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 (OHCA)s 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 OHCA events were presumed to be of cardiac etiology. The number of OHCA 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 OHCA 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

In addition, environmental factors can also be associated with the occurrence of cardiac arrests, 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. Recently, an association between summer temperature variability and survival was noted among elderly people with chronic disease. Other studies found an association between atmospheric pressure and changes in blood pressure or the occurrence of myocardial infarction. 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...
OHCA in Osaka, Japan, covering 8.8 million people. 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) in an area of 1,892 km², 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.

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, 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. 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. 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≤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.
Atmospheric Conditions and Occurrence of OHCAs

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...
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.

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 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–

| Temperature (°C) | Age (years) | Average in 1 day | Fluctuations in 1 day | Difference from the previous day |
|------------------|-------------|-----------------|----------------------|---------------------------------|
|                  | <18         | ≥75             |                      |                                 |
| Temperature (per 5°C increment) | <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) |
| Pressure (per 10-hPa increment) | <18 | 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) |
| Humidity (per 10% increment) | <18 | 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) |

AOR, adjusted odds ratio; CI, confidence interval; OHCA, out-of-hospital cardiac arrest.
and the occurrence of congestive heart failure, 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. 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. 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 OHCA.

**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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**References**

1. ECC Committee, Subcommittees, and Task Forces of the American Heart Association. 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. 

2. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraike A; Implementation Working Group for the All-Japan Utstein Registry of the Fire and Disaster Management Agency. Nationwide public-access defibrillation in Japan. N Engl J Med 2010; 362: 994 – 1004.
3. Iwami T, Nichol G, Hiraide A, Hayashi Y, Nishiuchi T, Kajino K, et al. Continuous improvements of “chain of survival” increased survival after out-of-hospital cardiac arrests: A large-scale population-based study. Circulation 2009; 119: 728 – 734.

4. 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2010; 122: $S639 – S946$.

5. Nolan JP, Soar J, Zideman DA, Biairent D, Bossaert LL, Deakin C, et al; ERC Guidelines Writing Group. European Resuscitation Council Guidelines for Resuscitation 2010 Section 1: Executive summary. Resuscitation 2010; 81: 1219 – 1276.

6. Japan Resuscitation Council. 2010 Japanese guidelines for emergency care and cardiopulmonary resuscitation. Tokyo: Health Shuppansha, 2011 (in Japanese).

7. Culić V, Eterović D, Mircić D, Giunio L, Lukin A, Fabijančić D. Triggering of ventricular tachycardia by meteorologic and emotional stress: Protective effect of beta-blockers and anxiolytics in men and elderly. Am J Epidemiol 2004; 160: 1047 – 1058.

8. Escobedo LG, Zack MM. Comparison of sudden and nonsudden coronary deaths in the United States. Circulation 1996; 93: 2033 – 2036.

9. Cupples LA, Gagnon DR, Kannel WB. Long- and short-term risk of sudden coronary death. Circulation 1992; 85: 111 – 118.

10. Burke AP, Farb A, Malcom GT, Liang VH, Smialek J, Virmani R. Coronary risk factors and plaque morphology in men with coronary disease who died suddenly. N Eng J Med 1997; 336: 1276 – 1282.

11. Nishiyama C, Iwami T, Nichol G, Kitamura T, Hiraide A, Nishiuchi T, et al. Association of out-of-hospital cardiac arrest with prior activity and ambient temperature. Resuscitation 2011; 82: 1008 – 1012.

12. Paradis NA, Halperin HR, Kern MB, Wenzel V, Chamberlain DA. Cardiac arrest: The science and practice of resuscitation medicine, 2nd edn. UK: Cambridge University Press, 2007.

13. Kaikkonen KS, Kortelainen ML, Linna E, Huikuri HV. Family history and the risk of sudden cardiac death as a manifestation of an acute coronary event. Circulation 2006; 114: 1462 – 1467.

14. Nakaji S, Parodi S, Fontana V, Umeda T, Suzuki K, Sakamoto J, et al. Seasonal changes in mortality rates from main causes of death in Japan (1970 – 1999). Eur J Epidemiol 2000; 16: 905 – 913.

15. Gordon DJ, Hyde J, Trost DC, Whaley FS, Hannan PJ, Jacobs DR, et al. Cyclic seasonal variation in plasma lipid and lipoprotein levels: The Lipid Research Clinics Coronary Primary Prevention Trial Placebo Group. J Clin Epidemiol 1988; 41: 679 – 689.

16. Robinson D, Hinohara S, Bevan EA, Takahashi T. Seasonal variation in serum cholesterol levels in health screening populations from the U.K. and Japan. J Med Syst 1993; 17: 207 – 211.

17. The Eurowinter Group. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. Lancet 1997; 349: 1341 – 1346.

18. De Lorenzo F, Sharma V, Scully M, Kakkar VV. Cold adaptation and the seasonal distribution of acute myocardial infarction. QJM 1999; 92: 747 – 751.

19. Zanobetti A, O’Neill MS, Gronlund CJ, Schwartz JD. Summer temperature variability and long-term survival among elderly people with chronic disease. Proc Natl Acad Sci USA 2012; 109: 6608 – 6613.

20. Weinbacher M, Martina B, Bart T, Drewe J, Gasser P, Gyr K. Blood pressure and atmospheric pressure. Ann NY Acad Sci 1996; 783: 335 – 336.

21. Danet S, Richard F, Montaye M, Beauchant S, Lemaire B, Graux C, et al. Unhealthy effects of atmospheric temperature and pressure on the occurrence of myocardial infarction and coronary deaths. A 10-year survey: The Lille-World Health Organization MONICA project (Monitoring trends and determinants in cardiovascular disease). Circulation 1999; 100: e1 – e7. http://circ.ahajournals.org/content/100/1/e1.full (accessed January 18, 2013).

22. Iwami T, Hiraide A, Nakashishi N, Hayashi Y, Nishiuchi T, Yukioka H, et al. Age and sex analyses of out-of-hospital cardiac arrest in Osaka, Japan. Resuscitation 2003; 57: 145 – 152.

23. Iwami T, Hiraide A, Nakashishi N, Hayashi Y, Nishiuchi T, Uejima T, et al. Outcome and characteristics of out-of-hospital cardiac arrest according to location of arrest: A report from a large-scale, population-based study in Osaka, Japan. Resuscitation 2006; 69: 221 – 228.

24. Iwami T, Kawamura T, Hiraide A, Berg RA, Hayashi Y, Nishiuchi T, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation 2007; 116: 2900 – 2907.

25. Osaka Prefecture Government. The population from the Basic Resident Register in 2007. http://www.pref.osaka.jp/shichoson/jukii/juki1903.html (accessed January 13, 2013) (in Japanese).

26. Hayashi Y, Iwami T, Kitamura T, Nishiuchi T, Kajino K, Sakai T, et al. Impact of early intravenous epinephrine administration on outcomes following out-of-hospital cardiac arrest. Circ J 2012; 76: 1639 – 1645.

27. Sasaki M, Iwami T, Kitamura T, Nomoto S, Nishiyama C, Sakai T, et al. Incidence and outcome of out-of-hospital cardiac arrest with public-access defibrillation: A descriptive epidemiological study in a large urban community. Circ J 2011; 75: 2821 – 2826.

28. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: The Utstein Style: A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. Circulation 1991; 84: 960 – 975.

29. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: Update and simplification of the Utstein templates for resuscitation registries: A statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). Circulation 2004; 110: 3385 – 3397.

30. Osaka District Meteorological Observatory. http://www.data.jma.go.jp/obd/stats/etrn/index.php (accessed January 13, 2013) (in Japanese).

31. Weerasinghe DP, MacIntyre CR, Rubin GL. Seasonality of coronary artery deaths in New South Wales, Australia. Heart 2002; 88: 30 – 34.

32. Stout RW, Crawford V. Seasonal variations in fibrinogen concentra- tions among elderly people. Lancet 1991; 338: 9 – 13.

33. Keatinge WR, Coleshaw SR, Cotter F, Mattock M, Murphy M, Chelliah R. Increases in platelet and red cell counts, blood viscosity, and arterial pressure during mild surface cooling: Factors in mortality from coronary and cerebral thrombosis in winter. Br Med J (Clin Res Ed) 1984; 289: 1405 – 1408.

34. Khan F, Spence VA, Belch JJ. Cutaneous vascular responses and thermoregulation in relation to age. Clin Sci (Lond) 1992; 82: 521 – 528.

35. Kolb S, Radon K, Valois MF, Héguy L, Goldberg MS. The short-term influence of weather on daily mortality in congestive heart failure. Arch Environ Occup Health 2007; 62: 169 – 176.