Air Pollution and Heart Health

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Goals of the Presentation

• What is air particle pollution and why is it important to public health?

• Does decreasing air particle pollution decrease mortality?

• Who is exposed? Are some people more vulnerable than others?

• Will changing demographics increase or decrease the burden of air pollution on heart health?

• What tools exist to be made aware of air quality?
“...[London's] Inhabitants breathe nothing but an impure and thick Mist, accompanied with a fuliginous and filthy vapor,... corrupting the Lungs and disordering the entire habit of their Bodies;...”

John Evelyn, *Fumifugium*, 1661
Air Pollution Disasters

1930 Meuse River Valley, Belgium
Three-day episode of severe air pollution - 6,000 fall ill and 63 die

1948 Donora, PA
Oct. 26 to 31: air pollution episode
20 dead out of 14,000 inhabitants

1952 London, England
Dec. 4 to 9: “Killer Fog” leaves 3,000 to 4,000 people dead

Donora, PA at noon on Oct. 29, 1948
London buses are escorted by lantern at 10:30 in the morning
The Great London Smog Dec 1952

- 12,000 excess deaths
- 2/3 of deaths in individuals > 65 years old
- Increased death rates persisted through the next summer
High PM Levels Diminish Visibility

Low PM

High PM

Clear Day
PM$_{2.5}$ = 5 µg/m$^3$

Haze
PM$_{2.5}$ = 40 µg/m$^3$

Boston, MA   June 1999
The WHO estimates that 500,000 people each year die from exposure to air pollutants.
How Small is PM?

- **PM$_{2.5}$**: Combustion particles, organic compounds, metals, etc.<br>  
  - Less than 2.5 μm (microns) in diameter

- **PM$_{10}$**: Dust, pollen, mold, etc.<br>  
  - Less than 10 μm (microns) in diameter

- **Human Hair**: 50-70 μm in diameter

- **Fine Beach Sand**: 90 μm in diameter

Images courtesy of the U.S. EPA
Health Effects Associated with Different Size PM

The EPA regulates PM on the basis of mass in different size ranges:

- Aerodynamic diameter
  - <10 µm (PM10)
  - <2.5 µm (PM2.5)
Composition of PM$_{2.5}$ at Urban and Rural Locations

- **East**: Organic carbon, sulfate & nitrate predominate
- **West**: Organic carbon, nitrate, and black carbon predominate
- Levels are highly variable on all scales:
  - Between continents
  - Between countries
  - Between regions
  - Between cities
  - Within cities

Bhatnagar, A. Circ Res 2006
Percentage of Total Deaths in the U.S.

50,000 - 60,000 excess deaths attributed to air pollution in the U.S.

Cause of Death:
- Cardiovascular Disease: 908061
- Cancer: 549787
- Respiratory Disease: 178539
- Accidents: 97298
- Diabetes Mellitus: 68379
- Kidney Disease: 62498
- Alzheimer’s Disease: 44507
- Septicemia: 30670
- Suicide: 29041
- Liver Disease: 26225
- Homicide: 16831

% of Total Deaths in the U.S.
Air Pollution and Cardiovascular Disease
A Statement for Healthcare Professionals From the Expert Panel on Population and Prevention Science of the American Heart Association

Robert D. Brook, MD; Barry Franklin, PhD, Chair; Wayne Cascio, MD; Yuling Hong, MD, PhD; George Howard, PhD; Michael Lipsett, MD; Russell Luepker, MD; Murray Mittleman, MD, ScD; Jonathan Samet, MD; Sidney C. Smith, Jr, MD; Ira Tager, MD

Abstract—Air pollution is a heterogeneous, complex mixture of gases, liquids, and particulate matter. Epidemiological studies have demonstrated a consistent increased risk for cardiovascular events in relation to both short- and long-term exposure to present-day concentrations of ambient particulate matter. Several plausible mechanistic pathways have been described, including enhanced coagulation/thrombosis, a propensity for arrhythmias, acute arterial vasoconstriction, systemic inflammatory responses, and the chronic promotion of atherosclerosis. The purpose of this statement is to provide healthcare professionals and regulatory agencies with a comprehensive review of the literature on air pollution and cardiovascular disease. In addition, the implications of these findings in relation to public health and regulatory policies are addressed. Practical recommendations for healthcare providers and their patients are outlined. In the final section, suggestions for future research are made to address a number of remaining scientific questions. (Circulation. 2004;109:2655-2671.)

Key Words: AHA Scientific Statements  ■  air pollution  ■  cardiovascular diseases  ■  respiration
Environmental Cardiology

- Provides historical perspective
- Introduces the emerging new field of Environmental Cardiology
- Outlines initial efforts and strategic approach to understanding risk

Weinhold B. Environ Health Perspect 112:a880-a887, 2004
News Focus

Particle air pollution clearly causes substantial deaths and illness, but what makes fine particles so toxic—the size, the chemical compound, or both?

Mounting Evidence Indicts Fine-Particle Pollution

Talk about heart-stopping news: Spending time in traffic may triple some people’s risk of having a heart attack an hour later. That’s what German researchers reported last October in the New England Journal of Medicine (NEJM), based on responses from 691 heart attack survivors about their activities in the days before they fell ill. The study seemed to support the notion that tiny air pollution particles from tailpipes, along with stress, could help trigger a heart attack. Yet in another recent study in which volunteer power plants can trigger heart attacks and worsen respiratory disease in vulnerable people, leading to perhaps 60,000 premature deaths a year in the United States. In response, the U.S. Environmental Protection Agency (EPA) in 1997 added new regula-Now the issue is getting another look as EPA faces a December 2005 deadline for revisiting its PM$_{2.5}$ standard. EPA scientists, after reviewing piles of new data implicating PM$_{2.5}$ in health effects, have proposed tightening the 1997 standard to further reduce ambient concentrations of fine particles. Some scientists and industry groups remain skeptical, noting that researchers still haven’t pinned down what makes particles dangerous—whether it’s mainly size, and that the tiniest particles are most potent; or chemistry,
Air Particle Pollution Exposure is Associated with CV Morbidity and Mortality

Integrated Science Assessment for Particulate Matter

“Epidemiologic evidence is sufficient to conclude that a causal relationship exists between:

short-term, and long-term exposure to PM$_{2.5}$ and mortality.”
PM is derived from many different sources
Daily Variability of Particulate Matter

Chapel Hill, NC

PM$_{10}$

PM$_{2.5}$

Sampling Date

07/28/95 09/06/95 10/18/95 12/11/95 02/21/96

Concentration (µg/m$^3$)

0 10 20 30 40 50

Courtesy of Robert Devlin
Three-Year Average 24-hour PM$_{2.5}$ Concentration by County: 2005-2007

Number of people residing within counties that reported county-wide average concentrations within the specified ranges (in millions)

- $\geq 20.1$ µg/m$^3$ [1 county]
- 18.1 – 20.0 µg/m$^3$ [7 counties]
- 15.1 – 18.1 µg/m$^3$ [53 counties]
- 12.1 – 15.0 µg/m$^3$ [242 counties]
- $\leq 12.0$ µg/m$^3$ [237 counties]
- No data
The Donora and London incidences were considered “aberration” due to freak weather patterns and not representative of typical air pollution.

The Clean Air Act has resulted in much less particulate air pollution than that seen in the 50s and 60s.

There was very little research done on the health effects of particles until the late 80s.
• Between city effects are somewhat smaller than within city effects
• Uncertainty increases as the PM concentrations decrease or increase above about 12 µg/m³
Why Were the Epidemiology Studies So Hard to Believe?

• Similar results were obtained from cities all around the world
  
  - But chemical composition differs geographically and temporally

• PM levels are very low compared with other particle exposures
  
  - One cigarette = 10x more than a 24 hour exposure to PM

• No widely accepted pathophysiological process or mechanism that could explain the epidemiology findings
Particulate Matter and Health Risk
Susceptible Groups

Clinical sub-groups demonstrating increased sensitivity or vulnerability to the adverse health effects of air particle pollution include:

- Aged adults
- Children
- Diabetes
- Cardiovascular disease
  - Heart failure
  - Ischemic heart disease
  - Arrhythmia
- Pulmonary disease
  - e.g. Asthma, COPD
- Genetic polymorphisms
People ≥65 Years Living in Counties with “poor air quality” 2000-2008

Population Attributable Risk (PAF)
Related to: the strength of the association between exposure to a risk factor and the prevalence of this risk factor within the population

Nawrot TS et al. The Lancet 2011
<table>
<thead>
<tr>
<th>Descriptors</th>
<th>Cautionary Statement</th>
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<tbody>
<tr>
<td><strong>Good</strong></td>
<td>No message</td>
</tr>
<tr>
<td>0 – 50</td>
<td></td>
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<tr>
<td><strong>Moderate</strong></td>
<td>Unusually sensitive individuals</td>
</tr>
<tr>
<td>51 – 100</td>
<td></td>
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<tr>
<td>Unhealthy for Sensitive Groups</td>
<td>Identifiable groups at risk - different groups for different pollutants</td>
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<td>101 - 150</td>
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<tr>
<td><strong>Unhealthy</strong></td>
<td>General public at risk; sensitive groups at greater risk</td>
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<td>151 - 200</td>
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<tr>
<td>Very Unhealthy</td>
<td>General public at greater risk; sensitive groups at greatest risk</td>
</tr>
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<td>201 - 300</td>
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Advice for Reducing Exposure to PM$_{2.5}$

- Know when and where PM$_{2.5}$ levels may be unhealthy
  - Any time of the year
  - Near busy roads, especially during rush hour
  - When there is smoke in the air
  - Check air quality forecasts

- Plan activities when and where levels are lower
  - Delay activities or move them indoors
  - Change your activity levels
  - Avoid exercising near busy roads

- Reduce your overall risk for heart disease or stroke

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Heart Disease, Stroke, and Outdoor Air Pollution

1. Did you know that air pollution can trigger heart attacks, stroke, and other health effects?
   - Medical studies show that air pollution can trigger heart attacks, stroke, and acute heart failure.

2. How can you protect your health?
   - Regular exercise is important for staying healthy, especially if you have heart disease.
   - By adjusting when and where you exercise, you can lead a healthier lifestyle and help reduce your risk of heart problems or stroke triggered by air pollution.

3. Are you at higher risk?
   - For most people, the risk is small. Other adults and people with risk factors for heart disease or stroke may be at greater risk. You are at greater risk if:
     - You have had a heart attack, angina, bypass surgery, angioplasty, or if you have diabetes, heart failure, heart rhythm problems, or chronic obstructive lung disease.
     - You may be at greater risk if you are of a higher risk group:
       - You are a man 60 years or older, or a woman 50 years or older.
       - You have a family history of stroke or heart disease (father or mother diagnosed before age 55 or diagnosed before age 65).
       - You have high blood pressure or high blood cholesterol.
       - You are overweight or not physically active.
       - You smoke cigarettes.

4. What steps can you take to reduce your risk?
   - Reduce your overall risk for heart disease or stroke.
Forecasts

- Over 400 cities
- Multi-pollutants (Ozone, PM$_{2.5}$, PM$_{10}$, CO, and NO$_2$)
- Disseminated to national (e.g., CNN, The Weather Channel, USA Today) and local media
- Available from Enviroflash and on mobile phone apps
Particulate air pollution alone or in combination with other air pollutants (CO, NOx, O3, SO2) contribute a significant public health burden.

Even low levels of air particle pollution are associated with risk.

Previous studies show a decrease in air pollution levels decreases cardiovascular and respiratory mortality.

Certain populations are more susceptible to the effects of air pollution. These include: aged-adults, children, and those with established heart disease, diabetes, asthma, and COPD.
Heart Disease Is the #1 Killer of American Men and Women

• Men and women of all ages are at risk
• More than 83 million are currently living with some form of CV disease
• More than 800,000 die each year from cardiovascular disease
• More than 150,000 were less than 65 years old
• Cardiovascular disease kills more women than the next 7 causes of death combined, and more than men

Cardiovascular Disease Still Kills More Women Than Men

Source: AHA 2004 Heart and Stroke Statistical Update.
Some counties in eastern NC have exceptionally high age-adjusted cardiovascular death rates.
### Outcome Disparities between Men and Women

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
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<tbody>
<tr>
<td>Deaths within one year of 1\textsuperscript{st} MI</td>
<td>25%</td>
<td>38%</td>
</tr>
<tr>
<td>Sudden deaths with no previous symptoms</td>
<td>50%</td>
<td>64%</td>
</tr>
<tr>
<td>Within 6 years of recognized MI, percent who will:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Have another MI</td>
<td>18%</td>
<td>35%</td>
</tr>
<tr>
<td>• Have a stroke</td>
<td>8%</td>
<td>11%</td>
</tr>
<tr>
<td>• Experience SCD</td>
<td>7%</td>
<td>6%</td>
</tr>
<tr>
<td>• Be disabled with heart failure</td>
<td>22%</td>
<td>46%</td>
</tr>
</tbody>
</table>

Source: AHA 2004 Heart and Stroke Statistical Update.
Incidence Rate of CVD
Number of Ideal Health Behaviors and Health Factors

Health Behaviors
- non-smoking
- body mass index
- physical activity
- healthy diet score

Health Factors
- total cholesterol
- blood pressure
- glucose
Heart Disease Affects Women in Every Age Group

Estimated Prevalence of CVD by Age and Gender

Source: AHA 2004 Heart and Stroke Statistical Update.
As the Population Ages, the Risk of Cardiovascular Disease Increases

Baby-boom generation born between 1946–1964

US Bureau of the Census, Adapted from Himes CL. Elderly Americans, Population Bulletin, 2002 56 {4}:4
Age-adjusted Percentage of U.S. Adult Obese or Diagnosed Diabetes

Obesity (BMI ≥30 kg/m²)

1994
- No Data
- <14.0%
- 14.0-17.9%
- 18.0-21.9%
- 22.0-25.9%
- >26.0%

2000
- No Data
- <4.5%
- 4.5-5.9%
- 6.0-7.4%
- 7.5-8.9%
- >9.0%

2009
- No Data
- <4.5%
- 4.5-5.9%
- 6.0-7.4%
- 7.5-8.9%
- >9.0%

Projected Future Cardiovascular Health Care Costs

Projected total (direct and indirect) costs of all CVD by age, 2010 to 2030

Billions in 2008$

- 18-44
- 45-64
- 65-79
- 80+ Years

Heidenreich P A et al. Circulation 2011;123:933-944
Final Thoughts

- 80 million + Americans are living with heart disease increasing their vulnerability to air pollutants.
- While there has been a reduction in CV mortality, the rising prevalence of obesity and diabetes is concerning.
- While advocacy and awareness campaigns have educated people about the risks of heart disease, many are still not aware of their risk of heart disease.
- Even fewer are aware of environmental triggers that can harm those living with some form of CV disease or DM.
- Incorporating an enviro. health risk message as part of a heart health campaign is likely to improve environmental health literacy and decrease short-term CV risk.
Special Thanks and Information

• Wayne Cascio, a cardiologist on staff at EPA
• Susan Stone, US EPA Air Office

Resources

• Airnow.gov
• EPA.gov/aging
• Greenversations