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Cardiovascular effects of air pollution

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Abstract

Introduction and Purpose:

Most cardiovascular problems are related to hypertension. Arterial hypertension is a persistent increase in blood pressure of 140/90 mm Hg or more. Hypertension usually does not cause symptoms for many years and if the blood pressure value is not regularly monitored, it is detected when complications occur in various organs (e.g. heart, kidneys, brain). The aim of the study was to determine the impact of air pollution on Cardiovascular effects. The article was based on the PubMed database.

State of Knowledge:

There are many factors that negatively affect the cardiovascular system (smoking, poor diet, sedentary lifestyle). Most of them can be corrected individually. Air pollution is such an example. Studies have been performed in many polluted cities around the world to investigate the relationship between air pollution and cardiovascular disease. Researchers found this to have a negative impact.

Summary:
This review describes what air pollution is in terms of particle size and their origin. Even though these particles enter the body through the respiratory tract, they can do just as much damage to the cardiovascular system and, based on some studies, even greater damage. At the end of the article, the focus is on personal and collective protection against air pollution.

Keywords: Particulate matter, Air pollution, Cardiovascular disease, environment, ,blood pressure, type 2 diabetes mellitus, hypertension, morbidity.

INTRODUCTION

Ambient air pollution (AAP) and particulate matters (PM) have been closely associated with adverse health effects such as cardiovascular diseases and respiratory disease. The largest parts of deaths is now known to be due to cardiovascular disorders. Unfortunately, the effect of PM size (PM10 and PM2.5) on cardiovascular disease has not been fully investigated. In today's urban world, PM is produced mainly by the combustion of fossil fuels and the use of combustion vehicles, and the individual components vary in size from a few nanometers to up to 10 microns in diameter. Concentrations PM in airborne are commonlyused for ambient air quality management worldwide. Air pollution is a mixture of gases and particulate matter. Some studies have shown a consistent increased risk of cardiovascular events associated with both long- and short-term exposure to airborne particulate concentrations. In this article, we assess the relationship between cardiovascular diseases and PM, with a particular focus on PM size. We discuss the association of PM10 and PM2.5, for example carbon monoxide (CO) and nitrogen dioxide (NO2), with morbidity and mortality due to cardiovascular diseases, stroke, and altered blood pressure. Studies that have been conducted around the world so far have consistently shown that both long- and short-term exposure to PM is associated with many cardiovascular diseases, including infarctions, ischaemia and myocardial, heart failure, arrhythmias, strokes and increased cardiovascular mortality. Evidence from cellular and toxicological experiments, controlled animal and human exposures have demonstrated several mechanisms by which particle exposure can trigger acute events and the chronic development of cardiovascular disease. (hypertension, arrhythmia and diabetes mellitus, Myocardial infarction). Although the risk to any one person at any time is small, given the huge number of people constantly exposed, PM air pollution poses a huge burden to global public health and is among the top 15 leading causes of mortality. (Data from the World Health Organization). [1], [2], [3]

Humanity faces many harmful environmental factors endemic to modern civilization including polluted drinking water, excessive noise, as well as the mounting risks posed by climate change. However, one of the greatest threats to public health is air pollution which is one of the main risk factors for morbidity and mortality. Over 90% of the global population is exposed to levels exceeding World Health Organization (WHO) Air Quality Guidelines (AQG). This pervasive and persistent nature of exposure explains why air pollution ranks among the leading risk factors for morbidity and mortality worldwide.

Recent calculations estimate that 3.15 million deaths per year can be attributed to PM2.5, placing it among the top 10 mortality risk factors worldwide. Although lung disease and cancer are promoted, the reality is that more than half of the health burden is caused by cardiovascular disease. Though PM2.5 impacts nearly everyone worldwide, the ecological-economic shifts during the past century have changed who is most vulnerable. PM2.5 now disproportionately concentrates among developing nations, particularly China and India. The adverse health effects of exposure to particulate matter (PM), including particles with a median aerodynamic diameter < 2.5 μm (PM2.5) and < 10 μm (PM10), are of great concern to governments and health organizations worldwide. The pulmonary effects of air pollution containing PM2.5 and PM10 include increased respiratory symptoms, decreased lung function, and increased incidence of chronic cough and bronchitis. Moreover, epidemiological and clinical studies increasingly show that air pollution is associated not only with respiratory and lung diseases, but also with cardiovascular diseases. Additionally, adverse health effects may be exacerbated in particularly vulnerable populations, including those with existing cardiovascular and respiratory diseases and older adults.
These populations tend to have more complex health problems after exposure to air pollution than healthy groups. Primary particles are emitted directly into the atmosphere, including: soot from diesel engines, while secondary particles are formed as a result of physicochemical transformations of gases, including: formation of nitrates, sulfates and sulfur dioxide (SO2). In 1997, the US Environmental Protection Agency (EPA) published 24-hour and annual average standards for PM2.5 (PM with a median aerodynamic diameter <2.5 μm), mainly focusing on this quantity because it can reach small respiratory tracts and alveoli. In general, larger particles tend to settle mainly in areas outside the chest, upper trachea and bronchi, while smaller particles (e.g. PM2.5) show greater deposition deep in the lungs. [1], [4], [5]

Nitrogen Oxides

Nitrogen oxides are reactive substances commonly understood to encompass nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen trioxide, nitrogen tetroxide (N_2O_4), and di-nitrogen pentoxide (N_2O_5). Most toxicological and epidemiological research has focused on NO2, because of the fact that NO2 is one of the regulated air pollutants for which standards are available worldwide. Motor vehicle emissions near busy streets can result in high local NOX concentrations. Significant human exposure may occur indoors. [1]

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless and tasteless gas that binds to hemoglobin with an affinity 250 times greater than oxygen, thereby interfering with the delivery of oxygen to tissues. CO is a highly poisonous gas, slightly lighter than air, which means that it easily mixes with it and spreads in it. Additionally, CO binds to cytochrome oxidase, exacerbates cellular hypoxia and binds to other extravascular proteins, for example myoglobin, cytochrome P-450, catalase and peroxidases. In some situations (e.g., inadequately ventilated parking facilities), CO can reach concentrations sufficient to cause a significant increase in carboxyhemoglobin levels in people with significant atherosclerotic or other heart disease. [1]

Sulfur Dioxide

Sulfur dioxide (SO2) is a highly irritating, colorless, soluble gas with a pungent odor and taste. It may form sulfuric acid in combination with water, which causes severe irritation to the eyes, mucous membranes and skin. In ambient air, the principal sources of SO2 include combustion of sulfur-containing fuels, especially in power plants and diesel engines. Elevated levels of SO2 have been associated with widespread illness in several 20th century air pollution catastrophes. [1]

CARDIOVASCULAR DISEASES ASSOCIATED WITH $PM_{2.5}$

Several published reports show a link between PM2.5 and cardiovascular disease. Some authors have shown a significant increase in the incidence of cardiovascular diseases, from 0.5% to 1.5%, for every 5–6 μg/m3 increase in PM2.5. An interesting and not obvious fact is that acute exposure to PM2.5 caused higher mortality from cardiovascular diseases than from respiratory diseases (69% due to cardiovascular diseases compared to 28% due to respiratory diseases). Moreover, a study conducted on 500,000 adolescents and adults with several years of follow-up showed that the risk of coronary heart disease, heart failure and arrhythmia increased by 8-18% for every 10.5 μg/m3 PM2.5. The American Heart Association issued a statement based on research published through March 2009 on the impact of air pollution on cardiovascular disease. Further, the Environmental Protection Agency (EPA) has also recognized the association between PM2.5, cardiovascular disease, and morbidity outcomes. A study on emergency admissions in Boston reported a significant association of PM2.5 with the risk of acute myocardial infarction. Another study conducted in 21 US cities also found an association between exposure to NO2 and PM10 and the risk of hospitalization. This Intermountain Heart Collaborative Study revealed a 4.5% increase in coronary artery disease with every 10 μg/m3 increase in PM2.5. These results reinforce the impact PM2.5 on public health. [2], [6], [7]

CARDIOVASCULAR DISEASES ASSOCIATED WITH PM_{10}

The impact of air pollution has been studied both in the USA and in Europe. It analyzed fine PM concentrations and the incidence of cardiovascular disease in 50 million people living in 20 of the largest U.S. cities in the U.S. This study revealed that a 0.68% increase in cardiopulmonary mortality was associated with a 10 μg/m3 increase in PM10 on the day before death. Similar results were also found in a European study (APHEA-2), which analyzed 43 million people in 29 major European cities. PM10 concentration increase every 10 μg/m3 increases the risk of death from cardiovascular causes by approximately 0.76%, which is a higher rate than in the case of respiratory diseases. So data from the US and Europe agree on PM10 and have shown a close link between air pollution and cardiovascular disease. [2], [8]

Short-Term Health Effects Studies

Many studies have focused on short-term relationships between pollution exposure and adverse outcomes. The 2 largest studies to date are the NMMAPS in the United States and the Air Pollution and Health: a European Approach (APHEA-2) project. These studies have produced remarkably consistent results. The NMMAPS study assessed outcomes in 50 million people in 20 of the largest U.S. cities. The average mortality rate was independently related to particle concentrations the day before death. Each 10-µg/m3 elevation in PM10 was associated with an increase of 0.21% (±0.06 SE) and 0.31% (±0.09 SE) for daily all-cause and cardiopulmonary mortality, respectively. The APHEA-2 study found slightly stronger associations between adverse health effects and air pollution. In a study of 43 million people in 29 European cities, the estimated increase in daily mortality was 0.6% for each 10-µg/m3 increase in PM10. Cardiovascular deaths were increased by 0.69%. APHEA-2 found that cities with higher levels of the copollutant NO2 exhibited larger associations between changes in PM concentrations and mortality. In the United States, this modifying effect of NO2 was not demonstrated. The APHEA-2 investigators speculated that this might reflect a higher proportion of NO2 that is derived from diesel exhaust in Europe. Extreme elevations in air pollution have also been associated with increased blood pressure during a prolonged air stagnation episode in Europe. Additionally, recent studies conducted in Seoul, South Korea, and Taiwan have shown a higher incidence of ischemic strokes in direct association with changes in ambient particle concentrations. Consistent results suggest that short-term increases in ambient particle levels may induce cardiac arrhythmias, worsen heart failure, and induce acute atherosclerotic and ischemic cardiovascular complications. [1], [2], [9], [10]

Long-Term Health Effects Studies

Harvard Six Cities was the first large, prospective study to demonstrate the adverse health effects of long-term exposure to air pollution. This study found that chronic exposure to air pollution is independently associated with cardiovascular morbidity and mortality. The increase in excess cardiovascular mortality resulting from long-term exposure to air pollution has long remained unclear. In an analysis of the ACS study, the investigators reported PM-mortality associations with the specific cause of death. [1]

Specific diseases

Much evidence links air pollution with increased cardiovascular morbidity and mortality. Several recent meta-analyses assessing the impact of short-term exposures to PM2.5 (per 10 µg/m3 increase during the prior few hours-to-days) have been published. In 34 studies, PM2.5 exposure significantly increased the risk for acute myocardial infarction by 2.5%.16 Hospitalization or death from heart failure (2.1%; 35 studies),17 stroke (1.1%; 94 studies),18 and arrhythmia (1.5%; 23 studies)19 have also been shown to be increased. Similar risks were also reported for short-term exposures to several gaseous pollutants (NO2, CO, CO2) with less consistent evidence for ozone. [5]

BLOOD PRESSURE

The relationship between air pollution and hypertension has been widely discussed and has been the subject of at least several meta-analyses. An increase in ambient PM2.5 concentration by 10 μg/m3 is associated with an increase in systolic and diastolic blood pressure of 1 to 3 mm Hg over the following days. Many studies have linked long-term exposure to chronic increases in blood pressure and an increased incidence of hypertension. Changes in blood pressure are routinely observed in carefully conducted, controlled human studies examining various vascular changes in response to air pollution. Additional evidence is that personal strategies to reduce air pollution show rapid results in lowering blood pressure, further supporting the direct impact of inhaling air particles on blood pressure. This body of evidence strongly supports a link between the global burden of air pollution and higher blood pressure levels and hypertension-related morbidity. [4], [11], [12], [13]

Myocardial infarction

Studies have examined the relationship between short-term changes in air pollution and daily changes in heart attack. A systematic review and meta-analysis of studies on short-term exposure to air pollution and heart attack found that PM2.5 along with nitrogen dioxide (NO2), sulfur dioxide and carbon monoxide were associated with an increased risk of heart attack. Patients with coronary artery disease may be particularly vulnerable. The best recent evidence for acute coronary syndrome (ACS) risk with PM2.5 comes from Utah, where concurrent-day PM2.5 was associated with an increase in acute coronary syndrome. Excess risk was observed only among individuals with coronary artery disease, leading to an increase in ST-segment elevation myocardial infarction. Long-term survival following ACS is also reduced by long-term PM2.5 exposure. [4], [14]

Heart failure

A meta-analysis of 35 studies showed that even short-term increases in the concentration of gaseous components and particulate matter were associated with an increased risk of hospitalization due to heart failure. A 10 μg/m3 increase in particular matters concentration increases the relative risk of hospitalization and mortality due to heart failure by 2.1%.
In a recent study from China in 26 cities with high PM2.5 concentrations, an interquartile increase in PM2.5 was associated with a relative 1.3% increase in heart failure hospitalizations. [4], [14]

Insulin resistance/diabetes

In a meta-analysis of studies involving a total of 2,371,907 participants and 21,095 incident cases of type 2 diabetes mellitus, the relative risk for diabetes increased by 39% per 10 μg/m3 of PM2.5. In a recent meta-analysis (13 studies), PM2.5 increased the risk of diabetes. [4], [15]

Cardiac arrhythmias

Exposure to air pollution has also been shown to cause atrial fibrillation. In a 2016 meta-analysis of several observational studies involving 461,441 participants, each 10-μg/m3 of PM2.5 was associated with a 0.89% increase in the population-attributable risk of atrial fibrillation. Evidence is limited regarding the risk of ventricular arrhythmias following exposure to air pollutants. [4], [16]

Mechanisms of Air Pollution–Mediated Cardiometabolic Disease

Knowledge of the mechanisms underlying systemic cardiovascular risk from air pollution is still developing but can be identified in 6 pathways: endothelial barrier dysfunction, inflammation, prothrombotic pathways, autonomic imbalance favoring sympathetic tone via afferent pathways the upper airways or lung, central nervous system effects on metabolism and hypothalamic-pituitary-adrenal axis activation and epigenomic changes.

Many of these pathways are interdependent and can cross-react and reinforce each other. Some pathways are more important for short-term exposures, while others play a more long-term role. Among the 3 primary initiating pathways are oxidative stress, direct translocation and effects of particles and secondary mediators. [4]

Primary initiating pathways

Role of oxidative stress

Oxidative stress, which can occur in the lungs and/or systemically in various vascular beds, can initiate many secondary processes. Oxidative stress to air pollution is the first response in humans, followed by a more delayed response when studied in detail, suggesting that oxidative stress may be an early stage. With long-term exposure, the progressive accumulation of particles in macrophages through phagocytosis may ultimately lead to the activation of pro-inflammatory pathways, the so-called frustrated phagocytosis. [4], [17], [18]

Direct translocation

Some particles may enter the systemic circulation directly and, together with the blood, cause changes in distant places. A study was performed initially on mice and then on humans with gold particles, which showed easy translocation into the systemic circulation, including penetration through the blood-brain barrier. May also be transported through axonal transport or through generation of secondary mediators and regulate efferent pathways controlling inflammation, metabolism, and blood pressure. [4]

Secondary effector pathways

Systemic vascular dysfunction and CV remodeling with air pollution

Evidence confirms the rapid and lasting impact of air pollution particles on vascular function in both animals and humans. Increased microvascular adhesion of inflammatory monocytes has been noted with concentrated PM2.5 exposure. Several controlled exposure studies in humans demonstrate that short-term exposure to PM2.5 and dilute diesel exhaust results in conduit or microvascular dysfunction. Studies of ultrafine particles, including inhalation of diluted diesel exhaust, have shown that they cause rapid endothelial dysfunction in the microcirculation.

It was also found that in the case of exposure to diesel exhaust, ischemic burden is much higher than in people using filtered air. Animal studies have shown a destructive effect of ozone on the endothelium, but it is possible that it was induced by too high a dose. [4], [19], [20]

Systemic inflammatory response

Studies in animals and humans have shown a short-term response of the bone marrow to exposure to air pollution. Recent experimental studies have clarified the nature of this response by demonstrating that long-term exposure to concentrated ambient PM2.5 promotes an efflux of Ly6hi+ monocytes from the bone marrow and promotes their eventual migration to adipose tissue, vasculature, and other inflamed tissue. Chemokine (C-X-C motif) receptor 3 knockout (CXCR3) may also be involved in transduction of PM2.5 effects and play a role in migration of T-cell. Possibly due to differences in study protocols, individual susceptibility, or unmeasured prior exposure, clear associations between exposure and inflammation have been less consistently observed in controlled, short-term studies. [4]

Prothrombotic pathways

Studies in a hamster model of arterial thrombosis showed rapid activation of platelets after inhalation of diluted particulate matter from diesel exhaust. In human studies, inhalation increased the thrombotic response, as assessed by ex vivo flow cell perfusion studies, and increased platelet and leukocyte aggregates after exposure. Rapid sensitization of platelets may occur as a result of direct contact with the lungs or translocation of ultrafine particulate matter. Activation of platelets as well as alteration of the plasminogen activator inhibitor in patients with other risk factors may heighten their susceptibility to CV events. [4]

Strategies to Mitigate Cardiovascular effects of Air Pollution

There are several approaches to mitigating the cardiovascular effects of air pollution, with particular emphasis on how healthcare professionals can play a key role in developing solutions. Investigators provide a rational clinical approach on how to help tackle the problem of air pollution at the level of the individual patient.

The Lancet Commission report highlights the importance of leadership from national decision-makers, resources and a clear action plan as key elements of successful programs. Furthermore, legal enforcement, backed by targets, technology and timetables, is important and, paradoxically, may be most needed in countries where air pollution control is best monitored. Several interventions have been shown to be at least partially effective in reducing PM2.5 exposures and in improving biomarkers of cardiometabolic health. The easiest and quite inexpensive method is to use portable indoor air purifiers. Portable air filters can reduce indoor PM2.5 levels by >50% and have been proven to improve a growing list of negative effects, including blood pressure, insulin sensitivity, inflammatory markers, stress hormones and metabolomics profiles. [4], [21]

Personal- and Local-Level Interventions to Reduce Exposures or Susceptibility to Air Pollution

At present, all personal protection strategies have the limitation that no trial has yet demonstrated that they reduce clinical cardiovascular events. Air pollution cannot be avoided because it is ubiquitous, and volcanoes, forest fires and other natural sources of particulate matter are part of our world and unavoidable. It is very important to educate the patient on how to protect himself and his loved ones to improve his overall health. Beyond what is required of a single entity, decision-makers play an important role. By introducing regulations that limit exposure to PM. By reducing modifiable exposure to PM, we will likely see reductions in morbidity and mortality. [4], [22]

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