Research Article

ISSN 2575-6087

Medical - Clinical Research & Reviews

Effects of Air Pollution on the Autonomic Cardiac Modulation: A Literature Review

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Received: 05 March 2018; **Accepted**: 07 April 2018

Citation: Juliana Regis da Costa e Oliveira, Luis Henrique Base, Luiz Carlos de Abreu, et al. Effects of Air Pollution on the Autonomic Cardiac Modulation: A Literature Review. Med - Clin Res & Rev. 2018; 2(2): 1-5.

ABSTRACT

Introduction: *The main cause of death in the world is cardiovascular diseases and among the different risk factors, we can mention air pollution.*

Objectives: *Describe the findings on the effects of air pollution on the autonomic cardiac modulation.*

Methods: *The research was conducted using Scopus, PubMed, Web of Science and SciELO, over the term from 1996 to 2016. Manuscripts written in Portuguese or English, with keywords environmental pollution; air pollution; cardiovascular system; autonomic nervous system, texts dealing with environmental pollution and its relation to human exposition and original papers with the full text available on line were included.*

Results: *The electronic search in databases resulted in 194 articles which were filtered according to gratuity full text delimited topic as well as the couple eliminated, resulting in 25 articles. Of these articles, 12 articles were included that specifically addressed the autonomic cardiac modulation. These remaining items were analyzed in Microsoft Office Excel 2010 program.*

Conclusion: *The effects of air pollution on autonomic cardiac modulation are, in short, a reduction in autonomic cardiac modulation facing air pollution and its increases.*

Keywords

Environmental pollution, Air pollution, Cardiovascular system, Autonomic nervous system.

Introduction

Air pollution could be defined as any form of matter or energy with intensity and in an amount, concentration, time or characteristics not according to established levels, that may change air: inappropriate, harmful or hurtful for health; inconvenient to the public well-being; harmful for materials, the fauna and the flora; harmful for safety, the use and enjoyment of property and the normal activities of the community [1].

This pollution is the result of a combination of particles – particulate matter (PM) - and gases that are released into the atmosphere mainly by industries, cars, thermoelectrical generators, and biomass and fossil fuels burning [2].

The main pollutants found in urban centers are: sulfur dioxide (SO_2); nitrogen dioxide (NO_2), hydrocarbons (HC), inhalable or thoracic PM, carbon monoxide (CO), ozone (O_3) and total suspended particles (TSP) [1,2].

Air pollution may cause different harmful effects in human beings. In the 68th World Healthy Assembly in 2015, it was pointed out that 4.3 millions of deaths occur every year of exposition to air pollution in indoor air pollution and 3.7 millions of deaths per year can be attributed to air pollution in open places; i.e., the

environment [3].

In spite of the legislation leading to dramatic reductions in air pollution levels, literature shows that pollution is still producing negative effects on human health. Mortality and hospital admissions increase along with the growth in particles concentration and pollutant gases [4].

In the cardiovascular system such increase in morbidity and mortality is mainly related to the exposure particulate matter, more specifically, the fine particles (particles with smaller diameter is equal to 2.5 μm – PM 2.5) [5].

The changes begin with the PM 2.5 from entering the respiratory system, after the deposition in the lungs is absorbed by the lung capillaries. These particles pass the membrane-capillary barrier and are able to inhibit phagocytosis and damaging inflammatory responses stimulate epithelial cells and gaining the interstitium, resulting in a variety of cardiovascular changes influencing negatively on cardiac function [6,7].

One of the changes is in the heart rhythm, which was closely related to autonomic nervous system activity, and can be evaluated by measuring heart rate variability (HRV) variations. The HRV was mediated by a balance between the sympathetic and parasympathetic branches of the autonomic nervous system, which is recognized as a marker for the prognosis of the incidence of ventricular arrhythmia [8].

Therefore, this study has as its objective to describe the findings on the effects of air pollution on the autonomic cardiac modulation.

Methods

Literature review (non-systematic review), with standardization for a better result through the following steps: (1) defining the issue of the survey; (2) delimiting the inclusion and exclusion criteria; (3) gathering selected papers; (4) analysis of the results, and (5) presentation of data.

The issue of the survey was defined as: "Which are the findings on the effects of air pollution on the autonomic cardiac modulation?" The following databases were consulted: Scopus, PubMed, Web of Science and SciELO, with the keywords "environmental pollution"; "air pollution" AND "cardiovascular system" OR "autonomic nervous system". The keywords were selected according to the Medical Subject Headings (MeSH) in the National Library of Medicine and also by their synonyms.

The collection period was from October 2015 to January 2016. Papers published between 1996 and 2016 were investigated. The inclusion criteria were: papers published in selected databases; texts written in English or Portuguese and original, with the full text available online. The exclusion criteria were: non-original papers, such as opinions, prefaces or a brief communication.

Initially, we were selected items with free full text. At the end of this stage, we excluded duplications. Secondly, we conducted a detailed reading of the abstracts of the selected articles, according to those that addressed only the relationship between air pollution and autonomic cardiac modulation. We excluded abstracts not related to the issue. The full texts then were evaluated, and then those with issues related to other body systems, nonhuman objects of study and not original articles, were excluded from this review.

The data obtained were organized, classified and analyzed with the software Microsoft Office Excel 2010, where they were also used to make the tables.

Results

The electronic search in the databases resulted in 79 papers in Scopus, 64 in PubMed, 27 in the Web of Science, and 23 in SciELO, constituting a total of 194 papers. Of the 194 selected studies, only 103 were considered included because they had free full text. Of these articles, 57 were duplicates, totaling 46 articles. They excluded studies involving other body systems, articles where the object of study were not human beings, not original articles, resulting in 25 articles. Of these articles, 12 articles were included that specifically addressed the autonomic cardiac modulation. These remaining papers were organized and analyzed with the software Microsoft Office Excel 2010.

The tables below showed the data of each paper, such as the identification of the authors and the year, the objectives and the conclusion (Tables 1).

Discussion

Literature shows, with increasingly more significant results, the effects on human health as morbidity and mortality associated to air pollutants. The main manifestations were related to the respiratory and cardiovascular systems, as a greater use of medications, functional limitation, and hospital admissions [21].

Heart diseases frequently manifest in an asymptomatic way, leading to diagnosis made late and with fatal outcomes. Small cardiac alterations may cause modifications in the autonomic nervous system (ANS) that influence the control of the cardiovascular system by interaction of the parasympathetic and sympathetic pathways [22].

However, it is possible to evaluate the ANS by using heart rate variability (HRV), which describes the oscillations of the intervals between consecutive heart beats (R-R intervals), and are related to the influences of the ANS on the sinus node in a noninvasive manner, inexpensively and easily made, being used to evaluate modifications in the cardiac autonomic control both in rest and during exercise [22,23].

HRV could be quantified by linear methods, divided into time and frequency domains, and non-linear, into chaos domain to evaluate the sympathetic and parasympathetic modulations on the organism [22].

Author/year	Objective	Conclusion
Gold DR, et al. 2000 [9]	To analyze the relation between air pollution and HRV in elderly patients living in Boston	Exposition to particles and ozone may decrease vagal tone, leading to HRV reduction.
Schwartz J, et al. 2005 [10]	Analyze air pollution on trafficking and HRV in healthy elderly.	Traffic particles, $PM_{2.5}$ are associated with control of autonomic disorders of the heart by altering the ratios rMSSD and pNN50 (increase) but strongest associations were observed with carbon black, an indicator of particle traffic, which was also associated with SDNN and LF/FR (increase).
Jia X, Song X, Shima M, Tamura K, Deng F, Guo X, 2011 [11]	Describe the effects of ozone exposure and HRV in healthy elderly subjects.	There is an association between short-term ozone exposure with cardiovascular effects, by decreasing the heart rate variability (decreased high frequency and an increase in high and low frequency) in healthy elderly.
Vallejo M, et al. 2006 [12]	Analyze the association between healthy young adults and environmental levels observed in the City area of metropolitan Mexico.	This observation reveals an acute effect related to environmental exposure to $PM_{2.5}$ in relation to HRV (decrease caused by vagal modulation) in sedentary young normal. The consequences for the long-term health of the association in healthy young adults are still unclear.
Riojas-rodriguez H et al, 2006 [13]	Evaluate the effect of particulate matter $PM_{2.5}$ and CO in HRV in patients with ischemic heart disease in Mexico City.	For this vulnerable group of patients, we found a consistent association between increased $PM_{2.5}$ and CO and decreased heart rate variability (decreased high frequency for each 10 mg / m3 $PM_{2.5}$ and a decrease of very low frequency) increasing susceptibility of patients at high risk for adverse cardiac events.
Schneider A, et al, 2010 [14]	To analyze the association between the capacity of heart rate deceleration, such as heart rate variability and environmental particulate matter (PM) in patients with CVD.	The analysis showed significant effects of air pollution as environmental particles on the parameters of heart rate deceleration and HRV that reflect the parasympathetic modulation of the heart in patients with CVD.
Feng Y, et al, 2015 [15]	Evaluate the PM exposure associated with HRV, as well as the potential effect modification of Framingham risk score (FRS) in adults in two cities differ in air quality.	There was a significant decrease in the total power and low power with high concentrations of PM_{10} in the city with high levels of PM but not in city low levels; significant modification of FRS in the city with high levels of PM under the influence PM_{10}. Interestingly, high PM_{10} was associated with a greater decrease in HRV in the subgroup with low FRS, but not in the group of high FRS. Thus, individual cardiac risk factors can modulate the association between air pollution particles and HRV in high exposure levels.
Liao D, et al, 2004 [16]	To analyze the associations in the short term, between pollutants (particulate matter of less than 10 m, ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide) and the cardiac autonomic control of a cohort with a population base.	Greater concentrations of environmental pollutants are associated to a lower cardiac autonomic regulation (SDNN and high frequency decreased), especially between people with existing cardiovascular disease.
Ren C, et al, 2011 [17]	Analyze if the environmental temperature changes may be associated with cardiac autonomic function in a longitudinal analysis (2000-2008) of the population, also related to particulate matter and ozone.	The temperature was associated with decreased HRV (increased high frequency and decreased low frequency) during the warm season (May-September), but not during the cold season (November to March) in a population of elderly men study in Boston and these associations were significantly modified by exposure to ozone, but not particulate matter.
Wu S, et al, 2013 [18]	To examine the associations between exposure to temperature and heart rate variability in healthy taxi drivers in the context of air pollution related to traffic.	The temperature, hot and cold, it was associated with changes in cardiac autonomic function (increase in temperature levels were associated with declines SDNN and increased low frequency and ratio high and low frequency) in healthy adults in the context of air pollution related to traffic.
Park SK, et al, 2007 [19]	Analyze whether the pollution from different places have different associations with HRV.	The effects of black carbon (BC) in all measures of HRV were stronger on days with southwest trajectories. Individuals who were examined on days when portions of air came from the West had the strongest associations with ozone. All particle pollution ($PM_{2.5}$, BC, and sulfates) were associated with increased LF / HF ratio on days with relatively short trajectories and on days when the air came from the northwest and west, compared with days of Northern trajectory.
Timonen KL, et al, 2006 [20]	To analyze the association between the daily variation of fine and ultrafine particles, and the cardiac autonomic control in a multicenter study, with elderly patients that have stable CVD.	The concentrations of ultrafine particles, NO_2 and CO were associated to an increase in cardiac vagal control. $PM_{2.5}$ was associated to a reduction in the vagal tone in Helsinki, while the opposite occurs in Erfurt, and in Amsterdam there were no clear associations between $PM_{2.5}$ and HRV. The results suggest that the cardiovascular effects from the environment and $PM_{2.5}$ could differ from each other, and that their effect could be modified by the characteristics of the individuals exposed and the sources of $PM_{2.5}$.

Table 1: Summary of the main publications that approached the topic of air pollution and autonomic cardiac modulation during 1996-2016.

The time domain methods use mathematically simple techniques to measure the variability present in R-R intervals, through analyses with time recordings of over 10 minutes, by estimations of its measurement and the variations in the HR pattern shifts over time, while the frequency domain methods use the spectrum analysis, allowing to break down the heart rate variation in a given period of time, into its essential oscillatory components; i.e. a time series is broken down into different frequency components [23].

In nonlinear analyses, the approach to the chaos theory considers dynamic, deterministic systems, ruled by nonlinear equations and sensitive to the initial conditions. This form of analysis could reflect more properly the alterations in the autonomic modulation of the biological systems, since there is evidence that the mechanisms involved in cardiovascular regulation probably interact with each other in a nonlinear fashion [24].

Between the nonlinear methods, the symbolic analysis stands out, a technique used to evaluate the autonomic responses beat by beat. In this analysis, initially every beat is appointed a "symbol", and these are analyzed in small patterns of 3 beats. By this analysis it is possible to verify the responses occurring in a small amount of time [25].

HRV analyses could be made by noninvasive and inexpensive methods, by using the widely used heart rate monitor Polar RS800CX (Polar Electo, Finland), aiding our insight on the ANS behavior when faced with very different stimuli [26].

Changes in HRV patterns are often associated with their health affected by reduced HRV, which contributes to increased cardiovascular morbidity and mortality [27].

According to Gould et al. [9], Schwartz J et al. [10] and Jia X et al. [11] is a decrease in vagal tone (NS parasympathetic), resulting in reduced HRV compared to exposure to air pollution (particulates and ozone) in adults and elderly healthy respectively. The same results were found in the study Vallejo M et al. [12] with young healthy and sedentary individuals and study of Rioja-Rodrigues et al. [13] in individuals with heart disease.

In the study Schneider et al. [14] showed the effect by an increase in pollutants on autonomic control in individuals without co-morbidities or with preexisting diseases, as in studies that showed a parasympathetic decrease. In study Feng Y et al. [15] who found decreased parasympathetic adults living in cities with high PM levels when compared to adults of cities with low levels of PM and decreased HRV in the subgroup with low risk factor, but not the group with excess risk factor.

In the Lion et al. [16] study, a sympathetic decrease was observed in association to atmospheric pollutants, mainly PM10 and people with clinical history of hypertension and CAD.

The temperature and the direction of air pollution wind may also interfere with HRV. In the study Ren C et al. [17] showed decreased heart rate variability (increase of vagal tone and sympathetic decrease) during the warm season, but not during the cold season in the elderly and those associations were significantly modified by exposure to ozone, but not particulate matter. In the study by Wu S et al. [18] HRV changes occurred (increased sympathetic) in both stations. In relation to wind direction, the HRV measures may also change, all particle pollution (PM2.5, BC and sulfates) were associated with increased LF / HF ratio in day's m the air came from the northwest and west compared to days north path [19].

The results found suggest that the cardiovascular effects and PM may differ from each other often because of the characteristics of individuals exposed and also due to the sources of PM [20].

In this way, it is possible to verify some controversies between the results found that can be explained by the fact of the subjects' ages, methods of measurement of pollution or HRV, presence of comorbidities, level of physical conditioning as well as variations in the composition of pollution and concentrations of exposures to different pollutants.

Thus, it is necessary to identify the effects of pollutants on human health, looking for practices to reduce pollutants in the short and mid-term, and advising patients as to the adoption of preventive measures to reduce the effects of pollutants present in external and inner environments to reduce the adverse effects related to such exposition.

Conclusion

The effects of air pollution on autonomic cardiac modulation are, in short, a reduction in autonomic cardiac modulation facing air pollution and its increases.

In view of these results and the poor quality of the breathing air, further studies in the area to understand the effects of air pollution on autonomic cardiac modulation are needed.

Acknowledgments

This research was financially supported by CAPES.

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