Primary Care, Income Inequality, and Stroke Mortality in the United States

A Longitudinal Analysis, 1985–1995

Leiyu Shi, MBA, DrPH; James Macinko, PhD; Barbara Starfield, MD, MPH; Jiahong Xu, MS, MPH; Robert Politzer, ScD

Background and Purpose—The goal of this study was to test whether primary care reduces the impact of income inequality on stroke mortality.

Methods—This study used pooled time-series cross-sectional analysis of 11 years of state-level data (n=549). Analyses controlled for education levels, unemployment, racial/ethnic composition, and percent urban. Contemporaneous and time-lagged covariates were modeled.

Results—Primary care was negatively associated with stroke mortality in models including all covariates ($P<0.0001$). The impact of income inequality on stroke mortality was reduced in the presence of primary care ($P<0.0001$) but disappeared with the addition of covariates ($P>0.05$).

Conclusions—In the absence of social policy that addresses sociodemographic determinants of health, primary care promotion may serve as a palliative strategy for combating stroke mortality and reducing the adverse impact of income inequality on health. **(*Stroke*. 2003;34:1958-1964.)**

Key Words: mortality ■ primary health care ■ socioeconomic factors ■ stroke prevention

There is considerable evidence of a significant association between income inequality and mortality, particularly within the United States.[1,2] In general, these studies have found that a greater gap in income distribution between the rich and poor in a given geographic area is associated with poorer population health in that area.

Increasingly, studies have examined the pathways and mechanisms through which income inequality affects health. Psychosocial theories emphasize the psychological effects produced by income disparities on groups and individuals in the population. These theories hold that disparities in income and social standing create stresses that can eventually damage health.[3,4] Social capital explanations hold that individual- and group-level social relationships influence health either directly or through more proximal factors. One hypothesis is that more egalitarian areas are more socially cohesive, leading to greater levels of trust and cooperation, less psychosocial stress, and consequently better health status. For example, Kawachi et al[5] demonstrated that when income differences are smaller, people are more trusting of one another and more likely to participate in communal activities, and this social cohesiveness is linked to lower overall mortality and better self-rated health.[6] Other investigators have suggested that the political and policy context that creates income inequality is itself a precursor to health inequalities.[7]

Our previously published studies showed that primary care may mitigate the adverse effects of income inequality on health.[8–10] Using 1990 US state-level data, we found a significant association between primary care physician supply and reduced mortality, increased life expectancy, and improved birth outcome, even after controlling for income inequality and population sociodemographic characteristics. Similar findings were noted using US metropolitan areas as the unit of analysis[9] and in mixed-level analyses.[10,12] Although different units of analyses (ie, state, metropolitan, and individual) show consistent findings, these studies were limited by their cross-sectional design in that they could not establish a causal relationship between primary care physicians and better health.

The present study addresses this limitation by using 11 years of US state-level data to examine the impact of primary care on stroke mortality and to assess the extent to which primary care attenuates the adverse effect of income inequality. An independent effect of primary care on reduced stroke mortality implies that primary care can ameliorate, although not necessarily overcome, the adverse effects of income inequality. This is particularly relevant in the United States,

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From the Johns Hopkins Bloomberg School of Public Health (L.S., J.M., B.S., J.X.) and Bureau for Primary Care, Health Resources and Services Administration, US Department of Health and Human Services (R.P.), Baltimore, Md.

Reprint requests to Leiyu Shi, MBA, DrPH, Associate Professor, Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, 624 N Broadway, Room 409, Baltimore, MD 21205. E-mail lshi@jhsph.edu

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where the reduction in income inequality is not an explicit societal priority, whereas reduction in health disparities among different population groups is.[13]

The logic of the connection between income inequality, primary care, and stroke mortality is that income inequality, by affecting psychosocial factors, may also exacerbate some risk factors for stroke. Moreover, stroke mortality is one of a number of conditions thought to be particularly amenable to primary care.[14] If primary care can, in fact, ameliorate some of the negative health impact of income inequality, we would expect to see the largest impact on those health outcomes most closely associated with better primary care. Therefore, this study tests the extent to which primary care may reduce the impact of income inequality on stroke mortality at the state level by pooling 11 years of state-level data and controlling for relevant covariates.

Methods

Data and Measures

Data for this study came from a variety of sources, including the Compressed Mortality Files, the US Department of Commerce and the Census Bureau,[15] the National Center for Health Statistics,[16] and the Centers for Disease Control and Prevention (CDC).[17] Physician data were obtained from the American Medical Association annual publication *Physician Characteristics and Distribution in the US*. Data were drawn from 1985 to 1995, the year of the latest data availability at the time of the study.

The dependent variable stroke mortality was standardized for age to the 1985 US population and expressed as the number of deaths per 100 000. Data were obtained from the Compressed Mortality Files compiled by the CDC using WONDER/PC software.[18] We used stroke mortality as an outcome for several reasons. First, stroke is a major cause of death and disability in the United States.[19] Second, control of risk factors—particularly hypertension, diabetes, and elevated serum lipids—can significantly reduce the incidence of stroke, and most are routinely provided through primary care.[11]

For the purpose of this study, physician primary care specialties included family practice and general practice, general internal medicine, and general pediatrics.[16,20] Family and general practice are often combined into 1 group called family medicine. Thus, primary care physicians referred to doctors of medicine per 10 000 civilian population who were in active office-based patient care in family medicine, internal medicine, and pediatrics. For the sake of brevity, this variable is called primary care throughout this article.

Income distribution was measured by the GINI coefficient, a commonly used indicator of income inequality wherein higher values indicate greater inequality in income distribution.[21] It is derived from the Lorenz curve, which is a mechanism to represent graphically the cumulative share of the total earned income accruing to successive income intervals.[22] Data used to calculate GINI came from the US Census Bureau Web site, which provides annual data on household income for 25 income intervals. Counts of the number of households that fall into each income interval, along with the total aggregate income and the median household income, were obtained for each state. The GINI coefficient was calculated with software developed for the US Census Bureau (Welniak E, unpublished software, 1988). We did not construct other measures of income inequality because prior studies using similar data indicated that the choice of income distribution did not appear to affect results.[12,23]

Additional sociodemographic variables known to be associated with population health were included in the analyses as covariates. They included the proportion of each state's population ≥25 years of age with less than middle school education (education), proportion of state workforce population currently unemployed (Unemploy), proportion of state population that is black (black), and proportion of each state's population that resides in urban areas (metro). The variables per capita income and percent of persons below the poverty level were included in the initial analysis but wee removed from final models because of their high intercorrelations with other sociodemographic covariates.

Design

The present study was a longitudinal ecological analysis of the unmixed type; ie, our analyses correlated ecological variables with ecological outcome.[24] The unit of analysis was the 50 US states. Only ecological variables or variables characteristic of groups rather than individuals were used. For example, the subjects of interest (availability of primary care and income dispersion) were ecological measures, and the study examined social and health system context rather than relationships at the individual level. Because we avoided making inferences about individuals from grouped data, no cross-level bias occurred.[24] One advantage of such an approach is the lower likelihood of random fluctuations in both numerators and denominators of the mortality and other rates through geographic aggregation at the state level. Using state-level aggregate data also had the advantage of attenuating the likely "crossover" effect encountered when smaller units of analysis are used for measuring availability of medical care and mortality.[17]

Statistical Analysis

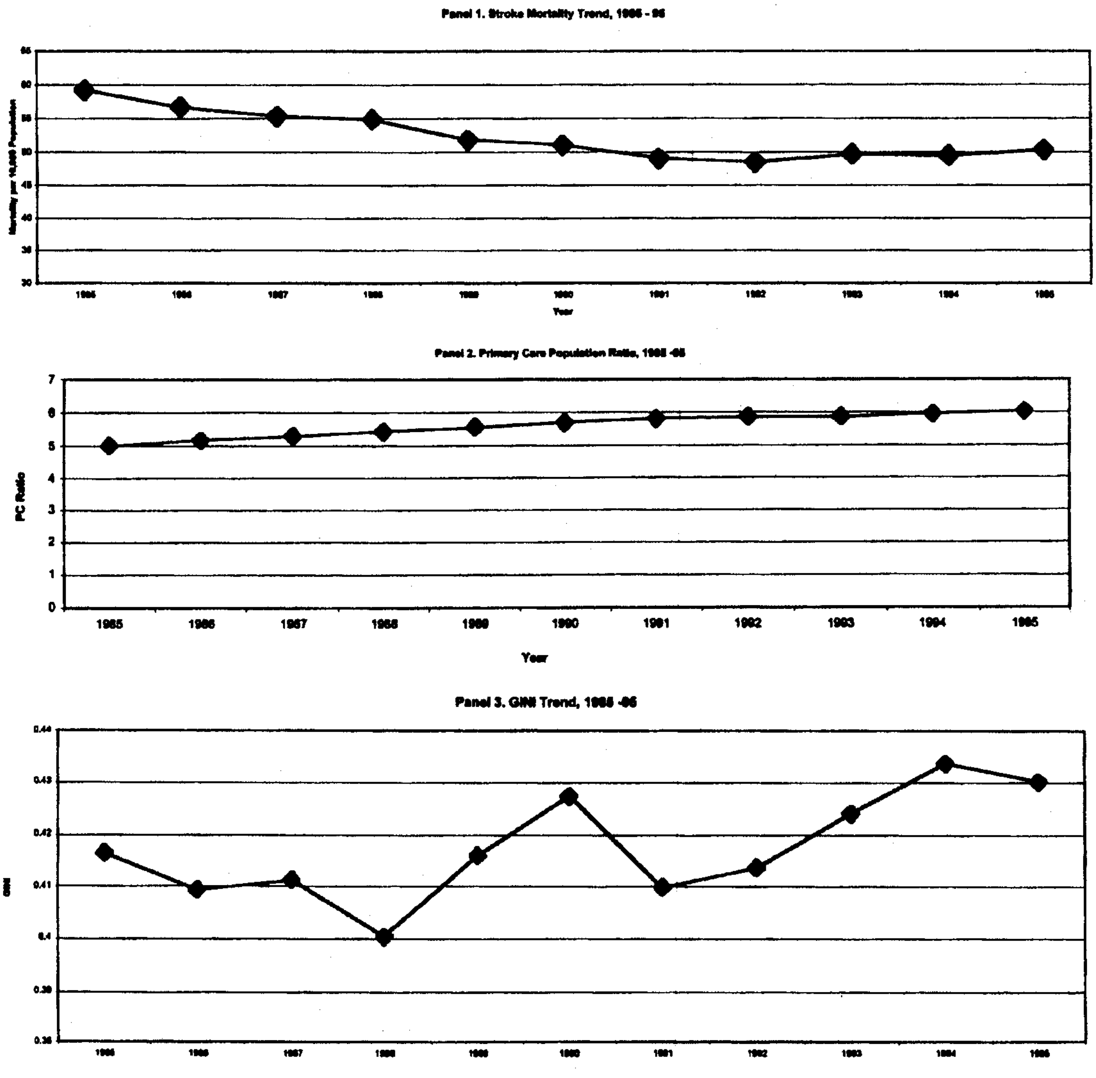
In analyzing the data, we first looked at the association between primary care, income inequality, sociodemographic covariates, and mortality using Pearson's correlation coefficients for intercorrelations. For longitudinal analyses, we used the mixed-model method (SAS PROC MIXED procedure) that applies particularly to research involving repeated measures.[25,26] This method permits the covariance structure to be incorporated into the statistical model and provides the flexibility of modeling not only the means of the data (as in the standard linear model) but also the variances and covariances. It allows for repeated measures of the outcome variable over time and both fixed and time-dependent covariates as necessary.

A set of nested models was designed to examine the extent to which primary care moderates the adverse effect of income inequality on stroke mortality. In model 1, only income inequality was used as a predictor of stroke mortality. A second model examined the same relation while adjusting for primary care. A third and final model examined the same relation while adjusting for both primary care and the sociodemographic characteristics of the state. Regression coefficients are presented, along with tests of significance. Changes in the regression coefficients of income inequality across models reflect the extent that primary care and sociodemographic characteristics moderate the effect of income inequality on stroke mortality. Nested models are compared (ie, model 3 versus 2; model 2 versus 1) by calculating the likelihood ratio test. This allows us to determine whether the additional covariates in each model are significantly different from zero.[27]

Because the effects of the predictors on mortality are expected to materialize over time, we also conducted longitudinal analyses with time lags. A total of 5 time-lagged models (from 1 to 5 years) were presented. A 1-year lagged model shows total mortality as a function of the independent measures of the previous year. A 2-year lagged model shows total mortality as a function of the independent measures of the year before the previous year, and so on. The time-lagged models not only more accurately portray the relationships between the measures but also identify when the most significant latent effect occurs.

Results

Between 1985 and 1995, there was a decline in stroke mortality in the United States. The mean state age-adjusted stroke mortality rate dropped ≈17%, from nearly 60 per 100 000 in 1985 to ≈50 per 100 000 population in 1995 (the Figure, top). In the same period, there was a steady increase in primary care physicians, from 5.02 to 6.04 per 10 000 population (the Figure, middle). Income inequality within states fluctuated during the period with an overall worsening



Top, Stroke mortality trend, 1985–1995; middle, primary care population ratio, 1985–1995; and bottom, GINI trend, 1985–1995.

trend; the mean of the GINI coefficient among states increased from 0.41 to 0.43 during the period (the Figure, bottom).

Table 1 presents the correlation matrix (1985 to 1995) among state-level stroke mortality, income inequality, primary care, and sociodemographic indicators. Because the data are longitudinal, we conducted this analysis 1 year at a time and reported the highest and lowest values for Pearson correlations. Correlations were considered significant only if every year was statistically significant. The table shows that primary care was negatively associated with stroke mortality for each year ($P<0.01$). Income inequality exhibited a wide range in its correlation with stroke mortality, from -0.07 to 0.51. Because income inequality measures fluctuated over time, they were not significant for every year. Among sociodemographic indicators, the percentage of the state population that was black was correlated with stroke mortality ($P<0.01$). The proportion of the state population with at least a high school education was negatively associated with stroke mortality ($P<0.01$), income inequality ($P<0.01$), and the proportion of the state that was black ($P<0.01$). There were no other statistically significant relationships among covariates.

Table 2 presents the regression coefficients, standard errors, and statistical significance of the mixed-model procedure, examining the extent to which income inequality and primary care affect state-level stroke mortality. In model 1 under the same year analysis, income inequality is found to be significantly associated with higher stroke mortality ($P<0.0001$). In model 2, primary care is significantly associated with lower stroke mortality ($P<0.0001$), and although income inequality remains statistically significant ($P<0.0001$), its magnitude is reduced from that in model 1. In model 3, the effects of income inequality and primary care on mortality are examined while controlling for sociodemographics. The addition of the sociodemographic variables significantly moderates the effect of income inequality, making it no longer significant. However, primary care remains independently significantly and inversely associated with stroke mortality. When the adverse effect of income inequality and sociodemographic covariates are controlled for,

TABLE 1. Pearson Correlation Matrix, 1985–1995*

	Stroke	GINI	PC	Black	Metro	Unemploy	Education≥12 y
Stroke mortality per 100 000 population	1.00						
GINI	−0.07, 0.51	1.00					
Office-based patient primary care doctor ratio	−0.38, −0.48†	−0.01, 0.11	1.00				
Proportion of Black, %	0.44, 0.65†	0.28, 0.69	−0.16, −0.38	1.00			
Proportion of Metro, %	−0.12, −0.21	0.01, 0.43	0.24, 0.35	0.21, 0.29	1.00		
Proportion of Unemploy, %	−0.06, 0.35	0.15, 0.60	−0.03, −0.51	0.17, 0.26	−0.05, 0.33	1.00	
Population ≥25 y and completed 12 y of education, %	−0.53, −0.70†	−0.37, −0.66†	0.27, 0.47	−0.67, −0.70†	0.03, 0.07	−0.16, −0.43	1.00
Mean	48.5, 59.2	0.40, 0.43	5.02, 6.04	0.09, 0.10	63.4, 67.0	5.2, 7.1	67.5, 78.5

PC indicates primary care. n=549.

*Range of correlations from 1985 to 1995. Asterisks represent all years' correlation coefficients that are statistically significant; otherwise, no asterisk is labeled. The bottom row is the range of means for each predictor from 1985 to 1995.

†$P<0.01$.

an increase of 1 primary care doctor per 10 000 population is associated with a reduction of 1.5 deaths caused by stroke per 100 000 population. Examination of the results of the likelihood ratio tests suggests that model 3 is superior to both models 2 and 1.

Results of the time-lagged models showed a pattern similar to that of the same-year (contemporaneous) set of models. Income inequality is significantly associated with mortality in model 1; its effect is reduced in model 2 and becomes insignificant with the addition of other covariates in model 3. A careful examination of the time-lagged models indicates that the effect of income inequality on stroke mortality increases slightly, peaking after 3 years, and declines gradually thereafter. The effect of primary care on stroke mortality decreases slightly over time (model 2: coefficient decreases from −3.8 in the same-year analysis to −3.7 in the 1-year lagged analysis, −3.6 in the 2-year analysis, −3.4 in the 3-year analysis, −3.2 in the 4-year analysis, and −3.1 in the 5-year analysis). In each set of time-lagged models, primary care consistently moderates the effect of income inequality on mortality. The inclusion of sociodemographic indicators (in model 3) reduces the effect of income inequality to insignificant, but the effect of primary care remains significant, except in the 4- and 5-year lagged models. The fact that statistical significance of primary care is reduced in the 4- and 5-year lagged analyses is not surprising, given that these analyses were performed using a sample size that greatly reduced the statistical power of the analysis (n=549 state-years in the contemporaneous model, n=300 state-years in the 5-year lagged model).

Discussion

Our study found that primary care was significantly associated with lower stroke mortality, even after controlling for income inequality and sociodemographic covariates. On average, an increase of 1 primary care doctor per 10 000 population (or about a 15% increase in average current levels) was associated with a reduction of 1.5 deaths per 100 000 population. Results of time-lagged models demonstrate that in addition to a contemporaneous effect, primary care also has a latent effect on stroke mortality. These findings are consistent with prior postulated benefits specific to primary care adequacy at the population level.[11] Primary care is intended to address the most common problems in the community to maximize health and well-being. It should integrate care when there is more than 1 health problem, deal with the context in which illness exists, and influence the responses of people to their health problems. It is care that organizes and rationalizes the deployment of all resources, basic as well as specialized, directed at promoting, maintaining, and improving health. According to the results of this study, primary care is associated with improvements in health—reductions in stroke mortality over time—while other risk factors positively associated with eroding health status—ie, income inequality and lwer levels of education—remained constant in the population or actually worsened. From a policy perspective, in the absence of social policy that addresses sociodemographic determinants of health, the promotion of primary care may serve as a palliative strategy for combating mortality and for reducing the adverse impact of income inequality. Such a hypothesis at least deserves consideration in the face of declining health levels in the United States relative to comparable industrialized nations.[28]

The data presented here show a trend toward decreased stroke mortality over time, as illustrated in the Figure (top). There are several possible explanations for this. First, there have been improvements in surgical and emergency room practice (eg, treating stroke as a medical emergency) that can increase the probability of survival and reduce the extent of stroke-related morbidity, especially if such treatments are administered within a narrow therapeutic time window.[29–31] It is likely that these factors have had a substantial impact on the decline in stroke mortality in the United States during the past decade.

However, at the same time that new techniques for emergency treatment of stroke have developed, new stroke prevention and treatment strategies have become increasingly common in primary care practice. These techniques include improved management of hypertension through the use of new therapeutic agents,[32] treatments for patients after myo-

TABLE 2. Predicted Stroke Mortality per 100 000 Population, 1985–1995

	Same Year*			1-Year Lag*			2-Year Lag*		
	1	2	3	1	2	3	1	2	3
INT	25.1 (4.9)	51.3 (4.9)	98.6 (5.7)	23.8 (4.9)	50.4 (5.0)	90.8 (5.8)	23.5 (4.9)	49.9 (5.2)	85.8 (6.3)
GINI	65.3¶ (11.4)	53.4¶ (10.4)	−14.8 (9.7)	67.1¶ (11.6)	53.3¶ (10.6)	−10.8 (10.0)	66.8¶ (11.7)	51.5¶ (10.8)	−11.4 (10.5)
PC		−3.8¶ (0.3)	−1.5¶ (0.3		−3.7¶ (0.4)	−1.4¶ (0.3)		−3.6¶ (0.4)	−1.2§ (0.4)
Black			32.7¶ (3.6)			33.4¶ (3.8)			34.4¶ (4.0)
Metro			−0.1¶ (0.01)			−0.1¶ (0.01)			−0.1¶ (0.01)
UE			−0.2 (0.1)			−0.2 (0.2)			−0.06 (0.2)
ED			−0.4¶ (0.05)			−0.3¶ (0.05)			−0.3¶ (0.1)
AIC	−1896.1	−1842.1	−1713.1	−1709.6	−1661.5	−1554.2	−1528.0	−1487.3	−1396.7
SBC	−1896.5	−1842.5	−1713.5	−1709.9	−1661.9	−1554.5	−1528.2	−1487.5	−1396.9
−2LL	3788.1	3680.2	3422.2	3415.2	3319.1	3104.3	3052.0	2970.6	2789.3
Δdf	...	1	4	...	1	4	...	1	4
$\Delta\chi^2$	...	107.9	258.0	...	96.1	214.8	...	81.4	181.3
LRT	...	107.9‡	64.5‡	...	96.1‡	53.7‡	...	81.4‡	45.3‡
n	549	549	549	499	499	499	449	449	449

INT indicates intercept; PC, primary care; UE, unemployment; ED, education; AIC, Akaike's information criterion; SBC, Schwarz's bayesian criterion; −2 LL, −2 log likelihood; LRT, likelihood ratio test ($\Delta\chi^2$ for 2 models/Δdf for 2 models).

*Estimated coefficient and standard error were provided from mixed models.

†$0.01<P<0.05$.

‡$0.001<P<0.01$.

§$0.0001<P<0.001$.

¶$P<0.0001$.

cardial infarct, and modification of lifestyle-related risk factors.[33] The wide application of such interventions has been estimated to have the potential to reduce stroke incidence by as much as 50%.[19] Within states, primary care has been found to be associated with use of recommended diagnostic technologies, referral to specialty care, and prompt use of appropriate therapeutic agents.[25,34] Evidence from England and Sweden shows that regional differences in primary care practice are even associated with stroke outcomes.[35] As a sensitivity test, we conducted bivariate analyses confirming that there was a statistically significant decrease in stroke mortality over time. To test whether this time trend was independent of our explanatory variables (ie, because of some unmeasured variable), we added the variable year to the multivariate time series models. The variable was not statistically significant (data not shown). This suggests that the explanatory variables used in our analysis also explain (at least in part) these trends over time, further strengthening the case for the association of primary care with reduced stroke mortality.

The results also suggest that primary care reduces the impact of income inequality on stroke mortality. Because this was an ecological study, we cannot say that individuals who suffer most from ill health resulting from income inequality would gain the most from improved primary care. However, we believe that our results are supported by a plausible causal chain leading from income inequality to stroke mortality. There is evidence that income inequality, through its negative effects on the psychosocial environment, contributes to increased stress and worse social relations and support at both the individual and population levels.[36] These conditions lead to a higher prevalence of cardiovascular disease risk factors such as smoking, hypertension, and obesity, most of which have also been shown to be more prevalent in areas with higher income inequality.[34,37] Primary care may be able to ameliorate some of the ultimate consequences of income inequalities at the population level by contributing to lower aggregate levels of risk factors such as hypertension, smoking, weight gain; improving statewide screening and early diagnosis activities; and developing systems to coordinate care.[11]

In interpreting the results of this study, several limitations require consideration. First, the finding of a relationship between primary care physicians and lower population mortality does not necessarily imply that the mere presence of more primary care physicians ensures either that more individuals in the population are exposed to primary care or that the delivery of primary care will produce better health outcomes at the individual level. Only studies performed at the individual level would test these hypotheses. However, we cannot understand or improve patterns of population health without engaging structural determinants at the societal level.[38] Moreover, although it is important to construct a model of health determinants that include relevant risk factors, many of these factors are collinear and therefore cannot be included in the same model.[32] The correlation between income inequality and black, for example, may have underestimated the overall effect of income inequality in model 3 because of the high correlation between these 2 variables.

Finally, although it was not possible to analyze some aggregate individual-level characteristics, an advantage to

TABLE 2. Continued

3-Year Lag*			4-Year Lag*			5-Year Lag*		
1	2	3	1	2	3	1	2	3
24.6 (5.1)	49.5 (5.5)	79.4 (6.6)	27.5 (5.1)	49.7 (5.6)	74.4 (6.6)	28.3 (5.2)	49.0 (5.8)	71.4 (6.9)
63.1¶ (12.2)	48.3¶ (11.3)	−11.1 (11.0)	54.7¶ (12.3)	42.8§ (11.5)	−14.8 (11.2)	51.8¶ (12.6)	42.5§ (11.9)	−13.4 (11.8)
	−3.4¶ (0.4)	−1.0† (0.4		−3.2¶ (0.4)	−0.8 (0.4)		−3.1¶ (0.5)	−0.6 (0.5)
		36.2¶ (4.3)			37.3¶ (4.5)			35.5¶ (5.0)
		−0.1¶ (0.01)			−0.1¶ (0.01)			−0.1¶ (0.02)
		0.02 (0.2)			0.1 (0.1)			0.2 (0.2)
		−0.2¶ (0.1)			−0.2‡ (0.1)			−0.2‡ (0.1)
−1350.0	−1317.5	−1240.2	−1169.6	−1143.8	−1078.6	−998.8	−977.9	−925.7
−1350.1	−1317.6	−1240.3	−1169.5	−1143.7	−1078.5	−998.6	−977.7	−925.5
2696.0	2631.0	2476.4	2335.1	2283.5	2153.2	1993.6	1951.8	1847.4
...	1	4	...	1	4	...	1	4
...	65.0	154.6	...	51.6	130.3	...	41.8	104.4
...	65.0‡	38.7‡	...	51.6‡	32.6‡	...	41.8‡	26.1‡
399	399	399	349	349	349	300	300	300

performing an ecological longitudinal analysis is that we were able to control for (but not estimate the value of) unmeasured ecological-level confounders. Time-invariant state-level characteristics such as stable state-level policy factors and persistent differences in infrastructure and resources were captured and controlled for in our analysis through the inclusion of state-level fixed effects in the statistical model.[39] As a final sensitivity test, results were analyzed for geographic trends within the major US regions as defined by the Census Bureau (ie, Northeast, South, Midwest, and West). Results (not shown) suggested that this region variable was negatively associated with stroke mortality ($P<0.01$). Analysis by region shows that this variation results from the fact that stroke mortality in the Northeast region was significantly lower than that of any other region. There are several possible explanations for this regional variation. First, there is likely to be regional variation in the presence and use of technology, surgical intervention, and management of stroke in hospitals. However, such regional variation also occurs in the distribution of primary care resources throughout the United States. That differences in primary care are at least partly responsible for regional variations in outcomes is supported by the statistical significance of an interaction term that captures regional differences in primary care. Although difficult to interpret directly, the significant interaction between primary care and region does provide additional evidence that at least some of the regional variation in stroke mortality is the result of differences in primary care resources and practice.

Another potential limitation of the present study is that primary care physician availability is likely to be an inadequate proxy for receipt of good primary care. Ultimately, we would like better information on the structural characteristics and practice features of primary care. Unfortunately, there are no data that make it possible to adequately characterize receipt of good primary care (as distinguished from receipt of ambulatory care services, which also include specialty care) at either the national or other levels. Other healthcare providers such as nurse-practitioners, physician assistants, and doctors of osteopathy also practice primary care but were not captured. For these reasons, it is likely that our analysis underestimates the overall contribution of primary care.

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