Impact of meteorological conditions and PM2.5 on the onset of acute aortic dissection in monsoonal climate

Xiao-Nan HE¹, Jin-Liang ZHAN², Cheng ZHANG³, Yu CHEN³, Wei GONG¹, Wang JI⁴, Shao-Ping NIE¹

¹Emergency Critical Care Center, Beijing AnZhen Hospital, Capital Medical University, Beijing, China
²School of Management and Economics, Beijing Institute of Technology, Beijing, China
³Department of Cardiology, China-Japan United Hospital Affiliated to Jilin University, Changchun, China
⁴Beijing Regional Climate Center, Beijing, China

Abstract

Objective  To investigate the impact of meteorological conditions and PM2.5 on the onset of acute aortic dissection in monsoonal climate. Methods  A linear regression analysis was performed in monsoonal climate epidemiological survey for a period of four years on the impact of meteorological factors (minimal temperature, mean temperature, maximal temperature, average daily surface temperature, day temperature range, relative humidity, mean wind speed, and atmospheric pressure) and PM2.5 concentration on the daily incidences of acute aortic dissections. Meteorological variables and PM2.5 concentration were retrieved on a daily basis from Beijing Regional Climate Center and the Ministry of Environmental Protection of the People’s Republic of China’s website, and the daily incidences of acute aortic dissections were retrieved from the Clinical Data Analysis and Reporting System in the Emergency and Critical Care Center of Beijing Anzhen Hospital. Results  During the study period (from January 2011 to December 2014), 1164 patients were identified as having acute aortic dissections. The corresponding incidences in spring and autumn were 0.96 and 1.00, respectively, which significantly higher than that in summer and winter. The incidences of acute aortic dissection in a day could be predicted by diurnal temperature range (DTR) using the following linear multiple regression models: incidences of acute aortic dissection = 0.543 + 0.025 \times DTR. Conclusion  This is the first study to show an attributable effect of DTR on acute aortic events in monsoonal climate. Our study confirms that meteorological variables were important factors influencing the incidence of acute aortic dissection.

Keywords: Acute aortic dissection; Meteorological conditions; PM2.5

1 Introduction

Acute aortic dissection (AAD) is the most common aortic catastrophe medical emergency with a death rate of 1% to 2% per hour for the first 24 hours in untreated patients.⁴ Therefore, AAD should have an important place in the awareness of physicians in the evaluation of emergency patients with acute chest pain, and identification of risk factors for occurrence of AAD is of great value.⁵ Some predisposing factors for AAD are well known, such as hypertension, bicuspid aortic valve, coarctation of the aorta or Turner’s syndrome, Marfan’s syndrome or other connective tissue disorders and pregnant women. It was recently that a number of studies have provided evidences that cardiovascular conditions such as coronary heart disease, hypertensive urgency, stroke and heart failure are associated with seasonal variations.⁶ Also, previous studies have shown that AAD is reported not evenly distributed over time, but to show peculiar temporal patterns varying with day of week, month and season of year.⁴ The incidence of AAD peaks in winter and lowest in summer. Meteorological conditions of different season may contribute to AAD onset.⁵ However, because of geographic and climate variations, there is a lack of consensus about the contributing factors. Moreover, few studies have investigated the synergistic effects of ambient air pollution and meteorological parameters on the onset of AAD. In this study, we investigate meteorological conditions and PM2.5 on the occurrence of AAD in monsoonal climate.

2 Methods

2.1 Meteorological data collections

Beijing has a semi-humid continental monsoon climate
with annual average temperatures 10–12°C. The dates range of our study is from January 1, 2011 to December 31, 2014 and the measurement sites are located in the 16 districts of Beijing. The Beijing Regional Climate Center has an accurate and reliable electronic meteorological database, which is readily available to the public through the following website, http://www.bjmb.gov.cn/. From this database, data on meteorological factors such as minimal temperature (°C), mean temperature (°C), maximal temperature (°C), diurnal temperature range (°C), relative humidity (%), mean wind speed, atmospheric pressure (hPa) and PM2.5 concentration are available on daily basis. Diurnal temperature range (DTR) was defined as the difference between maximal and minimal temperature within one day. Temporal patterns in AAD were assessed per month and season (spring: March-May, summer: June-August, autumn: September-November, winter: December-February).

2.2 Air quality data

Four air quality monitoring stations around Beijing Anzhen Hospital were chosen in our study. The average distance from the monitor sites to Anzhen Hospital is within 7.5 km. In the context analyses, we used 24-h average concentrations of PM2.5, which retrieved from the Ministry of Environmental Protection of the People’s Republic of China’ website (http://www.zhb.gov.cn/).

2.3 Clinical data collections

The daily data of all consecutive patients with nontraumatic AAD on emergency room visits were obtained from Emergency Critical Care Center of Beijing Anzhen Hospital, from January 1, 2011 to December 31, 2014. Patients included in this study primarily came from Beijing and nearby areas. The diagnosis of AAD was according to the 9th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-9), and confirmed by multidetector CT scanning. Patients were excluded if they had a clear aetiology such as Marfan’s syndrome, Loeys-Dietz syndrome, iatrogenic aortic disease secondary to cardiac surgery, thoracic endovascular aortic repair, or a history of operation for aortic disease. All patients with chronic dissections or previous operation were also excluded.

2.4 Statistical analysis

Data were analyzed on daily. Meteorological factors were used as predictors of AAD. The incidences of aortic dissections were regarded as event outcomes. All values are expressed as mean ± SE. Univariate analysis was performed after confirming the assumption of normality and homogeneity of variance across groups. Differences between groups were calculated using the unpaired Student t-test. For non-normally distributed data, the groups were compared using the Mann-Whitney U test or Wilcoxon rank test.

A linear regression model was built using minimal temperature (°C), mean temperature (°C), maximal temperature (°C), DTR (°C), relative humidity (%), mean wind speed, average daily surface temperature (°C), and atmospheric pressure (hPa). PM2.5 concentrations were used as variables and incidence of AAD events as dependent variables. The correlation coefficient (R) indicated the direction of correlation (positive or negative) among the variables. Correlation of determination (R²) measured the amount of variability in one variable that was shared by other, and the F ratio measured how much the model improved the prediction of the outcome compared with the level of inaccuracy.

Factors that significantly predicted incidence of AAD were subjected to multiple regression analysis. Differences were considered significant at $P < 0.05$. Data collection and statistical analyses were performed using the software package SPSS 24.0.

3 Results

3.1 The characteristics of Beijing’s climate

The characteristics of Beijing’s climate are four distinct seasons, typical of the northern temperate zone and a semi-humid continental monsoon climate with annual average temperature 10–12 °C. It is hot and rainy in summer, but cold and dry in winter. The distribution of precipitation season is very uneven, and 80% of the annual precipitation is concentrated in summer. The diurnal temperature range (DTR) has obvious seasonal change in Beijing from 2011 to 2014. The maximum DTR is in spring (11.6 °C) and autumn (10.4 °C). The minimum DTR are in winter and summer (9.5 °C). The climatic patterns of Beijing were shown in Figure S1–S3.

3.2 Seasonal variations of AAD

During the 4-year study period, there were 1164 patients diagnose with AAD in Beijing Anzhen Hospital. The average daily incidences of AAD were 0.80. There was a clear seasonal difference in the onset of AAD. Monthly variations of mean daily incidences of AAD were 0.51, 0.73, 0.94, 1.36, 0.60, 0.67, 0.44, 0.55, 0.92, 1.42, 0.66, and 0.77 from January to December (Figure 1). The presence of a day-of-week rhythmic variability of AAD onset was shown in Figure 2. The incidence of AAD is highest on Monday within a week. More incidences were observed in spring and autumn months, and fewer incidences in summer and winter months.
The average incidences of AAD were 0.67, 0.96, 0.55, and 1 in winter, spring, summer, and autumn, respectively (Figure 3).

3.3 Meteorological factors and PM$_{2.5}$ on the day of AAD

The differences in meteorological conditions between the days of AAD and the days without AAD are presented in Table 1. There were significant differences in minimal temperature ($^\circ$C), mean temperature ($^\circ$C), maximal temperature ($^\circ$C), DTR ($^\circ$C), relative humidity (%), average daily surface temperature ($^\circ$C) and PM$_{2.5}$ concentrations between days with and without AAD.

3.4 Linear multiple regression analysis results

Linear multiple regression results indicated that DTR was a predictor for AAD (Table 2). The incidence of AAD in a day could be predicted by DTR using the following linear multiple regression models: AAD incidence = 0.543 + 0.025 × DTR (linear multiple regression; $R = 0.078$, $R^2 = 0.006$, $F = 8.866$, $P = 0.003$).

Table 1. Comparison of the meteorological factors and PM$_{2.5}$ of days with and without AAD.

| Atmospheric parameters | Days without AAD | Days with AAD | $P$-value |
|------------------------|-----------------|---------------|-----------|
| Minimal temperature, $^\circ$C | 8.0 ± 11.8 | 9.3 ± 10.3 | 0.029 |
| Mean temperature, $^\circ$C | 12.8 ± 12.0 | 14.2 ± 10.3 | 0.016 |
| Maximal temperature, $^\circ$C | 17.8 ± 12.2 | 19.4 ± 10.4 | 0.007 |
| DTR, $^\circ$C | 9.8 ± 0.1 | 11.2 ± 0.1 | 0.046 |
| Relative humidity | 50.8± 20.7% | 53.8± 19.6% | 0.005 |
| Mean wind speed, m/s | 2.2 ± 0.9 | 2.1 ± 0.8 | 0.054 |
| Average daily surface temperature, $^\circ$C | 13.6 ± 13.6 | 15.3 ± 11.8 | 0.011 |
| Atmospheric pressure, hPa | 10126.5 ± 108.0 | 10124.4 ± 94.1 | 0.693 |
| PM$_{2.5}$ concentration, $\mu$g/m$^3$ | 104.5 ± 96.9 | 115.1 ± 105.3 | 0.041 |

Results are presented as mean ± SD; bold values indicate $P < 0.05$. AAD: acute aortic dissection; DTR: diurnal temperature range.

Table 2. Linear multiple regression analysis for AAD.

| B     | SE  | Beta | t    | $P$  |
|-------|-----|------|------|------|
| Constant | -0.543 | .090 | -6.013 | .000 |
| DTR ($^\circ$C) | .025 | .009 | .078 | 2.978 | .003 |

AAD: acute aortic dissection; DTR: diurnal temperature range.

4 Discussion

To the best of our knowledge, this is the first study to evaluate the effects of meteorological parameters and PM$_{2.5}$ on the occurrence of AAD in monsoonal climate. Previous studies have shown that meteorological factors are associated with the incident of AAD.$^{10-12}$ Other studies have shown that temperature extremes or transitions/variability in temperature can trigger AAD.$^{13,14}$ In this study, our data indicate a strong influence of DTR on the occurrence of AAD.
4.1 The time distribution of AAD

Recently, a significant circadian pattern for the occurrence of AAD has received attention including hourly, weekly, monthly, seasonally. It was found that a peak for the occurrence of AAD was within 8:00 to 10:00 and a nadir in 0:00 to 2:00. Moreover, a significant day-of-week pattern were found in the occurrence of AAD, with a peak on Monday and a nadir on Saturday. The causal link between weather factors and the incidence of AAD on seasonal basis was controversial. Some studies have reported that cold temperatures and aorta event rates increased more in populations living in cold climates than the ones living in warm climates. However, another study investigated the inconsistent effects of temperature on the incident of AAD revealed that the most frequent period was autumn/winter with 47% or 58% patients. In this study, we found that AAD onset is higher on Monday, in October, and in spring and autumn. This seasonal variation was similar to a recent observational retrospective study conducted by Chen, et al.

4.2 DTR, hypertension and incidence of AAD

Risk factors for aortic dissection include sex, age, hypertension, smoking, aneurysm, congenital disorders and inflammatory disease. Hypertension is considered as the most important risk factor for aortic dissection and is present in about 80% of patients with aortic dissection. Previous studies have reported that hypertension was present in 86% of individuals who subsequently developed AD, which conferred a population-attributable risk of 54%. It has been confirmed that blood pressure variations influence the incidence of AAD, and there are also correlations between hypertension and atmospheric temperature. Alpérovitch found that intraindividual blood pressure differences were strongly correlated with outdoor temperature and systolic blood pressure increased 8.0 mmHg when outdoor temperature decrease from 21.2°C to 7.9°C. Animal experiment confirmed that systolic blood pressure, diastolic blood pressure, and mean blood pressure all increased after rats exposed to below 5°C for 1–3 weeks, and the elevated blood pressure was irreversible after exposed for seven weeks.

Hemodynamic factors play an important role in the process and development of AAD. The blood flow velocity and pressure in aorta is high, and the elevated blood pressure could increased the shear stress which lead to intimal tear, eventually exposed the medial layer to the pulsatile blood flow. Furthermore, the increased vertical shear to the aorta would bring about the possibility of aortic dissection.

4.3 Meteorological conditions, PM2.5 and AAD

We found that the temperature conditions (minimal, mean and maximal), DTR, relative humidity, mean wind speed, average daily surface temperature, and PM2.5 concentration were higher in the days with AAD than that of without AAD. Multiple regression results demonstrated that DTR was a significant predictor for the incidence of AAD. The present study not only confirmed the associations between meteorological conditions and AAD, but also showed that DTR may predict the number of cases of AAD. However, there are other meteorological factors that have been shown to be associated with the increased incidence of AAD besides DTR. DTR was considered as an important index of climate variations as it provides more information than temperature alone. Previous study had shown that DTR was associated with emergency room admissions in Beijing. A few previous studies showed that the impact of DTR on cardiovascular and cardiopulmonary disease mortality was non-linear, and found that high DTR was significantly associated with daily mortality in several cities in China.

In our study, AAD onset is higher in April and October. Recently, with the economic development of northern China, most people are living in relatively warm conditions in the winter. Moreover, the universal air conditioning using in summer has made a relatively comfortable cool environment. However, the effect of season changes has been overlooked. Both April and October are during the period of heating and non-heating seasons in Beijing. The fluctuation of temperature may cause increased blood pressure and vasospasm, which may lead to increased risk of AAD. In addition, Kalkstein, et al. reported that there was a robust increase in the mortality curves in the transitional seasons of Minneapolis and Detroit in the USA. These findings were also similar to another study, which suggested that there was a mortality peak occurs in October (autumn) and a smaller jump in May (Spring) in Russia. Season alterations and sudden changes in temperature could cause patients’ conditions to deteriorate, but more studies are needed to further clarify the relationships between AAD, seasonal changes and treatment.

4.4 Limitations

There are some limitations to our study. Firstly, our data are from fixed-site monitoring stations, which may lead to inevitable measurement errors. Secondly, we only collected AAD data from one hospital, which decreased the generalizability of our results. Thirdly, we did not have data on living habits such as exercise and diet, which may confound our conclusions.
4.5 Conclusions

In summary, our results demonstrate an attributable effect of DTR on AAD in monsoonal climate in Beijing, China. We confirm that meteorological variables were important factors influenced the incidence of AAD. Our findings might be useful for the primary prevention of AAD exacerbated by DTR and may have implications for local policy makers working to identify and monitor individuals at increased risk of AAD.

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Figure S1. The temperatures of Beijing between January 2011 and December 2014.

Figure S2. Pressure and humidity of Beijing between January 2011 and December 2014.

Figure S3. DTR of Beijing between January 2011 and December 2014. DTR: diurnal temperature range.