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Critical Care

Association Between Atmospheric Conditions and Occurrence of Out-of-Hospital Cardiac Arrest

– 10-Year Population-Based Survey in Osaka –

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Background: Weather conditions affect the occurrence of cardiovascular disease. The aim of this study was to investigate the associations between atmospheric conditions including temperature, pressure, and humidity, and the occurrence of out-of-hospital cardiac arrests (OHCAs) with cardiac etiology.

Methods and Results: This study was a cross-sectional analysis of a prospective cohort that included all persons aged ≥18 years with OHCA in Osaka, from 1998 through 2007. The association between the number of daily OHCA events with various atmospheric conditions was analyzed using Poisson regression. A total of 28,806 adult OHCAs were presumed to be of cardiac etiology. The number of OHCAs in 1 day was inversely correlated with the day's mean atmospheric temperature. The regression coefficient was greater on the days under 18°C (r=–0.317, P<0.001) than on days over 18°C (r=–0.088, P<0.001). A positive linear relation was found between the number of OHCAs in 1 day and the day's mean atmospheric pressure (r=0.321, P<0.001). Under 18°C, every 5°C decrease in the daily mean temperature was associated with an 11% (95% confidence interval [CI]: 8–13%) increase in OHCA occurrence in the non-elderly group, and a 16% increase in the elderly group (95% CI: 14–19%).

Conclusions: The occurrence of adult OHCA with cardiac etiology increases with decreasing temperature of the day. Elderly people are more susceptible to severe weather conditions. (*Circ J* 2013; **77:** 2073–2078)

Key Words: Atmospheric temperature; Out-of-hospital cardiac arrest; Prevention

Three-quarters of deaths from coronary artery disease occur suddenly in out-of-hospital settings,[1,2] and approximately 60,000 sudden cardiac arrests are documented every year in Japan.[2] Although survival after out-of-hospital cardiac arrest (OHCA) has been improving, the absolute level is still low.[2,3] Accordingly, a preventive approach is needed to decrease the mortality from sudden cardiac arrests.[4–6]

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The occurrence of OHCA is associated with some patient characteristics including age, sex, body weight, medical history, family history, smoking habit, and activity before arrests.[7–11] In addition, environmental factors can also be associated with the occurrence of cardiac arrests,[12] and some studies have reported that weather conditions had affected the occurrence of cardiovascular disease. In winter or in cold environments, the incidence of heart disease is higher than during warmer seasons.[13–18] Recently, an association between summer temperature variability and survival was noted among elderly people with chronic disease.[19] Other studies found an association between atmospheric pressure and changes in blood pressure or the occurrence of myocardial infarction.[20,21] If we could predict an atmospheric condition-related OHCA, it would lead to new preventive measures against OHCA.

The Utstein Osaka project was launched in 1998, and is an ongoing, large, prospective, population-based cohort study of

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Table 1. Atmospheric Conditions

	Average in 1 day	Fluctuations in 1 day	Difference from the previous day
Temperature (°C)			
Mean ± SD	17.6±8.3	7.8±2.5	0.0±1.8
Range	−0.1 to 32.5	1.0 to 16.0	−8.1 to 6.7
Mode†	30.0	8.0	0.5
Pressure (hPa)			
Mean ± SD	1,014.7±6.7	5.3±3.3	0.0±4.5
Range	988.3 to 1,034.2	0.0 to 35.9	−20.6 to 24.5
Mode†	1,012.9	3.0	0.0
Humidity (%)			
Mean ± SD	63.2±10.7	33.3±10.2	0.0±11.1
Range	34.0 to 97.0	5.0 to 72.0	−44.0 to 43.0
Mode†	63.0	32.0	1.0

†Value that occurs most frequently in a given data set.

OHCA in Osaka, Japan, covering 8.8 million people.[3,22–24] In this study, we evaluated the association between occurrence of adult OHCA of cardiac etiology and atmospheric conditions during daytime, including temperature, pressure, and humidity.

Methods

Study Design, Subjects and Setting

This is a cross-sectional study of a prospective cohort, including all persons aged ≥18 years with OHCA of presumed cardiac origin who were treated by emergency medical service (EMS) personnel in Osaka Prefecture, Japan, from 1 May 1998 through 31 December 2007. Osaka Prefecture has 8,665,105 residents (in 2010)[25] in an area of 1,892 km^2, which includes both urban and rural communities, and is located at 135°E and at 34°N. Japan has 4 distinct seasons: a bitterly cold winter followed by a wet monsoon season; and then a very hot and humid summer between a mild spring and autumn. Osaka is located in a humid subtropical climate zone.

EMS System in Osaka Prefecture

The EMS system is operated by 34 local fire stations with their respective emergency dispatch centers, having a single-tiered system with 32 stations and a 2-tiered system with 2. Life support is provided 24 h per day. Details of the EMS system in Osaka have been reported elsewhere.[3,26,27]

Data Collection

Patient data were prospectively collected using a data form that included all core data recommended in the Utstein-style reporting guidelines for cardiac arrests,[28,29] such as sex, age, location of arrest, activities of daily living before arrest, witness status, initial cardiac rhythm, time-course of resuscitation, type of bystander-initiated cardiopulmonary resuscitation, return of spontaneous circulation, hospital admission, 1-month survival, and neurological outcome 1 month after the event. Cardiac arrest was defined as the cessation of cardiac mechanical activities and confirmed by the absence of signs of circulation. The arrest was presumed to be of cardiac origin unless it was caused by trauma, drowning, drug overdose, asphyxia, exsanguinations, or any other non-cardiac causes determined by a physician in charge, in collaboration with the EMS personnel. Date and time of arrest for the non-witness arrest cases is defined as the time of call receipt at EMS operator.

The data form was filled out by EMS personnel in cooperation with the physicians caring for the patient, transferred to the Information Center for Emergency Medical Services of Osaka, and then checked by the investigators. If the data sheet was incomplete, the relevant EMS personnel were contacted and questioned, and the data sheet was completed.

Meteorological data including hourly measured air temperature (°C), pressure (hPa), and humidity (%) were obtained from the Osaka District Meteorological Observatory database through the Internet.[30] The average weather in 1 day was defined as the mean of hourly measurements of 1 day, and fluctuation in 1 day as the difference between the maximum and minimum values.

Statistical Analysis

The primary outcome measure was the daily incidence of OHCA. Spearman rank correlation analysis and simple regression were used to assess the relationship between the daily averages of temperature, pressure, or humidity, and the daily incidence of OHCA.

For further analysis, we divided OHCA patients into 2 groups by age: 18–74 years old (non-elderly) and ≥75 years (elderly); and into 2 groups by atmospheric temperature on the day of OHCA: <18°C (cold) and ≥18°C (warm) according to the previous data showing that the incidence of coronary artery disease differs depending on whether temperatures were higher or lower than 18°C.[16] Poisson regression was performed to evaluate the associations of temperature per 5°C increment, pressure per 10-hPa increment, and humidity per 10% increment with the daily incidence of OHCA. After stratifying patients by age and atmospheric temperature, adjusted odds ratios (AORs) of temperature, pressure, and humidity for the daily incidence of cardiac arrest and their 95% confidence intervals (CIs) were calculated to examine the independent contribution of the average in 1 day, the fluctuation in 1 day, and the difference from the previous day of all 3 atmospheric variables. Two-sided $P \leq 0.05$ was regarded as statistically significant. Analysis was performed using SPSS Ver.16.0J (SPSS, Chicago, IL, USA).

Ethics

This study was approved by the institutional review board of Osaka University, with the assent of all EMS authorities and municipal governments in Osaka Prefecture, Japan.

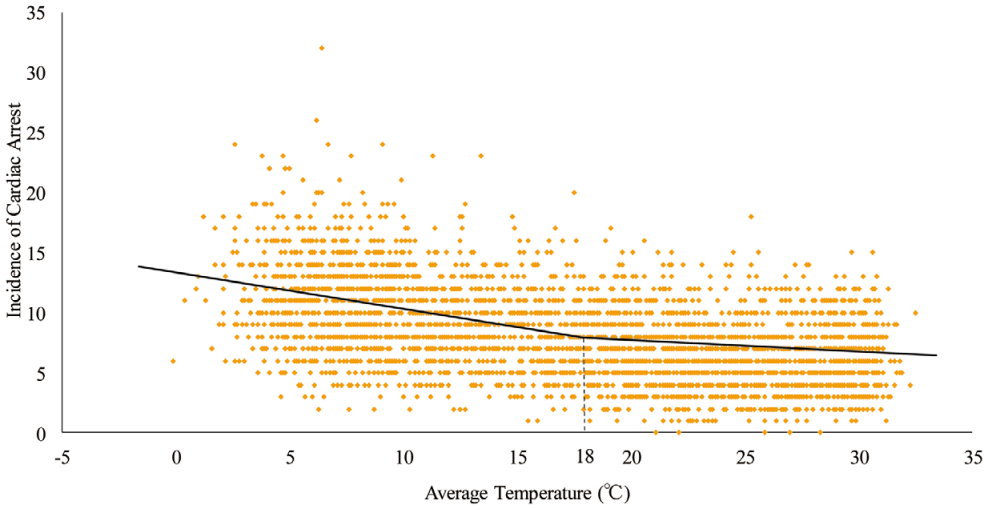

Figure 1. Daily incidence of adult out-of-hospital cardiac arrest of cardiac etiology vs. average daily temperature (n=28,806).

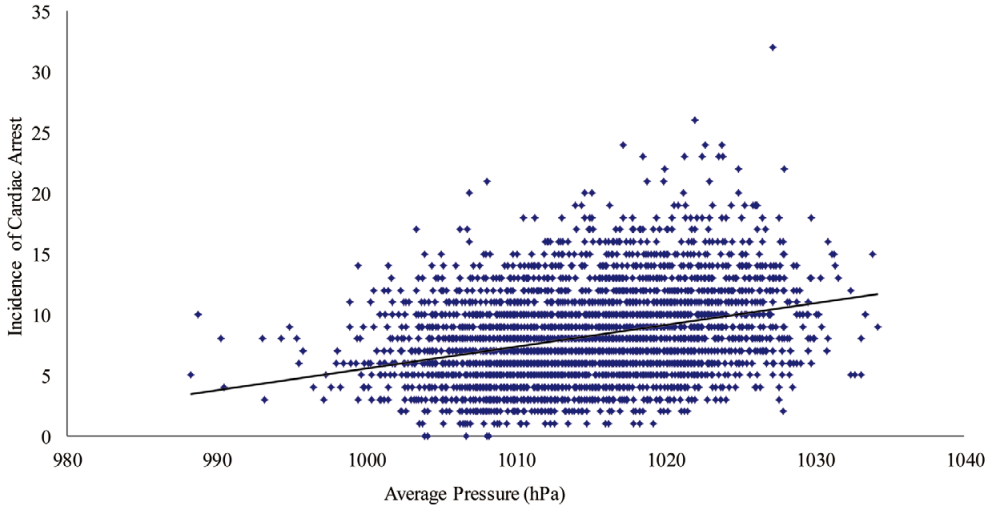

Figure 2. Daily incidence of adult out-of-hospital cardiac arrest of cardiac etiology vs. average daily pressure (n=28,806).

Results

Patient Baseline Characteristics and Atmospheric Conditions

During the 10 years, a total of 52,208 adult OHCAs were documented. Among them, resuscitation was attempted in 48,911, and 28,806 of them were presumed to be of cardiac etiology. Mean age was 71.9±14.9 years and the proportion of men was 58.5%.

Table 1 lists the average in 1 day, fluctuation in 1 day, and difference from the previous day of atmospheric temperature, pressure, and humidity in Osaka, Japan. The mean temperature in the year was 17.6°C with a range of –0.1 to 32.5°C; the mean pressure was 1,014.7 hPa, and the mean humidity was 63.2%.

Occurrence of OHCA According to Atmospheric Conditions

Figures 1–3 show the relationships between atmospheric conditions and the daily incidence of adult OHCA with cardiac etiology (n=28,806). Incidence of OHCA inversely correlated with average temperature. The linear regression line was bent at 18°C as we had hypothesized; the regression coefficient on days when the temperature was <18°C (r=–0.317, P<0.001) was greater than on the days when the temperature was >18°C (r=–0.088, P<0.001; Figure 1). Figure 2 shows a positive correlation between pressure and the incidence of OHCA (r=0.321, P<0.001). Meanwhile, Figure 3 shows a weak correlation between humidity and the incidence of OHCA (r=–0.179, P<0.001).

Atmospheric Conditions and OHCA Occurrence by Age and Temperature

Table 2 lists the AORs of atmospheric conditions for the occurrence of OHCA with cardiac etiology according to the 4

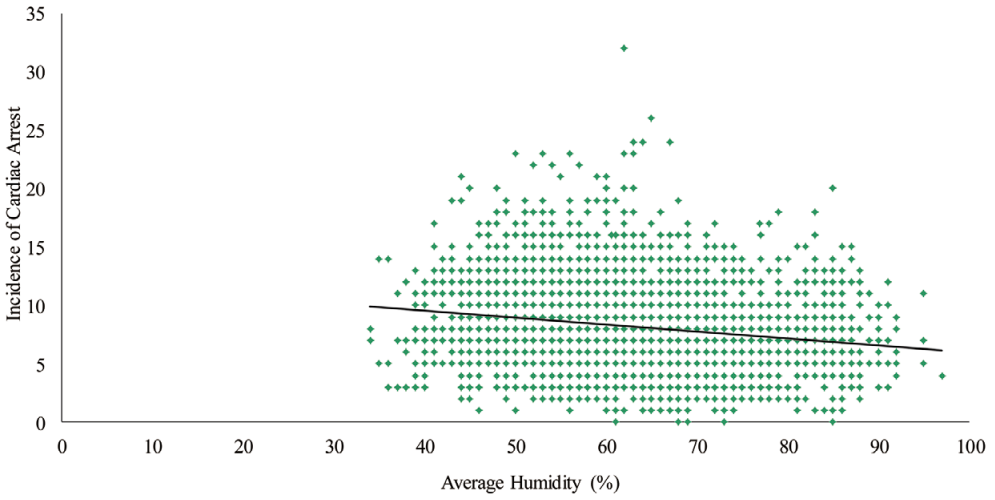

Figure 3. Daily incidence of adult out-of-hospital cardiac arrest of cardiac etiology vs. average daily humidity (n=28,806).

Table 2. Independent Association of Weather Conditions With Daily Incidence of OHCA

Temperature (°C)	Age (years)	Average in 1 day	Fluctuations in 1 day	Difference from the previous day
		AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Temperature (per 5°C increment)				
<18	<74	0.892 (0.866–0.919)	0.991 (0.933–1.053)	0.990 (0.926–1.059)
	≥75	0.835 (0.810–0.861)	0.989 (0.905–1.081)	1.008 (0.943–1.078)
≥18	<74	1.016 (0.978–1.055)	0.997 (0.939–1.059)	1.040 (0.941–1.150)
	≥75	0.912 (0.876–0.950)	1.013 (0.922–1.113)	0.964 (0.866–1.073)
Pressure (per 10-hPa increment)				
<18	<74	1.000 (0.954–1.048)	0.958 (0.895–1.026)	0.951 (0.893–1.013)
	≥75	1.060 (1.012–1.111)	1.136 (1.027–1.256)	0.908 (0.853–0.966)
≥18	<74	1.115 (1.051–1.183)	0.970 (0.906–1.038)	1.006 (0.919–1.101)
	≥75	1.012 (0.949–1.078)	0.963 (0.860–1.079)	0.860 (0.779–0.950)
Humidity (per 10% increment)				
<18	<74	0.999 (0.970–1.029)	0.989 (0.966–1.013)	0.979 (0.956–1.003)
	≥75	0.991 (0.962–1.020)	0.997 (0.962–1.034)	0.976 (0.953–0.999)
≥18	<74	1.005 (0.968–1.043)	0.993 (0.969–1.017)	0.977 (0.943–1.011)
	≥75	0.945 (0.908–0.984)	0.979 (0.941–1.017)	0.998 (0.962–1.036)

AOR, adjusted odds ratio; CI, confidence interval; OHCA, out-of-hospital cardiac arrest.

groups divided by age and temperature.

Under the cold condition, AOR 95% CI for a 5°C increase in the average temperature was 0.892 (0.866–0.919) in the non-elderly and 0.835 (0.810–0.861) in the elderly, respectively; that is, a 5°C decrease in the average temperature was associated with an 11% increase of OHCA occurrence in the non-elderly and a 16% increase in the elderly. Under the warm condition, AOR 95% CI for a 5°C increase in average temperature was 0.912 (0.876–0.950) in the elderly, that is, a 5°C decrease in the average temperature was associated with a 9% increase of OHCA occurrence increase in the elderly, whereas it was not significantly associated with OHCA occurrence in the non-elderly. There were no significant associations between fluctuations in 1 day or a difference from the previous day's temperature and the occurrence of OHCA (Table 2).

The AOR 95% CI for a 10-hPa increase in the average atmospheric pressure was 1.060 (1.012–1.111), that is, a 10-hPa increase in average pressure was associated with a 6% increase in OHCA occurrence in the elderly under the cold condition. AOR 95%CI for a 10-hPa increase in atmospheric pressure was 1.115 (1.051–1.183), that is, a 10-hPa increase was associated with a 12% increase in OHCA occurrence in the non-elderly under the warm condition. AOR 95% CI for a 10-hPa increase in the fluctuation in 1 day of atmospheric pressure was 1.136 (1.027–1.256), that is, a 10-hPa increase in fluctuation in 1 day of atmospheric pressure was associated with a 14% increase in OHCA occurrence in the elderly under the cold condition. AOR 95% CI for a 10-hPa increase in the difference of atmospheric pressure from the previous day was 0.908 (0.853–0.966), that is, a 10-hPa increase in the difference of pressure from the previous day was associated with a 10% decrease in OHCA occurrence in the elderly under the cold condition. AOR 95% CI for a 10-hPa increase in the difference of atmospheric pressure from the previous day was 0.860 (0.779–

0.950), that is, a 10-hPa increase in the difference of pressure from the previous day was associated with a 14% decrease in OHCA occurrence in the elderly under the warm condition (Table 2).

As for humidity, AOR 95% CI for a 10% increase in the average humidity was 0.945 (0.908–0.984), that is, a 10% increase in the average humidity was associated with a 6% decrease in OHCA occurrence in the elderly under the warm condition. AOR 95% CI for a 10% increase in difference of humidity from the previous day was 0.976 (0.953–0.999), that is, a 10% increase in difference of humidity from the previous day was associated with a 2% decrease in OHCA occurrence in the elderly under the cold condition (Table 2).

Discussion

This large population-based study has identified relationships between several representative atmospheric conditions and the occurrence of adult OHCA with cardiac etiology. Potential deleterious effects of low atmospheric temperature on cardiovascular mortality have been noted in by some studies from various countries,[8,14,31] but most studies included subject groups of limited age and sex,[17,21] and there are few studies that evaluated the associations between cardiac arrest with cardiac etiology and multiple meteorological factors. The present study, analyzing >28,000 adult OHCA with cardiac etiology cases, covering an 8.8-million population for a period of 10 years, is superior in terms of its statistical power and generalizability.

The present results indicated that decreased atmospheric temperature would be important for the occurrence of adult OHCA with cardiac etiology, as shown in previous studies.[17,21] Indeed, many previous studies have reported the relationship between temperature and heart disease,[17,18,21,31] several of them suggesting an association between low temperature and increased OHCA occurrence. There are some possible explanations for this association of low temperature with the occurrence of OHCA. Coldness-induced increase in platelets, red cells, blood viscosity, and plasma fibrinogen might cause coronary artery occlusion.[32,33]

The difference in the impact of atmospheric conditions on OHCA occurrence by age is another important finding of this study. Elderly people are more susceptible to changes in weather conditions than the young.[19] The low temperature-related higher incidence of OHCA in the elderly might be partly explained by the age-dependent decline in homeostasis, as reported by Khan et al.[34] The higher incidence of arterial disease in the elderly may also make them more susceptible to thrombosis.[33] The Eurowinter Group noted that winter mortality from heart disease could be reduced by wearing warmer clothes.[17] More attention should be paid to the risk of OHCA associated with low temperature, especially for elderly people. Moreover, elderly people were easily affected by atmospheric pressure or humidity in the present study. The relationship of atmospheric factors and OHCA occurrence may vary according to age.

We found a positive relationship between atmospheric pressure and OHCA occurrence, but it was much weaker than the relationship with low temperature. The MONICA Project, a large cohort study of myocardial infarction, reported a V-shaped relationship between pressure and the incidence of coronary events,[21] but their findings on low temperature were similar to the present ones. Differences in race across areas (Japanese or multiracial), age and sex (all adults of both sex or men 25–64 years old), outcomes (OHCA or coronary events), and baseline temperature, may be possible reasons for this inconsistency. Moreover, Kolb et al reported an association between pressure and the occurrence of congestive heart failure,[35] and asserted that pressure may have a certain effect on OHCA occurrence.

We found some associations between humidity and OHCA occurrence, but the effect was too weak to infer a steady relationship. There have been few studies reporting associations between coronary events and weather conditions other than temperature. Kolb et al assessed the influence of humidity on daily mortality from congestive heart failure, but failed to find any associations.[35] Thus, atmospheric factors other than temperature would have little influence on OHCA.

Study Limitations

This study has some limitations. First, the data were limited to a specific geographical area. Further studies covering more extensive areas with wider-ranging weather conditions and different demographic characteristics are needed because increases in mortality per 1°C fall in temperature differ between regions in a cold climate and those in a warm climate.[17] In addition, we were unable to assess the effect of combinations of atmospheric temperature and pressure, and the difference between rise and fall of atmospheric temperature. Although we obtained hourly meteorological data and merged them with the OHCA data, we did not know the exact weather conditions at the moment of cardiac arrest. The lack of information on patient medical or behavioral status is another limitation. We did not take into account the atmospheric conditions (eg, temperature) at the location of OHCAs.

Conclusions

Data from a large-scale population-based cohort show that the most important atmospheric factor serving to trigger adult OHCA with cardiac etiology was lower temperature on the day of occurrence. Elderly people are more susceptible to poor weather conditions. Preventive measures against OHCA with cardiac etiology that consider atmospheric conditions should be developed, especially for elderly people.

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