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

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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 function measured by heart rate variability parameters as well as in myocardial substrate and myocardial vulnerability 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). Levels of ambient ultrafine and fine particles will then be associated with health data from the cardiac rehabilitation panel study. This will be the first study with such highly susceptible cardiac patients where ultrafine PM level variation is well characterized. The results of this study will address policy questions about risks of ultrafine vs. larger particles, and the potential health effects of specific types of emission sources.

Introduction

- Objectives: assess the effects of ambient UFP exposure on cardiovascular morbidity in a panel of patients with acute coronary artery disease.
- Determining the specific components of PM responsible for adverse health effects is a high priority research need identified by NYSERDA and EPA.
- Patients within the University of Rochester Medical Center will be enrolled in the health study as they enter the Cardiac Rehabilitation program. These are patients with recent coronary events (myocardial infarction or unstable angina).
- UFP number and particle mass are measured continuously in the facility and at a central measuring site in Rochester.
- Levels of UFP and fine particles will then be associated with health data from the rehabilitation study.

Background

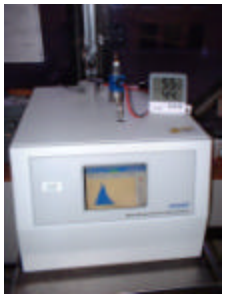
- UFP have been linked with excess cardiopulmonary morbidity & mortality.
- UFP have much higher number& surface area than larger particles (Table 1).
- UFP deposition is very high in the human respiratory tract.
- Controlled exposures to UFP at concentrations ranging from 10-50 $\mu g/m^3$ have altered cardiovascular function in healthy exercising volunteers in our laboratory (Figures 1 & 2). Data from these mouthpiece exposures generated several hypotheses for the present study.

Table 1: Number and Surface Area of Particles of Unit Density of Different Sizes at a Mass Concentration of 10 mg/m^3.

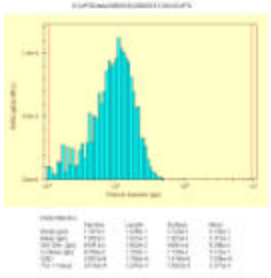
Particle Diameter μm	Particle Number $1/cm^3$	Particle Surface $\mu m^2/cm^3$
0.02	2,400,000	3016
0.1	19,100	600
0.5	153	120
1.0	19	60
2.5	1.2	24

Methods: Monitoring

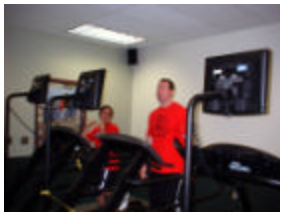
Ultrafine particle size distributions will be measured every four minutes alternately inside and outside the cardiac rehabilitation center. Data obtained includes total UFP number concentration, size fractionated number concentration, and the calculated mass concentration. The cardiac center data is 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).

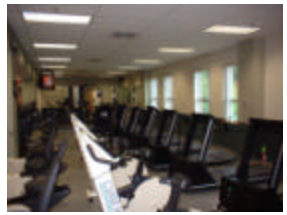


Air Monitoring Equipment



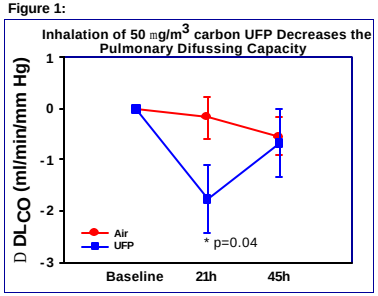
Typical outdoor particle size distribution





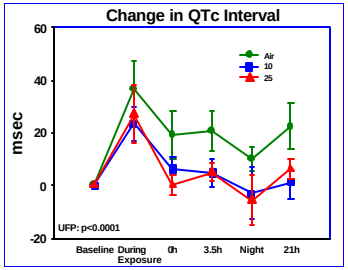
Indoor and Outdoor Sampling Sites

Figure 1:



Change in DL_{CO} before and after exposure to filtered air vs. 50$\mu g/m^3$ UFP. There was a significant decline in DL_{CO} 21 hours after exposure to 50$\mu g/m^3$ carbon UFP.

Figure 2:



Change in the QT interval on the EKG recording. The QT was significantly shortened after exercise plus exposure to UFP than after exercise plus air and persisted after the exposure was terminated.

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 rowing
- Assessments (Tables 2 and 3)
  - Borg scale perceived exertion
  - Holter monitoring – 2 hrs.
  - Blood draws

Exclusions

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

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

Parameter	Frequency	Observations per Patient	Total Observations (N=80)
Exercise program	2 X per week	20	1600
Blood samples	1 X per week	10	80
2-hr Holter recording	2 X per week	20	1600

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

Parameters	Resting Before and After Exercise	During Exercise
Heart rate	X	X
Time-domain HRV (SDNN)	X	X
Frequency-domain HRV (LF, HF)	X	
VPB frequency/complexity	X	X
QTc	X	
QT variability (QTV)	X	X
ST segment in lead III, V2, V5	X	X

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 vulnerability 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).