Environmental Lung Disease

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Disclosures

- Expenses to CHEST Regional Meeting paid for by CHEST
- Scientific Research:
  - AVOX Systems Grant (Boeing 787 Oxygen Supplementation Systems)
  - U.S. Department of Labor (RETAIIN Grant)
- Employed by: Mayo Clinic
Objectives

• Understand atmospheric divisions and the effects of reduced pressure at altitude
  - Partial pressure of gases vs. FiO2
  - Hypoxia
  - Dysbarisms

• Appreciate issues associated with ambient air pollution and smoking

• Review basics of toxic inhalations, including RADS
You decide to buy a ticket on Virgin Galactic and take a suborbital ride to the edge of space. During your flight you decide to pop the latch and determine the FiO₂ outside the capsule. What is the FiO₂ at 60,000 ft (18,882 m)?

A. 21%
B. 18%
C. 8%
D. 2%
E. Cannot calculate at that altitude
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A. 21%
B. 18%
C. 8%
D. 2%
E. Cannot calculate at that altitude
78% Nitrogen
21% Oxygen
1% Other Gasses
The air up here has the same composition—there is just less of it—it is thin!

Stratosphere where temperature is nearly constant about -55°C

Tropopause (33,000 ft. varying with latitude)

Theatre of weather

Troposphere where air temperature lessens according to altitude

Earth
The atmospheric "haystack"
<table>
<thead>
<tr>
<th>feet</th>
<th>meters</th>
<th>mm Hg</th>
<th>in Hg</th>
<th>lb/in²</th>
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<td>87.3</td>
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<td>16,764</td>
<td>68.8</td>
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<td>60,000</td>
<td>18,288</td>
<td>54.1</td>
<td>2.14</td>
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<td>19,812</td>
<td>42.3</td>
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<td>21,336</td>
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<td>30,480</td>
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### Time of Useful Consciousness

<table>
<thead>
<tr>
<th>Feet (thousands)</th>
<th>Kilometers</th>
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<tbody>
<tr>
<td>50</td>
<td>15.2</td>
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<tr>
<td>43</td>
<td>13.1</td>
<td>9 – 12 sec</td>
</tr>
<tr>
<td>40</td>
<td>12.2</td>
<td>15 – 20 sec</td>
</tr>
<tr>
<td>35</td>
<td>10.7</td>
<td>30 – 60 sec</td>
</tr>
<tr>
<td>30</td>
<td>9.1</td>
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</tr>
<tr>
<td>28</td>
<td>8.5</td>
<td>2.5 – 3 min</td>
</tr>
<tr>
<td>25</td>
<td>7.6</td>
<td>4 – 6 min</td>
</tr>
<tr>
<td>22</td>
<td>6.7</td>
<td>8 – 10 min</td>
</tr>
<tr>
<td>18</td>
<td>5.5</td>
<td>20 – 30 min</td>
</tr>
</tbody>
</table>
What do aviators, divers and soft drinks have in common?
“Liquid systems saturated with a dissolved gas”

- **Henry’s Law**
  - Amount of dissolved gas in solution varies directly with pressure of that gas over the solution
  - \( \frac{P_1}{P_2} = \frac{A_1}{A_2} \)

- **Decompression Sickness (DCS)**
  - Dissolved nitrogen equalizes with the surrounding environment as pressure changes
  - If the pressure change is too rapid it comes out of solution rapidly forming bubbles in the blood and tissues
NITROGEN BUBBLES COLLECT IN JOINTS

HELP! I HAVE BENDS

LONG PERIODS AT VERY HIGH ALTITUDES HELP BRING ON BENDS

PRESSURE DECREASE

I'M OK.

SEA LEVEL

OUCH! I HAVE BENDS

LESS PRESSURE

TOO GREAT AND RAPID A PRESSURE DECREASE = THE "BENDS"

MOST PRESSURE
Law of Boyle-Mariotte

\[ p_1 \times V_1 = p_2 \times V_2 \]

A given mass (volume) of a gas is inversely proportional to the pressure to which it is subjected.

<table>
<thead>
<tr>
<th>Altitude (ft)</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level</td>
<td>X 1</td>
</tr>
<tr>
<td>18’000ft</td>
<td>X 2</td>
</tr>
<tr>
<td>28’000ft</td>
<td>X 3</td>
</tr>
<tr>
<td>39’000ft</td>
<td>X 5</td>
</tr>
</tbody>
</table>
Boyle’s Law & Physiology

Trapping of gas

Paranasal Sinus (Sinus block)

Carious Teeth (Aerodontalgia)

Middle Ear (Earblock)

Result: Pain with pressure changes (descent)
Ambient Air Pollution
Which of the following compounds are NOT considered one of the regulated ambient air pollutants?

A. Ultrafine particles (PM 2.5)
B. Sulfur dioxide
C. Nitrogen dioxide
D. Carbon dioxide
E. Ozone
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B. Sulfur dioxide
C. Nitrogen dioxide
D. Carbon dioxide
E. Ozone
Sources of Transportation Air Pollution

Smog and soot → Health and welfare impacts

CO₂ and other greenhouse gases → Climate change

- Light Duty Vehicles
- Heavy Duty Vehicles
- Motorcycles
- Aircraft
- Nonroad Diesel Equipment
- Marine Engines/Ocean Vessels
- Locomotives
- Lawn & Garden
- Recreation Vehicles

ON ROAD

NONROAD

Source: US EPA
Emission reductions → Cleaner air & better health

**Catalytic converters**
in conjunction with unleaded gasoline and low sulfur levels significantly reduce hydrocarbon & nitrogen oxide emissions

**Fuel standards**
reduce exposure to pollutants like lead and benzene

**Engine technologies**
like computer controls, variable valve timing, multi-valve engines, turbo charging & gasoline direct injection improve fuel economy & reduce CO₂ emissions

**Transmission technologies**
like 7+ speeds, dual clutch transmissions (DCTs), & continuously variable transmissions (CVTs) improve fuel economy & reduce CO₂ emissions

**Diesel filters**
reduce particulate matter from on road & off road diesel engines

**Alternative vehicle technologies**
like plug-in electric vehicles & fuel cells = zero tailpipe emissions

**Better transportation planning**
for passengers & freight reduce emissions & fuel use
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Primary standard</th>
<th>Measuring method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone (O₃, ppm)</td>
<td></td>
<td>1-hr average ≤0.1 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8-hr average ≤0.06 ppm</td>
</tr>
<tr>
<td>PM₁₀ (µg/m³)</td>
<td></td>
<td>Annual arithmetic mean ≤50 µg/m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hr average ≤100 µg/m³</td>
</tr>
<tr>
<td>PM₂.₅ (µg/m³)</td>
<td></td>
<td>Annual arithmetic mean ≤25 µg/m³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hr average ≤50 µg/m³</td>
</tr>
<tr>
<td>Sulfur dioxide (SO₂, ppm)</td>
<td></td>
<td>Annual arithmetic mean ≤0.02 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hr average ≤0.05 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-hr average ≤0.15 ppm</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂, ppm)</td>
<td></td>
<td>Annual arithmetic mean ≤0.03 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hr average ≤0.06 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-hr average ≤0.10 ppm</td>
</tr>
<tr>
<td>Carbon monoxide (CO, ppm)</td>
<td>8-hr average</td>
<td>≤9 ppm</td>
</tr>
<tr>
<td></td>
<td>1-hr average</td>
<td>≤25 ppm</td>
</tr>
</tbody>
</table>

People residing in regions with air pollutant concentration above the primary standards may experience adverse health effect from poor air quality. PM, particulate matter.

Air Pollution and Noncommunicable Diseases
A Review by the Forum of International Respiratory Societies’ Environmental Committee, Part 1: The Damaging Effects of Air Pollution

Dean E. Schraufnagel, MD; John R. Balmes, MD; Clayton T. Cowl, MD; Sara De Matteis, MD, MPH, PhD; Soon-Hee Jung, MD, PhD; Kevin Mortimer, MB, BCH, PhD; Rogelio Perez-Padilla, MD; Mary B. Rice, MD, MPH; Horacio Riojas-Rodriguez, MD, PhD; Akshay Sood, MD, MPH; George D. Thurston, ScD; Teresa To, PhD; Anessa Vanker, MBChB, PhD; and Donald J. Wuebbles, PhD

Air pollution poses a great environmental risk to health. Outdoor fine particulate matter (particulate matter with an aerodynamic diameter < 2.5 μm) exposure is the fifth leading risk factor for death in the world, accounting for 4.2 million deaths and > 103 million disability-adjusted life years lost according to the Global Burden of Disease Report. The World Health Organization attributes 3.8 million additional deaths to indoor air pollution. Air pollution can harm acutely, usually manifested by respiratory or cardiac symptoms, as well as chronically, potentially affecting every organ in the body. It can cause, complicate, or exacerbate many adverse health conditions. Tissue damage may result directly from pollutant toxicity because fine and ultrafine particles can gain access to organs, or indirectly through systemic inflammatory processes. Susceptibility is partly under genetic and epigenetic regulation. Although air pollution affects people of all regions, ages, and social groups, it is likely to cause greater illness in those with heavy exposure and greater susceptibility. Persons are more vulnerable to air pollution if they have other illnesses or less social support. Harmful effects occur on a continuum of dosage and even at levels below air quality standards previously considered to be safe.

CHEST 2019; 155(2):409-416
Air Pollution not only affects the respiratory system but also other organ systems in the body – however, it is controllable and therefore, health effects preventable.
Which of the following statements are most correct regarding tobacco abuse and smoking cessation?

A. In the U.S., tobacco addition has risen to the second most common drug addiction behind use of marijuana.

B. Women who stop smoking during pregnancy increase their risk of having a low birth weight baby.

C. Counseling and medication are both effective for treating tobacco dependence, and using them together is more effective than using either one alone.

D. People of low SES are less likely to make quit attempts but are more successful in quitting smoking cigarettes than those in higher SES groups.
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C. Counseling and medication are both effective for treating tobacco dependence, and using them together is more effective than using either one alone.

D. People of low SES are less likely to make quit attempts but are more successful in quitting smoking cigarettes than those in higher SES groups.

Which of the following statements are most correct regarding tobacco abuse and smoking cessation?
Tobacco use can lead to tobacco/nicotine dependence and serious health problems including coronary artery disease, lung and other cancers, strokes, peripheral vascular disease, and other conditions.

Smokers can and do quit smoking. Since 2002 there are more former smokers than current smokers.

More people in the world are addicted to nicotine than to any other drug. Research suggests that nicotine may be as addictive as heroin, cocaine, or alcohol.

Quitting smoking is hard and may require several attempts. People who stop smoking often start again because of withdrawal symptoms, stress, and weight gain.
Disparities in tobacco use

People with low SES tend to smoke cigarettes more heavily

- Individuals living in poverty smoke cigarettes for a duration of nearly twice as many years as people with a family income of three times the poverty rate and with at least a Bachelor’s degree.
- “Blue-collar” workers are more likely to start smoking cigarettes at a younger age and to smoke more heavily than white-collar workers.

Secondhand smoke exposure is higher among people living below the poverty level and those with less education

People of low SES are just as likely to make quit attempts but are less likely to quit smoking cigarettes than those who are not
Tobacco use treatment and smoking cessation

• Among all current U.S. adult cigarette smokers, nearly 7 out of every 10 (68.8%) reported in 2010 that they wanted to quit completely.
• Reduced heart disease risk realized within 1 to 2 years of quitting smoking (for those smoking more than 1 pack per day).
• Women who stop smoking during pregnancy also reduce their risk of having a low birth weight baby.
Tobacco use treatment and smoking cessation

Quitting without assistance ("cold turkey" or cut down then quit)

Medications for quitting that have been found to be effective include the following:

- Nicotine replacement products
  - Nicotine patch [which is also available OTC or by prescription], gum, lozenge, inhaler, nasal spray
- Prescription non-nicotine medications
  - bupropion SR (Zyban®), varenicline tartrate (Chantix®)

Counseling and medication are both effective for treating tobacco dependence, and using them together is more effective than using either one alone.
Use of eCigarettes ("Vaping")

- eCigarettes may be less harmful than cigarette smoking
- eCigarettes still contain nicotine and are highly addictive
- "Vaping" may actually involve more nicotine delivery than traditional cigarettes
- If recommending smoking cessation, eCigarettes are NOT the ideal mechanism for doing so
- Prevalence of nicotine dependence has increased dramatically with a 900% increase in rates of e-Cigarette use reported in U.S. high school students ages 14-18
Toxic Inhalations

DANGER

Inhalation hazard.

Vapours are toxic.
Avoid exposure to vapours.
Wear proper personal protective equipment.
Diagnosis and Management of Work-Related Asthma*

American College of Chest Physicians
Consensus Statement

Susan M. Tarlo, MBBS, FCCP; John Balnes, MD, FCCP;
Ronald Balkisson, MD; Jeremy Beach, MD; William Beckett, MD, MPH, FCCP;
David Bernstein, MD; Paul D. Blanco, MD, FCCP; Stuart M. Brooks, MD;
Clayton T. Cowl, MD, MS, FCCP; Feroda Daroovala, MD, MPH, FCCP;
Philip Harper, MD, MPH; Catherine Leniere, MD, MS;
Gary M. Liss, MD, MS; Karin A. Pacheco, MD, MSPH;
Carrie A. Redlich, MD, MPH, FCCP; Brian Rowe, MD, FCCP;
and Julia Reitzel, MS

Background: A previous American College of Chest Physicians Consensus Statement on asthma in the workplace was published in 1995. The current Consensus Statement updates the previous one based on additional research that has been published since then, including findings relevant to preventive measures and work-exacerbated asthma (WEA).

Methods: A panel of experts, including allergists, pulmonologists, and occupational medicine physicians, was convened to develop this Consensus Document on the diagnosis and management of work-related asthma (WEA), based on part on a systematic review, that was...
ERS TASK FORCE REPORT

Guidelines for the management of work-related asthma


ABSTRACT: Work-related asthma, which includes occupational asthma and work-aggravated asthma, has become one of the most prevalent occupational lung diseases. These guidelines aim to upgrade occupational health standards, contribute importantly to transnational legal harmonisation and reduce the high socio-economic burden caused by this disorder.

A systematic literature search related to five key questions was performed: 1) diagnostic risk factors; 2) outcome of management options; 3) medical screening and surveillance; 4) controlling exposure for primary prevention. Each of the 1,329 retrieved papers was reviewed by two experts, followed by Scottish Intercollegiate Guidelines Network grading, and formulation of statements graded according to the Royal College of General Practitioners' three-star system.

Recommendations were made on the basis of the evidence-based statements, which comprise the following major evidence-based strategic points. 1) A comprehensive diagnostic approach considering the individual specific aspects is recommended. 2) Early recognition and diagnosis is necessary for timely and appropriate preventative measures. 3) A stratified medical screening strategy and surveillance programme should be applied to at-risk workers. 4) Whenever possible, removing exposure to the causative agent should be achieved, as it leads to the best health outcome. If this is not possible, reduction is the second best option, whereas respirators are of limited value. 5) Exposure elimination should be the preferred primary prevention approach.

KEYWORDS: Diagnostics, occupational asthma, occupational exposure, prevention, risk factors, surveillance
Consensus reached on several topics on Work-Related Asthma (WRA)

- Take a history to screen for WRA in all new onset or worsening asthma patients
- In all patients suspected with WRA, obtain a history of job duties, exposures, use of protective devices, presence of respiratory disease in co-workers, etc.
- For individuals with suspected sensitizer-induced occupational asthma (OA), carefully document history and use objective testing to improve diagnostic probability (e.g. serial peak flow readings, serial methacholine challenge, immunological assessments, induced sputum testing, etc.)
Consensus reached on several topics on WRA (cont.):

- In patients suspected with WRA who are continuing to work, record serial measurements of peak flow as part of the diagnostic evaluation (minimum 4x/day for at least 2 weeks)
- Focus on exposure control and remove patients from exposure in sensitizer-induced asthma
- An individual diagnosed with OA represents a potential sentinel event, so the workplace may need to be evaluated to identify and prevent other cases of OA -- and if sensitizer present, implement secondary prevention (e.g. questionnaires, screening spirometry, etc.)
Work-related asthma epidemiology

Work-related Asthma has a prevalence of 9-15% of all forms of asthma

Work-related asthma

Immunologic-induced asthma
- High-Molecular Weight Antigens
- Low-Molecular Weight Antigens

Irritant-induced asthma (RADS)
Inhalation of irritants, gases, fumes

Asthma with latency
Asthma without latency
Reactive Airways Dysfunction Syndrome (RADS)
Reactive Airways Dysfunction Syndrome (RADS)

- An asthma-like illness that occurs after a single exposure to high levels of a respiratory irritant (vapor, fume, smoke) frequently occurring after a workplace accident or spill.
- Symptoms develop within hours of exposure and are associated with methacholine challenge responsiveness.
- Symptoms and airway responsiveness often persist longer than one year and may be permanent.

Assessment and treatment of acute toxic inhalations

Clayton T. Cowl

Purpose of review
Acute toxic inhalation exposures affect thousands of individuals worldwide each year. The acute evaluation of these inhaled exposures is often fraught with difficulty in identifying a specific agent, may involve multiple compounds, and a wide variety of responses are seen depending on the physical properties of the specific toxicant, the length of time of inhalation, and the concentration of the exposure. Recognizing key aspects of the most common acute toxic inhalations is useful in developing a diagnosis and treatment strategy.

Recent findings
Use of sequential observations with flexible bronchoscopy has been the standard of care for assessing airway injury, and virtual bronchoscopy using computed tomographic images in a three-dimensional reconstructed image can now better identify airway narrowing. Use of [18F]fluorodeoxyglucose uptake, as measured by PET, has the potential for early recognition of delayed acute lung injury in toxic inhalation exposures. Development of a standardized respiratory injury grading system is ongoing with a recent multicenter trial nearly complete, allowing for more accurate estimates of eventual outcomes and guide levels of intensity of care for patients with acute inhalation injury. Removal from the source of exposure and airway support remain the first critical aspect of treatment, and additional therapies have been studied recently that focus on altering molecular mechanisms of acute cellular injury, expanding potential treatments beyond other pharmacotherapeutic strategies utilized previously such as mucolytics, bronchodilators, and inhaled anticoagulants.

Summary
Although a prevalent source of airway injury, exposure to acute toxic inhalants is often difficult to assess and prognosticate, and challenging to treat.

Keywords
Acute inhalation injury, acute toxic inhalants, gaseous inhalation, inhaled irritants, toxic inhalations
Smoke inhalation injuries

- Smoke inhalation injury is generally defined as the inhalation of thermal or chemical irritants with more than 23,000 injuries and 5,000–10,000 U.S. deaths per year.
- According to the WHO, more than 1 billion people develop airway and pulmonary inflammation as a result of inhaled smoke from indoor cooking fires, forest fires and burning of crops.
- Smoke toxicity is increasing because industrial products have shifted from woods and natural materials towards lighter construction materials, synthetics and petrochemicals, which ignite and burn 2x- to 3x-times hotter and faster.
Smoke inhalation injuries (cont.)

- Thermal injury, which is mostly restricted to the upper airway (exception: blast injury or steam inhalation)
- Chemical irritation of the respiratory tract
- Systemic toxicity from toxic gases
Smoke inhalation injuries (cont.)

Contact irritants -- particulates

• Cause cellular damage and massive edema
• Include particulate matter such as soot with particles larger than five microns lodging in the upper airways, causing mechanical obstruction
• Particles smaller than one micron are inhaled distally, where the carbonaceous soot is toxic to the macrophages. Heavy metals coating the surface of soot cause direct lung damage by forming free oxygen radicals which damage cilia and alveolar surfaces

Aldehydes and acrolein -- released when wood and cellulose burn

• Cause intense tearing, coughing, and choking with acrolein
What Things Do I Need to Consider in Assessing the Patient?

- Physical Properties of Gas
- Acute Clinic Findings as an Assessment of Injury Severity

**Common Types of Toxic Inhalations**

- Ammonia
- Cadmium
- Mercury
- Zinc chloride
- Mace & Tear Gas
- Hydrogen sulfide
- Ozone
- Sulfur dioxide
- Chlorine Derivatives
- Phosgene
- Nitrogen oxides
Smoke inhalation injuries (cont.)

Degradation of plastics creates most of the corrosive gases found in fires

- Plastics containing a chlorine molecule (e.g. polyvinyl chloride)
- Burning forms hydrogen chloride, phosgene, and HCl
- If superheated air has also been inhaled, swelling can be severe and cause rapid, significant airway obstruction.

Central systemic poisons (carbon monoxide or CO) and cyanide
Physical Properties of Toxic Irritants

- Size of particles
- Water solubility
- Concentration of substance in ambient air
- Density of substance
- Duration of exposure
- Presence or absence of ventilation
- Host factors
  - Age, smoking status, co-morbidities
  - Respiratory protection
## Water Solubility and Site of Initial Impact of Toxic Irritants

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<tr>
<th>Water Solubility</th>
<th>Initial Level of Impact</th>
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<tbody>
<tr>
<td>High</td>
<td>Nose</td>
<td>Ammonia</td>
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<tr>
<td></td>
<td>Pharynx</td>
<td>Chlorine</td>
</tr>
<tr>
<td></td>
<td>Larynx</td>
<td>Sulfur dioxide</td>
</tr>
<tr>
<td>Medium</td>
<td>Trachea</td>
<td>Ozone</td>
</tr>
<tr>
<td></td>
<td>Bronchi</td>
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</tr>
<tr>
<td>Low</td>
<td>Bronchioles</td>
<td>Nitrogen dioxide</td>
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<tr>
<td></td>
<td>Alveoli</td>
<td>Phosgene</td>
</tr>
</tbody>
</table>

Summary

- The Atmosphere, Hypobaric Hypoxia and Dysbarisms
- Air pollution
- Smoking
- Toxic Inhalations
Thank you for your attention!

Ευχαριστώ για την προσοχή σας