Regional air pollution severity affects the incidence of acute myocardial infarction triggered by short-term pollutant exposure: a time-stratified case-crossover analysis

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Abstract

Long-term exposure to air pollution results in a high incidence of cardiovascular disease. Many studies have found that short-term exposure to air pollution can trigger acute myocardial infarction. This study aims to determine whether results in areas with different levels of severity of air pollution are similar. The study design is a time-stratified case-crossover analysis. This was a retrospective study based on hospital medical records. The study period was since 1 January 2017 to 31 December 2018. Research data were collected from Taoyuan Hospital, located in an area with low severity of pollution, and Taichung Hospital, located in an area with high severity of pollution. The correlation between short-term air pollution exposure and acute myocardial infarction was analyzed. The correlation between short-term exposure to ambient air pollutants and acute myocardial infarction was not significant for the cases collected from Taoyuan Hospital (PM_{2.5} OR: 1.006 and 95% CI: 0.995–1.017; PM₁₀ OR: 0.996 and 95% CI: 0.988–1.003). However, for the cases collected from Taichung Hospital, short-term exposure to ambient PM_{2.5} (odds ratio: 1.021; 95% confidence interval: 1.002–1.040) and PM₁₀ (odds ratio: 1.010; 95% confidence interval: 1.001–1.020) resulted in high incidence of acute myocardial infarction. Short-term pollutant exposure will increase the incidence of acute myocardial infarction based on the severity of regional air pollution. In addition to addressing traditional cardiovascular disease risk factors, the government must formulate relevant policies for reducing air pollution and the resulting hazards to citizens' health.

Keywords Particulate matter · Regional air pollution severity · Short-term effect · Acute myocardial infarction · Time-stratified case-crossover analysis

Introduction

Acute myocardial infarction is major disease that leads to poor health conditions (WHO 2016). It poses a heavy financial burden on families and requires considerable society-based treatment. Lelieveld et al. (2019, 2020) used novel hazard ratio functions to reassess cardiovascular disease burden due

to ambient air pollution in Europe. The results imply that reducing air pollution can substantially curb the reduction of life expectancy (see also Oikonomou et al. 2020). Through their respective national health policies, governments have been investing considerable effort into reducing the incidence of myocardial infarction. Moving away from the traditional risk factors for myocardial infarction, scholars are increasingly focusing on the correlation between air pollution and cardiovascular disease (Brook et al. 2004; Miller et al. 2007; Pope et al. 2006; Xie et al. 2015).

The main pathophysiological framework used to explain the epidemiological association between exposure to ambient air pollutants and acute myocardial infarction is an increase in the mean resting arterial blood pressure due to an increase in the sympathetic tone and regulation of potential systemic vascular tone. With a transient increase in plasma viscosity and the amount of endothelial function damage, the risk of intravascular thrombosis increases, thus promoting the

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development of atherosclerosis (Brook et al. 2002; Pekkanen et al. 2002; Sun et al. 2010; Rao et al. 2018).

Most studies note that long-term exposure to ambient air pollutants increases the incidence of cardiovascular disease. Many studies have found that short-term exposure to air pollution can trigger acute myocardial infarction. However, whether results are similar across areas with different levels of severity of air pollution remains unclear (Milojevic et al. 2014; Wichmann et al. 2014; Wolf et al. 2015).

This study aims to determine whether the difference in the severity of air pollution in the study area influences the difference between short-term exposure and incidence of acute myocardial infarction.

Materials and methods

This study was conducted at Taoyuan Hospital and Taichung Hospital, which are 450-bed academic regional emergency responsibility teaching hospitals; these hospitals are located in Taoyuan and Taichung, Taiwan (ROC), respectively. These hospitals are located in areas with low and high severity of air pollution, respectively. Data were obtained from a retrospective review of patient medical records, including the date of illness onset, gender, age, body mass index, hypertension, hyperlipidemia, diabetes, smoking, drinking, and heart disease history of the patient and their family. This retrospective study involved patients in Taoyuan and Taichung who received a diagnosis of acute myocardial infarction from 1 January 2017 to 31 December 2018. The diagnosis of acute myocardial infarction requires an elevated number of myocardial enzymes and confirmation by cardiac catheterization. Residents or workers who had not lived in the locality for more than 1 year were excluded from this study.

The Air Quality Monitoring Station of the Environmental Protection Agency of the Executive Yuan provided information on environmental air pollutants. Each monitoring station obtains hourly air pollutant data and provides the 24-h-average daily concentration of pollutants, including PM_{2.5}, PM₁₀, ozone (O₃), sulfur dioxide (SO₂), and nitrogen dioxide (NO₂), as well as the temperature and humidity.

We examined the associations between short-term air pollutant exposure and acute myocardial infarction by using a time-stratified case-crossover design. The levels of ambient air pollutants on the date of onset of illness were compared with those 2 weeks before the onset. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using Poisson regression in the generalized linear model. Models were adjusted for average temperature and relative humidity on the day of an event.

Categorical variables were compared between groups using the χ^2 test and Student's *t* test; continuous variables are presented as mean $\pm$ standard deviation and were

compared using the *t* test. $P < 0.05$ was considered statistically significant. Data analyses were performed using SPSS version 22 (SPSS, Chicago, IL, USA).

Results

Based on the medical records of emergency departments and hospitalization, this study recruited 352 and 278 patients respectively from Taoyuan and Taichung hospitals. The diagnosis of acute myocardial infarction requires elevated number of myocardial enzymes and confirmation by cardiac catheterization. Residents or workers who had not lived in the locality for more than 1 year were excluded from this study.

Table 1 presents the demographic and medical data of patients from Taoyuan Hospital. Most acute myocardial infarctions occurred in men (76.40%). The average patient age was 62 years, and most of the patients were overweight (25 to <30 kg/m²). Among the traditional risk factors, hypertension and smoking were significant. Table 2 presents the demographic and medical-related data of patients from Taichung Hospital. Again, most acute myocardial infarctions occurred in men (71.58%). The average patient age was 66 years, and most of the patients were overweight (25 to <30 kg/m²). Among the traditional risk factors, hypertension and smoking were significant here, as well. The cases in Taoyuan and Taichung mainly comprised male older adults (mean average is 62 years old; 66 years old). The major risk factors were overweight, high blood pressure, and smoking. Table 3 shows no significant difference demographic and medical-related variables between the cases collected from Taoyuan Hospital and those from Taichung Hospital.

Compared with the analysis of air pollution concentration conducted 2 weeks before the onset of disease in patients. The occurrence of short-term exposure to ambient air pollutants and the incidence of acute myocardial infarction were not significant in the cases collected from Taoyuan Hospital (PM_{2.5} OR: 1.006 and 95% CI: 0.995–1.017; PM₁₀ OR: 0.996 and 95% CI: 0.988–1.003) (Table 4). However, for the cases collected from Taichung Hospital, short-term exposure to the ambient air pollutants of PM_{2.5} (OR: 1.021; 95% CI: 1.002–1.040) and PM₁₀ (OR: 1.010; 95% CI: 1.001–1.020) increased the incidence of acute myocardial infarction (Table 5). O₃, SO₂, and NO₂ displayed no significant correlations between short-term exposure of air pollution and incidence of acute myocardial infarction in Taoyuan and Taichung hospitals.

Discussion

The effects of short-term air pollution exposure and the incidence of acute myocardial infarction were found to be closely

Table 1 Demographic and medical-related variables of the patients from Taoyuan Hospital

Acute myocardial infraction		
	Number	Percentage
Total	352	100.00
Sex		
Male	269	76.40
Female	83	23.60
Age	62.90 ± 14.89	
Age group (years)		
<45	42	11.90
45–65	157	44.60
>65	153	43.50
BMI (kg/m ²)	27.51 ± 4.07	
<18.5	8	2.30
18.5 to <25	128	36.40
25 to <30	178	50.60
≥30	38	10.80
Hypertension		
Yes	244	69.30
No	108	30.70
Hyperlipidemia		
Yes	65	18.50
No	287	81.50
Diabetes mellitus		
Yes	131	37.20
No	221	62.80
Smoking		
Yes	229	65.06
No	123	34.94
Drinking		
Yes	79	22.40
No	273	77.60
Heart disease		
Yes	113	32.10
No	239	67.90
Family heart disease		
Yes	76	21.60
No	276	78.40

Table 2 Demographic and medical-related variables of the patients from Taichung Hospital

Acute myocardial infraction		
	Number	Percentage
Total	278	100.00
Sex		
Male	199	71.58
Female	79	28.42
Age	66.16 ± 16.71	
Age group (years)		
<45	46	16.55
45–65	99	35.61
>65	133	47.84
BMI (kg/m ²)	26.18 ± 4.31	
<18.5	3	1.08
18.5 to <25	109	39.21
25 to <30	122	43.88
≥30	44	15.83
Hypertension		
Yes	199	71.58
No	79	28.42
Hyperlipidemia		
Yes	93	33.45
No	185	66.55
Diabetes mellitus		
Yes	127	45.68
No	151	54.32
Smoking		
Yes	187	67.27
No	91	32.73
Drinking		
Yes	96	34.53
No	182	65.47
Heart disease		
Yes	83	29.86
No	195	70.14
Family heart disease		
Yes	67	24.10
No	211	75.90

related to the severity of air pollution in the study area. During the study period (01 January 2017–31 December 2018), poor air quality was indicated on only 7% of the days in the Taoyuan area, whereas in the Taichung area, this percentage was 30%. This result conforms to the findings in our analysis using a health insurance database, and the occurrence of acute myocardial infarction was positively correlated with average air pollution severity in the study area (unpublished data).

Similar findings have been reported in systematic reviews. In area with low severity of air pollution, short-term pollutant exposure did not increase the incidence of acute myocardial infarction (Milojevic et al. 2014; Wichmann et al. 2014; Wolf et al. 2015). Studies conducted in areas with moderate or high severity of air pollution have reported a positive correlation between short-term exposure to pollution and the incidence of acute myocardial infarction (Xu et al. 2017a, b; Ye et al. 2016; Liu et al. 2015; Yu et al. 2018).

Table 3 Demographic and medical-related variables of the cases collected from Taoyuan Hospital and Taichung Hospital

	Taoyuan Hospital (<i>N</i> = 352)	Taichung Hospital (<i>N</i> = 278)	<i>P</i>
Age, y	62.90 ± 14.89	66.16 ± 16.71	0.51
Male sex, <i>n</i> (%)	269 (76.40)	199 (71.58)	0.44
BMI (kg/m ²)	27.51 ± 4.07	26.18 ± 4.31	0.85
Hypertension, <i>n</i> (%)	244 (69.30)	199 (71.58)	0.53
Hyperlipidemia, <i>n</i> (%)	65 (18.50)	93 (33.45)	0.16
Diabetes mellitus, <i>n</i> (%)	131 (37.20)	127 (45.68)	0.43
Smoking, <i>n</i> (%)	229 (65.06)	187 (67.27)	0.62
Drinking, <i>n</i> (%)	79 (22.40)	96 (34.53)	0.27
Heart disease, <i>n</i> (%)	113 (32.10)	83 (29.86)	0.34
Family heart disease, <i>n</i> (%)	76 (21.60)	67 (24.10)	0.55

Wolhuter et al. (2021) used two major events in 2020, namely, the Australian bushfires and the COVID-19 pandemic lockdown, to illustrate the relationship between air pollution and cardiovascular disease. The Australian bushfires led to severe air pollution and increased the incidence of cardiovascular disease. Conversely, the COVID-19-related lockdown demonstrated that air pollutants can be effectively reduced, which lead to the potential reduction of cardiovascular disease events. Further, Giani et al. (2020) demonstrated that China and Europe experienced the short-term and long-term health effects of reduced air pollution due to the COVID-19 lockdown.

A patient's chronic health conditions can affect their susceptibility to acute myocardial infarction, but these factors are usually not measured accurately (Pope et al. 2015; Wolf et al. 2015). In 1991, Maclure et al. proposed the case-crossover study design, which is a method for studying transient effects on the risk of acute events. Our study employed a 2-week time interval; the air pollution level during the acute myocardial infarction event was compared with that 2 weeks before the event. This study design can reduce individual differences and the influence of confounding factors (Maclure 1991).

The mechanism through which long-term exposure to air pollution leads to cardiovascular disease development has

been proven; this can increase oxidative stress (OS), inflammatory stress, and vascular endothelial damage, leading to atherosclerosis (Seaton et al. 1995; Brook et al. 2004; Kodavanti et al. 2002). OS and inflammatory stress also influence many neurological diseases; however, no effective and safe treatment is available for neurological diseases. Rahman et al. (2021) reported that molecular hydrogen (H₂) is an antioxidant and an anti-inflammatory agent. It can be used for the prevention, treatment, and mitigation of H₂ administration. However, the efficacy of H₂ in preventing coronary atherosclerosis remains unknown.

COVID-19 infection mainly affects the respiratory system. However, an increasing number of studies reported neurological and cardiovascular abnormalities, as well. Furthermore, cardiovascular and neurological diseases are likely to be underlying causes of the risk of severe COVID-19 infection. To reduce the impact of neurological and cardiovascular diseases on patients with COVID-19, detailed risk analysis and the development of comprehensive management strategies are necessary (Sharma et al. 2021). In cardiovascular diseases, atherosclerosis leads to coronary artery stenosis, which takes time to accumulate. Long-term exposure to air pollution increases latent cardiovascular diseases. Short-term exposure to air pollution can produce OS and inflammation, increase the

Table 4 Incidence of short-term exposure to ambient air pollutants and acute myocardial infarction in the patients from Taoyuan Hospital

Poisson regression in the generalized linear model				
	OR	95% CI	95% CI	<i>P</i>
PM _{2.5}	1.006	0.995	1.017	0.315
PM ₁₀	0.996	0.988	1.003	0.253
NO ₂	0.998	0.975	1.021	0.848
SO ₂	1.051	0.897	1.233	0.536
O ₃	1.005	0.995	1.014	0.345

OR odds ratio; adjusted variables listed in the table, CI confidence interval

Table 5 Incidence of short-term exposure to ambient air pollutants and acute myocardial infarction in the patients from Taichung Hospital

Poisson regression in the generalized linear model				
	OR	95% CI	95% CI	<i>P</i>
PM _{2.5}	1.021	1.002	1.040	0.026
PM ₁₀	1.010	1.001	1.020	0.035
NO ₂	0.997	0.988	1.007	0.551
SO ₂	1.002	0.985	1.021	0.788
O ₃	1.007	1.000	1.014	0.057

OR odds ratio; adjusted variables listed in the table, CI confidence interval

burden on the heart, and trigger latent cardiovascular diseases. This explains why short-term exposure to air pollutants in areas with severe air pollution increases the risk of acute myocardial infarction.

This study has three strengths. First, we used medical records from two hospitals, and all patients were identified as having acute myocardial infarction based on records of cardiac catheterization. Second, we could confirm that all patients had been active near the hospital for a long time; therefore, the air pollution data from the corresponding monitoring station could represent the patient's exposure to air pollutants. Third, we compared the condition of the day of onset of disease with that on the same day 2 weeks prior to eliminate the effect of changes in patient's lifestyle and physical illness.

This study has two limitations. First, we could not determine the true air pollution exposure of the patients, which would have been affected by the use of protective equipment or working indoors. Second, we employed medical records from only two hospitals for analysis and research. The study results revealed a positive correlation in an area with high severity of air pollution but no correlation in an area with low severity of air pollution. We were unable to define high severity of air pollution precisely; doing so would require more research data.

Conclusion

The difference in the severity of regional air pollution has a serious short-term impact on the risk of acute myocardial infarction. Therefore, to fully prevent acute myocardial infarctions caused by exposure to ambient air pollutants, relevant laws and regulations should be complied with to control the level of ambient air pollutants to the greatest extent possible and thus reduce people's exposure to air pollutants.

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Author contribution C.-C.Y. was responsible for study design, acquisition, analysis and interpretation of data, and drafting the manuscript. P.-L.C. contributed to the design and interpretation of the analysis and drafting and critical revision of the manuscript. All authors provided approval for the final version of the manuscript and agree to be accountable for all aspects of the work.

Data availability The air pollution data was provided by the Protection Agency of the Executive Yuan (<https://airtw.epa.gov.tw/>). The full datasets used in this analysis are available from the corresponding author on reasonable request.

Declarations

Ethics approval The present study was approved by the Institutional Review Board of Tri-Service General Hospital, and all procedures were in accordance with prevailing ethical principles.

Consent to participate This is a retrospective case study. All cases have been treated before data collection to avoid patient identification. Therefore, patients' informed consent was not required.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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