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Tracking Stroke Hospitalization Clusters Over Time and Associations With County-Level Socioeconomic and Healthcare Characteristics

Linda J. Schieb, MSPH, Lee R. Mobley, PhD, Mary George, MD, MSPH, and Michele Casper, PhD

Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, Atlanta, GA (L.J.S., M.G., M.C.); and Arizona State University, Tempe, AZ (L.R.M.)

Abstract

Background and Purpose—This study evaluated clustering of stroke hospitalization rates, patterns of the clustering over time, and associations with community-level characteristics.

Methods—We used Medicare hospital claims data from 1995–1996 to 2005–2006 with a principal discharge diagnosis of stroke to calculate county-level stroke hospitalization rates. We identified statistically significant clusters of high- and low-rate counties by using local indicators of spatial association, tracked cluster status over time, and assessed associations between cluster status and county-level socioeconomic and healthcare profiles.

Results—Clearly defined clusters of counties with high- and low-stroke hospitalization rates were identified in each time. Approximately 75% of counties maintained their cluster status from 1995–1996 to 2005–2006. In addition, 243 counties transitioned into high-rate clusters, and 148 transitioned out of high-rate clusters. Persistently high-rate clusters were located primarily in the Southeast, whereas persistently low-rate clusters occurred mostly in New England and in the West. In general, persistently low-rate counties had the most favorable socioeconomic and healthcare profiles, followed by counties that transitioned out of or into high-rate clusters. Persistently high-rate counties experienced the least favorable socioeconomic and healthcare profiles.

Conclusions—The persistence of clusters of high- and low-stroke hospitalization rates during a 10-year period suggests that the underlying causes of stroke in these areas have also persisted. The associations found between cluster status (persistently high, transitional, persistently low) and socioeconomic and healthcare profiles shed new light on the contributions of community-level characteristics to geographic disparities in stroke hospitalizations.

Correspondence to: Linda J. Schieb, MSPH, Centers for Disease Control and Prevention, 4770 Buford Highway NE, MS F-72, Atlanta, GA 30341. lschieb@cdc.gov.

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Disclosures

None.

Keywords

acute stroke; epidemiology; geography; hospitalization; Medicare; risk factors

Since the first report highlighting the concentration of high stroke death rates in the Southeastern United States, many parameters of the phenomenon loosely referred to as the Stroke Belt have been documented.¹ Studies have shown that the excess burden of stroke in the Southeast exists for black and white women and men of all age groups.^{1–6} Furthermore, the pattern is evident regardless of the geographic unit that is used (eg, county, state economic area, state) and is observed for both stroke death and hospitalization rates.^{7–9}

Several studies monitored changes in the geographic pattern of stroke death over time ranging from 1939 to 1996.^{2,4,5} The results show persistence in regional patterns with important changes in subregional patterns (eg, within the Southeast, the concentration of high-rate counties shifted away from the coastal regions to the Mississippi Delta). Missing from the literature is the systematic monitoring of geographic patterns for stroke hospitalization rates at the local level over time.

In this study, we examined temporal trends in the geographic patterns of stroke hospitalization rates among Medicare beneficiaries aged ≥65, from 1995–1996 to 2005–2006. We identified statistically significant clusters of high-rate and low-rate counties in each period and tracked the counties that remained in high- or low-rate clusters over time, as well as the counties that transitioned into or out of high-rate clusters. We then compared socioeconomic and healthcare profiles of counties by their cluster status (ie, persistently high, persistently low, or transitional).

Methods

Study Population

Our study included hospital claims data for fee-for-service Medicare beneficiaries aged ≥65 for 1995, 1996, 2005, and 2006 from the Centers for Medicare and Medicaid Services' Medicare Provider Analysis and Review file, Part A. We defined a stroke hospitalization as a short-stay hospital claim with a principal (first-listed) discharge diagnosis of cerebrovascular disease by using the International Classification of Diseases, Ninth Revision, Clinical Modification codes 430 to 434 and 436 to 438. In this study, we refer to cerebrovascular disease as stroke. Beneficiaries were determined from the Medicare Denominator Files and were excluded if they were members of a health maintenance organization, died before July 1, or were <65 years on July 1 for each of the study years.

All stroke hospitalizations and Medicare beneficiaries were assigned to the county of the patient's residence in the Medicare claims files. The study years were combined to create 2 periods: 1995–1996 and 2005–2006. Two-year stroke hospitalization rates were calculated for each period and age-adjusted by using the 2000 US standard population weights.¹⁰ Data for independent cities in Virginia were merged with their surrounding counties. Only counties located in the 48 contiguous United States that had at least 1 neighboring county

were included (n=3074). Stroke hospitalization rates were calculated by using SAS software (version 9.1.3).¹¹ Maps were created by using ArcMap software (version 10.0).¹²

Spatial Clustering Analyses

We undertook a 2-step process to assess positive spatial autocorrelation, or clustering. All spatial clustering analyses were conducted by using GeoDa software (version 0.9.5-i),¹³ and the Empirical-Bayes standardization method was used to account for variance instability caused by small population size in the denominator of the rates. We first assessed global spatial autocorrelation across counties by using a queen contiguity matrix to calculate the Moran I coefficient.^{14,15} We then calculated the Local Indicators of Spatial Association (LISA)^{16,17} to identify the locations of statistically significant clusters of counties with either higher or lower than average rates of stroke hospitalizations at a statistical significance level of <0.01. GeoDa LISA test results identify the counties located at the center of each cluster. In our maps, clusters include the counties at the center of a cluster plus the spatial neighbors of those counties.

To examine temporal trends in the clustering of stroke hospitalization rates, we compared the LISA estimates for 1995–1996 with the estimates for 2005–2006. Counties were categorized as either persistently high (belonged to a high-rate cluster in both periods), persistently low (belonged to a low-rate cluster in both periods), transitional (transitioned into or out of a high-rate cluster), or no statistically significant clustering.

County-level variables describing the social environmental and healthcare profiles were obtained from the 2007 Area Resource File.¹⁸ The Area Resource File compiles data from numerous sources. The healthcare variables originated from the American Medical Association and the American Hospital Association. Variables describing the socioeconomic profiles originated from the US Census Bureau. The urban–rural status, persistent poverty, and retirement destination variables originated from the U S Department of Agriculture.

Results

Our study population included ≈56 million Medicare beneficiaries for 1995–1996 and ≈55 million for 2005–2006 (Table 1). The national age-adjusted stroke hospitalization rate was 18 per 1000 during 1995–1996 and decreased to 13.6 per 1000 during 2005–2006 (Supplemental I). Rates varied by age, sex, and race or ethnicity, with the highest rates in both periods observed among those aged ≥85, blacks, and men. The global Moran I statistic for 1995–1996 was 0.491 ($P=0.001$) and 0.506 ($P=0.001$) for 2005–2006, confirming that spatial clustering was present.

The LISA map for the total population in 2005–2006 (Figure 1) shows statistically significant clusters of both high-rate (22% of all counties) and low-rate counties (24% of all counties). The high-rate clusters were located in southern Appalachia and the Southeast, including much of Alabama, Mississippi, and Louisiana. The low-rate clusters were located in New England, the West, and the West North Central regions. Similar geographic patterns were observed for 1995–1996 (Supplemental Figures 1, 2, and 3).

LISA maps by sex for 2005–2006 (Figure 2) show very similar patterns of geographic clustering of stroke hospitalization rates for women and men, with the overall pattern of high-rate clusters in the Southeast maintained. Slight variations in the cluster locations are found in Texas and the Midwest. In addition, we calculated cluster statistics by race; these LISA maps (Supplemental Figures 1, 2, and 3) show a very similar pattern to Figure 1, with high-rate clusters located primarily in the Southeast and Pennsylvania.

Comparison of LISA estimates between 1995–1996 and 2005–2006 shows that 75% of counties located in a high-rate cluster in 1995–1996 remained in a high-rate cluster for 2005–2006 (n=435). These persistently high-rate counties were found primarily in Appalachia, Alabama, Mississippi, Louisiana, and the coastal regions of North Carolina and South Carolina (Figure 3). Similarly, 76% of counties that were in a low-rate cluster during 1995–1996 remained in a low-rate cluster during 2005–2006 (n=533). These persistently low-rate counties were located primarily in the Mountain States, sections of the West North Central region, New England, and central Virginia. Approximately 25% of counties that were in a high-rate cluster during 1995–1996 (n=148) were no longer part of a high-rate cluster during 2005–2006. These transitional counties that exhibited improvement in stroke hospitalization rates were located in the coastal regions of Georgia and northern Florida, middle Tennessee, parts of the Mississippi Delta region, and near Portland, Oregon. Counties that had not been part of a high-rate cluster during 1995–1996, but became part of a high-rate cluster during 2005–2006 (n=243; 10%) were located primarily in Texas, southern Oklahoma, and western Georgia.

Comparisons of socioeconomic and healthcare variables in persistently high-rate counties compared with persistently low-rate counties (Table 2) demonstrate that persistently high-rate counties had lower median income (\$32 475 vs \$40 698), higher proportions of people without a high school diploma (30.5% vs 17.2%), and higher proportions of people living in poverty (21.1% vs 12.9%). Furthermore, persistently high-rate counties had higher percentages of counties that were categorized as persistently poor (35.2% vs 4.7%), were more likely to be metropolitan (8.1% vs 5.1%), and were less likely to be designated as retirement destinations (6.7% vs 15.6%). In addition, persistently high-rate counties had fewer hospitals per 10 000 population than persistently low-rate counties (3.9 vs 8.0), but had a higher number of hospital admissions (10 146 vs 7009) and emergency room visits (43 836 vs 31 754) per 100 000, and fewer office-based general medicine physicians per 100 000 (23.3 vs 36.4).

In general, socioeconomic and healthcare profiles of counties that transitioned out of high-rate clusters were better than corresponding profiles for persistently high-rate counties (Table 2). When compared with persistently high-rate counties, counties that transitioned out of high-rate clusters had higher median incomes (\$36 057 vs \$32 475), lower proportions of people living in poverty (18.9% vs 21.1%), fewer short-term hospital admissions per 100 000 population (8274 vs 10 146), higher population growth (16.3% vs 5.3%), greater percentage of counties designated as retirement destinations (21.6% vs 6.7%), and were more likely to be located in a large metropolitan area (18.9% vs 8.1%). The profiles for counties that transitioned into high-rate clusters during 2005–2006 were similar to those that transitioned out, with socioeconomic conditions that were worse than the counties in

persistently low-rate clusters, but better than counties in persistently high-rate clusters. The urban/rural characteristics of these counties more closely matched those of the high-rate cluster counties with more counties located in small metropolitan areas.

Discussion

In this study, we found that clusters of counties with high- and low-stroke hospitalization rates remained largely intact from 1995–1996 to 2005–2006. Clusters of persistently high-rate counties were located predominantly in the Southeast and Appalachia. In contrast, clusters of persistently low-rate counties were located predominantly in New England and the West. However, changes in cluster status also occurred; 243 counties transitioned into high-rate clusters and 148 counties transitioned out of high-rate clusters. In general, socioeconomic and healthcare profiles were most favorable for persistently low-rate counties, followed by counties that transitioned into or out of high-rate clusters, and least favorable for persistently high-rate counties.

The observed geographic patterns of stroke hospitalization rates among Medicare beneficiaries are consistent with previously observed patterns of stroke incidence,^{9,19} prevalence,²⁰ and death.^{1–6} The consistency of these geographic patterns supports the hypothesis that place-based characteristics play an important role in the occurrence of stroke and its risk factors.^{21–25} We examined 2 sets of place-based characteristics: socioeconomic resources and healthcare resources.

Our finding that counties with persistently high rates of stroke hospitalizations had the least favorable socioeconomic resources is consistent with other community-level studies of socioeconomic resources and stroke.^{26,27} In France, neighborhoods with the least favorable socioeconomic resources (eg, higher levels of unemployment, percentage renting main residence, percentage without a car, income inequality) had the highest levels of stroke incidence.²⁷ A New Zealand study found community socioeconomic status (measured by average household income) to be inversely associated with the incidence of stroke, even after adjusting for individual income and individual-level risk factors for stroke.²⁶ In the United States, the Brain Attack Surveillance in Corpus Christi Project reported an inverse association between neighborhood-level socioeconomic status and risk for stroke. The association was reduced when individual-level socioeconomic status was included; however, individual-level socioeconomic status was not available for $\approx 50\%$ of the stroke cases.²⁸ Many other studies have documented the association between community-level socioeconomic resources and other cardiovascular conditions, including coronary heart disease,²¹ atherosclerosis,^{22,25} hypertension,^{23,24} and cardiovascular disease death.^{29,30} Socioeconomic resources at the community level are widely understood to influence opportunities for residents to engage in healthy lifestyles that influence their risk for stroke (eg, diet and exercise,³¹ low stress levels,³² access to health care³³).

Our findings that counties with persistently high-stroke hospitalization rates also had less access to primary health-care services (eg, fewer general practice physicians and more emergency room visits) are consistent with other studies that found higher rates of stroke death in communities with lower ratios of primary care physicians to the population.^{34,35}

Stroke is preventable. Access to quality preventive care is particularly important for stroke prevention because the main risk factors for stroke (ie, hypertension, high cholesterol, diabetes mellitus) are preventable, modifiable, and should be assessed in the primary care setting.^{36,37}

The observation that persistently high-rate counties had the fewest hospitals per population suggests that additional secondary treatment resources are needed in those counties. Increasingly, efforts are being made to provide telemedicine resources at hospitals located in rural areas to meet the need for specialized stroke treatment.³⁷

The finding that, in general, counties transitioning into and out of high-rate clusters for stroke hospitalizations had socioeconomic and healthcare profiles that were more favorable than counties in persistently high-rate clusters, but not as favorable as counties in low-rate clusters, supports the hypothesis that improvements in socioeconomic and health-care resources can reduce the burden of stroke hospitalizations. Additional spatiotemporal studies are needed that address the effect of changing community-level resources on the burden of stroke.

The limitations in this study are restricted primarily to those inherent in using administrative databases for surveillance studies. The Centers for Medicare and Medicaid Services' Medicare Provider Analysis and Review file does not include detailed nonbilling information and is subject to variation in coding practices. However, studies have found that International Classification of Diseases codes in administrative databases do accurately identify strokes.^{38–40} Our study population, traditional fee-for-service Medicare beneficiaries aged 65, represents $\approx 85\%$ of the Medicare population. Although 70% of all stroke hospitalizations occur among people aged 65, blacks tend to have strokes at younger ages than whites;^{41,42} therefore, our rates for blacks may be underestimates. In addition, Hispanic ethnicity is not coded as a mutually exclusive group in the race/ethnicity collected in the Medicare data, and Hispanics also tend to have strokes at younger ages than whites, leading to underestimates in those rates.^{42,43} Last, Centers for Medicare and Medicaid Services' Medicare Provider Analysis and Review Part A files do not distinguish between repeat hospitalizations and first-time hospitalizations; therefore, our data may include multiple hospitalizations for the same patient. Past studies have found a 1-year recurrence rate for stroke of $<14\%$.^{44–46}

The strengths of our study include the use of spatial statistics to identify and monitor county clusters of stroke hospitalization rates, the identification of transitional counties in addition to persistently high- and persistently low-rate clusters, and the inclusion of community-level healthcare profiles and socioeconomic profiles. The use of Medicare data enabled nationwide analysis of geographic patterns in stroke hospitalizations.

Summary

Age-adjusted stroke hospitalization rates among Medicare beneficiaries exhibited statistically significant and persistent spatial clustering in the United States. High-rate clusters were located predominantly in the Southeast and had the least favorable socioeconomic and healthcare profiles. In general, counties transitioning into and out of

high-rate clusters for stroke hospitalizations had socioeconomic and healthcare profiles that were more favorable than counties in persistently high-rate clusters, but not as favorable as counties in low-rate clusters. These findings add a new dimension to understanding the role that social determinants play on geographic disparities and the burden of stroke.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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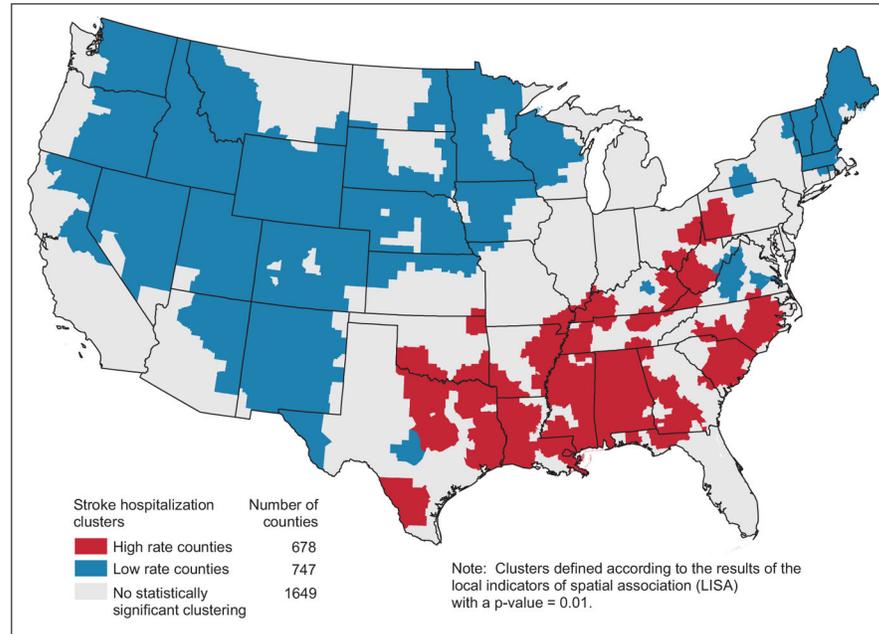
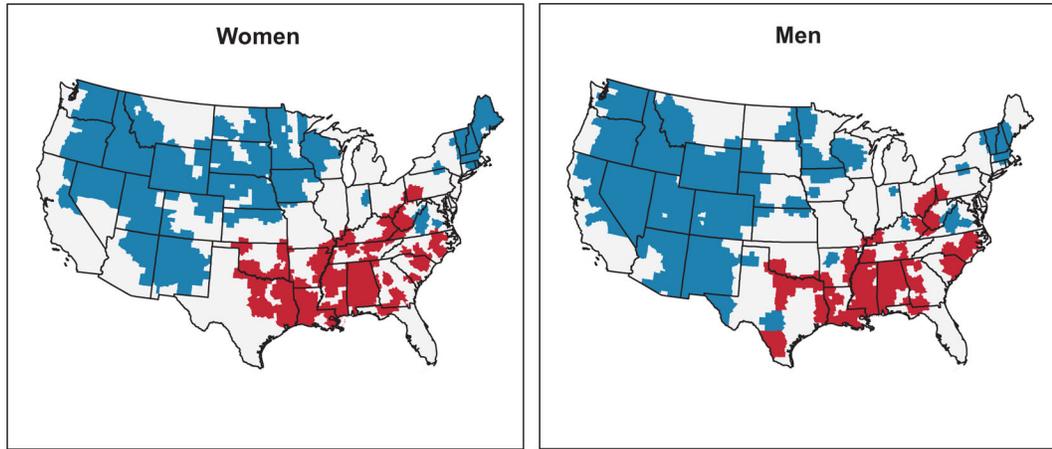


Figure 1. Clusters of age-adjusted stroke hospitalization rates among Medicare beneficiaries aged 65, 2005–2006—total population.



Stroke hospitalization clusters	Number of counties	
	Women	Men
High rate counties	643	570
Low rate counties	724	656
No statistically significant clustering	1707	1848

Note: Clusters defined according to the results of the local indicators of spatial association (LISA) with a p-value = 0.01

Figure 2. Clusters of age-adjusted stroke hospitalization rates among Medicare beneficiaries aged 65, 2005–2006 by sex.

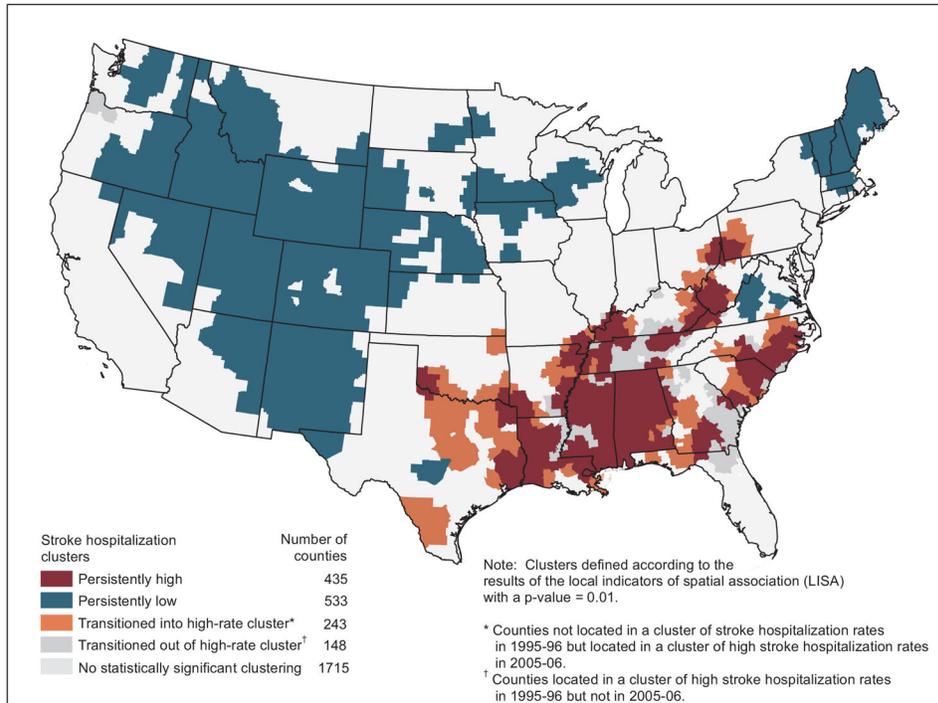


Figure 3. Clusters of age-adjusted stroke hospitalization rates among Medicare beneficiaries aged 65: persistently high, persistently low, transitioned into high-rate cluster, transitioned out of a high-rate cluster, 1995–96 and 2005–2006.

Sociodemographic Characteristics and Age-Adjusted Stroke Hospitalization Rates by Time, Medicare Beneficiaries Aged 65

Table 1

	Stroke Hospitalizations (%)		Medicare Beneficiaries (%)		Stroke Hospitalization Rate (per 1000)	
	1995–1996	2005–2006	1995–1996	2005–2006	1995–1996	2005–2006
Total	999 377	770 033	56 339 366	55 331 267	18.0	13.6
Age, y						
65–74	37.8	32.5	54.7	49.9	12.3*	9.1*
75–84	42.7	42.3	33.5	36.1	22.6*	16.3*
85+	19.5	25.2	11.8	14.0	29.3*	25.2*
Sex						
Women	56.0	55.0	59.6	57.7	16.3	12.4
Men	44.0	45.0	40.4	42.3	20.6	15.3
Race/ethnicity						
Black	9.7	10.4	7.8	8.0	22.3	18.3
Hispanic [†]	0.6	1.5	0.6	1.6	18.3	12.4
White	87.3	85.3	88.7	87.5	17.7	13.2
Other	2.4	2.8	2.9	3.0	16.2	13.6

* Age group–specific rate.

[†] Hispanic ethnicity is not coded as a mutually exclusive group in the race/ethnicity collected in the Medicare data.

Table 2

Stroke Hospitalization Rates: Comparison of Persistently High-Rate Counties With Persistently Low-Rate Counties, Counties That Transitioned out of a High-Rate Cluster, and Counties That Transitioned Into a High-Rate Cluster, Medicare Beneficiaries, 65 Years

	Persistent Counties				Transitional Counties			
	Column A		Column B		Column C		Column D	
	Value	P Value//	Value	P Value//	Value	P Value//	Value	P Value//
Number of counties	435		533		148		243	
Mean age-adjusted stroke hospitalization rate per 1000, 1995–1996	23.69	<0.001	13.08	<0.001	23.17	0.177	19.70	<0.001
Mean age-adjusted stroke hospitalization rate per 1000, 2005–2006	18.09	<0.001	9.41	<0.001	15.23	<0.001	17.48	0.011
Economic resources								
Median household income, 2005, \$	32 475	<0.001	40 698	<0.001	36 057	<0.001	35 019	<0.001
Median household income, 1995, \$	25 760	<0.001	31 311	<0.001	28 835	<0.001	27 027	0.016
Population in poverty, 2005, %	21.1	<0.001	12.9	<0.001	18.9	<0.001	19.0	<0.001
Population without a high school diploma, 2000, %	30.5	<0.001	17.2	<0.001	28.9	0.116	28.1	<0.001
Counties in persistent poverty, 2004, %	35.2	<0.001	4.7	<0.001	27.0	0.069	25.1	0.007
Health care								
Short-term general hospitals per 100 000 population, 2005, #/n	3.9	<0.001	8.0	<0.001	3.5	0.243	3.4	0.003
Short-term hospital beds per 100 000 population, 2005, #/n	301.7	0.392	367.1	0.392	261.1	0.032	235.5	<0.001
Short-term hospital admissions per 100 000 population, 2005, #/n	10 146	<0.001	7009	<0.001	8274	0.020	8480	0.050
Emergency room visits per 100 000 population, 2005, #/n	43 836	<0.001	31 754	<0.001	39 317	0.150	38 624	0.037
Office-based general practice MDs per 100 000 population, 2005, #/n	23.3	<0.001	36.4	<0.001	24.2	0.420	22.7	0.513
Office-based general practice MDs per 100 000 population, 1995, #/n	22.6	<0.001	31.9	<0.001	22.7	0.976	21.1	0.071
Urban/rural, 2003 ^{††}								

	Persistent Counties			Transitional Counties		
	Column A	Column B	Column C	Column D	Column E	Column F
	Persistently High-Rate Cluster [*]	Persistently Low-Rate Cluster [†]	Transitioned out of High-Rate Cluster [‡]	Transitioned into High-Rate Cluster [§]	Value	P Value
	Value	P Value	Value	P Value	Value	P Value
Large metro, %	8.1	<0.001	18.9	0.002	11.1	0.283
Small metro/micro, %	47.8	39.2	37.8		49.4	
Noncore adjacent, %	39.8	37.2	39.9		33.7	
Noncore nonadjacent, %	4.4	18.6	3.4		5.8	
Migration						
Population growth, 1995–2005, %	5.3	0.141	16.3	<0.001	11.6	<0.001
Retirement destinations, 2004, ^{¶¶} %	6.7	<0.001	21.6	<0.001	14.8	<0.001

^{*} Counties located in a cluster of low rates in both 1995–1996 and 2005–2006.

[†] Counties located in a cluster of high rates in both 1995–1996 and 2005–2006.

[‡] Counties located in a cluster of high rates in 1995–1996 but not in 2005–2006.

[§] Counties not located in a cluster of rates in 1995–1996 but located in a cluster of high rates in 2005–2006.

^{||} Results of a statistical comparison between values in this column and values among counties located in persistently high-rate cluster (Column A).

[¶] Data from the Area Resource File (ARF).

[#] US Census data from the ARF.

^{**} US Department of Agriculture (USDA) County Typology Codes from the ARF. Twenty percent or more of residents in poverty as measured in 1970, 1980, 1990, and 2000.

^{††} USDA Urban Influence Codes from the ARF.

^{†††} USDA County Typology Codes from the ARF. Counties in which the number of residents 60 years or older grew by 15% or more during 1990–2000.