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Prediction of the incidence of spontaneous intracerebral hemorrhage from meteorological data

Hiroshi Nakaguchi · Akira Matsuno · Akira Teraoka

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Abstract We analyzed the relationship between the incidence of spontaneous intracerebral hemorrhage (ICH) and various meteorological data (daily atmospheric air pressure, air temperature, precipitation, humidity, presence of typhoons, occurrence of the rainy season, wind velocity, and wind direction) for patients at Teraoka Memorial Hospital in Shin-ichi Town, Japan, from January 1, 2001 to December 31, 2003. All data were analyzed by contingency table analysis and multivariate regression analysis. From January 1, 2002 to December 31, 2003, we identified high-risk ICH days as those days for which the preceding 3 days mean recorded air pressure of 1,015 hPa or more and then conducted a statistical comparison of the incidence of ICH on high-risk ICH days with that on the other days. Our subjects were 164 patients with ICH. The relative risk of high-risk ICH days is 1.46 (Fisher's exact test, p=0.04). Mann–Whitney's *U*-tests indicate ICH tends to occur on days with lower maximum air temperature. Multivariate logistic regression analysis revealed that 3 incidences influence the occurrence of intracerebral hemorrhage (p<0.01 each): (1) days associated with 4-day periods of mean air pressure in excess of 1,015 hPa; (2) days during which a typhoon was approaching; and (3) days with west or southwest wind . Detailed examination of meteorological data indicates a relationship with the incident rate of ICH.

H. Nakaguchi (✉) · A. Matsuno
Department of Neurosurgery,
Teikyo University Chiba Medical Center,
3426-3 Anesaki Ichihara, Japan
e-mail: hnakaguchi@hi-ho.ne.jp

A. Teraoka
Department of Neurosurgery, Teraoka Memorial Hospital,
37 Shinichi,
Fukuyama, Japan

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Introduction

Meteorological data, including weather, atmospheric air pressure, and ambient temperature, are important for our social, economic and daily lives, and affect human activities in terms of restricting out-door activities, influencing traffic volumes, volume of crops, and generating expenses for the prevention of meteorological disasters and repair following such disasters. In addition, meteorological factors directly influence human health. For example, it is well known that the incidence of spontaneoous intracerebral hemorrhage (ICH) tends to increase during colder temperatures and during winter in temperate zones (Azevedo et al. 1995; Biller et al. 1988; Capon et al. 1992; Gill et al. 1988; Hannan et al. 2001; Inagawa et al. 2000; Jakovljevic et al. 1996; Khan et al. 2005; Nakaji et al. 2004; Ohwaki et al. 2004; Passero et al. 2000; Ramirez-Lassepas et al. 1980; Suzuki et al. 1987; Tsementzis et al. 1991; and Wang et al. 2002, 2003). Although the MONICA project (Danet et al. 1999) displayed that, for atmospheric pressure, a V-shaped relationship was detected, with a minimum of daily myocardial infarction and coronary deaths rates at 1,016 hPa, our experience prior to this study and some former reports (Capon et al. 1992; Gill et al. 1988; Wang et al. 2002, 2003; and Chen et al. 1995) indicated that ICH occurs frequently on days with higher air pressure and that cerebral infarction occurs frequently on days with lower air pressure.

There are many other meteorological factors, including influence of typhoons, the Japanese rainy season, and wind direction. Typhoons strike Japan about 11 times a year on average and provide the potential for disaster involving violent damage to property and danger to people. The relatively low mean air pressure and high air temperature on such days may act to reduce the occurrence of ICH. With an approaching typhoon, people may also stay indoors and cancel events and outdoor activities.

A stationary front occurs to the southeast of Japan from the middle of June until the beginning of July. This front leads to the Japanese rainy season, which is named 'Baiu' from ancient times. Baiu means cherry rain in Japanese because Japanese cherries ripen during this season. We thought that lower air pressure which often occurs over the Japanese Archipelago and moderate low air temperature during this season might induce the incidence of ICH to be averaged.

Wind tends to be dominantly from the west during winter in Japan. This wind pattern occurs because wintertime high air pressure generated on the Asian continent develops to the west of Japan and low atmospheric pressure develops to the east of Japan over the Pacific Ocean.

After due consideration of above mentioned viewpoints, we had expected that on the days with lower air temperature or higher air pressure or westerly wind, ICH might occur more frequently than on the other days, while on the days with lower air pressure or higher air temperature or typhoon approaching days, ICH might occur less frequently than on the other days.

We use multivariate analysis to investigate the influence on ICH of meteorological factors in a local area in Japan, in which population movement is small and which experiences four distinct seasons in a temperate monsoon region.

Materials and methods

In Japan, meteorological data, such as the distribution of atmospheric pressure, maximum and minimum air temperature, humidity, precipitation, morning and afternoon weather, wind velocity, and wind direction, are presented for every major city by the Japanese Meteorological agency. We obtained the daily meteorological data detailed above for Shin-ichi town for the period January 1, 2001 until December 31, 2003. For this period, we also acquired data from all patients with ICH who were admitted to or visited outpatient clinics at Teraoka Memorial Hospital, and these data were then statistically compared. On admission, computed tomography (CT) scans were performed on those patients with acute onset of neurological defects who were suspected of suffering from ICH. If ICH due to arterio-venous malformation, Moyamoya Disease, or cerebral aneurysms was suspected on initial CT scans or from past histories of the patients, we then performed magnetic resonance imaging and angiogram, computed tomography angiogram, or digital subtraction angiogram studies. We did not consider ICH with arterio-venous malformation, cerebral aneurysms, brain tumor, Moyamoya disease, or head injury. For cases who awoke with a deficit in the morning, onset time was defined as 0600 hours (Japanese local standard time). Shin-ichi Town is situated at the west edge of the Fukuyama Basin, which is surrounded by mountains. Although there are two other hospitals in this area, they do not have neurosurgeons or neurophysicians on staff, and Teraoka Memorial Hospital has an arrangement with these hospitals that all patients with ICH are transferred to Teraoka Memorial Hospital at the acute stage of ICH. Therefore, we consider that almost all patients with ICH and certain neurological deficits who were living within the west part of the Fukuyama Basin area would have visited Teraoka Memorial Hospital.

Daily humidity, precipitation, wind velocity and wind direction for Hiroshima City, the nearest observation platform to Shin-ichi Town for which the Japanese Meteorological Agency records these data, is published by the Japanese Meteorological Agency in the meteorological almanac. A typhoon is defined as a tropical cyclone in which the maximum central wind velocity is 17.2 m/s or more and which originate in the northwest Pacific Ocean or South China Sea and assault the Asian Continent, the Philippine islands, and Japan. On the basis of meteorological charts for 0900 hours, days of approaching typhoons are defined as those days on which a typhoon is within 1,000 km of Shin-ichi Town.

Considering that the mean air pressure and mean air temperature were 1,015 hPa and 20°C and the Fisher's exact test indicated that *p*-values for the incidence of ICH were the lowest on the days with maximum air temperature less than 17°C and on the days with mean air pressure more than 1,015 hPa at Shin-ichi Town during 2001, days with a high risk of ICH are defined as those days that were preceded by 3 days of mean air pressure in excess of 1,015 hPa (type A high risk ICH days) and days that were preceded by 3 days of mean air temperature of less than 17°C (type B high risk ICH days); these high-risk days were compared to the other days by division table analysis (prospective study).

For statistical analysis of the data, we undertook Mann–Whitney's *U*-tests (to analyze relationships between occurrence and nonoccurrence of ICH for each continuous variable including maximum and minimum air temperature, mean air pressure, mean wind velocity, and average humidity), Pearson's linear regression analysis (to investigate the correlation between two continuous variables including air temperature and air pressure), Fisher's exact test or chi square test (to investigate relationships between occurrence of ICH and alternative meteorological and carendrical factors by means of two by two contingency table analysis) and multivariate logistic regression analysis (mentioned below in detail) using GraphPad Instat 3 software (GraphPad Software) and StatView 4.11 software

(SAS Institute). Relative risks (RR) of ICH, with 95% confidence intervals (95% C.I.) determined using the Katz approximation, were calculated from contingency tables for each meteorological factor (maximum air temperature, minimum air temperature, atmospheric air pressure, daily averaged humidity, precipitation, daily mean velocity of wind, typhoon approaching days, Baiu and each season). All *p*-values are two-sided. To investigate the association between various meteorological factors and the incidence of ICH and to generate odds ratios as an estimate of relative risk, we used multiple logistic-regression techniques, with the occurence of ICH as the dependent variable. The independent variables are the meteorological factors including the maximum air temperature of the day, maximum air temperature of the day before, days of maximum temperature under 17°C, days of maximum air temperature of the day before under 17°C, days associated with 4-day periods of mean air maximum temperature under 17°C that begin 3 days prior to the day of interest, the minimum air temperature of the day, the atmospheric air pressure of the day, the atmospheric air pressure of the day before, days associated with 4-day periods of mean air pressure in excess of 1,015 hPa that begin 3 days prior to the day of interest, daily mean velocity of wind, west and south-west winds, south wind, daily averaged humidity, precipitation, typhoon approaching days, Baiu (the Japanese rainy season), seasons (winter and spring), the day of the week, and national holidays including the day of the week and national holiday.

To investigate the relationship between the diurnal fluctuation of air temperature, air pressure and the incidence of ICH, we found the remainder from maximum air temperature to minimum air temperature, difference between maximum air temperature (or mean air pressure) on the occurrence day, and maximum air temperature (or mean air pressure) on the day before (or on the following day), and statistically analyzed the relationship between the incidence of ICH and those factors (by means of contingency table analyses and logistic regression analyses). However, there was no statistically significant difference (*p*-value >0.05 each).

Results

One hundred and sixty four patients with ICH were enrolled in our study. Table 1 lists differences in various meteorological data and the incidence rate of ICH and Table 2 lists a contingency table analysis of meteorological data and the occurrence of ICH. The background population of Teraoka Memorial Hospital, as calculated from the national census of 2000, is approximately 72,000, and the population based incident rate of ICH is 76/100.000/year.

For the 2 years of the prospective study, the percentage of days with occurrence of ICH to supposed high risk days were 18.0% for type A (RR of type A was 1.46 and 95% C.I. was 1.03~2.07, and the percentage of days with occurrence of ICH to non-high risk days was 12.3%), 18.4% for type B (RR was 1.37 and 95% C.I. was 0.98~1.92, and the percentage of days with occurrence of ICH to non-high risk days was 13.4%), and 18.3% for type A and B (RR was 1.32 and 95% C.I. was 0.93~1.85, and the percentage of days with occurrence of ICH to non-high risk days was 13.9%). A Fisher's exact test proved a significant difference for type A (p=0.041), but not for type B, and for type A and B (p=0.076, 0.132).

Air pressure was strikingly in inverse proportion to maximum air temperature. The equation is

$$MMT = -1.496MAP + 1539.755;\ R = 0.892,\ p < 0.0001 \quad (1)$$

where MMT=mean monthly maximum air temperature, MAP=mean monthly air pressure, and the coefficient of correlation (R) and the p-value were calculated by Pearson's linear regression analysis.

R.R. of ICH each month is in inverse proportion to the mean maximum air temperature. The equation is

$$MRR = -0.021MMT + 1.411;\ R = 0.587,\ p = 0.0449 \quad (2)$$

where MRR=monthly relative risk, MMT=mean monthly maximum air temperature, and the coefficient of correlation (R) and the p-value were calculated by Pearson's linear regression analysis.

Mann–Whitney *U*-tests indicate statistically significant differences between the days with occurrence of ICH and those without occurrence of ICH for maximum air temperature (p=0.01), maximum air temperature of the day before (p =0.04), mean maximum air temperature for the 2 days (or 3 days) before the day of interest (p=0.04 or 0.03), and minimum air temperature (p=0.01).

Average humidity and precipitation do not show any correlation with air pressure, air temperature, or incidence of ICH.

During a westerly wind, wind velocity tended to be strong (Mann–Whitney *U*-tests, p<0.0001). ICH occurred more frequently during west and southwest winds (Fisher's exact test, p=0.0391). The wind tended to blow more from the south-west from May until August and from the west from November until January (Fisher's exact test, p<0.0001, each). From May to August, ICH occurred more frequently during a southwest wind (chi square test, p=0.0375) and on days with air pressure of 10,15 or more (Fisher's exact test, p=0.0229). Winds from the west and southwest dominated on days with maximum air temperature less than 17°C (Fisher's exact test, p=0.0058).

Table 1 Meteorological categories, characteristics, and relative risk of hypertensive intracerebral hemorrhage. Significant coefficients (p <0.05) are shown in bold. *RR*: relative risk of hypertensive intracerebral hemorrhage

	Mean maximum air temperature (°C) (SD)	Mean minimum air temperature (°C) (SD)	Mean air pressure (hPa) (SD)	Mean daily average humidity (%) (SD)	Mean precipitation (mm) (SD)	Mean wind velocity (m/s) (SD)	Dominant wind direction	Case / day number	RR	95% C.I. (Fisher's exact test *p*-value)
Weather										
Fine or fair	21.8 (8.5)	12.5 (8.9)	1,016.8 (7.2)	63.5 (8.1)	2.5 (7.7)	7.7 (1.6)	N	60 / 423	0.9	0.68~1.23 (0.60)
Cloudy	20.6 (7.9)	12.7 (8.3)	1,015.7 (6.6)	69.0 (9.9)	2.2 (6.0)	7.4 (1.8)	N	68 /417	1.2	0.89~1.61(0.27)
Rainy	18.9 (7.6)	13.8 (8.1)	1,012.5 (6.4)	79.2 (10.8)	14.5 (19.5)	7.8 (2.6)	N	30 /228	0.86	0.62~1.18 (0.40)
Snow	6.3 (1.8)	0.5 (1.5)	1,019.0 (5.2)	70.9 (8.1)	1.7 (3.6)	8.4 (2.3)	W	6 / 26	1.53	0.74~3.14 (0.27)
Wind direction										
North	19.1 (7.5)	11.0 (7.5)	1,017.1 (7.2)	68.1 (11.1)	3.6 (10.4)	7.6 (1.7)		102 /699	0.95	0.71~1.27 (0.73)
Northeast	20.3 (8.9)	13.3 (3.1)	1,015.1 (9.2)	62.0 (9.7)	1.7 (5.0)	7.1 (1.8)		1 / 9	0.75	0.12~4.80 (1.00)
East	27.7 (10.1)	21.4 (9.5)	1,011.9 (7.6)	65.9 (11.1)	2.6 (6.4)	7.4 (1.5)		0 / 7	0	-~- (0.60)
Southeast	30.7 (5.5)	24.9 (0.8)	1,009.3 (3.1)	73.7 (17.5)	20.7 (35.8)	7.7 (1.7)		0/3	0	-~- (1.00)
South	27.1 (5.9)	20.0 (7.2)	1,011.4 (5.1)	72.9 (10.9)	7.0 (15.8)	7.4 (2.4)		20 / 170	0.76	0.49~1.19 (0.24)
Southwest	25.1 (7.9)	17.7 (8.2)	1,013.0 (5.3)	71.2 (10.1)	3.3 (7.8)	6.5 (1.6)		20 /108	1.25	0.82~1.92 (0.32)
West	11.7 (6.3)	4.6 (5.7)	1,015.0 (5.6)	66.3 (10.0)	3.0 (9.6)	9.5 (2.2)		20 / 90	1.49	0.98~2.26 (0.09)
Northwest	15.6 (6.8)	8.9 (7.2)	1,010.4 (3.3)	73.3 (7.8)	8.8 (10.2)	9.3 (2.5)		1 / 9	0.68	0.10~4.37 (1.00)
Seasons										
Spring (March~May)	19.2 (5.1)	10.5 (5.3)	1,015.3 (6.4)	64.7 (13.3)	4.6 (11.3)	7.7 (2.0)	N	51 / 276	1.34	0.99~1.81 (0.07)
Summer (June~August)	29.6 (3.4)	22.9 (3.1)	1,009.0 (4.1)	72.5 (10.3)	6.5 (14.6)	7.1 (2.2)	S	32 / 276	0.73	0.51~1.04 (0.08)
Autumn (September~November)	22.6 (5.9)	14.2 (6.1)	1,017.1 (5.6)	68.5 (9.4)	3.6 (11.5)	7.8 (1.8)	N	33 / 273	0.76	0.53~1.09 (0.14)
Winter (December~February)	10.1 (3.1)	2.6 (2.8)	1,020.7 (5.8)	70.4 (8.9)	1.9 (4.7)	7.9 (1.7)	N	48 / 270	1.25	0.92~1.70 (0.17)
Typhoon										
Approaching days	27.9 (5.4)	20.4 (5.6)	1,011.7 (5.9)	68.9 (10.5)	4.4 (11.2)	7.9 (2.4)	N	15 / 208	0.44	0.26~0.73 (0.0005)
The other days	18.6 (7.9)	10.8 (8.1)	1,016.4 (6.9)	69.0 (11.2)	4.1 (11.3)	7.6 (1.8)	N	149 / 887	2.29	1.37~3.80 (0.0005)
Baiu (Japanese rainyseason)	27.7 (3.0)	21.9 (2.4)	1,008.2 (3.8)	77.4 (9.9)	10.4 (18.6)	6.9 (2.4)	S	21 / 138	1.02	0.67~1.56 (0.90)
Other days	19.4 (8.3)	11.3 (8.3)	1,016.6 (6.7)	67.8 (10.7)	3.2 (9.4)	7.7 (1.9)	N	143 / 957	0.98	0.64~1.50 (0.90)
Average or total number	20.3 (8.3)	12.6 (8.6)	1,015.5 (7.0)	69.0 (11.2)	4.2 (11.3)	7.6 (1.9)		164 / 1,095		

Table 2 Contingency table analysis of meteorological data and the occurrence of ICH

	ICH(+)	ICH(−)	Total	RR	95% C.I. (Fisher's exact test *p*-value)
Days of maximum temperature					
Under 17°C	79	344	423	1.51	1.14~2.01 (0.005)
More than 17°C	85	604	689	0.66	0.50~0.88 (0.005)
Days of maximum air temperature of the day before					
Under 17°C	75	346	421	1.38	1.04~1.83 (0.029)
More than 17°C	89	602	691	0.72	0.55~0.96 (0.03)
Days associated with 4-day periods of mean air maximum temperature					
Under 17°C that begin 3 days prior to the day of interest	78	348	426	1.46	1.10~1.94 (0.009)
More than 17°C	86	600	686	0.68	0.52~0.91 (0.009)
Days of minimum temperature					
Under 11°C	89	419	508	1.41	1.06~1.87 (0.018)
More than 11°C	75	529	604	0.71	0.53~0.94 (0.018)
Days of air pressure					
In excess of 1,015 hPa	96	460	556	1.41	1.06~1.88 (0.022)
Less than 1,015	68	488	556	0.71	0.53~0.94 (0.022)
Days associated with 4-day periods of mean air pressure					
In excess of 1,015 hPa that begin 3 days prior to the day of interest	108	512	620	1.53	1.13~2.07 (0.005)
Less than 1015 hPa	56	436	492	0.65	0.48~0.88 (0.005)
Days with west or southwest wind	40	166	206	1.42	1.03~1.96 (0.039)
Other days	124	782	906	0.7	0.51~0.97 (0.039)
Summer and autumn	65	489	554	0.66	0.49~0.88 (0.005)
Winter and spring	99	459	558	1.51	1.13~2.02 (0.005)
Total	164	948	1,112 (1,095 days)		

On days during which a typhoon was approaching, the incidence of ICH tended to be markedly low (Table 2). On these days, air pressure tended to be below 1012 hPa and maximum air temperature tended to be 17°C or over (Fisher's exact test, $p<0.0001$, each).

During the Japanese rainy season, mean air pressure was prominently low (mean air pressure was 1,008.2 hPa, SD=3.8, mean maximum air temperature was 27.7°C, SD=3.0), as a stationary front is situated on the northeast of the Pacific Ocean, and all the Japanese archipelago is covered by low pressure areas. During this period, the incident rate of ICH was average (RR=1.0), air pressure was less than 1,012 hPa, and maximum air temperature was more than 17°C (Fisher's exact test, $p<0.0001$).

In terms of the seasons, ICH tended to occur in spring and winter (chi square test, $p=0.044$). Days with maximum air temperature of more than 20.33°C (yearly mean value) included 46.55% of the days in spring, 100% in summer, 61.96% in autumn, and 0% in winter ($p<0.0001$), while days with air pressure of more than 10,15.54 hPa (yearly mean value) included 25.84% of the days in spring, 1.12% in summer, 30.11% in autumn, and 83.39% in winter ($p<0.0001$). Fair days were more frequent in autumn (50.73% vs all 38.58%, Fisher's exact test, $p<0.0001$) and cloudy days were more common in spring and rare in autumn ($p=0.0112$).

In terms of day of the week, the relative risk of ICH was relatively low on Sunday and high on Saturday. But there were no statistically significant difference between day of the week and the incidence of ICH (chi-square test and Fisher's exact test, $p>0.05$).

The results of analyses using the forward stepwise method of multivariate logistic-regression are shown in Table 3. Among independent variables including the maximum air temperature of the day, maximum air temperature of the day

Table 3 Multivariate logistic regression analysis of the incidence rate of ICH and meteorological variables

	Adjusted OR	95%	CI *p*-value
Days associated with 4-day periods of mean air pressure in excess of 1,015 hPa that begin 3 days prior to the day of interest	1.45	1.01–2.07	0.0416
Days during which a typhoon was approaching	0.44	0.25–0.78	0.0048
Days with west or southwest winds	1.53	1.03–2.28	0.035

before, days of maximum temperature under 17°C, days of maximum air temperature of the day before under 17°C, days associated with 4-day periods of mean air maximum temperature under 17°C that begin 3 days prior to the day of interest, the minimum air temperature of the day, the atmospheric air pressure of the day, the atmospheric air pressure of the day before, days associated with 4-day periods of mean air pressure in excess of 1,015 hPa that begin 3 days prior to the day of interest, daily mean velocity of wind, west and south-west winds, south wind, daily averaged humidity, precipitation, typhoon approaching days, Baiu (the Japanese rainy season), seasons (winter and spring), the day of the week, national holidays the day of the week and national holiday, we could find these three factors to be statistically significant (Table 3).

Discussion

In this study, we demonstrated a correlation between various meteorological factors such as air temperature, air pressure, approaching typhoon, and wind direction and a high incidence of ICH in Japan. Although this relationship is not considered to be useful in forecasting days with a higher incidence of ICH because they were induced mainly from retrospective data, we can identify in advance those days that are likely to have a high risk of ICH in Japan. We stress the proposal that in order to minimize the incidence of ICH on these days, a warning should especially be given to those who are candidates for apoplexy with risk factors of arteriosclerosis.

Relationship between air pressure and the incidence of ICH

Various reports have tried to demonstrate a relationship between air pressure and the incidence of ICH (Capon et al. 1992; Gill et al. 1988; Wang et al. 2002, 2003; and Chen et al. 1995). The incidence of ICH in the study area tends to be high when air pressure is above the yearly mean value (1,015 hPa) for two-three days preceding the day of interest or is high on the day of interest. Chen et al. (1995) classified air pressure into higher (1,022 or more), middle (1,022–1,008), and lower (1,008 or less) pressure days, and reported that the daily occurrence of ICH was significantly higher on higher pressure days compared with lower pressure days. However, in both their report and ours, regression analysis of air pressure shows no significant effect on the occurrence of ICH. This is interpreted to occur because under a gradual increase of pressure people acclimatize to the air pressure, and increased blood pressure and tensed sympathetic nerves are normalized.

Under higher air pressure, peripheral vessels at the body surface are compressed and constricted causing high systolic blood pressure, heart load increase, and the stimulation of sympathetic nerves. In addition, during high air pressure, oxygen saturation can increase and activate both mind and body to engage in excessive activity, including physical exercise. Higher air pressure is therefore considered to raise the incidence of ICH by direct or indirect effects. In contrast, during low pressure the enlarged floor of peripheral vessels causes engorgement in the peripheral tissue; the solubility of oxygen or carbon dioxide decreases. As extended peripheral vessels cause systemic hypotension during times of low air pressure, we consider that the incidence of ICH may decrease at this time.

Relationship between air temperature and the incidence of ICH

Numerous reports demonstrate that in temperate or subtropical zones, ICH shows a negative correlation with ambient temperature (Biller et al. 1988; Jakovljevic et al. 1996; Passero et al. 2000; Tsementzis et al. 1991; Gallerani et al. 1994; Shinkawa et al. 1990). This relationship is generally explained as resulting from the fact that colder air temperature induces the constriction of peripheral arteries in the body surface; this in turn leads to an increase in systemic blood pressure (Brennan et al. 1982). Temperature related to it may produce cerebral stroke by changing other internal conditions such as blood viscosity and blood coagulability; platelet and erythrocyte counts, blood viscosity, and catecholamine secretion increase with decreasing temperature (Keatings et al. 1984). Concentrations of clotting factor VII, antithrombin III, and cholesterol decrease with decreasing temperature, while fibrinolytic activity increases (Bull et al. 1979).

In the current study, the maximum and minimum air temperature show an inverse correlation with the occurrence of ICH, especially if the maximum air temperature is less than 17°C, where a high incidence of ICH is observed. In addition, the mean air temperature for the two-three days prior to onset shows a significant correlation with the incidence of ICH. In addition to the trends described above, lower ambient temperature increases air pressure and causes stress on the body surface; this leads to compression of the peripheral vessels and a high incidence of ICH.

In the present study, we found no correlation between diurnal fluctuation, ambient temperature or air pressure change after or before the onset and occurrence of ICH. A study in Hisayama Town (Shinkawa et al. 1990) shows that sharp fluctuations in air temperature lead to a high incidence rate of ICH; this result is mainly due to the fact that the subject consisted of a small population (1621) and patients with ICH numbered only 51 over a 24-year period. Ohwaki et al. (2004) reported that days on which ICH occurred had a minimum temperature that was less than the previous day. We consider that the finding of Ohwaki et al. reflects their biased subjects, which consisted mostly of comatose patients on admission.

In our study, Mann-Whitney's U-tests indicate ICH tends to occur on days with lower maximum air temperature (p= 0.01). In contrast to air pressure, under low ambient temperature people may fail to acclimatize to the air temperature; increased blood pressure and tensed sympathetic nerve therefore persists. This occurs because under cold conditions, acclimation to the lower air temperature and enlargement of the peripheral vessels may result in cold damage to peripheral tissue, especially on extremities; this induces a life-threatening decrease in systemic body temperature.

Wind direction and wind velocity

ICH tends to occur more frequently on days with a west or southwest wind. In our study, wind was predominantly from the west during winter and from the southwest from May to August. From May to August, in the southwest wind, air temperature tended to be lower in our study. ICH is therefore considered to occur more frequently in a west or southwest wind than other wind directions.

Days during which a typhoon is approaching

On days during which a typhoon is approaching, the incidence of ICH is extremely low. One of the interesting results of this study is that we can clearly prove that a meteorological factor (the approach of a typhoon) has a negative influence on the occurrence of a disease.

Lastly, as these analyses were performed in a local area of Japan situated in the temperate zone with an oceanic monsoon climate, and considering the variety of weather patterns throughout the world, applying our results to other areas of the world contains a degree of uncertainty. However, this study provides an interesting example of the way in which climate influences susceptibility to seasonal disease.

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