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# Air pollution effects on myocardial infarction

## Efeitos da poluição do ar no infarto do miocárdio

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### ABSTRACT

**OBJECTIVE:** Myocardial infarction is an acute and severe cardiovascular disease that generally leads to patient admissions to intensive care units and few cases are initially admitted to infirmaries. The objective of the study was to assess whether estimates of air pollution effects on myocardial infarction morbidity are modified by the source of health information.

**METHODS:** The study was carried out in hospitals of the Brazilian Health System in the city of São Paulo, Southern Brazil. A time series study (1998-1999) was performed using two outcomes: infarction admissions to infirmaries and to intensive care units, both for people older than 64 years of age. Generalized linear models controlling for seasonality (long and short-term trends) and weather were used. The eight-day cumulative effects of air pollutants were assessed using third degree polynomial distributed lag models.

**RESULTS:** Almost 70% of daily hospital admissions due to myocardial infarction were to infirmaries. Despite that, the effects of air pollutants on infarction were higher for intensive care units admissions. All pollutants were positively associated with the study outcomes but SO<sub>2</sub> presented the strongest statistically significant association. An interquartile range increase on SO<sub>2</sub> concentration was associated with increases of 13% (95% CI: 6-19) and 8% (95% CI: 2-13) of intensive care units and infirmary infarction admissions, respectively.

**CONCLUSIONS:** It may be assumed there is a misclassification of myocardial infarction admissions to infirmaries leading to overestimation. Also, despite the absolute number of events, admissions to intensive care units data provides a more adequate estimate of the magnitude of air pollution effects on infarction admissions.

**KEYWORDS:** Air pollution, adverse effects. Cardiovascular diseases. Time-series study.

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### RESUMO

**OBJETIVO:** O infarto do miocárdio é uma doença cardiovascular grave que tem como indicação a internação em unidades de terapia intensiva, com poucos indicados para admissão em enfermarias. O objetivo do estudo foi investigar se as estimativas dos efeitos da poluição atmosférica nas internações por infarto do miocárdio são modificadas de acordo com a fonte de informações de saúde.

**MÉTODOS:** Em hospitais do Sistema Único de Saúde (SUS), na cidade de São Paulo, foi realizado estudo de séries temporais (1998-1999) tendo como desfechos as internações por infarto em unidades de terapia intensiva e em enfermarias, em pessoas acima de 64 anos. Foram utilizados modelos lineares generalizados, controlados para sazonalidade (de longa e curta duração) e variáveis climáticas. Foram construídos

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modelos distribuídos de defasagem polinomial de terceiro grau, para avaliar os efeitos acumulados nos oito dias anteriores à exposição.

**RESULTADOS:** Aproximadamente 70% das internações por infarto no miocárdio ocorreram em enfermarias. Apesar disso, os efeitos da poluição sobre os casos foram maiores nas internações em unidades de terapia intensiva. Todos os poluentes mostraram uma associação positiva com os desfechos, mas o SO<sub>2</sub> apresentou uma associação mais robusta e estatisticamente significativa. O aumento do intervalo interquartil para as concentrações observadas do SO<sub>2</sub> foi associado ao aumento em 13% (IC 95%: 6-19) e 8% (IC 95%: 2-13) nas internações em unidade de terapia intensiva e enfermarias, respectivamente.

**CONCLUSÕES:** Pode-se supor que exista um erro de classificação das internações por infarto nas enfermarias, superestimando o número de internações. No entanto, o menor número de internações por infarto do miocárdio em unidades de terapia intensiva, é o indicador mais adequado para estimar os efeitos da poluição atmosférica nas internações por infarto.

**DESCRIPTORIOS:** Poluição do ar, efeitos adversos. Doenças cardiovasculares, estudo de séries temporais.

## INTRODUCTION

The incidence and prevalence of cardiovascular diseases have increased in the last decades and became one of the main causes of death among adults.<sup>3,18</sup> In metropolitan areas, increasing levels of air pollutants constitute an additional risk factor for those diseases.<sup>22,24</sup> Most of the epidemiological studies quantifying air pollution effects on human health have focused on mortality events, reporting both chronic and acute strong and robust associations.<sup>2,5,18,21</sup>

The interest in investigating cardiovascular disease morbidity has increased in the last years. Lin *et al*<sup>13</sup> recently studied the association between air pollution and ischemic cardiovascular emergency room visits in São Paulo, Brazil. Environmental CO was associated with angina and acute myocardial infarction in a short lag time. Santos *et al*<sup>20</sup> conducted a study, also in São Paulo, following 48 healthy traffic workers daily exposed to eight hours of urban air pollution, evaluating blood pressure and heart rate. The results showed increased blood pressure and decreased heart rate variability during the highest polluted periods. These effects are in agreement with other reports on cardiovascular effects of urban air pollution exposure.<sup>4,9,19</sup>

Despite the severity of cardiovascular events, most patients will not present fatal outcomes and will be cared at emergency room services and/or admitted to intensive care units or infirmaries. These morbidity outcomes are highly relevant in order to get a precise estimative of cardiovascular air pollution health effects.

In the present study, it was assessed the effects of daily variation of urban air pollutants on myocardial infarction (MI) hospital admissions using data from intensive care units (ICU) and regular infirmaries of the Brazilian Health System (SUS) hospitals.

## METHODS

Hospital admissions due to MI, classified according to the ICD-10,<sup>25</sup> were obtained from the Public Health Data Analysis System Division (DATASUS) for 112 SUS hospitals in the city of São Paulo, Southern Brazil, between January 1998 to December 1999. It was selected the daily number of admissions due to MI in two admission sectors: infirmaries and ICU.

The *Companhia de Tecnologia de Saneamento Ambiental* (São Paulo State Environmental Protection Agency - Cetesb) provided daily records of NO<sub>2</sub>, SO<sub>2</sub>, CO, O<sub>3</sub> and PM<sub>10</sub> for the same period. By the time of the study, there were 13 monitoring stations spread all over the city, although not all of them measured all pollutants at that time. It was adopted the average of all stations that measured each pollutant as a citywide exposure status. The measurement adopted for CO was the highest 8-hour moving average in five stations, NO<sub>2</sub> and O<sub>3</sub> concentrations were computed as the highest hourly average in four stations, and for PM<sub>10</sub> (12 stations) and SO<sub>2</sub> (13 stations) there were adopted the 24-hour averages. All pollutants were measured in the period from 1:00 am to 12:00 pm. Information on daily minimum temperature and relative humidity were obtained from the *Instituto de Astronomia e Geofísica da Universidade de São Paulo*

**Table 1** - Descriptive analysis of the main variables. São Paulo, 1998-1999.

Variable	Daily mean	SD	5%	IQR	95%	N
MI admissions						
Intensive care unit	7.90	4.63	1.00	7.00	16.00	717
Infirmaries	18.50	12.51	3.00	16.00	45.00	724
Weather						
Temperature (°C)	15.21	3.42	9.80	5.40	20.60	724
Humidity (%)	81.09	8.34	64.78	10.30	93.00	724
Pollutants						
SO <sub>2</sub>	14.75	8.16	5.31	10.00	31.57	724
NO <sub>2</sub>	100.19	42.88	48.01	54.67	189.77	724
O <sub>3</sub>	72.10	38.69	24.78	50.23	145.13	724
PM <sub>10</sub>	48.34	21.41	25.73	22.50	95.89	724
CO	2.93	1.39	1.30	1.42	5.92	724

MI: Myocardial infarction SD: Standard deviation; IQR: Interquartile range; N: Days of observations

(University of São Paulo Institute of Astronomy and Geophysics, IAG-USP).

In order to evaluate the association between air pollution and hospital admissions due to MI, generalized additive Poisson regression distributed lag models<sup>8,21</sup> were applied. The two study outcomes were the number of admissions due to MI in elderly admitted to two hospital units: ICU and infirmaries. The explanatory variables were smooth function of time, temperature and humidity and dummy variables for days of the week. Based in previous studies,<sup>13</sup> it was employed two-day moving average for temperature and humidity.

It was considered the LOESS smoother, available in S-Plus<sup>TM</sup> 2000 software, using more stringent convergence parameters in order to assure convergence of its iterative estimation procedures.<sup>6</sup> The smoothing parameter for time was chosen in such a manner as to control the seasonality, removing long-term trends out of the data and minimizing the autocorrelation of the residuals. If there were any remaining autocorrelation, autoregressive terms were added to the model.

The effect of air pollution on mortality is distributed over time, i.e., the number of admissions in a single day may be due to the exposure to air pollution not only on that day but also over the preceding days.

Considering that, it was used third degree polynomial distributed lag models (PDL) to investigate a 8-day cumulative effect (lag 0 through lag 7) because it can provide a biologically plausible lag structure.<sup>2</sup> The sum of the effect of a unit increase in air pollution on a single day is the sum of regression coefficients for each day ( $\beta_0 + \dots + \beta_7$ ). The standard errors of the estimates are given by the variance of the sum of  $\beta_0 + \dots + \beta_7$ , adjusting for over dispersion. It was estimated percentage increases and 95% confidence intervals (CI) in MI due to interquartile range increases in air pollutants concentrations.

## RESULTS

Table 1 shows the descriptive analysis of the main variables included. Almost 70% of the daily hospital admissions due to MI were to infirmaries. None of air pollutants had daily concentrations above the Brazilian air quality standards.\*

Table 2 presents the Pearson correlations coefficients of the main variables. Both infirmaries and ICU admissions had positive significant correlations with pollutants, except O<sub>3</sub>, and several pollutants were correlated to each other.

Table 3 shows the percentage increase and 95% CI for hospital admissions to ICU and infirmaries due to MI. SO<sub>2</sub> presented a positive significant association

**Table 2** - Pearson correlation of the main variables. São Paulo, 1998-1999.

Variable	Infirmary	ICU	Temperature	Humidity	SO <sub>2</sub>	NO <sub>2</sub>	O <sub>3</sub>	PM <sub>10</sub>
Infirmary	1.00							
ICU	0.64**	1.00						
Temperature	-0.03	-0.08*	1.00					
Humidity	0.02	-0.08*	0.02	1.00				
SO <sub>2</sub>	0.28**	0.35**	-0.34**	-0.44**	1.00			
NO <sub>2</sub>	0.30**	0.31**	-0.05	-0.34**	0.70**	1.00		
O <sub>3</sub>	-0.09*	0.03	0.05	-0.37**	0.31**	0.40**	1.00	
PM <sub>10</sub>	0.21**	0.23**	-0.23**	-0.54**	0.77**	0.76**	0.41**	1.00
CO	0.18**	0.16**	-0.04	-0.36**	0.52**	0.65**	0.00	0.69**

\*p<0.05; \*\*p<0.01

ICU: Intensive care unit

\*Brasil, Conselho Nacional do Meio Ambiente. Resolução nº 3, de 28 de junho de 1990. Diário Oficial da União, Brasília (DF), 22 ago 1990, Seção I, p. 15937-9.

with both hospital admissions dependent variables. The percentage increase of ICU admissions was 58% greater than infirmaries admissions. An interquartile range increase on SO<sub>2</sub> concentration was associated with increases of 13% (95% CI: 6-19) and 8% (95% CI: 2-13) on ICU and infirmary MI admissions, respectively. ICU admissions were also associated with O<sub>3</sub> (9.3% increase). Only PM<sub>10</sub> presented percentage increase in infirmaries higher than in ICU.

Figure depicts interquartile percentage increase of the distributed lag models to infirmaries and ICU for the air pollutants included in the study. All models had the same behavior, showing high coefficients in lag 0 and 1. Only SO<sub>2</sub> and O<sub>3</sub> showed positive and statically significant sum of effects (lag 0 through lag 7).

**DISCUSSION**

Air pollution was positively associated with increases in the daily number of MI admissions to ICU and infirmaries, and the pollutant that presented the strongest association with both outcomes was SO<sub>2</sub>.

In recent studies carried out in São Paulo, SO<sub>2</sub> has been associated with mortality and morbidity out-

**Table 3** - Percentage increase and 95% CI of myocardial infarction in hospital admissions at intensive care units and infirmaries. São Paulo, 1998-1999.

Variable	Intensive Care Units %	(95% CI)	Infirmary %	(95% CI)
PM <sub>10</sub>	3.2	(8.6-2.2)	5.0	(9.8-0.1)
SO <sub>2</sub>	12.9	(19.4-6.4)	7.5	(13.3-1.7)
NO <sub>2</sub>	3.8	(11.4-3.8)	2.8	(9.4-3.7)
CO <sub>2</sub>	-0.2	(6.6-6.7)	-3.1	(2.3-8.6)
O <sub>3</sub>	9.3	(17.4-1.1)	5.3	(12.7-2.1)

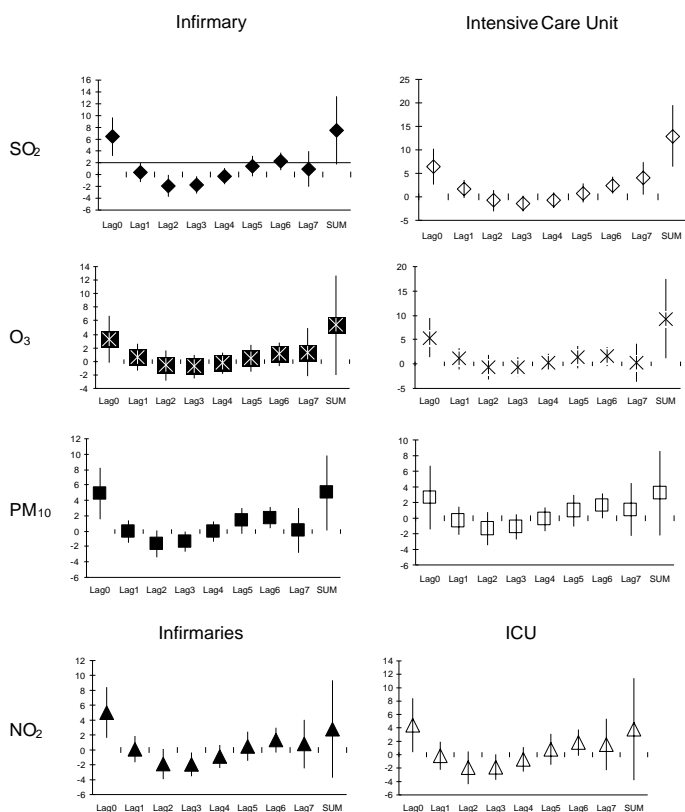
comes.<sup>12,15</sup> Although the usual levels of SO<sub>2</sub> found in São Paulo are not above the standard limits, they constitute a good marker of automotive emissions, the main pollution source in the city of São Paulo. The city has a population of nine million inhabitants and an automotive fleet of four million vehicles, i.e., almost one vehicle for every two inhabitants, suggesting that SO<sub>2</sub> may be a proxy for PM<sub>2.5</sub> levels.

PM<sub>10</sub> and O<sub>3</sub> were also associated to the studied outcomes. The PM<sub>10</sub> levels were associated with the daily number of MI admissions to infirmaries. This pollutant has been frequently associated to cardiovascular morbidity and mortality in several cities worldwide,<sup>1,11,14</sup> and a number of hypotheses were raised about the possible mechanisms that could be responsible for such effects. Some of them involve inflammatory responses triggering endothelial dysfunction, atherosclerosis, and thrombosis; alterations on ion channel function in myocardial cells, and effects on the autonomic nervous system.<sup>23</sup>

The daily number of MI admissions in ICU also presented an association with ozone levels. This association has also been reported in the literature, although much less frequently.<sup>10</sup>

The PDL models indicated a short-time lag between the increase in air pollution and MI occurrence. The patterns of lag structure for the effects of air pollution on myocardial infarction events have been found by other authors,<sup>2,17,24</sup> in studies carried out in the United States. In fact, this behavior found in observational studies is supported by experimental studies that have showed increases in cardiovascular events within one hour after the exposure.<sup>7</sup>

The SO<sub>2</sub> effect on ICU admissions was higher than on infirmaries admissions. It is possible that patients admitted to ICU presented more severe disease. There are fewer vacancies than the actual demand of MI cases in the city. In the last decades, cardiovascular diseases have increased in São Paulo because of intense



**Figure** - Percentage increases and 95% confidence intervals of myocardial infarctions admissions to infirmaries and intensive care units due to air pollutants: 8-day distributed lag models and cumulative effects. São Paulo, 1998-1999.

urbanization process, epidemiological transition, and increased life expectancy.<sup>16,\*</sup> Cardiovascular diseases has been the main causes of mortality, and MI is the third main cause in the cardiovascular group.\* In this scenario MI severity has been a criterion of choice that may be determining ICU admissions. Using MI admissions to ICUs in epidemiological studies may help estimating the effect of air pollution among those patients with more severe diseases. This is a very important point that has been considered by policy decision makers. Many authors have reported

the effects of air pollutants on the cardiovascular system, but none has analyzed the relationship between MI admissions to ICU and air pollution.

Differently from respiratory diseases, the effects of air pollution on cardiovascular diseases in São Paulo are still being characterized. This study contributes to estimate the impact of air pollution in morbidity, and shows that hospital admissions to intensive critical care units may be a good indicator of cardiovascular effects and air pollution.

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