Desert Dust Is a Risk Factor for the Incidence of Acute Myocardial Infarction in Western Japan

Ryuichi Matsukawa, MD, PhD; Takehiro Michikawa, MD, PhD; Kayo Ueda, MD, PhD; Hiroshi Nitta, PhD; Tomohiro Kawasaki, MD, PhD; Hideki Tashiro, MD, PhD; Masahiro Mohri, MD, PhD; Yusuke Yamamoto, MD, PhD

Background—Recently, there has been increasing concern about adverse health effects of exposure to desert dust events. However, the association between dust and the incidence of ischemic heart diseases is unknown. The aim of the present study was to elucidate whether Asian dust (AD), a windblown sand dust originating from mineral soil in China and Mongolia, is associated with the incidence of acute myocardial infarction (AMI).

Methods and Results—We investigated the data regarding hospitalization because of AMI among 3068 consecutive patients from 4 AMI centers in Fukuoka, Japan, and data for AD from April 2003 to December 2010. We applied a time-stratified case-crossover design to examine the association between AD and the incidence of AMI. Using a conditional logistic regression analysis, we estimated the odds ratios of AMI associated with AD after controlling for ambient temperature and relative humidity. The occurrence of AD events 0 to 4 days before the day of admission was significantly associated with the incidence of AMI. In particular, the occurrence of AD 4 days before admission was significantly associated with the onset of AMI.

Conclusions—These data suggest that exposure to AD a few days before symptom onset is associated with the incidence of AMI. (Circ Cardiovasc Qual Outcomes. 2014;7:743-748.)

Key Words: air pollution ■ dust ■ myocardial infarction

Recently, there has been increasing concern about adverse health effects of exposure to desert dust events, natural phenomenon in which a windblown sand dust originating from the mineral soil of deserts transported to downwind areas. Desert dust clouds carry not only coarse particles but also fine particles and various chemical components from anthropogenic sources during its long-range transport.

Exposure to elevated level of fine particles is known to trigger ischemic heart diseases. However, studies examining the association between coarse particles and cardiovascular diseases are inconsistent. Recent studies focusing on desert dust events suggested that coarse particles had stronger effects on mortality during Saharan dust days than those during non-Saharan dust days. Especially, Pérez et al showed that Saharan dust was associated with cardiovascular mortality. However, we are unaware of studies that examined whether exposure to desert dust triggers acute myocardial infarction (AMI).

Fukuoka prefecture is located in Western Japan and is nearest to the Asian continent; thus, it often experiences Asian dust (AD) events, a windblown sand dust originating from mineral soil in China and Mongolia. Recently, it has been reported that AD exposure is associated with the risk of asthma and atherothrombotic brain infarction in Japan. It is suggested that AD clouds carry not only desert dust but also microorganisms, chemical components, and gaseous pollutants. AD has become an object of public concern in Japan with respect to preventing respiratory and cardiovascular diseases. However, it remains unknown whether AD is associated with the risk of coronary heart disease. We focused on the association between AD events and the incidence of AMI, particularly in patients with coronary heart diseases. In the present study, we used a time-stratified case-crossover design to elucidate the association between AD and the incidence of AMI.

Methods

Patient Data

Patient data were retrospectively collected from the 4 hospitals in Fukuoka prefecture, including Saiseikai Fukuoka General Hospital in Fukuoka city, JCHO Kyushu Hospital in Kitakyushu city, St. Mary’s Hospital, and Shin-Koga Hospital in Kurume city (Figure 1). This study included data for patients aged ≥20 years with AMI admitted to the 4 participating hospitals within 24 hours of onset between April 2003 and December 2010.

The Data Supplement is available at http://circoutcomes.ahajournals.org/lookup/suppl/doi:10.1161/CIRCOUTCOMES.114.000921/-/DC1. Correspondence to Ryuichi Matsukawa, MD, PhD, Division of Cardiology, Cardiovascular and Aortic center of Saiseikai Fukuoka General Hospital, 1-3-46 Tenjin Chuo-ku, Fukuoka 810-0001, Japan. E-mail matukawa@cardiol.med.kyushu-u.ac.jp

© 2014 American Heart Association, Inc.

Circ Cardiovasc Qual Outcomes is available at http://circoutcomes.ahajournals.org DOI: 10.1161/CIRCOUTCOMES.114.000921
WHAT IS KNOWN

• Exposure to elevated levels of fine particulate matter is known to be associated with ischemic heart disease morbidity and mortality.
• The association between desert dust particles and cardiovascular diseases, however, has been inconsistent.

WHAT THE STUDY ADDS

• We investigated the association between Asian dust, a windblown sand dust originating from mineral soil in China and Mongolia and the incidence of AMI.
• We found an increased risk of myocardial infarction within 4 days after an Asian dust event (based on a visibility standard), even after adjusting for humidity, temperature, small particulate matter, and other copollutants.

2003 and December 2010. We included patients with a final diagnosis of ST-segment–elevation MI and non–ST-segment–elevation MI. The diagnosis of AMI (both ST-segment–elevation MI and non–ST-segment–elevation MI) was determined according to the universal definition of MI proposed by the Joint European Society of Cardiology (ESC)/American College of Cardiology Foundation (ACCF)/American Heart Association (AHA)/World Heart Federation (WHF) Task Force.10 The study was approved by the institutional review board at each participating hospitals.

AD and Meteorologic Data

Data for ground-level observations of AD events and meteorologic variables were measured at the Fukuoka local meteorologic observatory. The occurrence of an AD event was generally determined according to a visibility-based observation at the same observatory (http://www.jma.go.jp/en/kosals). An AD event is reported when the visibility reduces to <10 km. The daily mean ambient temperature and relative humidity were calculated using hourly measurements.

Air Pollutant Data

Data for air pollutants were obtained from the atmospheric environmental database of the National Institute for Environmental Studies. Air pollutants included suspended particulate matter (SPM), photochemical oxidants, defined as a mixture of ozone and other secondary oxidants generated by photochemical reactions, nitrogen dioxide (NO2), and sulfur dioxide (SO2). SPM monitored in Japan is theoretically assumed to be particles with a diameter of <7 μm and is characterized by smaller size distribution than particulate matter <10 μm in aerodynamic diameter (PM10). There are 8 monitoring stations in Fukuoka city, 14 in Kitakyushu city, and 4 in Kurume city. Therefore, we averaged the daily values and assigned the citywide means of SPM, NO2, and SO2 and the 8-hour moving average concentrations of photochemical oxidants to the patients who admitted to the hospital located in the corresponding city.

Statistical Analysis

A time-stratified case-crossover design11 was applied to examine the association between exposure to AD events and the risk of hospitalization for AMI. Within-subject comparisons were made between a case period and control periods. A case period was defined as the day of hospitalization. As control periods, we selected the corresponding days of the week in the same month of the same year as the case period. This control selection strategy is expected to adjust for time-invariant covariates such as long-term trend, seasonality by design.12 For example, if a hospitalization because of AMI occurred on May 20, 3 control days were selected: May 6, 13, and 27. We used a conditional logistic regression model and estimated the odds ratios (ORs) and 95% confidence intervals of hospitalization associated with AD events after adjustment for the 4-day average ambient temperature and relative humidity from the case day to 3 days prior. Because the effects of AD events were assumed to persist over the course of a few days, we used AD events occurring on the case day (day 0) up to a few days earlier, and examined single lag effect (days 0–5) and cumulative lag effect (day 0–1, to days 0–5). In addition, SPM, photochemical oxidants, NO2, and SO2 were added in the basic model to adjust for the effects of copollutants.

The visibility-based observation of AD events does not have information on the amount of the dust particles. According to the previous study,13 it is possible that the association is more obvious with AD events with higher particle level than those with lower particle level. Hence, we also performed the same conditional logistic regression analysis using heavy AD events (AD events with an SPM concentration of ≥50 μg/m3 [median value]), taking into consideration the amount of coarse particles in AD. In addition, to examine the effect modification, we performed stratified analyses according to age strata (<65 and ≥65 years) and sex. We checked for statistical interactions using cross-product terms of age strata or sex with AD events. All analyses were performed using the STATA 11 software package (StataCorp LP; College Station, TX).

Results

Patient Characteristics and Air Pollutant Concentrations

There were 3068 patients with AMI in this study. A total of 1954 patients (63.7%) were aged >65 years, and 879 patients (28.7%) were women. There were 75 days in the study period when an AD event was observed, and most of the AD events were observed from March to May (AD days; Figure 2). A summary of the statistics of the air pollutants on days with and without AD events is shown in Table 1. The concentrations of pollutants excluding NO2 tended to be higher on the days with AD events than on those without AD events.

AD and the Incidence of AMI

The occurrence of AD 4 days before admission (day 4) was significantly associated with the incidence of AMI (Figure 3A; OR, 1.33; 95% confidence interval, 1.05–1.69). We also examined the association for cumulative lags. The occurrence of AD events at days 0 to 4 was significantly associated with the incidence of AMI (Figure 3B; OR, 1.20; 95% confidence interval, 1.02–1.40). Because most of AD events occurred in March to May, we repeated the analysis using the data limited to this season (Table in the Data Supplement). The association and its lag pattern were similar to that observed using year-round data. From these results, further analyses focused on the association between AD and AMI at day 4 and days 0 to 4. Although we further adjusted for each air pollutant individually or all the pollutants simultaneously, the positive associations between the occurrence of AD on days 0 to 4 and day 4 and the risk of AMI remained (Table 2). When we examined the relationship between heavy AD events, defined by the SPM concentration, and the risk
of AMI, a similar association was found between the onset of AMI and the occurrence of heavy AD events (OR at day 4, 1.43 [95% confidence interval, 1.03–1.98]; OR at days 0–4, 1.21 [0.99–1.46]). The association between AD and the incidence of AMI on days 0 to 4 did not differ according to the age strata or sex (Table 3).

**Discussion**

The findings of the present case-crossover study suggested that AD is a potential trigger of AMI. Few studies have investigated whether short-term exposure to desert dust is associated with the cardiovascular morbidity.9 Recently, Kamouchi et al9 showed that AD is associated with the frequency of atherothrombotic brain infarction but not other types of ischemic stroke. The mechanisms underlying the occurrence of both atherothrombotic brain infarction and AMI are considered to be similar. The common background between these diseases is thrombus formation attributable to atherosclerotic plaque.

The mechanisms by which exposure to AD increases the incidence of AMI are unknown. The levels of air pollutants, including both particulate and gaseous pollutants, excluding NO2 were increased during AD events compared with those measured in the periods without AD events (Table 1). We observed that heavy AD events, defined by the SPM concentration, were also associated with the risk of AMI hospitalization. It has been reported that fine PM and SO2 and NOx from coal-fired power plant were associated with cardiovascular risk.14,15 Furthermore, it has also been said that smaller particles could have greater risk for cardiovascular disease.16 We observed the association of AD events on AMI hospitalization. However, we cannot identify culprit elements of AD for cardiovascular risk. We speculate that AD may have more adverse health effects because of the contaminated with finer particles and anthropogenic chemicals when AD passed through heavily industrial areas with coal-fired power plants.

Previous animal and human studies have led to some hypotheses regarding the mechanisms underlying the adverse cardiovascular effects of short-term particulate matter exposure.17 These studies suggest that inhaled particles induce systemic oxidative stress,18 inflammation,19,20 autonomic dysfunction, including tachycardia, reductions in heart rate variability and hypertension,18,20–22 and hypercoagulability.23,24 Therefore, the particulate matter contained in AD may stimulate plaque rupture according to these mechanisms, resulting in AMI. Another possibility is that unidentified substances are also involved in AD. A previous study demonstrated that microbial components adhering to AD induce allergic lung inflammation.25 Therefore, a systemic response to these adhered unknown microorganisms originating from the distant desert may accelerate inflammation and thrombosis. Further studies are needed to clarify the underlying mechanisms.

AD events contribute to a sharp increase in coarse particles in Japan.1 Several studies have shown that elevated concentration of fine particulate matter is associated with hospitalization attributable to ischemic heart disease.24 On the contrary, the association between coarse particles and cardiovascular risk is less studied and the results are inconsistent. Peters et al24 observed a positive but insignificant association between coarse particles and AMI. Peng et al24 found no significant association between coarse particles and hospital admissions for cardiovascular diseases after adjustment particulate matter <2.5 μm in aerodynamic diameter (PM2.5). Host et al4 examined the association between coarse particle and
cardiorespiratory hospitalization and observed significant positive association only with those attributable to ischemic heart disease for the elderly. AD particles may be modified by chemical components from anthropogenic sources during its long-range transport. Further studies should focus on health effects of different size distribution and various chemical characterization of AD.

There are some limitations associated with the present study. Limited number of cases and AD days could have resulted in limited statistical power. Especially, we examined the association during the potential lags. Therefore, observed association could be observed by chance. Further study with larger sample size would be necessary. No detailed information was available regarding patient behavior, the degree of

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>City</th>
<th>Days</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>25th Percentile</th>
<th>50th Percentile</th>
<th>75th Percentile</th>
<th>Maximum</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPM, μg/m³</td>
<td>Fukuoka</td>
<td>AD days</td>
<td>75</td>
<td>58.1</td>
<td>31.9</td>
<td>21.5</td>
<td>38.4</td>
<td>48.6</td>
<td>66.2</td>
<td>170.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>29.7</td>
<td>14.3</td>
<td>6.6</td>
<td>19.4</td>
<td>26.3</td>
<td>36.8</td>
<td>105.7</td>
</tr>
<tr>
<td></td>
<td>Kitakyushu</td>
<td>AD days</td>
<td>75</td>
<td>52.6</td>
<td>29.8</td>
<td>14.8</td>
<td>34.2</td>
<td>45.8</td>
<td>59.1</td>
<td>154.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>25.4</td>
<td>13.9</td>
<td>5.0</td>
<td>15.2</td>
<td>22.2</td>
<td>32.1</td>
<td>114.6</td>
</tr>
<tr>
<td></td>
<td>Kurume</td>
<td>AD days</td>
<td>75</td>
<td>55.4</td>
<td>27.5</td>
<td>21.3</td>
<td>40.1</td>
<td>49.2</td>
<td>55.8</td>
<td>148.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2754</td>
<td>32.6</td>
<td>14.8</td>
<td>2.9</td>
<td>22.2</td>
<td>30.0</td>
<td>39.8</td>
<td>107.2</td>
</tr>
<tr>
<td>Ox, ppb</td>
<td>Fukuoka</td>
<td>AD days</td>
<td>75</td>
<td>56.6</td>
<td>13.2</td>
<td>13.6</td>
<td>48.2</td>
<td>58.2</td>
<td>65.8</td>
<td>88.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>43.3</td>
<td>15.2</td>
<td>4.5</td>
<td>33.4</td>
<td>41.5</td>
<td>52.5</td>
<td>123.0</td>
</tr>
<tr>
<td></td>
<td>Kitakyushu</td>
<td>AD days</td>
<td>75</td>
<td>57.3</td>
<td>16.8</td>
<td>14.8</td>
<td>55.4</td>
<td>55.4</td>
<td>65.6</td>
<td>115.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>40.2</td>
<td>14.6</td>
<td>5.7</td>
<td>30.4</td>
<td>39.0</td>
<td>49.1</td>
<td>127.9</td>
</tr>
<tr>
<td></td>
<td>Kurume</td>
<td>AD days</td>
<td>75</td>
<td>54.1</td>
<td>15.0</td>
<td>17.6</td>
<td>52.4</td>
<td>54.3</td>
<td>65.8</td>
<td>90.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>41.8</td>
<td>16.5</td>
<td>5.5</td>
<td>29.9</td>
<td>39.5</td>
<td>52.2</td>
<td>99.0</td>
</tr>
<tr>
<td>NO₂, ppb</td>
<td>Fukuoka</td>
<td>AD days</td>
<td>75</td>
<td>14.5</td>
<td>6.3</td>
<td>5.0</td>
<td>9.3</td>
<td>13.1</td>
<td>18.5</td>
<td>31.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>14.7</td>
<td>6.8</td>
<td>1.9</td>
<td>9.6</td>
<td>13.5</td>
<td>18.9</td>
<td>51.9</td>
</tr>
<tr>
<td></td>
<td>Kitakyushu</td>
<td>AD days</td>
<td>75</td>
<td>18.2</td>
<td>8.6</td>
<td>6.7</td>
<td>12.2</td>
<td>15.6</td>
<td>22.8</td>
<td>45.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>18.8</td>
<td>7.3</td>
<td>2.4</td>
<td>13.3</td>
<td>18.0</td>
<td>23.5</td>
<td>53.8</td>
</tr>
<tr>
<td></td>
<td>Kurume</td>
<td>AD days</td>
<td>75</td>
<td>15.6</td>
<td>5.4</td>
<td>6.1</td>
<td>12.0</td>
<td>15.4</td>
<td>19.2</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>15.4</td>
<td>6.0</td>
<td>1.8</td>
<td>10.9</td>
<td>14.9</td>
<td>19.4</td>
<td>37.6</td>
</tr>
<tr>
<td>SO₂, ppb</td>
<td>Fukuoka</td>
<td>AD days</td>
<td>75</td>
<td>4.5</td>
<td>1.7</td>
<td>1.5</td>
<td>3.2</td>
<td>4.4</td>
<td>5.7</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>3.7</td>
<td>1.6</td>
<td>0.7</td>
<td>2.5</td>
<td>3.5</td>
<td>4.6</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>Kitakyushu</td>
<td>AD days</td>
<td>75</td>
<td>4.4</td>
<td>1.9</td>
<td>1.3</td>
<td>2.9</td>
<td>4.2</td>
<td>5.5</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2757</td>
<td>3.6</td>
<td>1.7</td>
<td>0.5</td>
<td>2.4</td>
<td>3.3</td>
<td>4.4</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>Kurume</td>
<td>AD days</td>
<td>75</td>
<td>4.1</td>
<td>1.5</td>
<td>1.3</td>
<td>2.6</td>
<td>4.3</td>
<td>4.3</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-AD days</td>
<td>2756</td>
<td>3.9</td>
<td>2.0</td>
<td>0.4</td>
<td>2.2</td>
<td>3.7</td>
<td>5.2</td>
<td>15.8</td>
</tr>
</tbody>
</table>

AD indicates Asian dust; Ox, photochemical oxidants; ppb, parts per billion; and SPM, suspended particulate matter.

*P values for the difference of concentrations of each pollutant between AD days and non-AD days were determined by Student t test.
individual exposure to AD and other air pollutants, or coronary risk factors, such as hypertension, dyslipidemia, and diabetes mellitus. In addition, the data for AD events provided by the Japan Meteorological Agency were dependent on the distance of visibility. Although we defined heavy AD events according to the SPM concentration, further studies of AD events based on quantitative measurements (eg, the Light Detection and Ranging system) are needed.

In conclusion, we observed an association between AD events and the occurrence of AMI. Exposure to AD may be a trigger of AMI.

Sources of Funding
This study was supported by Grants-in-Aid for Scientific Research (24310024) from the Japan Society for the Promotion of Science (Tokyo, Japan).

Disclosures
None.

References


Desert Dust Is a Risk Factor for the Incidence of Acute Myocardial Infarction in Western Japan

Ryuichi Matsukawa, Takehiro Michikawa, Kayo Ueda, Hiroshi Nitta, Tomohiro Kawasaki, Hideki Tashiro, Masahiro Mohri and Yusuke Yamamoto

_Circ Cardiovasc Qual Outcomes_. 2014;7:743-748; originally published online July 29, 2014; doi: 10.1161/CIRCOUTCOMES.114.000921

_Circulation: Cardiovascular Quality and Outcomes_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Copyright © 2014 American Heart Association, Inc. All rights reserved.

Print ISSN: 1941-7705. Online ISSN: 1941-7713

The online version of this article, along with updated information and services, is located on the World Wide Web at:

http://circoutcomes.ahajournals.org/content/7/5/743

Data Supplement (unedited) at:

http://circoutcomes.ahajournals.org/content/suppl/2014/07/29/CIRCOUTCOMES.114.000921.DC1

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in _Circulation: Cardiovascular Quality and Outcomes_ can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:

http://www.lww.com/reprints

Subscriptions: Information about subscribing to _Circulation: Cardiovascular Quality and Outcomes_ is online at:

http://circoutcomes.ahajournals.org//subscriptions/
Supplemental Table Association between Asian dust (AD) and the incidence of acute myocardial infarction (95% CI) during March to May (794 cases)

<table>
<thead>
<tr>
<th>Lag</th>
<th>Adjusted OR*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day0</td>
<td>1.19</td>
<td>0.89-1.59</td>
</tr>
<tr>
<td>Day1</td>
<td>1.07</td>
<td>0.80-1.44</td>
</tr>
<tr>
<td>Day2</td>
<td>0.99</td>
<td>0.74-1.31</td>
</tr>
<tr>
<td>Day3</td>
<td>1.22</td>
<td>0.93-1.61</td>
</tr>
<tr>
<td>Day4</td>
<td>1.23</td>
<td>0.92-1.65</td>
</tr>
<tr>
<td>Day5</td>
<td>0.99</td>
<td>0.73-1.35</td>
</tr>
<tr>
<td>Day0-1</td>
<td>1.11</td>
<td>0.87-1.42</td>
</tr>
<tr>
<td>Day0-2</td>
<td>1.08</td>
<td>0.86-1.34</td>
</tr>
<tr>
<td>Day0-3</td>
<td>1.14</td>
<td>0.93-1.40</td>
</tr>
<tr>
<td>Day0-4</td>
<td>1.20</td>
<td>0.99-1.47</td>
</tr>
<tr>
<td>Day0-5</td>
<td>1.14</td>
<td>0.94-1.38</td>
</tr>
</tbody>
</table>

OR: odds ratio; CI: confidence interval
*Adjusted for 4-day averaged ambient temperature and relative humidity from lag0 to lag3