rated general health: Very Good or Good	Self-rated general health: Fair or Poor
		Adjusted hazard ratios (95% confidence intervals)			
ALL PARTICIPANTS	N = 12,510				
≥0.80	5,838 (46.7%)	1.03 (0.88, 1.21)	0.72 (0.48, 1.09)	1.09 (0.89, 1.33)	1.11 (0.77, 1.61)
≥0.85 (base case)	3,209 (25.7%)	1.01 (0.85, 1.21)	0.66 (0.41, 1.07)	1.01 (0.82, 1.26)	1.39 (0.95, 2.04)
≥0.90	1,713 (13.7%)	1.05 (0.84, 1.31)	0.80 (0.45, 1.42)	0.96 (0.72, 1.27)	1.69 (1.07, 2.67)
WHITE PARTICIPANTS	N = 8,513				
≥0.80	4,289 (50.4%)	1.02 (0.84, 1.23)	0.76 (0.49, 1.17)	1.16 (0.92, 1.48)	0.87 (0.51, 1.46)
≥0.85 (base case)	2,405 (28.3%)	0.99 (0.81, 1.21)	0.67 (0.40, 1.10)	1.11 (0.87, 1.42)	1.01 (0.58, 1.76)
≥0.90	1,326 (15.6%)	0.97 (0.74, 1.26)	0.75 (0.41, 1.39)	0.99 (0.72, 1.36)	0.83 (0.49, 1.40)
BLACK PARTICIPANTS	N = 3,997				
≥0.80	1,549 (38.8%)	1.02 (0.75, 1.37)	---	0.91 (0.62, 1.34)	1.34 (0.79, 2.29)
≥0.85 (base case)	804 (20.1%)	1.05 (0.74, 1.46)	---	0.73 (0.45, 1.19)	1.83 (1.06, 3.14)
≥0.90	387 (9.7%)	1.26 (0.83, 1.91)	---	0.80 (0.42, 1.54)	2.13 (1.15, 3.95)

* Results were derived from Cox proportional hazards models that treat fragmentation as a time-varying exposure, consider 12 months of the exposure at a time and outcomes that occur in the 3 months immediately following the exposure period, and occur over up to 11.8 years of follow-up. Fragmentation is measured with the reversed Bice-Boxerman Index. We were not able to calculate results for black participants with excellent self-rated health because they had too few events.

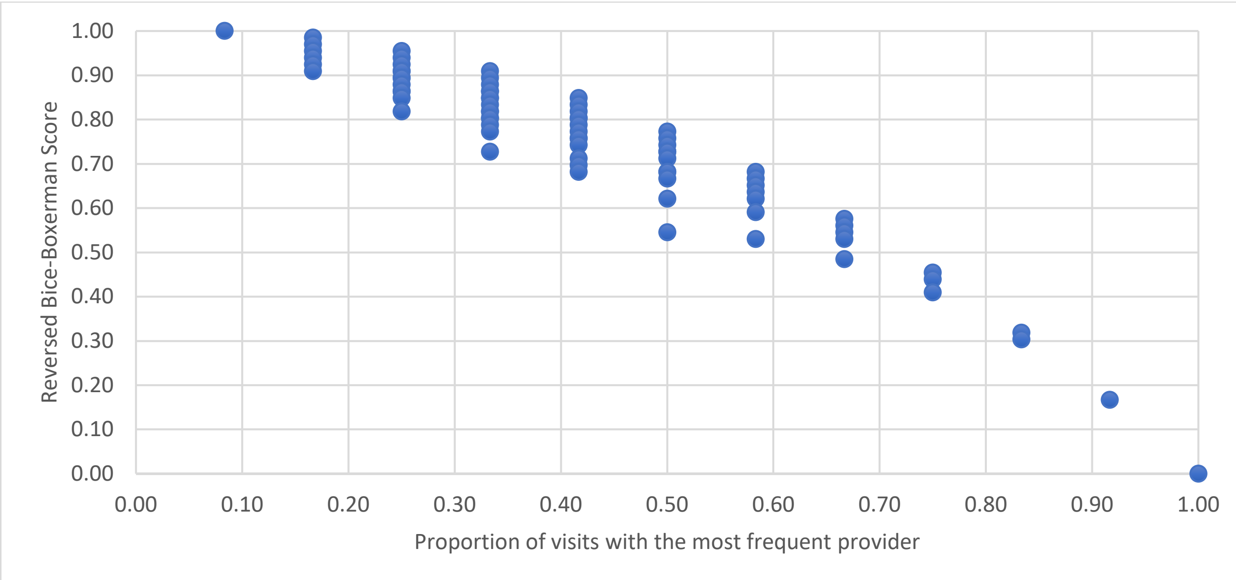
Table S6. Fully adjusted hazard of incident stroke, overall and stratified by self-rated general health and race, modeling fragmentation as a variable with four levels*

Fragmentation score	N (%)†	Number of strokes†	Overall	Self-rated general health: Excellent	Self-rated general health: Very Good or Good	Self-rated general health: Fair or Poor
			Adjusted hazard ratios (95% confidence intervals)			
ALL PARTICIPANTS	N = 12,510					
≤0.80	6672 (53.3%)	324	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
0.81-0.84	2629 (21.0%)	138	1.04 (0.84, 1.28)	0.85 (0.51, 1.42)	1.14 (0.89, 1.47)	0.81 (0.47, 1.39)
0.85-0.89	1496 (12.0%)	77	1.00 (0.79, 1.26)	0.55 (0.27, 1.12)	1.10 (0.82, 1.46)	1.06 (0.63, 1.80)
≥0.90	1713 (13.7%)	72	1.06 (0.84, 1.34)	0.70 (0.38, 1.27)	1.01 (0.75, 1.37)	1.63 (1.00, 2.67)
WHITE PARTICIPANTS	N = 8,513					
≤0.80	4224 (49.6%)	218	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
0.81-0.84	1884 (22.1%)	108	1.05 (0.82, 1.34)	0.92 (0.54, 1.58)	1.17 (0.86, 1.58)	0.76 (0.36, 1.62)
0.85-0.89	1079 (12.7%)	51	1.02 (0.78, 1.33)	0.61 (0.30, 1.26)	1.24 (0.90, 1.71)	0.77 (0.36, 1.64)
≥0.90	1326 (15.6%)	54	0.98 (0.74, 1.30)	0.68 (0.35, 1.30)	1.08 (0.77, 1.53)	1.13 (0.54, 2.35)
BLACK PARTICIPANTS	N = 3,997					
≤0.80	2448 (61.2%)	106	1.00 (ref)		1.00 (ref)	1.00 (ref)
0.81-0.84	745 (18.6%)	30	0.98 (0.66, 1.45)	---	1.10 (0.69, 1.74)	0.79 (0.35, 1.76)
0.85-0.89	417 (10.4%)	26	0.88 (0.54, 1.42)	---	0.71 (0.37, 1.40)	1.41 (0.67, 2.96)
≥0.90	387 (9.7%)	18	1.23 (0.79, 1.90)	---	0.78 (0.40, 1.54)	2.18 (1.11, 4.28)

* Results were derived from Cox proportional hazards models that treat fragmentation as a time-varying exposure, consider 12 months of the exposure at a time and outcomes that occur in the 3 months immediately following the exposure period, and occur over up to 11.8 years of follow-up. Fragmentation is measured with the reversed Bice-Boxerman Index. We were not able to calculate results for black participants with excellent self-rated health because they had too few events.

† The sample size should be interpreted as the number of participants with the given level of fragmentation in the first year of observation. The number of strokes should be interpreted as the event count for the participants who had the given level of fragmentation in the first year of observation. The models, however, treat fragmentation as a time-varying exposure.

Figure S2. An illustrative nomogram showing how fragmentation scores (reversed Bice-Boxerman scores*) vary with the proportion of visits with the most frequently seen provider, among those with 12 ambulatory visits†



*Higher scores reflect more fragmentation of care.
†Republished with permission of MJH Life Sciences, from eAppendix D in Kern et al., Fragmented ambulatory care and subsequent emergency department visits and hospital admissions among Medicaid beneficiaries. Am J Manage Care 2019 Mar;25(3):107-112; permission conveyed through Copyright Clearance Center, Inc.