Environmental Research 142 (2015) 374–379

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Triggering of myocardial infarction by increased ambient fine particle concentration: Effect modification by source direction

Philip K. Hopke[a,*], Cathleen Kane[b], Mark J. Utell[c], David C. Chalupa[c], Pramod Kumar[a], Frederick Ling[d], Blake Gardner[e], David Q. Rich[b]

[a] Center for Air Resources Engineering and Science, Clarkson University, Potsdam, NY, USA
[b] Department of Public Health Sciences, University of Rochester School of Medicine and Dentistry, Rochester, NY, USA
[c] Division of Pulmonary and Critical Care Medicine, Department of Medicine, University of Rochester Medical Center, Rochester, NY, USA
[d] Division of Cardiology, Department of Medicine, University of Rochester Medical Center, Rochester, NY, USA
[e] Central Utah Clinic, St George, Utah, USA

ARTICLE INFO

Article history:
Received 29 January 2015
Received in revised form
25 June 2015
Accepted 27 June 2015

Keywords:
PM2.5
Myocardial infarction
Back trajectory
Secondary pollutants

ABSTRACT

Background: Previously, we reported a 18% increased odds of ST-elevation myocardial infarction (STEMI) associated with each 7.1 μg/m^3 increase in $PM_{2.5}$ concentration in the hour prior to MI onset. We found no association with non-ST elevation myocardial infarction (NSTEMI). We examined if this association was modified by $PM_{2.5}$ source direction.
Methods: We used the NOAA HYbrid Single-Particle Lagrangian Trajectory (HYSPLIT) model to calculate each hourly air mass location for the 24 hours before each case or control time period in our previous $PM_{2.5}$/STEMI case-crossover analysis. Using these data on patients with STEMI ($n=338$), hourly $PM_{2.5}$ concentrations, and case-crossover methods, we evaluated whether our $PM_{2.5}$/STEMI association was modified by whether the air mass passed through each of the 8 cardinal wind direction sectors in the previous 24 h.
Results: When the air mass passed through the West-Southwest direction (WSW) any time in the past 24 h, the odds of STEMI associated with each 7.1 μg/m^3 increase in $PM_{2.5}$ concentration in the previous hour (OR=1.27; 95% CI=1.08, 1.22) was statistically significantly ($p=0.01$) greater than the relative odds of STEMI associated with increased PM2.5 concentration when the wind arrived from any other direction (OR=0.99; 95% CI=0.80, 1.22). We found no other effect modification by any other source direction. Further, relative odds estimates were largest when the time spent in the WSW was 8–16 h, compared to ≤7 h or 17–24 h, suggesting that particles arising from sources in this direction were more potent in triggering STEMIs.
Conclusions: Since relative odds estimates were higher when the air mass passed through the WSW octant in the past 24 h, there may be specific components of the ambient aerosol that are more potent in triggering STEMIs. This direction is associated with substantial emissions from coal-fired power plants and other industrial sources of the Ohio River Valley, many of which are undergoing modifications to reduce their emissions.

1. Introduction

Increased ambient particulate matter (PM) concentrations have previously been associated with an increased risk of myocardial infarction (Rich et al., 2010; Mustafic et al., 2012). Using data on acute coronary syndrome events treated at the Strong Memorial Hospital Cardiac Catheterization Laboratory and ambient air pollution measured in Rochester, New York, Gardner et al. (2014) reported that each 7.1 μg/m^3 increase in ambient $PM_{2.5}$ concentration in the previous 1 h was associated with an 18% increase in the relative odds of a ST-elevation myocardial infarction (95% CI=1%, 38%), but no association with non-ST elevation myocardial infarction (NSTEMI; OR= 0.93; 95% CI= 0.78, 1.09).

Recently, Rich et al. (2013) reported larger relative odds of myocardial infarction associated with increased $PM_{2.5}$ concentrations when the air pollution mixtures were laden with secondary PM species (sulfate, nitrate, and/or organics). These results suggest that secondary particulate matter that is formed through active, oxidative atmospheric chemistry, may be more important in inducing MIs than primary fine particle aerosol. Air masses coming

* Corresponding author.
E-mail address: phopke@clarkson.edu (P.K. Hopke).

http://dx.doi.org/10.1016/j.envres.2015.06.037

into an area or region would transport different amounts of secondary species and therefore, there may be relationships between atmospheric transport direction and incidence of PM mediated MI events.

Beginning in about 2008, there have been a number of major changes in large sources in the source regions to the west and southwest of the Rochester. Between 2008 and 2014, the Province of Ontario has phased out most of its fleet of coal-fired power plants including the Nanticoke Thermal Generating Station that had been the largest source of SO_2 in North America (Scientific American, 2013). At the same time, there have been substantial reductions in the emissions from the generating stations in the upper Ohio River Basin, in part as a result of legal action against a major utility in the region (USEPA, 2007) and utilities beginning to make changes is response to the Cross-State Air Pollution Rule (USEPA, 2011) that has recently been allowed by the courts to go into effect (US Court, 2014).

In this analysis, we examined whether our previously reported $PM_{2.5}$/STEMI relative odds estimate was modified by where the air mass was in the past 24 h. Using air parcel back trajectory analysis, samples were grouped based on their likely upwind origins during this 24 h period. This analysis was performed to determine the extent of reductions in airborne PM that can be attributed to these reductions in upwind emissions, and to evaluate whether fine particles from different upwind origins were associated with cardiovascular health effects in residents of Rochester, New York.

2. Methods

2.1. Study population and outcome definition

The study population used in our analysis has been described previously (Gardner et al., 2014). Briefly, the University of Rochester Medical Center (URMC) Cardiac Catheterization Laboratory stores and maintains a database of all acute coronary syndromes treated, including information on the subject (age, race, sex, residential address, previous co-morbidities and procedures, etc.) and the clinical event (i.e. onset date and time, acute coronary syndrome type, etc.). Acute coronary syndromes, either STEMI, NSTEMI, or unstable angina, were defined using the current American College of Cardiology (ACC)/American Heart Association (AHA) guidelines (O'Gara et al., 2013). For STEMI, on the presenting electrocardiogram (EKG), this is defined as ST segment elevation greater than 1 mm in 2 or more contiguous precordial leads, or 2 or more adjacent limb leads, or new or presumed new left bundle branch block in the appropriate clinical setting (angina or angina equivalent) and the appearance of detectable cardiac myocyte biomarkers (indicating myocardial necrosis). For NSTEMI, the diagnosis is made by appearance of detectable cardiac myocyte biomarkers (indicating myocardial necrosis) in the blood of a patient without the requirement of the EKG changes associated with STEMI. Unstable angina was not included since the diagnosis of unstable angina can sometimes be based solely on clinical judgment without objective criteria of cardiac ischemia to support the diagnosis of an acute coronary syndrome.

Onset time (date and hour) was self-reported by each patient (or kin if patient was unable to communicate) upon arrival to the URMC Cardiac Catheterization Laboratory. Only patients that presented to the URMC Cardiac Catheterization Laboratory were included in this study.

From these acute coronary syndrome data, we retained all STEMI and NSTEMI events occurring from January 1, 2007 to December 31, 2010 (N=3889), where symptom onset date and time were available, and those where the patient resided within 15 miles of our pollutant monitoring station in Rochester, New York, resulting in n=338 STEMI and n=339 NSTEMI available for analysis. This study was approved by the University of Rochester Medical Center Research Subjects Review Board.

2.2. Air pollution and meteorology measurements

Pollutant concentration data used in the study were measured at the New York State Department of Environmental Protection site in Rochester, New York, located approximately 1500 m from an interstate highway. $PM_{2.5}$ was measured continuously using a Tapered Element Oscillating Microbalance (TEOM; ThermoFisher, Franklin, MA) for each hour during the study period (January 1, 2007 to December 31, 2010). Hourly temperature and relative humidity data were also measured at the site. These hourly pollutant concentration and weather data were used in all statistical analyses described below.

2.3. Air mass back trajectory estimates

Air mass back trajectories were calculated using the NOAA Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT, version 4.7) model (Draxler and Rolph, 2003). The metrological data set REANALYSIS was used to produce 4 trajectories per day starting at 0:00, 6:00, 12:00, and 18:00 local time with a starting height of 500 m. The choice of starting height is based on prior experience in a variety of Potential Source Contribution Function (PSCF) applications (Cheng et al., 1993a, 1993b; Fan et al., 1995; Polissar et al., 1999, 2001; Lupu and Maenhaut, 2002) and represents a reasonable representation of transport in the upper portion of the surface boundary layer. One hour endpoints were estimated for 4 days backward in time, but only the final 24 h were used in this analysis.

The cardinal direction of any single point in a trajectory was defined by the angle between a line due north from the monitor site, and a line from the air mass location to the monitor site. If that angle was 0–45° then the point was assigned to the NNE; ENE if the angle was 45–90°; ESE if greater than 90° to 135°; SSE if greater than 135° to 180°; SSW if greater than 180° to 225°; WSW if greater than 225° to 270°; WNW if greater than 270° to 315°; and NNW if greater than 315° to 360°.

For the analysis, we created 8 variables that indicated the cardinal sectors through which each 24 h trajectory passed. There are 24 1-hour endpoints in each trajectory and each endpoint was assigned to one of the 8 directional sectors. Then each of the 8 variables was assigned a value of 0 or 1 depending if there were any endpoints that fell into that sector during that time period. For example, the indicator variable for NNE is equal to 1 if at least one endpoint along the trajectory was within the NNE sector. Each day might have indicators for more than one direction equal to 1, so each cardinal direction was analyzed in separate equations. For example, we examined if the odds of STEMI associated with increased $PM_{2.5}$ concentrations in the previous hour was modified by whether the air mass passed through the NNE sector, and then separately in 7 separate equations repeated this analysis for the other 7 cardinal wind directions. We also conducted sensitivity analyses, described below, to evaluate if our findings were robust to this sector definition.

2.4. Study design

We used a time-stratified case-crossover design (Levy et al., 2001; Maclure,1991) which we and others have used in studies of ambient air pollution and myocardial infarction (Rich et al., 2010; Sullivan et al., 2005; Pope et al., 2006; Zanobetti and Schwartz, 2005), and that has been deemed the preferred referent selection approach (Janes et al., 2005; Mittleman, 2005). This design is