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Research Article

Extreme levels of ambient air pollution adversely impact cardiac and central aortic hemodynamics: the AIRCMD-China study

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Abstract

Ambient air pollution is an independent risk factor for cardiovascular diseases. However, the underlying mechanisms have yet to be fully elucidated. We performed a panel study on 65 nonsmoking patients with metabolic syndrome, with four repeated clinical visits between 2012 and 2013 in Beijing, China. Cardiac and central aortic hemodynamic parameters were measured by pulse wave analyses as subendocardial viability ratio, ejection duration, and central aortic pressure. We also calculated rate-pressure product parameter and collected peripheral blood for analyses. High levels of ambient particulate matter with diameter $\leq$10 and 2.5 μm (PM_{10} and $PM_{2.5}$), black carbon, sulfur dioxide, and nitrogen dioxide were 121.3, 99.5, 6.5, 24.5, and 59.2 $\mu g/m^3$, respectively. Short- to medium-term exposures to high levels of ambient air pollution adversely impacted central hemodynamics-derived surrogates of myocardial perfusion and oxygen demand. Each 10 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with significant decreases of 0.67% (95% confidence interval: −2.84, −0.22) in subendocardial viability ratio at moving average 35 days (MA35) and an increase of 0.31 in rate-pressure product (95% confidence interval: 0.03, 0.59) at MA5. In conclusion, our results suggest that impaired myocardial perfusion and increased myocardial oxygen demand may play importantly mechanistic roles in air pollution–attributed cardiovascular diseases. J Am Soc Hypertens 2017;■(■):1–8. © 2017 Published by Elsevier Inc. on behalf of American Society of Hypertension.

Keywords: Central hemodynamics; myocardial oxygen demand; myocardial perfusion.

Introduction

Numerous epidemiologic studies have demonstrated associations between short-, medium-, and long-term exposures to ambient air pollution and increased risk for cardiovascular events, including myocardial infarction, heart failure, and stroke.[1–4] While the entire population appears to be at risk, some evidence suggests that individuals with cardiometabolic disorders, including hypertension, diabetes mellitus, or the metabolic syndrome (MetS), may be more vulnerable to air pollution.[5–7] A wealth of studies has elucidated

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putative biological mechanisms that may account for this association,[1] an aspect that may be particularly relevant relates to underlying mechanisms that may confer selective vulnerability. In this regard, individuals with hypertension and/or concomitant diabetes are known to have abnormal cardiac and central hemodynamics that could adversely impact their prognosis. Very little is known on the potential role of altered cardiac and central aortic hemodynamics and their role in influencing air pollution–mediated cardiovascular effects. Subendocardial viability ratio (SEVR), also known as the Buckberg index,[8] is a cardiac hemodynamic parameter that is thought to represent a surrogate for myocardial oxygen supply and demand relative to myocardial perfusion. Rate-pressure product (RPP), the product of the heart rate and systolic blood pressure (SBP), crudely represents myocardial oxygen demand and is mainly relies on heart rate, systolic ventricular wall tension, and myocardial contractility.[9] In addition, both ejection duration ([ED] reflecting the duration of ventricular systole) and central aortic pressure (reflecting left ventricular afterload) are positively correlated with myocardial oxygen demand. Previous studies have demonstrated that ambient air pollution exposure is associated with impaired central hemodynamic parameters, such as pulse wave velocity and augmentation index.[10,11] Though prior animal experiments reported reduced myocardial perfusion reserve and increased myocardial oxygen demand from inhalation of carbon monoxide (CO) or concentrated ambient particles (CAPs),[12–15] no human study examined the association of air pollution exposures with functional surrogates of myocardial perfusion and oxygen demand. Further, given the extremely high levels of ambient fine particulate matter ($PM_{2.5}$) in China, which has been estimated to contribute to 0.28 million coronary heart disease deaths annually,[16] the effects of $PM_{2.5}$ in a vulnerable population of patients with insulin resistance/type 2 diabetes is of particular relevance. The AIRCMD-China study is a prospective panel study of 65 nonsmoking patients with MetS, with four repeated clinical visits between 2012 and 2013 in Beijing.[17–19] We aimed to evaluate the associations of short- to medium-term exposures to high levels of ambient air pollution with alterations in cardiac and central aortic hemodynamics which relative to myocardial perfusion and oxygen demand. We were also interested in evaluating whether the associations could be modified by cardiometabolic factors, including high-density lipoprotein (HDL), apolipoprotein A1 (Apo-A1), triglyceride/high-density lipoprotein ratio (TG/HDL), and homeostasis model assessment of insulin resistance (HOMA-IR).

Methods

Study Patients and Design

Current analysis is based on data collected between February 14, 2012, and July 4, 2013, in the AIRCMD-China study. The research protocol for this study has been published previously with details.[17–19] In specific, we recruited 65 nonsmoking patients with MetS from clinics affiliated with Peking Union Medical College Hospital following diagnosis criteria defined by International Diabetes Federation criteria specific for Asians. The patients were at 35–75 years of age and completed a screening visit followed by four repeated and equally spaced clinical visits within 1 year. At the screening visit, we obtained baseline information for each patient from questionnaires and measurements, including demographic characteristics, anthropometrics, and medical history. During the follow-up, clinical examinations for all patients with overnight fasting were conducted in the early morning at each visit. Before examination, each patient rested for 10 minutes in a quiet and temperature-controlled room. The study was approved by the Institutional Review Board at Peking Union Medical College Hospital, and each patient signed a written informed consent (NCT01548300) at recruitment.

Clinical End Points

The radial artery pressure waveforms were recorded using the applanation tonometry (SphygmoCor; AtCor Medical, NSW, Australia) which was a noninvasive central aortic blood pressure monitoring device and analyzed using computer software. Central aortic pressure, including central aortic systolic pressure (CASP) and central aortic diastolic pressure (CADP), were derived from radial pressure waveforms using generalized transfer function. SEVR and ED were also estimated from pulse wave analysis. SEVR can be derived from dividing diastolic pressure time index by systolic pressure time index (SEVR = DPTI/SPTI). ED referred to the time period of left ventricular ejection during systole. Additionally, after resting for 10 minutes, supine SBP, diastolic blood pressure, and heart rate were measured using the Omron HEM 907XL device. Three readings were recorded, and then, we calculated the average for analysis. In addition, mean arterial pressure was calculated as (SBP + 2 × diastolic blood pressure)/3, and RPP was calculated by the product of SBP and heart rate (RPP = SBP × heart rate/100). Fasting peripheral vein blood samples were also collected to assed HDL, Apo-A1, TG, plasma glucose, and plasma insulin levels. Additionally, we derived TG/HDL and HOMA-IR using a formula: (fasting glucose × fasting insulin)/22.5.

Air Pollution and Meteorological Parameters

During the study period, daily average concentrations of ambient air pollution, including particulate matter, with diameter $\leq$10 and 2.5 μm (PM_{10} and $PM_{2.5}$), black carbon (BC), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) were measured from different locations. Ambient $PM_{2.5}$