Association of a higher density of specialist neuroscience providers with fewer deaths from stroke in the United States population

Clinical article

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Object. Stroke is a leading cause of death and disability. Given that neurologists and neurosurgeons have special expertise in this area, the authors hypothesized that the density of neuroscience providers is associated with reduced mortality rates from stroke across US counties.

Methods. This is a retrospective review of the Area Resource File 2009–2010, a national county-level health information database maintained by the US Department of Health and Human Services. The primary outcome variable was the 3-year (2004–2006) average in cerebrovascular disease deaths per million population for each county. The primary independent variable was the combined density of neurosurgeons and neurologists per million population in the year 2006. Multiple regression analysis was performed, adjusting for density of general practitioners (GPs), urbanicity of the county, and socioeconomic status of the residents of the county.

Results. In the 3141 counties analyzed, the median number of annual stroke deaths was 586 (interquartile range [IQR] 449–754), the median number of neuroscience providers was 0 (IQR 0–26), and the median number of GPs was 274 (IQR 175–410) per million population. On multivariate adjusted analysis, each increase of 1 neuroscience provider was associated with 0.38 fewer deaths from stroke per year ($p < 0.001$) per million population. Rural location ($p < 0.001$) and increased density of GPs ($p < 0.001$) were associated with increases in stroke-related mortality.

Conclusions. Higher density of specialist neuroscience providers is associated with fewer deaths from stroke. This suggests that the availability of specialists is an important factor in survival after stroke, and underlines the importance of promoting specialist education and practice throughout the country.
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KEY WORDS • stroke • Area Resource File database •
neurologist density • neurosurgeon density • vascular disorders

STROKE is among the leading causes of death and disability in the US.^{3,5} Health care costs for patients with stroke present a significant economic burden^{10,14} due to several factors, including prolonged hospitalizations, inpatient and outpatient rehabilitation, and long-term care requirements.^{10,14} Although the contribution of GPs in improving health care outcomes has been widely recognized, the impact of specialist care on public

health improvement, particularly the impact of neuroscience providers, has not been investigated.⁷

One feature of the ACA, which was passed in May 2010, was the incentives for primary care to improve public health care outcomes. Specialist neuroscience providers, including neurologists and neurosurgeons, are currently not provided with the same incentives under the ACA, despite having a potentially large effect on outcomes after stroke. A recent study using the ARF, a national health resource information database, demonstrated that increased density of general surgeons is associated with a reduced mortality rate from motor vehicle

Abbreviations used in this paper: ACA = Affordable Care Act; ARF = Area Resource File; CL = confidence level; GP = general practitioner; IQR = interquartile range.

crashes,⁷ probably as a result of the availability of acute trauma teams. Given that strokes are a similarly frequent cause of death, and neurologists and neurosurgeons hold special expertise in this area relative to other members of the health care team, we postulated that the density of neurosurgeons and neurologists within a given geographical area would be related to reduced numbers of deaths from stroke. The purpose of the present study was to investigate this hypothesis and to quantify any relationship between the availability of specialist neuroscience providers and reduction in stroke-related deaths.

Methods

Study Design

We performed a retrospective analysis of the ARF 2009–2010, a national county-level health information database maintained by the US Department of Health and Human Services. The primary outcome variable was the 3-year (2004–2006) average in stroke deaths per million population for each county. The primary independent variable was the density of neuroscience providers. This was calculated as the total number of neurologists plus neurosurgeons per million population in the year 2006, given the continuum in stroke care from medical to surgical. Data on the numbers of neurologists and neurosurgeons were reported from the American Medical Association Physician Master File to the ARF.

Statistical Analysis

Multiple linear regression analysis was performed (SAS version 9.2, Windows XP Pro), adjusting for density of GPs (general internal medicine, family medicine, and GPs per million population in the year 2006, reported by the American Medical Association Physician Master File); urbanicity of the county (with rural counties defined as having a rural-urban continuum level ≥ 4); and socioeconomic status of the county (including measures of persistent poverty and low education level as defined by the US Department of Agriculture's Economic Research Service). Counties with persistent poverty are defined as those where 20% or more of residents were poor as measured by the most recent census. Low-education counties are defined as those where 25% or more of the residents 25–64 years old had neither a high school diploma nor a General Educational Development diploma. A p value of < 0.05 was considered to bear statistical significance.

Results

Descriptive Statistics

A total of 3141 counties were analyzed. The mean and median number of annual stroke-related deaths per million population was 625 and 586, respectively (SD 275, IQR 449–754). The mean number of neuroscience providers in a county was 21 (SD 52), and the maximum number of neuroscience providers in a county was 1113, with most of the counties having no neurologists or neurosurgeons (median 0, IQR 0–26). The mean and median number of GPs per million population was 314 and 274, respectively (SD 231, IQR 175–410) (Table 1). Of the counties studied, 2051 (65.3%) were found to have a rural-urban continuum level of ≥ 4 and were therefore considered rural. Also, 622 counties were coded as having low educational status, and 386 counties were described as having poorer financial status (Table 2).

Predictors of Stroke Deaths

On unadjusted analysis, each increase of 1 neuroscience provider per million population was associated with 0.71 fewer stroke deaths per million population (95% CI -0.89 to -0.52 , $p < 0.001$) (Table 3). On multivariate analysis, adjusting for urbanicity, socioeconomic status, and GP density, each increase of 1 neuroscience provider per million population was associated with 0.38 fewer stroke deaths per million population (95% CI -0.57 to -0.19 , $p < 0.001$). In contrast, on multivariate analysis, each increase of 1 GP per million population was associated with 0.143 more stroke deaths per million population (95% CI 0.102 to 0.184, $p < 0.001$) (Table 4).

When the effect of other socioeconomic factors on stroke deaths within a county were analyzed, rural location ($p < 0.001$) was also associated with significant increases in the rate of stroke deaths, whereas persistent poverty and low educational levels were not significant.

Subgroup Analysis

Additional subset analysis found that the relationship between neuroscience provider density and stroke deaths existed both in rural areas (regression coefficient -0.59 , 95% CI -1.01 to -0.18 , $p = 0.005$) (Table 5) and in urban areas (regression coefficient -0.28 , 95% CI -0.44 to -0.11 , $p = 0.001$) (Table 6).

Discussion

In the US, stroke is a leading cause of death and dis-

TABLE 1: Descriptive statistics for cerebrovascular disease deaths, neuroscience providers, and GPs*

Variable	Min	Max	Med	25th Percentile	75th Percentile	Mean	SD
3-yr average cerebrovascular disease deaths/ million population in 2006	0	2432	586	449	754	625	275
no. of neuroscience providers/million population in 2006	0	1113	0	0	26	21	52
no. of GPs/million population in 2006	0	3859	274	175	410	314	231

* The 3-year average included data from 2004 to 2006. Abbreviation: med = median.

TABLE 2: Frequency and percent for rural county, low educational level, and persistent poverty

Variable*	Frequency	%	Cumulative Frequency	Cumulative %
rural county in 2003				
0	1090	34.7	1090	34.7
1	2051	65.3	3141	100
low education code in 2004				
0	2519	80.2	2519	80.2
1	622	19.8	3141	100
poverty code in 2004				
0	2755	87.7	2755	87.7
1	386	12.3	3141	100

* Rural county is defined as having a rural-urban continuum level ≥ 4 .

ability in adults.^{3–5,17,22,23,26,35} The incidence of stroke is estimated at 750,000 cases per year, and has been steadily increasing.²⁹ A wide variability of stroke prevalence and stroke-related mortality has been observed in different countries, in different states of the US, and even in different counties of the same state. Several investigators have attempted to shed light on this phenomenon. In a global analysis, Johnston et al.²¹ demonstrated that stroke-related mortality was 3.5 times higher in low-income countries than in middle- and high-income countries. The researchers, contrary to what they had initially expected, noticed a lower incidence of cardiovascular risk factors in the poorer countries. Despite this, the lack of appropriate preventive measures in combination with limited access to health care probably contributes to the higher mortality rate observed in lower-income countries.

Within the US, stroke-related mortality appears to vary by race and geographic region. The highest incidence has been reported in the “buckle of the Stroke Belt” (coastal regions of North Carolina, South Carolina, and Georgia) and in the “Stroke Belt states” (remainder of North Carolina, South Carolina, and Georgia, as well as Mississippi, Tennessee, Arkansas, and Louisiana).³⁶ Various groups have investigated the association of various factors with this phenomenon.^{16,25,30,33,36} Most studies, however, have focused on factors associated with increased stroke incidence rather than higher case fatality. Lower socioeconomic status, hypertension, and diabetes have most commonly been associated with higher stroke

prevalence. Several international studies have been in agreement with these results.^{2,6,12,18,19} In particular, a study from the People’s Republic of China¹⁸ has demonstrated that more than 70% of the variance in stroke incidence could be accounted for by differences in the prevalence of hypertension. These observations have also been validated by a study in Malmö, Sweden,¹² an area especially suitable for epidemiological studies, because all the patients are treated in a single academic center. Similar conclusions have been reached by Italian investigators,⁶ who supported that their study was controlled for the disparities in accessibility of care, since their country’s health-care system is publicly funded, providing universal access and comprehensive coverage.

The aforementioned studies, with the exception of Cesaroni et al.,⁶ have focused almost exclusively on investigating the effect of cardiovascular risk factors on the geographic variations of the incidence and mortality rates of stroke. The potential impact of timely access to specialized care has not been addressed. This is a potentially important (and modifiable) predictor of stroke outcomes. Our study has demonstrated a significant positive effect of increased density of neurologists and neurosurgeons on stroke survival. Although data on other specific risk factors were not available in the ARF, our multivariate regression analysis demonstrated a sustained effect after controlling for socioeconomic status and urbanicity of the county. In the literature,^{6,12,16,18,25,30,33,36} there is an established association of lower socioeconomic status with

TABLE 3: Univariate unadjusted analysis for 3-year average cerebrovascular disease deaths in a county*

Variable	Regression Coefficient	95% CI		p Value	R ²
		Lower CL	Upper CL		
no. of neuroscience providers/million population in 2006	−0.71	−0.89	−0.52	<0.001	0.018
no. of GPs/million population in 2006	0.15	0.11	0.19	<0.001	0.016
persistent poverty in 2004	18.22	−11.12	47.55	0.224	0.0005
low educational level in 2004	17.58	−6.58	41.75	0.154	0.0006
rural county in 2003	170.99	151.65	190.32	<0.001	0.087

* Unadjusted for urbanicity, low educational level, persistent poverty, neuroscience providers, and GPs. Throughout the tables, negative values denote fewer deaths.

TABLE 4: Multivariate adjusted analysis for 3-year average cerebrovascular disease deaths in a county*

Variable	Regression Coefficient	95% CI		p Value
		Lower CL	Upper CL	
intercept	488.93	468.12	509.74	<0.001
no. of neuroscience providers/million population in 2006	-0.38	-0.57	-0.19	<0.001
no. of GPs/million population in 2006	0.14	0.10	0.18	<0.001
persistent poverty in 2004	-21.07	-53.21	11.06	0.199
low educational level in 2004	4.38	-22.33	31.09	0.748
rural county in 2003	155.52	134.85	176.20	<0.001

* Adjusted for urbanicity, low educational level, persistent poverty, neuroscience providers, and GPs; model $R^2 = 0.104$.

increased cardiovascular risk factors in the US, allowing us to hypothesize that the latter should not be affecting our analysis after controlling for the former. In addition, the present analysis was performed on the county level, recognizing the importance of small-scale variations as underlined by previous studies.³⁰

It has been shown^{1,29} that comprehensive stroke centers have a beneficial impact on patient outcomes. A health system can be described as comprising 3 domains:⁷ 1) structure (buildings, equipment, human capital); 2) process (triage, operational algorithm); and 3) outcomes. The contribution of providers both in the structure and the process domains of this model demonstrates their important role in outcomes. Several lines of evidence point to the value of access to appropriate health systems in the outcomes after stroke.^{1,13,29} Along the same lines, telemedicine and telestroke care is increasingly used to provide timely care in stroke patients.^{8,9,28} Recent studies have demonstrated increased stroke-related mortality during the weekends, potentially due to the decreased availability of specialized care providers.^{20,32} The “week-end effect” has been eliminated in comprehensive centers with around-the-clock availability of neurologists, neurosurgeons, and intensivists.^{1,29} This is in agreement with the observed positive effect of more neuroscience providers in decreasing stroke mortality rates in the current analysis.

As demonstrated in our study, there is considerable disparity in the density of neurologists and neurosurgeons practicing among various counties throughout the country. Most counties have no local neurosurgical availability, probably due to a concentration of neurosurgeons around tertiary care centers. The contribution of both specialties,

however, in timely interventions is extremely important in stroke, in which emergency care is of paramount importance. Timely diagnosis and treatments supported by significant evidence, such as thrombolysis,²⁷ endovascular interventions,^{15,24,31} external ventricular drainage,¹¹ and hemicraniectomy,³⁴ as well as other options such as hematoma evacuation¹¹ in select patients with hemorrhagic stroke are dependent on the immediate availability of neurologists and neurosurgeons.

Our study suggests that an increase of 3 neuroscience providers would be associated with 1 less stroke death per million population. The observed negative effect of primary care providers on stroke mortality rates is difficult to explain. It could potentially be attributed to the decreased density of specialists in counties with a high percentage of primary care providers, or it could be a result of increased recruitment of GPs to high-risk areas. The effect of GPs on primary stroke prevention by risk factor control is probably significant. It appears, however, that stroke-related mortality is mostly dependent on the availability of neurological providers who can provide timely interventions and secondary prevention. In addition, the current study does not analyze the potential effect of neuroscience provider density on stroke morbidity, which may clearly be improved by early diagnosis and intervention. The data in this study demonstrate a public health benefit of neurological and neurosurgical services.

Attempts to improve accessibility to specialized neurological providers locally in underserved areas would probably benefit from multiple strategies, including educational support, medical malpractice reform, and protection of reimbursement, in addition to the development of more effective comprehensive stroke centers in the com-

TABLE 5: Multivariate adjusted analysis for 3-year average cerebrovascular disease deaths in a rural county*

Variable	Regression Coefficient	95% CI		p Value
		Lower CL	Upper CL	
intercept	650.62	627.37	673.87	<0.001
no. of neuroscience providers/million population in 2006	-0.59	-1.01	-0.18	0.005
no. of GPs/million population in 2006	0.14	0.09	0.19	<0.001
persistent poverty in 2004	-28.08	-67.97	11.80	0.167
low educational level in 2004	-8.50	-43.37	26.38	0.633

* Adjusted for low educational level, persistent poverty, neuroscience providers, and GPs; model $R^2 = 0.021$.

TABLE 6: Multivariate adjusted analysis for 3-year average cerebrovascular disease deaths in an urban county*

Variable	Regression Coefficient	95% CI		p Value
		Lower CL	Upper CL	
intercept	480.82	457.53	504.10	<0.001
no. of neuroscience providers/million population in 2006	−0.28	−0.44	−0.11	0.001
no. of GPs/million population in 2006	0.13	0.06	0.20	<0.001
persistent poverty in 2004	43.39	−13.18	99.96	0.133
low educational level in 2004	43.19	6.39	79.99	0.021

* Urban county is defined as having rural-urban continuum level 1, 2, or 3. The analysis was adjusted for low educational level, persistent poverty, neuroscience providers, and GPs; model $R^2 = 0.024$.

munity. The ACA, which was passed in 2010, attempts to improve primary care provision by incentivizing primary care at the level of residency training and physician reimbursement. The important role of neurologists and neurosurgeons in decreasing the mortality rate of stroke, the significant contribution of cerebrovascular disease to overall nationwide health care costs, and the scarcity of these providers throughout vast areas of the country, suggest an added importance of promoting vascular neurological practice.

This study has limitations that should be considered. Although an association is demonstrated between neuroscience provider density and reduced stroke-related deaths, a causal relationship cannot be proven by the data. As discussed above, the data do not provide an estimate for the additional effect of neuroscience providers on stroke morbidity, which may be significant. In addition, other markers of the overall quality of the stroke care system (for example specialist equipment and multidisciplinary staffing) were not available in the ARF, and therefore we cannot control for these potential confounders. Furthermore, the data are limited by the accuracy of the initial administrative coding of diagnoses, provider designation, and socioeconomic factors. In addition, the rates of mortality from different types of stroke (for example, ischemic vs hemorrhagic) and specific individual interventions (for example, medical vs surgical) were not available to us, and therefore this study is unable to answer which aspects of stroke management may be most effective in reducing mortality rates. Other individual characteristics such as age and cardiovascular risk factors, which have previously been shown to influence stroke-related mortality, are not considered in our analysis because these data were not available. Another limitation of the current analysis is that not all neurosurgeons and neurologists routinely treat stroke patients, and the data used were not specific to those neuroscience providers involved in stroke care. Finally, the study provides a county-level analysis, which may not always be applicable to individual patients and providers.

Conclusions

Stroke is a major cause of death in the US. A higher density of neuroscience providers is associated with a significant reduction in deaths from strokes across US counties. This suggests that availability of local neurologists

and neurosurgeons may be an important factor in the overall likelihood of survival after stroke, and therefore underlines an importance of promoting specialist clinical neuroscience education and practice throughout the country.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Desai, Bekelis, Ball. Analysis and interpretation of data: Desai. Drafting the article: Desai. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Desai. Statistical analysis: Zhao.

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