Original Article

Influence of Air Pollution on Hospital Admissions in Adult Asthma in Northeast China

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Abstract

Background: Asthma is a common chronic respiratory disease and is related to air pollution exposure. However, only a few studies have concentrated on the association between air pollution and adult asthma. Moreover, the results of these studies are controversial. Therefore, the present study aimed to analyze the influence of various pollutants on hospitalization due to asthma in adults.
Methods: A total of 1019 unrelated hospitalized adult asthma patients from Northeast China were recruited from 2014 to 2016. Daily average concentrations of air pollutants (particulate matter <2.5 μm [$PM_{2.5}$], particulate matter <10 μm [PM_{10}], sulfur dioxide [SO_2], nitrogen dioxide [NO_2], and carbon monoxide [CO]) were obtained from the China National Environmental Monitoring Centre website from 2014 to 2016. Cox logistic regression analysis was used to analyze the relationship between air pollutants and hospital admissions in adult asthma.
Results: The maximum odds ratio (*OR*) value for most air pollutants occurred on lag day 1. Lag day 1 was chosen as the exposure period, and 8 days before onset was chosen as the control period. Three pollutants ($PM_{2.5}$, CO, and SO_2) were entered into the regression equation, and the corresponding *OR* (95% confidence interval) was 0.995 (0.991–0.999), 3.107 (1.607–6.010), and 0.979 (0.968–0.990), respectively.
Conclusions: A positive association between hospital admissions and the daily average concentration of CO was observed. CO is likely to be a risk factor for hospital admissions in adults with asthma.

Key words: Air Pollution; Asthma; Carbon Monoxide; Particulate Matter; Sulfur Dioxide

Introduction

Atmospheric pollution is still a worldwide problem. According to the World Health Organization (WHO), 92% of the world's population lives in areas where atmospheric pollutant levels exceed the WHO limits. Three million deaths a year are linked to atmospheric pollution exposure,[1] contributing to 5.4% of all deaths.[2]

As a developing country, air pollution in China has become a serious problem and has attracted the attention of researchers. China's population-weighted average exposure to particulate matter <2.5 μm ($PM_{2.5}$) is 52 μg/m^3, and 92% of the Chinese population experience >120 h of unhealthy air (US EPA standard) and 38% experience unhealthy average concentrations.[3] According to the environmental data released by the Ministry of Environmental Protection of China in 2016, the ambient air quality comprehensive index (5.17) of Changchun, in the northeast region of China, where we reside, ranks 36th of 74 cities.[4] The geographical distribution of average $PM_{2.5}$ in various provinces of China from 2004 to 2008 was 17.64–30.34 μg/m^3 in Jilin Province,[5] which exceeds the 10 μg/m^3 annual mean of the WHO guideline limits. Of the risk factors that constitute the number of attributable disability-adjusted life-years (DALYs) in China, ambient air pollution was ranked fourth in terms of the age-standardized DALY rate in 2010, after dietary risk factors, high blood pressure, and tobacco exposure.[6]

As urban air quality declines, the risk of stroke, heart disease, lung cancer, and chronic and acute respiratory diseases, such

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as asthma, increases for people who live in these areas.[7] Asthma is a common chronic respiratory disease. $PM_{2.5}$ exposure increases the risk of developing asthma, and both $PM_{2.5}$ and NO_2 increase the risk of developing wheeze, the cardinal symptom of asthma, in adult women.[8] However, research has focused on the impact of air pollution on childhood asthma,[9-11] and few studies have concentrated on the effects of air pollution on adult asthma. Moreover, a number of studies[12,13] do not support the link between air pollution and asthma. Therefore, the present study aimed to analyze the influence of various pollutants on hospitalization due to asthma in adults.

Methods

Ethical approval

All patients gave written informed consent and were informed of the study protocol. Demographic and clinical characteristics of the patients were collected following a review of their medical records. The study was approved by the ethics committee of the First Hospital of Jilin University.

Subjects

A total of 1019 unrelated hospitalized adult asthma patients from Northeast China were recruited between 2014 and 2016, who did not have infections, allergies, or irregular treatments. The patients from 11 cities or counties in Northeast China were diagnosed in three hospitals in Changchun, Jilin Province.

Data on air pollutants

Data on the daily average concentrations of air pollutants were obtained from the China National Environmental Monitoring Centre website, which mainly monitors six pollutants: $PM_{2.5}$, particulate matter <10 μm (PM_{10}), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO).

Statistical analysis

The statistical package SPSS software version 16.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. Cox logistic regression analysis was performed to analyze the hysteresis effect of different pollutants to determine the exposure period and control period. The influence of various pollutants on hospitalization due to asthma was analyzed on the day of the maximum lag effect. A $P < 0.05$ was considered statistically significant.

Results

Characteristics of the patients with asthma

A total of 1019 adult asthma patients were included in the study (450 males and 569 females; 106 smokers and 913 nonsmokers). The mean age of the patients was 55.2 ± 14.2 years.

Hysteresis effect of different pollutants

On lag day 0, the odds ratio (*OR*) (95% confidence interval [*CI*]) of $PM_{2.5}$, PM_{10}, CO, NO_2, and SO_2 was 0.999 (0.997–1.002), 1.000 (0.998–1.002), 0.984 (0.691–1.403), 0.996 (0.988–1.004), and 0.992 (0.982–1.002), respectively. On lag day 1, the *OR* (95% *CI*) of $PM_{2.5}$, PM_{10}, CO, NO_2, and SO_2 was 1.000 (0.997–1.003), 1.000 (0.998–1.002), 1.156 (0.745–1.792), 1.002 (0.992–1.012), and 0.993 (0.982–1.005), respectively. On lag day 2, the *OR* (95% *CI*) of $PM_{2.5}$, PM_{10}, CO, NO_2, and SO_2 was 0.999 (0.996–1.003), 0.999 (0.997–1.002), 0.886 (0.578–1.359), 1.002 (0.992–1.012), and 1.002 (0.922–1.013), respectively. On lag day 3, the *OR* (95% *CI*) of $PM_{2.5}$, PM_{10}, CO, NO_2, and SO_2 was 1.000 (0.998–1.003), 1.000 (0.998–1.002), 1.089 (0.750–1.582), 1.000 (0.991–1.008), and 0.992 (0.982–1.002), respectively. The maximum *OR* value for most air pollutants occurred on lag day 1; therefore, one day before onset (lag day 1) was chosen as the exposure period [Table 1].

Relationship between hospital admissions in adult asthma and air pollution

One day before onset (lag day 1) was chosen as the exposure period and 8 days before onset was chosen as the control period. To control for "the effect of the week", multiple logistic regression analysis was performed, and only three pollutants ($PM_{2.5}$, CO, and SO_2) were entered into the regression equation. The *OR* (95% *CI*) of $PM_{2.5}$, CO, and SO_2 was 0.995 (0.991–0.999), 3.107 (1.607–6.010), and 0.979 (0.968–0.990), respectively [Table 2].

Discussion

Air pollution is complex as its chemical constituents and physicochemical properties are not confined to a single independent "particle" but a distinct environmental "toxin" as in this study, which is a major environmental risk to health and affects almost all countries in the world and almost all parts of the society. Air pollution and its related health impact have become a major concern over the past few years, as only one person in ten lives in a city with clear air according to the WHO air quality guidelines.[14,15] Studies on the burden of disease attributed to ambient air pollution, using methodology developed for the Comparative Risk Assessment study, have indicated that air pollution was regarded as exposure risk factor for acute lower respiratory disease, chronic obstructive pulmonary disease, stroke, ischemic heart disease, and lung cancer. Many other diseases have also been associated with air pollution, but were not included in this assessment as the evidence was insufficient.[14] For example, air pollution was not regarded as an etiological factor and was not included in the Global Initiative for Asthma. A systematic review and meta-analysis[16] of the association between air pollutants and asthma emergency room visits (ERVs) and hospital admissions showed that air pollutants were associated with a significant increased risk of asthma ERVs and hospitalizations, which was consistent with our study findings. However, stronger associations were found in hospitalized males, children, and elderly patients during warm seasons with a lag of 2 days or more. The mechanisms by which pollutants induce these effects are

Table 1: Hospital admissions in adult asthma patients when concentrations of air pollutants changed on different lag days

Parameters	OR (95% CI)			
	Lag day 0	Lag day 1	Lag day 2	Lag day 3
$PM_{2.5}$	0.999 (0.997–1.002)	1.000 (0.997–1.003)	0.999 (0.996–1.003)	1.000 (0.998–1.003)
PM_{10}	1.000 (0.998–1.002)	1.000 (0.998–1.002)	0.999 (0.997–1.002)	1.000 (0.998–1.002)
CO	0.984 (0.691–1.403)	1.156 (0.745–1.792)	0.886 (0.578–1.359)	1.089 (0.750–1.582)
NO_2	0.996 (0.988–1.004)	1.002 (0.992–1.012)	1.002 (0.992–1.012)	1.000 (0.991–1.008)
SO_2	0.992 (0.982–1.002)	0.993 (0.982–1.005)	1.002 (0.922–1.013)	0.992 (0.982–1.002)

$PM_{2.5}$: Particulate matter <2.5 μm; PM_{10}: Particulate matter <10 μm;SO_2: Sulfur dioxide; NO_2: Nitrogen dioxide; CO: Carbon monoxide; *CI*: Confidence interval; Lag day 0: Zero day before onset; Lag day *n*: *n* day before onset; *OR*: Odds ratio.

Table 2: Multifactorial models to assess the relationship between hospital admissions for adult asthma and concentrations of air pollutants

Air pollutants	B	SE	Wald	P	OR	95% CI
$PM_{2.5}$	−0.005	0.002	5.131	0.024	0.995	0.991–0.999
CO	1.134	0.337	11.348	0.001	3.107	1.607–6.010
SO_2	−0.021	0.006	13.447	<0.001	0.979	0.968–0.990

$PM_{2.5}$: Particulate matter <2.5 μm; SO_2: Sulfur dioxide; *OR*: Odds ratio; *CI*: Confidence interval; SE: Standard error.

not completely understood. A review discussing whether air pollution contributed to the initiation of new cases of asthma proposed by the UK's Committee on the Medical Effects of Air Pollutants included four main mechanisms: oxidative stress and damage, airway wall remodeling, inflammatory pathways and immunological responses, and enhancement of respiratory sensitization to aeroallergens.[17] In addition, various studies[18-22] have also suggested that exposure of bronchial epithelial cells to NO_2, O_3, and diesel exhaust particles inhibited ciliary beat frequency and resulted in the synthesis and release of pro-inflammatory mediators, including eicosanoids, cytokines, and adhesion molecules. Ambient airborne PM generally contains fungal spores and pollen, which have been associated with exacerbation of asthma.[23,24] Exposure to ambient airborne PM was shown to cause oxidative and nitrosative stress, airway hyper-responsiveness, airway remodeling, and exacerbation of chronic inflammation.[25,26] However, other researches revealed that there was no significant association or relationship between asthma discharge rates and exposure to air pollutants ($PM_{2.5}$ and O_3).[12] Therefore, there is significant controversy regarding this issue.

In the present study, we found that different pollutants ($PM_{2.5}$, PM_{10}, CO, NO_2, and SO_2) had hysteresis effects on hospital admissions in adult asthma patients using regression analysis. The hysteresis effects of $PM_{2.5}$ and CO involved a lag of 1 and 3 days ($OR \geq 1$), the hysteresis effect of PM_{10} involved a lag of 0, 1, and 3 days ($OR \geq 1$), the hysteresis effect of NO_2 involved a lag of 1, 2, and 3 days ($OR \geq 1$), and the hysteresis effect of SO_2 involved a lag of 2 days ($OR \geq 1$). The greater the OR value, the higher the risk of hospital admissions in adult asthma patients due to elevated concentrations of air pollutants. In summary, the maximum *OR* value of most air pollutants occurred with a lag of 1 day. Therefore, 1 day before onset (lag of 1 day) was chosen as the exposure period and 8 days before onset was chosen as the control period to control for "the effect of the week". Using multiple logistic regression analysis, the results showed that the concentrations of $PM_{2.5}$, CO, and SO_2 influenced hospital admissions in adult asthma patients, and the positive association between hospital admissions and concentration of CO was most significant, which demonstrated that CO is possibly a risk factor for adult asthma. Therefore, controlling the release of CO can reduce the incidence of bronchial asthma.

A review study[27] summarized the association between asthma and $PM_{2.5}$ components. The authors showed that a positive association between asthma and $PM_{10-2.5}$, O_3, and NO_2 was established in most studies. The majority of studies found no significant association between SO_2 and asthma. However, evidence regarding the positive association between CO and asthma is much more consistent. Our results on the association between asthma and the concentration of CO are consistent with the above review, but a positive association between asthma and $PM_{10–2.5}$, O_3, and NO_2 was not found. This may be related to the small sample size, cold weather, and the small variation in pollutant concentration in Changchun.

In 2012, the UK's Committee on the Medical Effects of Air Pollutants indicated that outdoor air pollution may play a role in causing asthma in susceptible individuals who live close to busy roads with a lot of truck traffic. However, compared with other factors, air pollutants may only make a small contribution to the development of asthma and in only a small proportion of the population.[17] Thus, more research into the etiology of asthma is required.

In conclusion, a positive association between hospital admissions and the daily average concentration of CO was observed. CO is likely to be a risk factor for hospital admissions in adults with asthma.

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Conflicts of interest

There are no conflicts of interest.

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空气污染对中国东北地区成人支气管哮喘住院的影响

摘要

背景：支气管哮喘是一种常见的慢性呼吸系统疾病，与大气污染暴露有关。然而，仅有一些研究集中在大气污染与成人支气管哮喘的关系方面，且这些研究结果并不一致。本研究旨在探讨多种大气污染物对成人支气管哮喘住院的影响。

方法：收集自2014年至2016年住院的中国东北地区成人支气管哮喘患者，共1019名。从中国环境监测总站网站上获取2014年至2016年患者所在地区的日平均大气污染物（$PM_{2.5}$、PM_{10}、SO_2、NO_2、CO）浓度，应用Cox回归分析空气污染物与成人支气管哮喘患者住院之间的关系。

结果：滞后效应分析显示多数大气污染物的最大*OR*值出现在发病前1天，因此，以发病前1天为暴露期、发病前8天为对照期，共有3种污染物（$PM_{2.5}$、CO 和SO_2）被纳入回归方程，*OR* (95%*CI*) 分别是0.995 (0.991-0.999)、3.107 (1.607-6.010)和0.979 (0.968-0.990)。

结论：成人支气管哮喘住院与日平均CO浓度存在正相关，CO可能是成人支气管哮喘患者住院的危险因素。