Seasonal fluctuation in the incidence of intracranial aneurysm rupture and its relationship to changing climatic conditions

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Seasonal and climatic variations have been linked to the occurrence of some types of cerebrovascular disease; however, the conditions that lead to intracranial aneurysm rupture are not known. The purpose of the present study was to determine whether seasonal and climatic conditions are related to intracranial aneurysm rupture.

Data provided by the Connecticut Health Information Management and Exchange were analyzed for all patients with a primary diagnosis of aneurysmal subarachnoid hemorrhage (SAH) for the fiscal years 1981, 1983, 1985, 1987, 1988, and 1989. Patient records were correlated with climatic conditions for the years 1981 to 1989 obtained from the National Climatic Data Center, National Oceanic and Atmospheric Administration, National Environmental Satellite Data, and Information Service.

During the time periods studied, 1487 patients with a primary diagnosis of aneurysmal SAH were treated by reporting hospitals. Seasonal variation in the incidence of aneurysmal SAH and admission clustering were observed but differed significantly between men and women. Men showed a single large peak in late fall (Roger’s r = 11.5, p < 0.005), whereas women had an annual peak occurring in late spring (Roger’s r = 10.3, p < 0.01). Substantial climatic change occurred during the 72 hours prior to 10 of the 14 clusters of men who were admitted (p < 0.01, Yates' corrected chi-square 7.33, df = 1). In contrast, clusters of women admitted were not related to preceding climatic change (p > 0.25, Yates' corrected chi-square 0.06, df = 1).

Hospital admissions for aneurysmal SAH display seasonal fluctuation, with women showing a different seasonal pattern from men. Changing climatic conditions precede aneurysm rupture in men but not in women, which suggests that weather is causally related to aneurysm rupture in men, and that factors that lead to aneurysm rupture in women may be different from those in men. These data do not explain why weather fronts or gradients are associated with aneurysm rupture in men.

KEY WORDS · subarachnoid hemorrhage · intracranial aneurysm · climate · seasonal variation · gender

INTRACRANIAL saccular aneurysms are a common occurrence; however, rupture occurs considerably less often. Autopsy studies estimate that approximately 5% of the adult population have cerebral aneurysms, whereas the average annual incidence of aneurysmal subarachnoid hemorrhage (SAH) is only 10 in 100,000 people. The conditions that favor aneurysm formation may be different from those that lead to rupture. Available evidence is consistent with the hypothesis that intracranial saccular aneurysms form when the mechanisms for arterial repair cannot compensate for pre-existing arterial weakness or ongoing arterial injury. Less is known about the conditions associated with aneurysm rupture; enzymatic injury to the aneurysm dome and rheological factors, other than simple blood pressure and hemodynamics, are potential mechanisms that may produce aneurysm rupture.

Seasonal and climatic variations have been linked to the incidence of some types of cerebrovascular disease; however, a relationship between seasons, climatic conditions, and intracranial aneurysm rupture has not been defined.

The purpose of the present study was to determine whether seasonal and climatic conditions are related to intracranial aneurysm rupture.
Clinical Material and Methods

Patient Characteristics

Data on patient characteristics provided by the Connecticut Health Information Management and Exchange (CHIME, Wallingford, Connecticut), a statewide clinical database of records submitted voluntarily by all of Connecticut's 36 acute care, nongovernmental hospitals, were analyzed for all individuals with a primary diagnosis of aneurysmal SAH (ICD-9-CM = 430) for the fiscal years 1981, 1983, 1985, 1987, 1988, and 1989. Data analyzed for each patient included length of hospital stay, admission date, number of days after admission during which the principal procedure and two secondary procedures were performed, hour of admission, patient's age, zip code, length of stay in intensive care unit and critical care unit, patient's sex, patient's temperament, admission medical service, patient's race, identity of individual or company paying for treatment, primary diagnosis and six other secondary diagnoses, primary and three secondary procedures performed, number of beds at treating hospital, service to which attending physician belonged, service to which the physician performing the first three procedures belonged, and service to which the admitting physician belonged.

Climatic Data

Hourly meteorological conditions for Bradley Field in Hartford, Connecticut for the years 1981 to 1989 were obtained from the National Climatic Data Center, National Oceanic and Atmospheric Administration, National Environmental Satellite Data, and Information Service (Asheville, North Carolina). The data analyzed included hourly ceiling height, sky conditions, visibility, weather and/or obstruction to vision, thunderstorms, tornados, squalls, rain, rain showers, freezing rain, drizzle, freezing drizzle, snow, snow pellets, ice crystals, snow showers, snow grains, sleet, hail, small hail, fog, ground fog, blowing dust, blowing sand, smoke and/or haze, dust, blowing snow, blowing spray, sea-level pressure, dewpoint temperature, wind direction, wind speed, station pressure, dry-bulb temperature, wet-bulb temperature, relative humidity, total sky cover, amount, type and height of cloud layers, and opaque sky cover.

Population Data

The national census figures reported for 1980 (3,102,816 people) and 1990 (3,226,929 people) were used to calculate the annual estimated population of the state of Connecticut for each study year using linear interpolation. These population values were used to calculate the annual incidence of aneurysmal SAH.

Statistical Analysis

Data sets were stored and merged using a relational database,* and statistical analysis and graphing were performed using computerized statistical software.†

In addition to descriptive statistics, the statistical significance of frequency data (that is, sex, annual incidence) was assessed using Yates' corrected chi-square test.

The statistical significance of cyclical fluctuations in hospital admissions for SAH was determined by applying Roger's test to the data sets after the baseline occurrence (nonseasonal, noncyclical) of aneurysmal SAH was subtracted. Raw series data (monthly incidence of aneurysmal SAH) were smoothed for the purposes of graphic presentation using a distance-weighted least-squares filter as described by McLain.65

Daily meteorological conditions were compared to daily patient admissions by calculating Pearson correlation coefficients. Statistical significance was determined by calculating and adjusting probabilities using the Bonferroni correction.

For the purposes of statistical analysis, an "admission cluster" was defined as three or more patients with the primary diagnosis of aneurysmal SAH admitted to Connecticut hospitals within a 24-hour period. A "male admission cluster," therefore, was three or more men admitted to Connecticut hospitals within a 24-hour period with the primary diagnosis of aneurysmal SAH. Climatic conditions preceding an admission cluster were compared to those expected by random chance alone using a Yates' corrected chi-square statistic.

Results

Patient Characteristics

During the time periods studied, 1487 patients with a primary diagnosis of aneurysmal SAH were treated by reporting hospitals. Women outnumbered men by a ratio of 1.7:1 (p < 0.05). The mean age for the group was 55.1 ± 17.5 years. Caucasians accounted for 84.1% of all patients, with 9.8% being Black, and only 2.5% Hispanic. More than one-third of all patients died before hospital discharge and only 38.5% were well enough to return home at the time of hospital discharge.

Seasonal Patterns

The annual incidence of SAH did not change during the decade studied (p < 0.05, mean 7.81 patients/100,000 people, range 7.67 to 8.09). There was, however, a marked seasonal variation in the incidence of aneurysmal SAH. When all patients were considered, no statistically significant seasonal fluctuation in the occurrence of intracranial aneurysm rupture was observed (Roger's r = 4.1, p > 0.01). The graph displayed in Fig. 1 left suggests the possibility of two peak periods: one in late fall and another in late spring.

Statistically significant seasonal fluctuation in the occurrence of aneurysm rupture, however, was observed when patients were considered according to sex. Seasonal patterns differed significantly between men and women suggesting that different factors may be

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† Systat software supplied by SYSTAT, Evanston, Illinois.
Subarachnoid hemorrhage and weather

![Graphs depicting the seasonal variation of aneurysmal subarachnoid hemorrhage (SAH) for all patients studied (left), for men (center), and for women (right). The points illustrate the actual number of patients per month and the line represents a distance-weighted least-squares fit. Left: Two peak periods of seasonal variation in SAH are identified. The largest peak occurred in late fall and a smaller peak occurred in late spring. Center and Right: Seasonal patterns differed significantly between men (center) and women (right), suggesting that different factors may be associated with aneurysm rupture in men than in women.](image)

associated with aneurysm rupture in each group (Fig. 1 center and right). Men had a low baseline level of admissions during most of the year, with a large increase in late fall (Roger's r = 11.5, p < 0.005). Women, on the other hand, showed an annual peak occurring in late spring (Roger's r = 10.3, p < 0.01).

Patient Clustering and Meteorological Conditions

The number of patients admitted each day was studied for a 3-year consecutive time period from August 3, 1986, through September 26, 1989. This time period was chosen because it was the largest time block of consecutive patient data available.

To determine whether daily meteorological conditions correlated with the daily hospital admissions for SAH, the number of patients admitted each day was compared to daily extremes of dry-bulb temperature, wet-bulb temperature, dewpoint temperature, relative humidity, and barometric pressure using Pearson correlation coefficients and probabilities adjusted using the Bonferroni correction. Patient admissions were also compared to daily change in dry-bulb temperature, wet-bulb temperature, dewpoint temperature, relative humidity as well as the presence or absence of thunderstorms, liquid or frozen precipitation. No correlation was found between the climatic conditions occurring on the day of hospital admission and the daily incidence of SAH admission for the entire patient group or either sex alone.

To determine whether changing meteorological conditions immediately preceded aneurysm rupture, weather conditions for 72 hours preceding an admission cluster were compared to those expected by random selection. Over the 3-year period studied, 14 "male admission clusters" were identified. A substantial climatic change, which was defined as a decrease in maximum daily dewpoint of greater than 25° or a fall in maximum daily barometric pressure of greater than 55 mm Hg within the preceding 72 hours, occurred within 72 hours of male admission clusters in 10 of the 14 clusters (Fig. 2 left and right). To add perspective to the relationship of weather to SAH in men, similar climatic changes preceded only 10 of 50 randomly selected days. The frequency with which these meteorological conditions preceded male admission clusters differed significantly from those expected by random chance alone (p < 0.01, Yates' corrected chi-square 7.33, df = 1). Preceding changes in other climatic conditions were not found to correlate with male admission clusters.

Unlike male admission clusters, "female admission clusters" were not related in a statistically significant way to a preceding climatic change. Some female admission clusters occurred on the same day as some male admission clusters, particularly when the preceding climatic change was especially severe; however, this constellation of circumstances did not occur with sufficient frequency to reach statistical significance. In all, 39 female admission clusters were identified over the 3-year study period. Using the same strict parameters to define a substantial antecedent climatic change that were applied to the group of men, changing meteorological conditions preceded only eight female admission clusters and did not differ significantly from those expected by random chance alone (p > 0.25, Yates' corrected chi-square 0.06, df = 1). Preceding changes in other climatic conditions were not found to correlate with female admission clusters.

Discussion

The influence of natural forces such as the climate on human health has been recognized for years. Although considerable attention has been given to the re-
relationship of human illness and the static characteristics 
or absolute dimensions of various meteorological 
parameters.\cite{3,6,8,10,12,14,17,23,26,27,29,31,41,43,45,52,55,60,61,67,70}
It is likely that dynamic weather fluctuations are more 
closely linked to the precipitation of human illness.\cite{4,5,7,13,14,35,43,47,54,70}
Many types of illness, particularly acute 
vascular phenomena, show clear cut seasonal fluctua-
tions. In these situations the possibility that any ob-
served association with static weather conditions is 
merely an epiphemomenon, as both cycle in a seasonal 
fashion, cannot be excluded.

Little attention has been devoted to the seasonality and 
meteorological conditions associated with aneu-
rysmal SAH. Aneurysmal SAH is a particularly dev-
astating illness that usually occurs without warning.\cite{18}
The ability to identify factors that are associated with 
aeurysm rupture may lead to preventive strategies. 
Several small studies\cite{3,5,47,60} failed to identify seasonal 
change in the incidence of subarachnoid hemorrhage; 
however, when larger patient groups were considered 
a clear seasonal pattern emerges.\cite{29,35} A seasonal vari-
ation in the incidence of aneurysmal SAH was also 
found in this study.

In the present study, seasonal patterns of SAH dif-
served significantly between men and women, suggest-
ing that different factors may be associated with aneu-
rysm rupture in men than in women. Men had a low 
baseline level of admissions during most of the year 
with a large increase in late fall, whereas women 
showed an annual peak occurring in late spring. In ad-
dition to seasonal variations, patient admissions 
appeared to cluster on certain days.

To explore the possibility that climatic conditions 
were associated with fluctuations in the daily incidence 
of aneurysmal SAH, meteorological conditions were 
correlated with SAH admissions. Although immediate 
meteorological conditions did not correlate with the 
ocurrence of SAH climatic changes occurring during the 
3 days before admission were well correlated. Clusters 
of admissions for SAH composed of men were pre-
ceded by a significant climatic change either in the form 
of precipitation, falling barometric pressure, dropping 
dewpoint temperature, or a combination of these fac-
tors. Unlike men, clusters of women were not related 
to preceding climatic change.

Weather fronts or gradients are known to precede 
other types of acute vascular illnesses.\cite{4,5,7,13,14,35,43,47,48,54,70}
To our knowledge, the hypothesis that aneu-
rysmal SAH may also be related to weather in this fashion 
was first proposed by TM Sundt Jr. (personal com-
muunication, 1983), who observed clustering of deaths due 
to SAH after the first heavy snow each year in Rochester, 
Minnesota.

The temporal relationship of weather change to 
admission for aneurysmal SAH in men found in this 
study is consistent with a causal relationship. Cold 
temperatures are known to increase blood pressure,\cite{1,2, 
8,10,11,26,27,36,39,43,68}
increase blood viscosity,\cite{40} and alter 
band coagulation.\cite{13,25,28,62,68} The full physiological and 
biochemical effects of passing weather fronts or gra-
dients, however, are not known. Hypertension and in-
creased viscosity may produce mechanical damage 
to the aneurysm wall and altered coagulation factors 
may lead to enzymatic damage. These conditions 
are all thought to be associated with aneurysmal 
SAH.\cite{20,22,24,32,34,49,57,62,63}

Alternatively, weather may be linked to aneurysmal 
SAH less directly. Changing climatic conditions may 
alter behavior patterns in men or provoke illnesses that 
eventually lead to SAH.\cite{12,31}

The data collected for this study link changing cli-
matic conditions to aneurysm rupture in men and 
indicate that at least some factors that lead to aneurysm 
rupture in men affect women differently. The data pre-
sented here, however, do not explain why weather 
fronts or gradients, particularly during the blustery last 
few months of the year, are associated with aneurysm 
rupture in men.
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