Original Article

The relationship between ischemic stroke and weather conditions in Duzce, Turkey

Harun Gunes¹, Hayati Kandis¹, Ayhan Saritas¹, Suber Dikici², Ramazan Buyukkaya³

¹ Department of Emergency Medicine, Duzce University School of Medicine, Duzce, Turkey

² Department of Neurology, Duzce University School of Medicine, Duzce, Turkey

³ Department of Radiology, Duzce University School of Medicine, Duzce, Turkey

Corresponding Author: Harun Gunes, Email: haroonsun@hotmail.com

BACKGROUND: Weather conditions are thought to increase the risk of stroke occurrence. But their mechanism has not yet been clarified. We investigated possible relationships between ischemic stroke and weather conditions including atmospheric pressure, temperature, relative humidity, and wind speed.

METHODS: One hundred and twenty-eight patients with ischemic stroke who had been admitted to our hospital between January 1 and December 31, 2010 were enrolled in this study. We investigated the relationship between daily cases and weather conditions the same day or 1, 2, and 3 days before stroke.

RESULTS: A negative correlation was found between maximum wind speed and daily cases 3 days before stroke. As the relationship between daily cases and changes of weather conditions in consecutive days was evaluated, a negative correlation was found between daily cases and change of atmospheric pressure in the last 24 hours.

CONCLUSIONS: The maximum wind speed 3 days before stroke and change of atmospheric pressure in the last 24 hours were found to increase the cases of ischemic stroke. We recommend that individuals at risk of ischemic stroke should pay more attention to preventive measures, especially on days with low maximum wind speed, on subsequent 3 days, and on days with low atmospheric pressure in the last 24 hours.

KEY WORDS: Weather conditions; Ischemic stroke; Turkey

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INTRODUCTION

It has been reported that weather conditions may increase the risk of stroke occurrence.^[1] Well-known risk factors of ischemic stroke (IS) such as age, gender, genetic factors, and diseases like hypertension, diabetes mellitus, and heart disease cannot change day-by-day, thus weather conditions are thought to be the causative factors triggering stroke events.^[2]

Weather conditions cause some physiologic changes. For example, blood pressure, erythrocyte and thrombocyte counts, and blood viscosity are increased in cold weather.^[3] Plasma fibrinogen concentration is higher in older patients especially in cold weather.^[4] An increase of body temperature

is associated with increased levels of coagulation factors.^[5] The existing theory suggests that changes in atmospheric pressure may exert stress on atherosclerotic plaque, resulting in rupture of the plaque.^[6]

This study was conducted because there are four seasons and different weather conditions every year in Turkey. We evaluated the possible relationships between IS occurrence and weather conditions such as atmospheric pressure, weather temperature, relative humidity, and wind speed.

METHODS

The patients in our study retrieved the computerized

archival system of our hospital. Name, gender, file number, complaints on admission, history of complaints, medical history, results of physical examination, results of laboratory tests, and results of imagings including computed tomography (CT) and magnetic resonance imaging (MRI), treatments, in-hospital and out-patient follow-up, and diagnoses of patients were reviewed. Print versions of the files of the patients in our hospital's archive were also reviewed.

A total of 321 patients with cerebrovascular disease (International Classification of Diseases 10 diagnosis codes: G46, G46.8, I63.9, I66.3, I67, I67.8, I67.9, I69, I69.8) were retrieved using the computerized archival system in our hospital between January 1 and December 31, 2010. We reviewed both computerized records and archival files of the 321 patients retrospectively. Patients who were diagnosed with cerebrovascular disease due to hemorrhagic stroke, transient ischemic attack or stroke history, and those who were diagnosed with IS because of changes of consciousness on admission induced by hypoglycemia, septic shock, and intoxication were excluded. At last, 132 patients with IS were found. They were subjected to CT and/or MRI, and reports were written by a radiologist. Symptom onset time for each patient was taken from files of the patients. Four patients were excluded from the study because the exact time of their symptom onset was not known. The remaining 128 patients were found to meet the inclusion criteria for IS. Daily cases were determined on the day when patients started to complain.

Patient age, sex, hospitalization period, systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, pulse rate, white blood cell count, hemoglobin, hematocrit, platelet count, serum glucose, urea, creatinine, Na^+ , K^+ , and Cl^- values were obtained using the computerized archival system.

The maximum, minimum, and mean values of daily atmospheric pressure, weather temperature, and relative humidity, and daily maximum wind speed in Duzce between January 1 and December 31, 2010 were obtained from the Turkish State Meteorological Service.

The relationship was determined between daily cases and the following conditions: (1) daily weather conditions of the days in which patients began to complain; (2) weather conditions of 1, 2, and 3 days before the day in which patients began to complain; (3) changes in weather conditions in a day up to 3 days before the day in which patients began to complain; (4) changes in weather conditions in consecutive days up to 72 hours before the day in which patients began to complain.

The data of this study are shown in Tables 1–3. One-way variance analysis (ANOVA) was used to determine the relationship between daily cases and daily weather conditions. Sidac and LSD tests were used in post-hoc analysis by which a significant relationship was found with ANOVA analysis. SPSS version 18.0 for Windows was used for statistical analysis, and $P < 0.05$ was considered statistically significant. This study was approved by the local ethics committee.

RESULTS

Fifty-nine (46.1%) of our patients were male, and their mean age was 72 ± 10 years. Descriptive features of our patients are shown in Table 1. No significant relationship was found between daily cases and mean atmospheric pressure, air temperature, relative humidity and maximum wind speed in the same day ($P = 0.441$; $P = 0.942$; $P = 0.615$; $P = 0.617$, respectively).

There was a relationship between daily case numbers and weather conditions of the day and 1, 2, and 3 days before the event. But a significant relationship was found between daily case numbers and maximum wind speed 3 days ago ($P = 0.048$). Post-hoc analysis with LSD test revealed that if the maximum wind speed 3 days ago was low, the risk of IS increased markedly ($P = 0.015$) (Table 2) (Figure 1).

No significant relationship was found between daily cases and change of weather conditions in a day ($P > 0.05$). While evaluating the relationship between daily cases and change of weather conditions in consecutive days, we found a significant relationship between case numbers and change of atmospheric pressure in the last 24 hours ($P = 0.019$). Post-hoc analysis using Sidak test showed that change of lower pressure in the last 24 hours increased the possibility of IS occurrence ($P = 0.048$) (Table 3, Figure 2).

Figure 1. Maximum wind speed (Mx. Wn. S.) 3 days before the occurrence of stroke. LSD test in post-hoc analysis revealed a significant difference between days with no patient and days with 2 patients ($P = 0.015$).

Table 1. Demographic characteristics, hospital stay, blood pressure, complete blood count, and biochemical parameters of the patients

Variables	Mean±standard deviation	Minimum	Maximum
Age (years)			
All patients	72±10	38	94
Male patients	70±10	47	87
Female patients	74±10	38	94
Hospitalization period (days)	10±14	0	119
Systolic blood pressure (mmHg)	157±32	90	290
Diastolic blood pressure (mmHg)	88±20	49	160
Mean arterial pressure (mmHg)	111±22	63	190
Pulse rate (beats/minute)	87±21	50	170
White blood cell count (/μL)	9 133±3 971	1 160	26 900
Hemoglobin (mg/dL)	12.9±1.7	7.2	19.0
Hematocrit (%)	38±5	25	55
Platelet count (/μL)	247 559±80 288	92 600	583 000
Glucose (mg/dL)	148±54	75	342
Urea (mg/dL)	47±25	19	172
Creatinine (mg/dL)	1.08±0.78	0.40	8.29
Na ⁺ (mEq/L)	138±4	124	166
K ⁺ (mEq/L)	4.2±0.6	2.6	7.0
Cl ⁻ (mEq/L)	103±5	87	138

Figure 2. Minimum, maximum and mean values of atmospheric pressure in the last 24 hours for days with no patients (0) and with 1, 2, and 3 patients. A significant difference was found between pressure change in days with no patients (0) and days with 1 patient (1) in post-hoc analysis with Sidak test ($P=0.048$). Actually, a more prominent difference was observed between change of atmospheric pressure in the last 24 hours in days with no patient (0) and in days with 3 patients, but this difference was not statistically significant because the number of days with 3 patients was small (only 5 days).**Table 2.** The relationship between daily weather conditions and daily cases

Time of the event	Mean±standard deviation				P value
	0 patient	1 patient	2 patients	3 patients	
The event day					
Mean pressure (mbar)	997.2±5.8	996.5±5.0	995.2±4.3	995.3±4.8	NS*
Mean temperature (°C)	15.2±7.4	15.7±7.7	14.8±7.0	15.1±3.0	NS*
Mean relative humidity (%)	76.7±13.2	75.7±14.9	80.4±11.0	73.1±11.2	NS*
Maximum wind speed (m/s)	6.2±2.5	6.0±2.2	5.6±2.2	7.0±3.3	NS*
One day before the event					
Mean pressure (mbar)	996.7±5.7	997.5±5.3	996.2±4.4	998.9±3.9	NS*
Mean temperature (°C)	15.4±7.2	15.4±8.2	15.3±6.6	14.5±2.5	NS*
Mean relative humidity (%)	76.7±13.2	76.1±14.6	77.8±12.7	71.7±14.4	NS*
Maximum wind speed (m/s)	6.3±2.5	6.0±2.2	5.6±2.2	4.6±1.4	NS*
Two days before the event					
Mean pressure (mbar)	996.8±5.5	996.9±5.6	995.6±5.4	1 000.6±6.3	NS*
Mean temperature (°C)	15.4±7.4	15.4±7.6	15.0±7.4	12.9±4.4	NS*
Mean relative humidity (%)	76.5±13.5	76.1±13.9	78.1±12.3	75.2±16.3	NS*
Maximum wind speed (m/s)	6.3±2.4	6.0±2.5	5.6±2.2	5.8±1.5	NS*
Three days before the event					
Mean pressure (mbar)	996.9±5.7	996.7±4.9	995.7±5.1	999.0±8.7	NS*
Mean temperature (°C)	15.6±7.3	15.3±7.5	13.8±8.3	13.1±4.4	NS*
Mean relative humidity (%)	75.9±13.1	76.7±15.0	85.0±9.7	74.3±10.8	NS*
Maximum wind speed (m/s)	6.4±2.5	6.0±2.2	4.7±1.9	5.0±1.2	0.048

*: Statistically not significant.

Table 3. The relationship between daily cases and change of atmospheric pressure in consecutive days

Time points	Mean±standard deviation				P value
	0 patient	1 patient	2 patients	3 patients	
0–24 hours					
Pressure change (mbar)	6.7±5.5	4.9±4.8	4.8±4.3	2.8±2.9	0.019
Temperature change (°C)	10.0±5.7	10.6±5.4	8.9±4.4	14.5±6.2	NS*
Relative humidity change (%)	45.2±18.1	43.8±18.0	45.8±18.0	59.4±20.6	NS*
24–48 hours					
Pressure change (mbar)	6.3±5.3	6.2±6.0	4.8±3.1	5.5±4.3	NS*
Temperature change (°C)	10.1±5.5	10.4±5.9	10.3±4.8	15.0±6.4	NS*
Relative humidity change (%)	45.4±18.3	44.0±17.7	46.5±14.2	49.6±25.1	NS*
48–72 hours					
Pressure change (mbar)	6.0±5.3	6.7±5.4	5.7±4.6	7.3±9.0	NS*
Temperature change (°C)	10.1±5.7	10.3±5.4	11.4±4.4	11.7±8.8	NS*
Relative humidity change (%)	45.9±17.8	44.4±18.7	37.4±16.1	53.0±17.0	NS*
72–96 hours					
Pressure change (mbar)	5.9±5.3	7.2±5.7	4.8±4.5	6.1±4.4	NS*
Temperature change (°C)	10.5±5.6	9.6±5.8	9.7±4.0	11.9±6.3	NS*
Relative humidity change (%)	45.8±18.1	44.1±17.5	42.8±17.2	53.4±22.9	NS*

*: Statistically not significant.

DISCUSSION

The possible relationship between weather conditions and IS occurrence has not yet been clarified. We found that IS cases increase daily when the maximum speed of wind is low 3 days before stroke or change of atmospheric pressure in the last 24 hours.

No significant relationships were observed between daily cases and weather conditions.^[7-10] But some studies found such relationship.^[2,11-14]

Possible relationships were noted between daily cases, daily mean temperature, and atmospheric pressure;^[7] between daily temperature, air pressure, and relative humidity;^[8] between daily mean temperature, air pressure, mean wind speed, maximum wind speed, relative humidity, and Chinook winds;^[9] and between daily weather conditions^[10] in different countries. However, there was no statistically significant relationship.

Cases of stroke were seen predominantly in hot days.^[2] Emergency transports coded as stroke decreased when temperature or relative humidity increased.^[11] But the findings may be misleading because the cases were transported with ambulance and coded as stroke. However they were not definitely diagnosed until imaging studies were performed at the hospital. Feigin et al^[12] found that low temperature and mean atmospheric pressure increased the risk of IS; but the study was conducted in the Siberia region of Russia where weather is cold, suggesting that the results may not reflect the true relationship between weather conditions and IS. Iwamoto et al^[13] also found that IS occurs frequently in the elderly in hot days. They studied only five elderly cases which make us to think about whether generalization of the results is proper or not.

We did not find any relationship between daily cases and weather conditions of the same day, which supports the conclusion that the effect of weather conditions is not seen in the same day. One study^[14] reported a significant relationship between number of cases and weather conditions in previous days, and the other^[7] found no significant relationship. Hong et al^[15] found that low temperature increased the risk of IS, and the most powerful effect was seen after exposure to cold weather.

Cowperthwaite and Burnett^[7] found no significant relationship between daily cases and daily temperature, pressure and humidity 1, 2, 3, 5, and 7 days before stroke. We also did not find any relationship between daily cases and mean temperature, pressure and humidity 1, 2, and 3 days before stroke. These studies^[15,7] did not evaluate possible effects of wind speed, but we found that daily cases increased if maximum wind speed was low 3 days before stroke. Nonetheless, we are unable to explain how

the lower wind speed may trigger IS 3 days later.

IS may be related not only to weather conditions but to changes of weather conditions. Studies^[6,7,14,16] found that there was no relationship between daily cases and changes of weather conditions, and others^[10,17-20] reported relationships between daily cases and changes of weather conditions.

In many countries, no relationship was found between changes of atmospheric pressure and stroke;^[6] between daily cases and changes of atmospheric pressure, temperature, and relative humidity;^[7] between changes of weather temperature and number of IS cases;^[14] and between mean daily temperature and IS cases^[16] each month. Studies^[6,7] investigated possible relationships between stroke and changes of weather conditions in a single day. In our study there was a significant relationship between daily cases and changes of atmospheric pressure in the last 24 hours.

Jimenez-Conde et al^[10] found a significant relationship between non-lacunar ISs and a decrease in atmospheric pressure compared to previous days. But in our study, the risk of IS increased if change of atmospheric pressure in the last 24 hours was moderate; this finding is opposite to that of Jimenez-Conde et al.^[10] It is possible that human body may need a daily atmospheric pressure cycle as it needs a light cycle and plays a role in pathophysiology of IS. Thus, IS may be triggered when the change of daily atmospheric pressure is not great. A strong relationship was observed between IS and decrease of air temperature.^[17] Gomes et al^[18] found a relationship between stroke incidence and a decline in minimum temperature ≥ 3 °C in 2 of consecutive 10 days. In another study Gomes et al^[19] found that a decline of minimum temperature >2.4 °C in any 2 consecutive days in a week and stroke incidence are significantly correlated. These two studies were performed in Maputo, Mozambique where daily temperature varies between 14 °C and 30 °C throughout the year.^[18] The temperature in Maputo may affect the results of these studies. Additionally, cases of stroke, hemorrhagic and ischemic, were included in the studies, but cases of ischemic and hemorrhagic stroke are significantly different in clinical entities and pathophysiology. The increased number of stroke cases after a decrease of air temperature may be due to increased cases of hemorrhagic stroke. Mostofsky et al^[20] reported a higher risk of IS in hours and days after a moderate decrease of temperature. As mentioned above, we did not find such relationship between decrease of air temperature and stroke occurrence. Because the small number of cases and the short study period, the possible relationship between IS and changes of weather conditions may be not statistically significant.

No studies have shown a relationship between daily cases and maximum wind speed 3 days before the event. Our study showed that IS cases increased as the atmospheric pressure was low in the last 24 hours. But the mechanism that IS may be triggered by the two factors is not clear.

Our study has also limitations. First, the study was performed in one city, so the results may be identical to areas with similar weather conditions. Second, it was a retrospective study with the data of only one year, thus the number of cases are limited. Some possible relationships may be overlooked. Third, three IS cases were admitted to the hospital within 5 days. Finally, the data of our study were only from one center. We tried to decrease the impact of the limitations by screening patients to include patients with an exact diagnosis of ischemic stroke. We investigated the final diagnosis of patients while re-evaluating their imaging studies.

In conclusion, we found two factors that related to the occurrence of IS. First, the low maximum wind speed increased the number of IS cases after 3 days. Second, the number of cases increased when the change of atmospheric pressure was minimal in the last 24 hours. Hence, if patients are at risk clinicians should take preventive measures against IS in these periods. The two factors may play a role in stroke occurrence, and we suggest that long-term studies with a large number of cases are needed to confirm our findings and determine the role of the two factors in the pathophysiology of IS.

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Conflicts of interest: Authors have no commercial associations or sources of support that might pose a conflict of interest.

Contributors: Gunes H proposed the study. All authors contributed to the design and interpretation of the study, and approved the final manuscript.

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