Air Quality: What an internist needs to know

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Goals for this talk - to address the following questions

- Why do we care about fine particulate matter (PM)?
- Why does Utah have a problem with PM?
- Where does it come from?
- How does air pollution effect health?
- Does changing PM levels lead to clinically important changes in human health?
- What do I tell my patients?
- Why do we need more study of air pollution?

Photo: S. Hoch (Atmos. Sci)
Global annual PM$_{2.5}$ levels

Nasa.gov
Deaths from air pollution

7 million people died in 2012 from air pollution
(1 in 8 total global deaths) WHO 2014

World Health Organization, 2014
“Criteria Pollutants” Defined in the Clean Air Act

- Particulate matter
- Ozone
- Lead
- Carbon monoxide
- Sulfur oxides
- Nitrogen dioxide
Inversion conditions in Utah worse than ever; area hospitals see spike in patients

Fox13 News
February 12, 2016

The American Lung Association State of the Air has given Salt Lake County grades of F for ozone and particulates
Particulate matter

• Complex mixture of small particles and droplets
  – acids (such as nitrates and sulfates)
  – organic chemicals
  – metals
  – soil or dust particles

• PM$_{10}$ – aerodynamic diameter < 10 $\mu$m
  – Inhalable course particles

• PM$_{2.5}$ – aerodynamic diameter < 2.5 $\mu$m
  – Fine particles
  – Major factor in haze
PM$_{2.5}$ - Why size matters
Where does the PM come from?

Directly emitted particles 1/3

Indirect reactions 2/3

We contribute to both direct & indirect PM
Salt Lake Valley
PM$_{2.5}$ Concentration at Hawthorne

Exceeded NAAQs in 2013 (35 days), 2014 (13 days), 2015 (5 days) and 2016 (10 so far)

Beijing annual average
Roughly 75 µg/m$^3$
Delhi recently reached over 900 µg/m$^3$
What are our Sources of Pollution?

Mobile sources responsible for 57% of emissions and are decreasing

Areas sources are responsible for about 27% of emissions and are decreasing

Point sources are responsible for about 16% of emissions and are increasing

Data for Salt Lake County from DAQ SIP December 13, 2014
London, December 1952
London
December 5-9, 1952
Epidemiologic data concerning the impact of air pollution

- Extensive epidemiologic evidence linking exposure to air pollution to effects on human health
  - Total mortality/life expectancy
  - Cardiopulmonary mortality
    - Cardiovascular events (MI, strokes, sudden death)
  - Asthma
    - Incidence
    - Attacks
  - Worsening of symptoms for patients with cigarette-related lung disease (COPD)
  - Cancer
    - WHO has declared air pollution the second most important attributable cause of cancer after cigarettes
Correlation of mortality with air quality - Harvard Six Cities Study

- Prospective study with enrollment in 1979 and follow-up through 1990’s
- City specific mortality during early ('80's) and late ('90's) periods and over entire study
- Mortality inversely related to level of fine particulates during each period
- Similar correlations both for overall mean exposure and for exposure in the year prior to death

S- Steubenville, H- Harriman, T- Topeka, W- Watertown, L- St Louis, P- Portage

Dockery et al.  NEJM 1993;329:1753-9
Organ-specific information concerning the impact of air quality on health

Emphysema and chronic bronchitis
Asthma
Severe pneumonia
Lung Cancer

Strokes
Accelerated loss of mental function

Heart attacks
Arrhythmias
Sudden death
Long and short term effects on cardiovascular disease

• Long term:
  – Large national cohort studies demonstrate direct relationships being PM2.5 local exposure and both total mortality and cardiovascular mortality
    • CVD risk increases 10% for each 10 μg/M³ increase in PM2.5
      – Thurston et al. Environmental Health Perspectives 2016

• Short term:
  – Local studies from Utah have demonstrated increased risk of heart attacks during 1-3 days after onset of increased PM2.5 pollution
    • 4% increased rate for each 10 μg/M³ increase in PM2.5
      – Pope et al. Circulation 2006
Short term exposure to particulate matter pollution is associated with increased cardiovascular events

- Triggering acute ischemic events
  - Myocardial infarction
  - Ischemic stroke
  - Evidence of injury on electrocardiograms
- Increased blood viscosity
- Decreased heart rate variability
- Triggering arrhythmias
- Secondary particles may be more important than primary particles
Assessed pollutant exposure, changes in pulmonary function; airway inflammation

Randomized cross over trial
60 adults with mild to moderate asthma taking two leisurely 2-hr walks in London

McCreanor et al. NEJM 2007; 357:2348
### Pollutant exposure

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Oxford St</th>
<th>Hyde Park</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PM$_{2.5}$ ($\mu g/m^3$)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>28.3</td>
<td>11.9</td>
</tr>
<tr>
<td>Range</td>
<td>13.9–76.1</td>
<td>3–55.9</td>
</tr>
<tr>
<td><strong>Ultrafine particles (thousands/cm$^3$)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>63.7</td>
<td>18.3</td>
</tr>
<tr>
<td>Range</td>
<td>39.5–92.4</td>
<td>10.3–37.1</td>
</tr>
<tr>
<td><strong>Elemental carbon ($\mu g/m^3$)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>7.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Range</td>
<td>3.9–16</td>
<td>0.4–6.7</td>
</tr>
<tr>
<td><strong>Nitrogen dioxide ($\mu g/m^3$)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>142</td>
<td>21.7</td>
</tr>
<tr>
<td>Range</td>
<td>10.7–289</td>
<td>2.4–146</td>
</tr>
</tbody>
</table>
Changes in pulmonary function during and after Exposure on Oxford Street and in Hyde Park

- Key correlations were with PM$_{2.5}$, ultrafine particles, elemental carbon and nitrogen dioxide
- Significant increases in markers of airway inflammation

McCreanor et al. NEJM 2007; 357:2348
Impact of air pollution on cognitive function

• Nurses’ Health Study
  – 19,000 women aged 70-81
  – Followed over time with estimates of PM2.5 and course particle exposure
  – Decline in cognitive function on sophisticated testing associated with increased pollution
  – An increment of 10 $\mu$g/m$^3$ long term PM exposure was cognitively equivalent to aging by approximately 2 years

Arch Intern Med 2012; 172:219
Effects of Air Pollution on Children

- Incidence of asthma
- Acute asthma exacerbations
- Lung growth
- Lost IQ points
Protecting the Tails of the Curve

72,500 intellectually impaired
72,500 intellectually gifted
108,750 intellectually impaired
36,250 intellectually gifted

Utah Population Census 2012: 2.9 million
Distant relations

- We know that particles deposit in the peripheral lung.
- How do these particles induce or impact disease in distant organs?
  - Heart
  - Brain
Simkhovich et al. J Am Coll Cardiol 2008
Reduction in Fine Particulate Air Pollution and Mortality: Extended Follow-up of the Harvard Six Cities Study
Fine particulate air pollution and life expectancy in the US

- Detailed monitoring information at the county level
- Looking at late 1970’s and early 1980’s and at late 1990’s and early 2000’s
- Cross-sectional comparisons within each period
- Proxies for smoking, access to health care, etc.
- Temporal comparisons between periods; each county as its own control

Pope et al. NEJM 2009; 360: 376
Pope et al. 2009: Results

- Air quality improved over time across the country
- Life expectancy increased (2.72 years)
- During each period, cross-sectional data showed negative association between life expectancy and pollution levels
- Reduction of 10 µm/m³ resulted in increase of 0.61 ± 0.2 years life
- Benefit regardless of baseline level; in fact greater increase for those areas with less pollution initially
- From 1980 through 2000, improved air quality accounted for approximately 15% of change in life expectancy
Geneva Steel Strike

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When the steel mill was open, total children’s hospital admissions for respiratory conditions **approx. doubled.**
What should we tell our patients about exercise?

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Increased lung particle deposition during exercise

Daigle et al. Inh Toxic 2003
Impact of particulate air pollution on cycle work capacity

Physiologic Changes with Pollution Exposure

Flow mediated vasodilation

Pulmonary artery pressure
Particle exposure decreases as you move further from a highway.

Where you run matters.

With respect to ozone, when you run matters too.

Rundell et al.
Inhalat Toxicol 2006
Reducing personal exposure to PM air pollution improves cardiovascular health in patients with coronary artery disease

- Study carried out on the streets of Beijing
- 98 individuals with stable coronary artery disease
- 2 hour walks on different days, with or without a high efficiency mask
- Mean ambient PM$_{2.5}$ = 74 µg/m$^3$

Langrish et al. Environ Health Perspect 2012,120:367
Decreased pollution effects when wearing the high efficiency mask

- The mask was comfortable
  - \((=0.64 + 1\) on scale 0-10, where 0=completely comfortable\)
- Small but statistically significant:
  - Decreased electrocardiogram changes
  - Decreased mean arterial pressure
  - Increased heart rate variability
- Improved sense of well-being
- No effect on heart rate or energy expenditure
What do I tell my patients?

• Pay attention to air quality; note if your symptoms change.
• When air quality is poor, it is particularly important to use your medications properly.
• During “bad air” days:
  – Exercise away from roadways
  – Exercise indoors
  – Stay indoors
• Starting to think about masks for high-risk individuals when outdoors
Why Do We Need More Study of Air Pollution?

• We have only scratched the surface of the biological responses to air pollution
  – Mechanisms
  – Temporal relationships – cumulative effects vs. acute exposures vs. repeated exposures
  – Better understanding of specific diseases

• Why do individuals exposed to the same pollutants have different responses?

• What can be done to alleviate or interrupt these processes beyond limiting exposure?
Why Do We Need More Study of Air Pollution?

• What are the contributions of specific components of air pollution?

• What are the key components/synergies?
  – Are the health effects of particulates related largely to size or chemical composition?

• Atmospheric chemistry - what are the limiting reactions?

• Geospatial relationships?

• Economic and behavioral aspects of the burden of air pollution?
Program for Air Quality, Health and Society

• Multidisciplinary program
  – Health Sciences
    • Mechanistic biology
    • Population sciences
  – Engineering
    • Measurements
    • Combustion and emissions
  – Atmospheric sciences
  – Economics, public policy, law
## Cost-benefit of the Clean Air Act 1990-2020

<table>
<thead>
<tr>
<th>Case</th>
<th>Cases prevented (2020)</th>
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</thead>
<tbody>
<tr>
<td>Adult mortality – particles</td>
<td>230,000</td>
</tr>
<tr>
<td>Infant mortality – particles</td>
<td>280</td>
</tr>
<tr>
<td>Mortality – ozone</td>
<td>7100</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>75,000</td>
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<tr>
<td>Acute myocardial infarction</td>
<td>200,000</td>
</tr>
<tr>
<td>Asthma exacerbation</td>
<td>2,400,000</td>
</tr>
<tr>
<td>Emergency room visits</td>
<td>120,000</td>
</tr>
<tr>
<td>Lost school days</td>
<td>5,400,000</td>
</tr>
<tr>
<td>Lost work days</td>
<td>17,000,000</td>
</tr>
</tbody>
</table>
Thank you