Ultrafine Particles and Cardiac Responses: Evaluation in a Cardiac Rehabilitation Center

MJ Utell1, W. Beckett1, L. Kopin1, W. Zareba1, MW Frampton1, J. Bisognano1, D. Oakes1, D. Chalupa1, D. Ogulei2, and PK Hopke2.
1University of Rochester Medical Center, Rochester, NY and 2Clarkson University, Potsdam, NY

Abstract

Epidemiological studies demonstrate that ambient particulate (PM) pollution increases cardiac morbidity and mortality. A current research gap is the role that different PM components (organics, metals, ultrafines) play in cardiovascular health effects. The objectives of this study are to assess the effects of ambient ultrafine particle (UFP) exposure on cardiovascular morbidity in a panel of patients with coronary artery disease. Since we have previously characterized year-round UFP temporal variation in Rochester, NY, we have designed a study to examine the cardiovascular responses to UFP in community dwelling patients undergoing medically monitored exercise rehabilitation after acute coronary events. In this study, UFP number and particle mass will be measured continuously in the cardiac rehabilitation Center and at a central measuring site in downtown Rochester. Other EPA Criteria Pollutants are also measured in downtown Rochester. Patients from an active cardiac rehabilitation program within the University of Rochester Medical Center will be offered enrollment in the health effects study as they enter the Cardiac Rehabilitation program. These are patients who have had a recent coronary event such as myocardial infarction or unstable angina leading to coronary stenting. The program involves supervised, graded twice-weekly exercise sessions for a total of 10 weeks. The project will assess the following specific hypotheses that in vulnerable subjects with ischemic heart disease:
1) Elevated levels of ambient ultrafine and fine particles are associated with slower and compromised rehabilitation; 2) Elevated levels of ambient ultrafine and fine particles are associated with changes in autonomic nervous system system function measured by heart rate variability parameters as well as in myocardial substrate and system function measured by heart rate variability parameters as well as in myocardial substrate and myocardial viability measured by QRS duration, QT interval, ST segment changes and T wave abnormalities; and 3) Elevated levels of ambient ultrafine and fine particles are associated with changes in biomarkers of enhanced cardiovascular risk, including systemic inflammation (C-reactive protein) and hypercoagulability (fibrinogen).

Methods: Monitoring

Ultrafine particle size distributions will be measured every four minutes alternately inside and outside the cardiac rehabilitation center. Data obtained includes total UFP number concentration, size fractionated number concentration, and the calculated mass concentration. The cardiac center data is supplemented by the UFP data collected at a central DEC site two miles from the center. The DEC site also measures several EPA criteria pollutants and meteorological variables (wind speed and direction, temperature).

Methods: Clinical

80 patients with coronary artery disease will exercise for 30 minutes in the cardiac rehabilitation center.

Protocol

- Baseline questionnaire
- Twice weekly x 10 weeks
- Treadmill exercise, bike and cycle
- Assessments (Tables 2 and 3)
- Borg scale perceived exertion
- 2-hr Holter monitoring – 2 hrs.
- Blood draws

Exclusions

- Recent coronary artery surgery
- Valvular heart disease
- Current smokers
- Unable to tolerate exercise

Table 1: Number and Surface Area of Particles of Unit Density of Different Sizes at a Mass Concentration of 90 g/m³

<table>
<thead>
<tr>
<th>Particle Diameter (µm)</th>
<th>Particle Number (10⁶)</th>
<th>Particle Surface (10⁻⁶ cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>2,400,000</td>
<td>3016</td>
</tr>
<tr>
<td>0.25</td>
<td>19,100</td>
<td>600</td>
</tr>
<tr>
<td>1.0</td>
<td>153</td>
<td>120</td>
</tr>
<tr>
<td>2.5</td>
<td>19</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 2: Summary of health outcomes (based on 80 participants)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
<th>Observations per Patient</th>
<th>Total Observations (NHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise program</td>
<td>2 per week</td>
<td>80</td>
<td>1600</td>
</tr>
<tr>
<td>Blood samples</td>
<td>1 per week</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>2-hr Holter recording</td>
<td>2 per week</td>
<td>20</td>
<td>1600</td>
</tr>
</tbody>
</table>

Table 3: List of Noninvasive ECG Parameters to be used in the study.

Speculation and Hypothesis

We hypothesize that in vulnerable subjects with ischemic heart disease:
1) Elevated levels of ambient ultrafine and fine particles are associated with slower and compromised rehabilitation.
2) Elevated levels of ambient ultrafine and fine particles are associated with changes in autonomic nervous system function measured by heart rate variability parameters as well as in myocardial substrate and myocardial viability measured by QRS duration, QT interval, ST segment changes and T wave abnormalities
3) Elevated levels of ambient ultrafine and fine particles are associated with changes in biomarkers of enhanced cardiovascular risk, including systemic inflammation (C-reactive protein) and hypercoagulability (fibrinogen).