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Incidence of Stroke and Season of the Year: Evidence of an Association

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Evidence of seasonal variation in the incidence of stroke is inconsistent. This may be a likely consequence of one or more methodological shortcomings of the studies investigating this issue, including inappropriate analytic models, insufficient length of time, small sample size, and a regional (vs. national) focus. The authors' objective was to ascertain whether an association exists between season of the year and the incidence of stroke by using a methodological approach designed to overcome these limitations. The authors used a longitudinal study design involving 72,779 veterans hospitalized for stroke at any Veterans Affairs hospital nationally during the years 1986–1995. These data were analyzed by using time series methods. There was clear evidence of a seasonal occurrence for stroke in general. This seasonal effect was found for ischemic stroke, but not for hemorrhagic stroke. The peak occurrence was in mid-May. Neither the region (i.e., climate) nor the race of the patient substantially modified the seasonal trend. An explanation for this pattern remains to be determined. *Am J Epidemiol* 2000;152:558–64.

cerebrovascular disease; incidence; risk factors; season

The existence of a seasonal pattern in the occurrence of stroke remains controversial. Over the past 3 decades, there have been numerous investigations into the existence of an association between season of the year and stroke incidence (table 1). Many of these studies, conducted in different countries throughout the world, including those in Europe, Asia, Australia, and North America, report an association (1–17). However, other investigations find no evidence supporting seasonal variation in stroke rates (18–20). Moreover, among those studies that report a seasonal effect, the season of peak stroke incidence varies. For example, several investigators identify the highest stroke incidence rates as occurring during autumn (4, 6, 7, 12, 13, 15), while others find that the highest rates occur either in winter (1–3, 5, 6, 8–11, 14, 16, 17) or in spring (4, 7, 12, 13).

The inconsistent findings may be attributable, in part, to several study design limitations in these previous investigations. First, many of the studies examine only 1- to 4-year time periods, limiting confidence in any inference that a real association exists (2–4, 6, 8, 11, 12, 14, 19). Generally, 5 or more years should be studied in order to have a solid basis for making inferences across years, and at least 50 observations are needed for an appropriate time series study (21–24). Second, some of the studies rely upon techniques that are not valid for assessing seasonal trends (3, 6, 7, 11, 12, 14, 16, 18). Appropriate statistical techniques for describing cycles in time require the use of frequency or time domain analyses (21–27). Third, many of the studies examine isolated and often small geographic regions (1–7, 10–13, 15–20). Thus, the reported seasonal patterns may reflect a regional rather than a broader, more global phenomenon. Finally, in some of the studies, the examination of seasonality is without respect to specific stroke type: hemorrhagic versus ischemic (9, 11, 12, 14). Because hemorrhagic and ischemic strokes have different pathophysiologic mechanisms, the relation of each stroke type to seasonality may also differ. Thus, analyses that combine all stroke types may misrepresent the effect of seasonality on specific types of stroke.

In this report, we present the results of a more refined analysis that examines seasonal trends in stroke incidence. We conducted a frequency domain time series analysis of stroke incidence during a 9-year period using a nationwide patient population comprised of 72,779 veterans who had been hospitalized for acute stroke at any of the 172 Veteran Affairs (VA) medical facilities. In our analyses, we consider

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Abbreviations: CI, confidence interval; ICD-9-CM, *International Classification of Diseases*, Ninth Revision, Clinical Modification; VA, Veterans Affairs.

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TABLE 1. Summary of reports on seasonal trend in the occurrence of stroke

Reference no.	Analysis method (no.)*	Location	No.	Years	Peak	Trough
All strokes						
18	6	Framingham, MA	637	40	None†	NR‡
12	7	Fargo, ND, and Moorhead, MN	688	2	Spring, late fall†	NR
14	7, 8	England and Wales	NR	1	Winter†	Summer†
5	2	University of L'Aquila, Italy	667	18	January§	NR
10	3	Hisayama, Japan	308	24	February§	NR
11	7, 8	Akita Prefecture, Japan	2,168	1.5	Winter†	Summer
9	1, 9	New Zealand	NR	5	Winter (June to Aug.)§	Summer (Dec. to Feb.)§
Ischemic stroke						
18	7	Framingham, MA	637	40	None†	
16	10	Bellevue Hospital, New York, NY	993	9	Winter†	NR
19	5	Oxfordshire Community Stroke Project	675	4	None§	Summer†
2	4	West Midlands, Great Britain	30,679	3	Winter§	Late summer§
1	3	Ferrara, Italy	161	9	February§	NR
6	7	Umbria, Italy	375	3	Winter†	NR
5	3	University of L'Aquila, Italy	667	18	January§	NR
3	8	Dijon, France	418	2	"Cold" season†	NR
10	4	Hisayama, Japan	308	24	March§	NR
ICH‡						
18	7	Framingham, MA	637	40	None†	NR
17	3	St. Paul-Ramsey Hospital, Saint Paul, MN	128	6	January§	NR
19	5	Oxfordshire Community Stroke Project	675	4	None§	
2	4	West Midlands, Great Britain	30,679	3	None§	
3	8	Dijon, France	418	2	None†	
5	3	University of L'Aquila, Italy	667	18	January§	NR
6	7	Umbria, Italy	375	3	Autumn†	NR
10	4	Hisayama, Japan	308	24	January§	NR
SAH‡						
18	7	Framingham, MA	637	40	None†	NR
20	4	Mayo Clinic, Rochester, MN	113,131	30	None§	
13	4	Connecticut	1,487	6 years in a 9-year period	Males: late fall§ Females: late spring§	NR
19	5	Oxfordshire Community Stroke Project	675	4	None	
15	4	Tyrol, Austria	286	11	Late fall§	NR
4	1	Northern France	238	3	April, Sept.†	June, July†
2	4	West Midlands, Great Britain	30,679	3	Winter§	Late summer§
8	6	International Cooperative Aneurysm Study	3,521	2.5	February§	NR
7	7	Denmark	1,076	5	Spring, fall†	Summer, winter†
10	4	Hisayama, Japan	308	24	None§	NR
Ill-defined						
2	4	West Midlands, Great Britain	30,679	3	Winter§	Late summer

*Analysis methods: 1, time domain time series analysis; , harmonic regression (frequency domain time series analysis; adds harmonics until model assumptions are met). (Harmonic regression and single cosinor analysis refer to similar analyses, except that single cosinor fits only one frequency); 3, single cosinor analysis (fits 1 harmonic only) (Harmonic regression and single cosinor analysis refer to similar analyses, except that single cosinor fits only one frequency); 4, Roger's R (the periodogram and Roger's R refer to the same method); 5, Walter and Elwood method (the Walter and Elwood method is a generalization of Edward's method, but is not generally the same as the periodogram); 6, chi-square; 7, graphs; 8, tables; 9, ratio to moving average; 10, odds ratio.

† Based on observed frequencies.

‡ NR, not reported; ICH, intracranial hemorrhage; SAH, subarchnoid hemorrhage.

§ Based on model.

stroke type, climate region within the United States, and the patient's race.

MATERIALS AND METHODS

Patient population

From VA hospital discharge data, we identified veterans who had been hospitalized for acute stroke at any VA hospital in the United States between October 1, 1986 and September 30, 1995. The VA maintains a centralized hospital discharge database that contains data on every discharge from a VA hospital from 1970 onward. Because of changes in the elements of the database in 1986 and for pragmatic considerations of time and resources, we confined our analysis to the period 1986–1995. Patients were included in our study population if they were males aged 45 years or older who were community dwelling prior to admission and had either a hemorrhagic or an ischemic stroke as their primary discharge diagnosis, where stroke was defined by the clinically modified version of *International Classification of Diseases*, Ninth Revision, Clinical Modification (ICD-9-CM) codes 430–432, 434, or 436. These codes are known to identify individuals with stroke with a high degree of accuracy; the proportion of patients with true strokes within these codes range from 67 percent for patients with ICD-9-CM code 436 to 100 percent for ICD-9-CM code 430 (28). Our patients may have had other cerebrovascular disease codes among their listed diagnoses, such as transient ischemic attack (ICD-9-CM code 435), carotid artery stenosis or occlusion (ICD-9-CM code 433), and unspecified or prior cerebrovascular disease events (ICD-9-CM codes 437 and 438). However, such patients were excluded if any of these latter codes were the only ones listed. To improve the likelihood that the patient population was composed of only those patients who had been admitted for acute stroke, we further restricted the population to patients who had been admitted initially to medicine service, neurology service, or medical intensive care for acute stroke (ICD-9-CM codes 430–432, 434, and 436) or for symptomatic conditions highly related to acute stroke—hemiplegia (ICD-9-CM code 342) and aphasia (ICD-9-CM code 784.3). In addition, we included only the first stroke experienced by a given patient during the study period because recurrent stroke may be more a function of clinical factors (e.g., inadequate preventive therapy) than of season. The latter strategy, however, is imperfect in that it may fail to exclude patients with a prior stroke who appear early in the study period (and especially in the first year). Thus, patients who were hospitalized for stroke earlier in the study period may have had a higher likelihood of a prior stroke than did patients who appear later in the study period. As a sensitivity analysis of the effect of these potentially erroneous inclusions, we excluded the data for the first year of the study period and analyzed the remaining data as described in the Data analysis section below. This reanalysis yielded results that were not substantively different from those using all years of the data. Therefore, we utilized the entire data set in our analysis.

Key variables

Stroke occurrence period. We defined stroke occurrence in terms of the number of acute stroke admissions per week, in which the patient's date of hospital admission determined the week to which the stroke was assigned. We chose a weekly cycle to maximize the number of observation points while minimizing administrative artifacts that occur with a shorter period. That is, preliminary investigation showed a clear intraweek cycle with a peak on Mondays and a trough on the weekends, suggesting an administratively related artifact to stroke incidence when viewed on a daily basis. To minimize the spurious pattern in stroke occurrence that was associated with the greater number of admissions on Monday, we defined the week, or 7-day period, as the period from Thursday through the following Wednesday. We also examined longer periods of occurrence (i.e., 2- and 4-week intervals); the results were similar to those based on weekly incidence.

Stroke type. We subclassified acute stroke into two categories: hemorrhagic and ischemic. Hemorrhagic stroke was defined by ICD-9-CM codes 430–432, while ischemic stroke was defined by ICD-9-CM codes 434 and 436. It was not possible with these administrative data to classify ischemic strokes into subtypes.

Climate region. To understand the potential modifying effect of climate, we examined two regions of the United States: Northeast and Southeast. These regions were defined at a state level according to a standard climate region map (29). The Southeast region included the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, Washington, DC, and West Virginia. The Northeast region included the states of Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Dakota, Vermont, and Wisconsin. The climate regions among the Western states were more varied, yielding relatively small cohorts of stroke patients who resided within those areas; therefore, in our regional analysis, we did not include the Western climate regions.

Patients' race. Because African Americans experience higher rates of stroke, we were also interested in whether race modified the association between season and the incidence of acute stroke. We obtained data on the patient's race from the hospital discharge record; race is recorded with a high degree of consistency and accuracy within extant VA databases (30). For this analysis, we included only those patients who were either African American or Caucasian. These two racial/ethnic groups comprise approximately 94 percent of all patients hospitalized at VA medical facilities.

Data analysis. Time series analyses were conducted to determine seasonal trends in the nationwide incidence of all strokes and the nationwide incidence of ischemic and hemorrhagic strokes separately. We also examined statistically and graphically differences in trends between the climate regions and the races.

For our time series modeling of stroke occurrence, we focused on frequency domain analyses because time domain analyses are most appropriate for forecasting purposes. The frequency domain analyses used were the periodogram (21, 22, 24), also known as Roger's R (25), and harmonic regression (21, 22, 24), which also has been referred to as cosinor analysis (27). It should be noted that single cosinor analysis considers only one harmonic (i.e., cycle pattern) in the model, while harmonic regression/cosinor analysis allows multiple harmonics in the model. As with any regression-based methodology, the crucial assumption is independent and identically distributed error terms that are normal in distribution, with a mean of zero and a constant variance. With time series data, it is necessary to ensure that the harmonic regression accounts for any lack of independence in the original data so that the residuals meet the necessary assumptions. To test the residuals for adherence to the assumption of independence, Fisher's kappa (i.e., test for a sinusoidal component buried in "white space"), the large sample approximation to the Durbin-Watson d (i.e., test for first-order autocorrelation), and the Bartlett Kolmogorov-Smirnov test (i.e., test of departure from independence over all frequencies) (21, 22, 24) were used. The normality of the residuals was tested using the Shapiro-Wilkes test (21, 22).

We began our analysis of the nationwide incidence of all strokes with a graph of the data. We then used nonparametric curve-fitting techniques to explore the shape of the trend over time. Figure 1 is a plot of the actual data with a nonparametric smoothing spline. The kernel and lowess

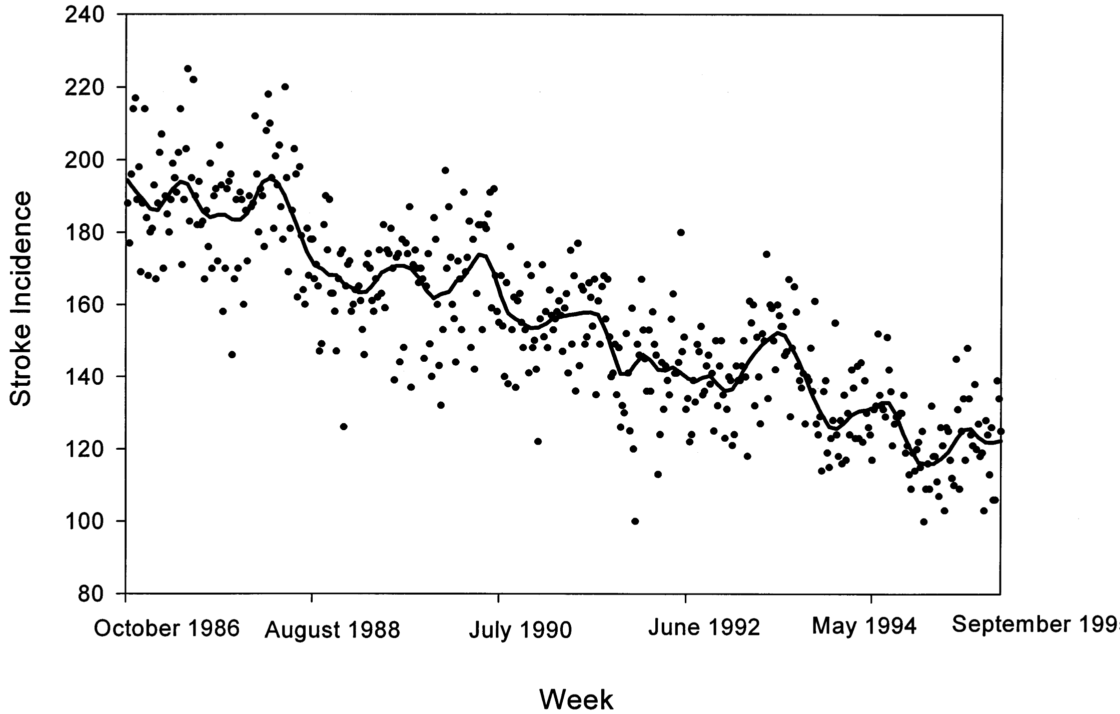

FIGURE 1. Actual weekly incidence (dots) and predicted trend (solid line) of stroke among veterans hospitalized at VA medical centers nationally over the period October 1986 to September 1995, derived from a nonparametric smoothing spline.

smoothers were also generated and compared with the smoothing spline. These three approaches yielded similar results. As clearly shown in figure 1, there were cyclical trends in the data, and thus, we proceeded with harmonic regression techniques. A periodogram was constructed to determine the largest Fourier harmonic present in the residuals. The yearly harmonic was the largest cycle present and so was added to the model. This initial harmonic indicated the primary cyclical trend in the data. Further residual analysis indicated a 3-year harmonic. The model containing the linear, 1-year, and 3-year cycles had residuals that passed all tests for independence and normality. The analysis of stroke type began with fitting ischemic and hemorrhagic strokes separately. The models were built in the same forward stepwise manner as described above. Peaks and troughs were identified as the highest and lowest predicted value for a week in a 1-year interval, respectively. For each peak and trough, we constructed a 95 percent confidence interval.

For examination of the question of whether the trends in ischemic stroke were different in African Americans and Caucasians, the model for ischemic stroke was expanded to include a term for race and the interaction between race and the linear, 1-year, and 3-year cycles. The test of the interaction between race and the linear trend is a test of whether the rate of decline in ischemic stroke incidence in African Americans and Caucasians is the same. The test of the interaction between race and the yearly cycle is a test of whether the amplitude of the yearly cycle is the same in African Americans and Caucasians. The test of the interaction between race and the 3-year cycle is a test of whether the amplitude of the 3-year cycle is the same in African Americans and Caucasians. Similarly, to examine the question of whether the trends in ischemic stroke were different in the Northeast and Southeast, the model for ischemic stroke was expanded to include a term for region and the interaction between region and the linear, 1-year, and 3-year cycles. This model was fit to the subset of ischemic strokes in which patients were in the Northeast or Southeast regions. The *p* values were adjusted to reflect the varying sample sizes of the subanalyses.

RESULTS

Population characteristics

Our population of stroke patients was composed of 72,779 individuals (table 2). The mean age was 66 years (standard deviation = 9.98, range, 20–106 years). Approximately 70 percent of the cohort were Caucasian, 24 percent was African American, 4 percent was Hispanic, and the remaining 2 percent were of other racial/ethnic groups. Ischemic strokes accounted for 91 percent of all strokes during the study period. Approximately one fourth of patients resided in the Northeast, while a slightly greater percentage resided in the Southeast. The mean number of stroke events per week was 154.7 (standard deviation = 26.9, range, 23–225 strokes).

TABLE 2. Characteristics of patients hospitalized for acute stroke at VA medical centers, 1986–1995

Demographic characteristics	No.	%
Age (years)		
<45	2,112	2.9
45–54	5,518	7.6
55–64	21,775	29.9
65–74	30,393	41.8
75–84	10,839	14.9
≥85	2,142	2.9
Racial/ethnic group		
Caucasian	51,183	70.3
African American	17,068	23.5
Hispanic	2,886	4.0
Other	1,642	2.2
Stroke type		
Ischemic	66,295	91.1
Hemorrhagic	6,484	8.9
Period of occurrence		
10/86–9/87	9,861	13.5
10/87–9/88	9,615	13.2
10/88–9/89	8,644	11.9
10/89–9/90	8,603	11.8
10/90–9/91	8,117	11.2
10/91–9/92	7,376	10.1
10/92–9/93	7,503	10.3
10/93–9/94	6,850	9.4
10/94–9/95	6,210	8.5
Region (ischemic type)		
Northeast	18,555	25.5
Caucasians	14,093	19.4
African Americans	4,462	6.1
Southeast	20,791	28.6
Caucasians	14,227	19.5
African Americans	6,564	9.0

Season and occurrence of stroke

Our time series modeling using frequency analysis indicated a general downward linear trend in the occurrence of stroke over the 9-year period (F value = 1,102, $p < 0.001$). In addition, there was a significant seasonal (1-year) trend (F value = 26, $p < 0.0001$) for all acute strokes and a significant 3-year cycle (F value = 15, $p = 0.0001$). Figure 2 shows the predicted incidence of stroke based upon the harmonic regression model. From this model, the average peak location occurred on the week of May 13 (95 percent confidence interval (CI): week of May 4th to week of May 22nd), with an average trough occurrence the week of December 8 (95 percent CI: week of November 29th to week of December 17th).

Stroke type and seasonality of stroke

When we examined the evidence for seasonality according to type of stroke, we found a clear indication of a seasonal pattern in the occurrence of ischemic strokes only. As occurred for all strokes, the ischemic stroke model contained a decreasing linear trend with significant 1-year (F value = 32, $p < 0.0001$) and 3-year (F value =16, $p < 0.0001$) cycles. The periods of high and low occurrence also were similar to those for all strokes. While there was a decreasing linear trend in the occurrence of hemorrhagic strokes, we were unable to fit the harmonic regression model that would satisfy all of the model assumptions, most likely a consequence of the small number of observations. We therefore restricted our race and climate region analyses to ischemic stroke.

Race and seasonality of ischemic stroke

The test for interaction between race and each of the major parameters (linear trend and 1- and 3-year cycles) was significant only for the linear trend (F value = 31, $p < 0.0001$), indicating that the rate of decrease in stroke incidence is different in African Americans and Caucasians. The average peak for African Americans was the week of May 12 (95 percent CI: week of May 3rd to week of May 21st), while the average trough was the week of November 24 (95 percent CI: week of November 14th to December 4th). Among Caucasians, the average peak occurred the week of May 15 (95 percent CI: week of May 4th to week of May 24th), while the average trough occurred the week of December 15 (95 percent CI: week of December 4th to week of December 24th).

Climate region and seasonality of ischemic stroke

The tests for the interaction between climate region and the linear, yearly, and 3-year cycles were not significant. In the Northeast climate region, the average peak was the week of May 2 (95 percent CI: week of April 24th to week of May 11th), and the average trough was the week of November 18 (95 percent CI: week of November 8th to week of November 27th). For the Southeast climate region, the average peak was the week of May 23 (95 percent CI: week of May 11th to week of June 5th), and the average trough was the week of December 14 (95 percent CI: week of December 8th to week of December 21st).

DISCUSSION

In our national study of stroke occurrence among veterans for the period of 1986–1995, we found clear evidence of a seasonal pattern for stroke in general and for ischemic stroke in particular. Peak occurrence was during mid-May, with the lowest occurrence in early December. Hemorrhagic strokes could not be fully modeled, but appeared to lack a seasonal pattern. Neither climate region nor patient's race appeared to strongly influence the seasonal pattern. An explanation for the observed springtime peak in occurrence remains to be determined.

Previous studies presented an inconsistent and conflicting picture regarding a seasonal pattern in the occurrence of stroke (table 1). While some of the studies reported a sea-

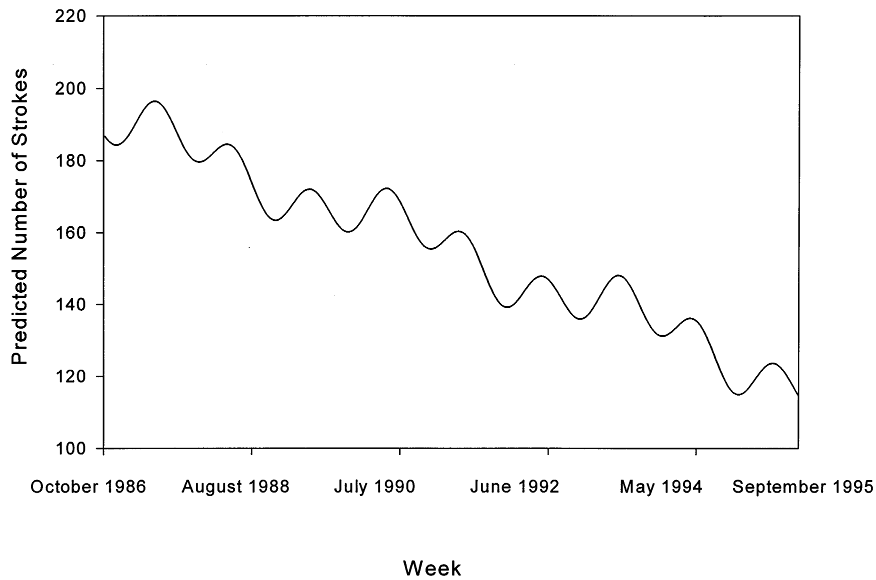

FIGURE 2. Predicted incidence of stroke among veterans hospitalized at VA medical centers nationally over the period October 1986 to September 1995, derived from the fitted nonparametric regression model.

sonal occurrence, others indicated its absence. Moreover, among studies indicating a seasonal occurrence to stroke, the identified season of highest occurrence has varied, including autumn, winter, and spring. The inconsistency of these results may be a reflection of one or more problems in the study designs. These problems include use of an inappropriate analytic model, insufficient length of time, small sample size, and focus on a single region.

In our investigation, we took specific steps to avoid these methodological limitations. We utilized a patient population of 72,779 patients who were hospitalized during an 9-year period, used frequency domain time series analytic techniques that are the most appropriate techniques for modeling this type of data, and had a national patient population. Thus, we have confidence in our findings of a seasonal pattern of stroke incidence, in which the peak is in spring and the trough is in autumn.

In addition to a seasonal pattern, there was a statistically significant 3-year cycle in the occurrence of stroke. The 3-year cycle, however, is not the primary cycle, as evidenced by figure 2; it is the yearly trend that is the primary cycle. The 3-year cycle is necessary to satisfy model assumptions. Moreover, with a 9-year study period, the number of 3-year cycles is too few to provide a reasonable basis for drawing conclusions.

We also observed a decline in the number of stroke admissions over time. Although consistent with reports of a declining incidence of stroke during the 1970s and 1980s, with stabilization in the early 1990s (31, 32), our observation may be a consequence of a declining patient population, since we use counts of events rather than rates per se. However, if total hospital admissions is accepted as a first approximation of the hospital patient population, a declining patient population is unlikely to account for all or most of this linear decreasing trend in stroke occurrence. While overall VA hospital admissions declined 16 percent, from 626,158 to 528,805, during our 9-year study period, the proportion of admissions for stroke (as a first approximation of the stroke incidence rate) declined 25 percent, from 1.6 percent in fiscal year 1987 to 1.2 percent in fiscal year 1995. Thus, we believe that, as with the general population, there has been a true decline in stroke occurrence among veterans who use the VA health care system.

We recognize, though, that the interpretation of our findings must be considered with due regard to the inherent limitations of our data. First, we used hospital discharge data rather than detailed medical record data. Although we attempted to maximize the likelihood of including all eligible acute stroke patients in our patient population, some degree of misclassification bias may be present. That is, we may have missed some acute stroke patients while failing to exclude nonstroke cerebrovascular disease patients or nonacute stroke patients (i.e., patients who were admitted for stroke rehabilitation, evaluation of their cerebrovascular circulation, or surgical intervention to prevent future stroke). However, we selected patients in such a way as to maximize the likelihood that they had had an acute stroke. We focused on those diagnoses (ICD-9-CM codes 430–432, 434, and 436) that have a high probability of being stroke (28). Moreover, we restricted the cases to those who were admitted from the community to those medical services that clinically manage acute strokes: neurology service, medicine service, and intensive care units. Finally, because patients who first occur early in the study period may have a higher likelihood of inclusion when their "first" stroke is actually a recurrent stroke, we conducted a sensitivity analysis in which we excluded the data from the first year of the study period; the results of that analysis were unchanged from those reported. Thus, while the extent of the possible misclassification bias is unknown, we suspect it is low.

Another limitation is that we considered two broad categories of stroke: ischemic and hemorrhagic. We cannot exclude the possibility that subtypes of ischemic stroke may not have seasonal variation or that subtypes of brain hemorrhages may be associated with season of the year. For example, some previous studies have indicated that subarachnoid hemorrhage is associated with a seasonal occurrence (2, 4, 7, 8, 13, 16).

Third, our population of stroke patients was composed almost entirely of men who were hospitalized in VA facilities. Approximately 10 percent of veterans use the VA health care system for their health care (33). Veterans who receive their health care at VA facilities tend to be older, sicker, and poorer than the other veterans and the general male population. Thus, the pattern observed for these patients may not be representative of the US male population or of US population as a whole.

Fourth, the observed seasonal pattern may be an administrative artifact rather than a true occurrence. We doubt this explanation because we took care to define our periods of observation to be independent of artificially induced patterns of admission. For example, we used the week as our period of observation and defined it on a Thursday through Wednesday basis to compensate for fewer admissions on weekends and more admissions on Mondays. Moreover, we explored alternative periods of observation (2 and 4 weeks) and found results similar to those presented here. Finally, we are aware of no VA administrative policies regarding eligibility for VA care that would yield peak admissions for stroke in the spring and the least admissions during late autumn. Given these limitations, we found that ischemic stroke is associated with a seasonal pattern of occurrence, with the highest occurrence being in mid- to late spring. We are hesitant to speculate on the underlying factor(s) that would account for such an association and urge further investigations to confirm and explain our observed seasonal cycle.

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REFERENCES

1. Gallerani M, Trappella G, Manfredini R, et al. Acute intracerebral haemorrhage: circadian and circannual patterns of onset. Acta Neurol Scand 1994;89:280–6.
2. Gill JS, Davies P, Gill SK, et al. Wind-chill and the seasonal variation of cerebrovascular disease. J Clin Epidemiol 1988; 41:225–30.
3. Giroud M, Beuriat P, Vion P, et al. Stroke in a French prospective population study. Neuroepidemiology 1989;8:97–104.
4. Lejeune J, Vinchon M, Amouyel P, et al. Association of occurrence of aneurysmal bleeding with meteorologic variations in the north of France. Stroke 1994;25:338–41.
5. Pasqualetti P, Natali G, Casale R, et al. Epidemiological chronorisk of stroke. Acta Neurol Scand 1990;81:71–4.
6. Ricci S, Celani MG, Vitali R, et al. Diurnal and seasonal variations in the occurrence of stroke: a community-based study. Neuroepidemiology 1992;11:59–64.
7. Rosenorn J, Ronde F, Eskesen V, et al. Seasonal variation of aneurysmal subarachnoid haemorrhage. Acta Neurochir (Wien) 1988;93:24–7.
8. Vinall PE, Maislin G, Michele JJ, et al. Seasonal and latitudinal occurrence of cerebral vasospasm and subarachnoid hemorrhage in the northern hemisphere. Epidemiology 1994;5:302–8.
9. Douglas AS, Russell D, Allan TM. Seasonal, regional and secular variations of cardiovascular and cerebrovascular mortality in New Zealand. Aust N Z J Med 1990;20:669–76.
10. Shinkawa A, Ueda K, Hasuo Y, et al. Seasonal variation in stroke incidence in Hisayama, Japan. Stroke 1990;21:1262–7.
11. Suzuki K, Kutsuzawa T, Takita K, et al. Clinico-epidemiologic study of stroke in Akita, Japan. Stroke 1987;18:402–6.
12. Alter M, Christoferson L, Resch J, et al. Cerebrovascular disease: frequency and population selectivity in an upper midwestern community. Stroke 1970;1:454–65.
13. Chyatte D, Chen TL, Bronstein K, et al. Seasonal fluctuation in the incidence of intracranial aneurysm rupture and its relationship to changing climatic conditions. J Neurosurg 1994; 81:525–30.
14. Haberman S, Capildeo R, Rose FC. The seasonal variation in mortality from cerebrovascular disease. J Neurol Sci 1981;52: 25–36.
15. Langmayr JJ, Obwegeser A, Ortler M. Seasonal rupture of aneurysms. J Neurosurg 1995;83:182–3.
16. McDowell FH, Louis S, Monahan K. Seasonal variation of non-embolic cerebral infarction. J Chronic Dis 1970;23:29–32.
17. Ramirez-Lassepas M, Haus E, Lakatua DJ, et al. Seasonal (circannual) periodicity of spontaneous intracerebral hemorrhage in Minnesota. Ann Neurol 1980;8:539–41.
18. Kelly-Hayes M, Wolf PA, Kase CS, et al. Temporal patterns of stroke onset: The Framingham Study. Stroke 1995;26:1343–7.
19. Rothwell PM, Wroe SJ, Slattery J, et al. Is stroke incidence related to season or temperature? Lancet 1996;347:934–6.
20. Schievink WI, Wijdicks EFM, Meyer FB, et al. Seasons, snow, and subarachnoid hemorrhage: lack of association in Rochester, Minnesota. J Neurosurg 1995;82:912–13.
21. Wei WWS. Time series analysis. New York, NY: Addison-Wesley Publishing Company, 1990.
22. Brocklebank JC, Dickey DA. SAS system for forecasting time series. Cary, NC: SAS Institute, Inc., 1986.
23. Edwards JH. The recognition and estimation of cyclic trends. Ann Hum Genet 1961;25:83–7.
24. Fuller WA. Introduction to statistical time series. New York, NY: John Wiley & Sons, Inc., 1996.
25. Roger JH. A significance test for cyclic trends in incidence data. Biometrika 1977;64:152–5.
26. Walter SD, Elwood JM. A test for seasonality of events with a variable population at risk. Br J Prev Soc Med 1975;29:18–21.
27. Nelson W, Tong YL, Lee J, et al. Methods for cosinor-rhythmometry. Chronobiologia 1979;6:305–23.
28. Leibson CL, Naessens JM, Brown RD, et al. Accuracy of hospital discharge abstracts for identifying strokes. Stroke 1994; 25:2348–55.
29. Birdsall SS, Florin JW. Regional landscapes of the United States and Canada. New York, NY: John Wiley & Sons, Inc., 1985:31.
30. Beattie MC, Swindle RW, Tomko LA, et al. Department of Veterans Affairs Databases Resource Guide. Version 1.0 (SDR 91–009). Washington, DC: Health Services Research & Development Service, 1992.
31. Modan B, Wagener DK. Some epidemiological aspects of stroke: mortality/morbidity trends, age, sex, race, socioeconomic status. Stroke 1992;23:1230–6.
32. May DS, Kittner SJ. Use of Medicare claims data to estimate national trends in stroke incidence, 1985–1991. Stroke 1994;25: 2343–7.
33. Ashton CM, Petersen NJ, Wray NP, et al. The Veterans Affairs Medical Care System: Hospital and clinic utilization statistics for 1994. Med Care 1998;36:793–803.