SHARE

BEST PRACTICES

# Air Pollution as a Cause of Cardiovascular Disease: Looking beyond Traditional Risk Factors

Coralynn S. Sack, MD

*Dr. Sack (cssack@uw.edu) is a fellow in the Division of Pulmonary and Critical Care Medicine, University of Washington.*

The World Health Organization (WHO) estimates that air pollution is responsible for an estimated 7 million deaths per year worldwide.[1] Although the link between respiratory illnesses and air pollution is well known, the majority of these deaths are attributed to cardiovascular disease. Exposure to air pollution may be responsible for as much as 7% of nonfatal myocardial infarctions and 18% of sudden cardiac deaths.[2] No safe thresholds have been established, and even present-day concentrations in the United States are associated with increased mortality.

## Pathophysiology

Fossil fuel combustion, the predominant source of air pollution in the United States, releases a complex mixture of gaseous, liquid, and semi-solid particles. The principle components of this mass include carbon dioxide ($CO_2$), oxides of nitrogen ($NO_x$), sulfur dioxide ($SO_2$), volatile organic compounds (VOC), and particulate matter (PM). Globally, the practice of biomass burning for heating, cooking, and other indoor activities is a major contributor to air pollution. PM is further categorized by aerodynamic diameter as coarse (2.5-10 μm), fine (<2.5μm), or ultrafine (<20.1μm). The majority of studies show that $PM_{2.5}$ levels (<2.5μm) are most highly correlated with morbidity and mortality, but adverse effects are likely a result of the complex interaction between these various organic and inorganic components.

Given the multitude of pollutants and heterogeneity of individual exposure, assessment of an individual's risk can be challenging. Although ambient air quality monitors and predictive spatial models are now highly sophisticated, no reliable biomarker for individual exposure has been developed. Inhaled dose is affected by physiologic characteristics, such as tidal volume and respiratory rate, and behavioral characteristics, such as the amount of time spent outdoors, commuting, or engaged in physical activity. Furthermore, the internal response to a given dose is thought to vary according to polymorphisms in anti-oxidant genes, effects of other environmental toxins, and chronic medical conditions. Those with pre-existing coronary artery disease, diabetics, pregnant women, and other susceptible groups are likely to be at substantially higher risk.

The exact pathologic mechanism of air pollution is still unknown, but several biologically plausible pathways have been suggested per the table on page 13. After inhalation, air pollution particles deposit throughout the lungs, with larger particles settling in the airways and the smaller particles reaching the terminal bronchioles and alveoli. Upon deposition, particles can cross the epithelial barrier to enter the systemic circulation, activate sensory receptors in the lung, or trigger local and systemic inflammation. These initial insults lead to disruption of lipid metabolism, systemic oxidative stress, and alteration in the autonomic nervous system. Controlled exposure experiments in humans have also shown subclinical cardiovascular effects occurring after acute exposure, such as alteration in blood pressure, endothelial dysfunction, decreased heart rate variability, and decreased cardiac output. Seen over the long term, these changes are thought to contribute to the pathophysiology of peripheral vascular disease, ischemic events, cardiomyopathy, and congestive heart failure.[2]

It is important to recognize that air pollution not only causes chronic cardiovascular disease but also acute cardiovascular events. Acute exposure, over the course of one to several days, is associated with increased cardiovascular hospital admissions, heart failure, fatal and non-fatal myocardial infarctions, and ischemic strokes. The effect of more chronic exposures is of even greater magnitude, with mortality increasing by 3-76% per 10ug/$m^3$ elevation in long-term average $PM_{2.5}$ exposure.[3]

## Clinical Management

As health care professionals, we traditionally focus efforts on preventing coronary artery disease through the control of personally modifiable risk factors, such as diabetes, hypertension, or tobacco use. While there is good evidence for a causal association between air pollution exposure and disease, it is less clear how we should counsel patients to best reduce their risk.

There is little evidence on whether lifestyle or pharmacologic interventions can mitigate the adverse effects of air pollution. Given the proposed importance of oxidative stress on the underlying pathophysiology, several experiments have examined whether antioxidants and other specific micronutrients may be beneficial in preventing cardiovascular disease.[4] However, results have been mixed

continued on page 2

continued from page 1

and, in some instances, suggest that antioxidant supplementation may actually worsen markers of subclinical cardiovascular disease.

Similarly, it is unclear whether physicians should counsel their patients to avoid outdoor activity when pollutant levels are high. The beneficial effects of regular exercise likely outweigh adverse effects, and many individuals may be unable to afford access to fitness centers or other indoor recreational venues. It is possible that behavioral modifications, such as wearing a face mask during workouts, may be able to reduce cardiovascular responses.[4] Nonetheless, vulnerable populations—such as the elderly, diabetic patients, or those with pre-existing cardiopulmonary disease—should be advised to follow local air quality forecasts and plan exercise accordingly.[5]

## Advocacy

The risks associated with exposure to ambient air pollution are substantial when applied to the entire population.[3] As the global economy rapidly urbanizes, air quality will be an ongoing concern. In 2016, record-breaking pollutant levels occurred in China and Southeast Asia, and more than 85% of the global population is regularly exposed to concentrations exceeding World Health Organization standards.[6] Furthermore, while air pollution is ubiquitous, it disproportionally affects individuals with lower socioeconomic status who may be forced to live or work in areas with high levels of pollutants. As health care providers, we need to understand the detrimental health effects associated with air pollution and also advocate for public policies that will help reduce exposure.

## References

1. World Health Organization. Burden of disease from ambient and household air pollution. http://www.who.int/phe/health_topics/outdoorair/databases/en/. Published August 19, 2016. Accessed November 26, 2016.
2. Cosselman KE, Navas-Acien A, Kaufman JD. Environmental factors in cardiovascular disease. *Nat Rev Cardiol* 2015; 12(11): 627-42.
3. Brook RD, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation* 2010; 121(21): 2331-78.
4. Franklin BA, Brook RD, Pope C Arden. Air pollution and cardiovascular disease. *Curr Probl Cardiol* 2015; 40(5): 207-38.
5. Brook, RD, et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation* 2004; 109(21): 2655-71.
6. Brauer M, et al. Ambient air pollution exposure estimation for the global burden of disease 2013. *Environ Sci Technol* 2016; 50(1): 79-88.

*SGIM*

**Adverse Cardiovascular Effects of Air Pollution Exposure**[2]

| Exposure Source | Pollutants | Physiologic Mechanisms | Subclinical Effects | Cardiovascular Clinical Outcomes |
|---|---|---|---|---|
| Fossil fuels | • Carbon dioxide ($CO_2$)<br>• Oxides of nitrogen ($NO_x$)<br>• Sulphur dioxide ($SO_2$)<br>• Volatile organic compounds ($VOC_s$)<br>• Particulate matter (PM) | • Disruption of lipid metabolism<br>• Systemic oxidative stress<br>• Autonomic nervous system changes | • Endothelial dysfunction<br>• Atherosclerosis<br>• Blood pressure changes<br>• Decreased heart rate variability<br>• Decreased cardiac output | **Acute:**<br>• Arrhythmia<br>• Myocardial infarction<br>• Ischemic stroke<br>• Heart failure<br>**Chronic:**<br>• Increased cardiovascular mortality<br>• Cardiomyopathy<br>• Peripheral arterial disease |