Environmental Impact of Anesthesia

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Learning Objectives

• Discuss the relationship between pollution and public health
• Define Life Cycle Analysis (LCA)
• Summarize key inhaled anesthetic pollution findings
• Identify opportunities for anesthesiology practice improvement

Disclosure: no relationships with industry

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#ClimateChange #ASA2019 #ClinicalSustainable
Why sustainability?

- We live in a finite world
- Human health is dependent on environmental health
“Climate Change is a Medical Emergency”

Lancet Commission on Health and Climate Change, WHO, UN

7000+ higher education institutions, 6 continents
Pollution a leading cause of non-communicable disease/deaths

- 9 million premature deaths, 16% of all global deaths
- Disproportionately affects the poor
- Air pollution and climate change closely linked
- Welfare losses estimated at $4.6 TRN/year, 6.2% global output.
- Cost of inaction high, while ROI for pollution control significant

Lancet Commission on Pollution and Health, 2018
Impact of Climate Change on Human Health

- Injuries, fatalities, mental health impacts
- Asthma, cardiovascular disease
- Heat-related illness and death, cardiovascular failure
- Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus
- Forced migration, civil conflict, mental health impacts
- Respiratory allergies, asthma
- Extreme heat
- More extreme weather
- Changes in vector ecology
- Increasing allergens
- Malnutrition, diarrheal disease
- Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms
- Severe weather
- Air pollution
- Rising temperatures
- Rising CO2 levels
- Increasing water supply impacts
- Water quality impacts
- Environmental degradation
Climate change will be the defining issue for health systems in the 21st Century. Health Professionals have the knowledge, cultural authority, and responsibility to protect health from climate change. “

Margaret Chan, MD, Director General, World Health Organization
Intergovernmental Panel on Climate Change
Special Report on Global Warming of 1.5°C
October 8, 2018

• Already seeing harm from 1°C global warming
• Likely to reach 1.5°C between 2030-2052
• Anthropogenic CO2 emissions need to fall by 45% by 2030, and reach ‘net zero’ by 2050 to limit to 1.5°C by 2100
• Possible within laws of chemistry and physics. Unprecedented in scale

“The next few years are probably the most important in all of human history.”
Debra Roberts, IPCC Co-Chair
Environmental impacts can occur at each stage of the life cycle and can be non-intuitive.

Need to consider all stages in order to inform large-scale design or policy decisions.

Need to consider multiple environmental impacts, to ensure that we are not simply shifting burdens from one impact to another.

Courtesy M. Eckelman
US health sector
10% of national GHGs emissions

• If health care were a country, it would rank 13th in the world for GHG emissions
• US health care public health damages from pollution 614,000 DALYs (especially air pollution + climate change)
• Similar in magnitude as the 44,000-88,000 deaths due to medical errors
• Pollution prevention the new patient safety movement

Eckelman, Sherman, PLoS ONE 2016
Eckelman, Sherman, Am. J. Public Health 2017
Global healthcare sector GHG emissions
4.6% of global total emissions
(2250 Mt CO2e) in 2016
Relative National Health Sector GHG emissions in NHS-England

- Major categories:
  - building energy use
  - Travel (staff and patients)
  - Procurement
- 2.5% GHG emissions from anesthetic gases (in the UK, especially N₂O)
- 5% of acute care organization carbon footprint from anesthetic gases

Sustainable Development Unit, NHS 2013 report
Clinical Sustainability is central to the aims of Quality Improvement

- Deliver maximum health gain/experience of care
- At minimal financial cost
- While adding value at every opportunity, for the most people

\[
\text{VALUE} = \frac{\text{Outcomes for patients \& populations}}{\text{Environmental} + \text{Social} + \text{Financial costs}}
\]

Sherman, et al., Reducing pollution from the health care industry, JAMA 2019
What happens to inhaled anesthetics?

- 95% vented out the roof of the hospital
- Destroy ozone layer
- Greenhouse gases
- Emissions not controlled

Courtesy S. Ryan, UCSF
WAG: One hour of anesthetic like driving a car...miles

(EPA 2012 USA fuel efficiency average, 23.9 mpg)

<table>
<thead>
<tr>
<th>1-MAC-hour</th>
<th>Sevoflurane 2.2%</th>
<th>Isoflurane 1.2%</th>
<th>Desflurane 6.7%</th>
<th>N₂O* 0.6-MAC-hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 L/min</td>
<td>XXXX</td>
<td>4</td>
<td>93</td>
<td>29</td>
</tr>
<tr>
<td>1.0 L/min</td>
<td>4</td>
<td>7</td>
<td>189</td>
<td>57</td>
</tr>
<tr>
<td>2.0 L/min</td>
<td>8</td>
<td>15</td>
<td>378</td>
<td>112</td>
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<tr>
<td>5.0 L/min</td>
<td>19</td>
<td>38</td>
<td>939</td>
<td>282</td>
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<tr>
<td>10.0 L/min</td>
<td>38</td>
<td>74</td>
<td>1,876</td>
<td>564</td>
</tr>
</tbody>
</table>

Free Smart Phone App Calculator!
Life Cycle Assessment (LCA)
Propofol vs. Inhaled Anesthetics

Life Cycle Greenhouse Gases of Anesthetic Drugs (1-MAC-hr)

Waste phase = pink and red.
Non-waste phases (manufacturing, transportation, use) = blue.
NOTE: Des and Iso @ 1LPM, Sevo @ 2LPM, Prop @ 100 mcg/kg/min (70kg)
What about Non-inhaled Anesthetics?

- Regional/Peripheral Nerve Blocks
- Neuraxial
- Total Intravenous Anesthesia
Life Cycle GHG Emissions of Alternative Anesthetic Clinical Care Pathways

MAC=Monitored Anesthesia Care; PNB=Peripheral Nerve Block; GIH=General Inhaled (Sevo); TIVA=Total Intravenous Anesthesia

Sherman, Tunceroglu, Parvatker, Eckelman

APSF project
Environmental impact importance by time horizon

Weights by Time Horizon

- Long (100+ yrs)
- Medium (10-100 yrs)
- Short (0-10 yrs)

Impact Category

- Global Warming
- Fossil Fuel Depletion
- Criteria Air Pollutants
- Water Intake
- Cancerous Effects
- Ecological Toxicity
- Eutrophication
- Land Use
- Noncancerous Effects
- Smog Formation
- Indoor Air Quality
- Acidification
- Ozone Depletion

Sherman, Barrick, ”Pick your poison”, A&A 2018
GHG Emissions and Hysterectomy

Example that choices matter: GHG Emissions and Operating Theatres in Three Health Systems

Figure 2: Relative contribution of scopes 1, 2, and 3 to the carbon footprint of operating theatres at (A) Vancouver General Hospital, (B) University of Minnesota Medical Center, and (C) John Radcliffe Hospital.


Do we need desflurane?

• Faster wake times for surgeries < 90”
• Surgeries > 110”, comparable wake up times (85% MAC decrement in VRG)
• Researchers kept at 1-MAC until very end of surgery
• Faster wake up ➔ more $??
  – Patient payer mix
  – Patient volume
  – Staff compensation system

Yale-New Haven Health System

• **Eliminated** Desflurane from formulary, 2013
• Saved approximately
  • 186,690 kg CO$_2$e/year
  • 456,455 passenger vehicle miles driven/year
• Sevoflurane use up slightly, isoflurane no difference; assumed no difference in TIVA/regional
• Saved $1.2 million across health system/year by eliminating desflurane drug and vaporizers

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
University of Utah

• **Cash challenge**: electively cut desflurane use by 50%
• Reduced inhaled anesthetic acquisition costs by $308,000
• saved WAG GHG equivalent of 5.4 million miles driven
  – without increasing their turnover times
  – without increasing PACU discharge times
  – Propofol usage did not increase
  – Isoflurane use did increase
  – Sevoflurane use stayed the same
• **Behavior change gone within one year**

Courtesy H. Hopf, U. Utah
• Educational campaign
• Info stickers on vaporizers (point of decision-making)
• Saved approximately:
  • 2,865,430 kg CO$_2$e/year
   ↓ Desflurane
   ↓ N2O
  • 7,005,941 passenger vehicle miles driven/year
  • $300,000 in inhaled drug purchase costs/year
• Behavior change sticking
Changes in use of desflurane and sevoflurane and carbon emissions
University of British Columbia 7 hospitals

Between 2012-2018, saved 8.9 million kg (66% reduction) = 1,700 cars on the road

Alexander, et al. CJA 2018
Oregon: 8 hospitals
Provider performance reports

2016-2018, saved 4,996,172 kg CO2e = 12,156,135 passenger vehicle miles driven
$636,000 per year saved
No difference in out of room time or PACU time

Agent Selection (%)

GHG emissions (mtCO₂e)

Cost ($)

Desflurane
Sevoflurane
Isoflurane

Courtesy Brian Chesebro, MD
Annual GHG emissions associated with anesthetic usage in Kaiser Permanente’s Northern California facilities

Between 2014 and 2017, Kaiser Permanente’s Northern California region achieved a 39% reduction in GHG emissions associated with its use of anesthetic agents, thanks mainly to replacing desflurane with anesthetics that have lower Global Warming Potential.

Sources of Kaiser Permanente’s greenhouse gas emissions in 2016 (operations only)

- Purchased electricity: 66.1%
- Medical CO₂ and SF₆ gases: 0.0%
- Anesthetic agents: 3.1%
- Fleet vehicles: 1.4%
- Refrigerants: 3.0%
- Stationary combustion (diesel): 6.2%
- Stationary combustion (natural gas): 26.2%

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Scaling Up Inhaled Anesthetic Practice Improvement: The Role of Environmental Sustainability Metrics

• Removing environmentally offensive options
• Creating barriers, e.g. locking up vaporizers
• Financial incentives
• Educational campaigns
• Point-of-care information: $$, GHG
• Feedback reports
• Financial penalties, e.g. pay-for-performance, carbon taxes

Sherman and Berkow, A&A 2019
SUS 01: FGFs

- Percentage of cases with mean FGF ≤ 3 L/min, during admin of inhaled anesthetics
- Inclusion: inhaled anesthetic ≥ 30 min. from placement of airway device to its removal
- Exclusion:
  - Cases in which inhaled anesthetics not used
  - Cases with maintenance period < 30 min
  - Cases where > 20% of FGF values manually entered
SUS 01: FGFs

Overall Performance

× 73%  Target 90%

Counts

<table>
<thead>
<tr>
<th>SUS-01 Result</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passed</td>
<td>21,696</td>
</tr>
<tr>
<td>Failed</td>
<td>7,902</td>
</tr>
<tr>
<td>Excluded</td>
<td>40,400</td>
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<tr>
<td></td>
<td>70,007</td>
</tr>
</tbody>
</table>

Table: Breakdown of Primary Cause

<table>
<thead>
<tr>
<th>SUS-01 Result</th>
<th>SUS-01 Result Reason</th>
<th>Case Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluded</td>
<td>Total Duration of Gas Flow/Agent Over...</td>
<td>20,945</td>
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<tr>
<td>Excluded</td>
<td>Duration of Maintenance Period (=&gt; 3...)</td>
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<tr>
<td>Excluded</td>
<td>Is Valid Case</td>
<td>2,205</td>
</tr>
<tr>
<td>Excluded</td>
<td>Incidence of Manually Entered Gases...</td>
<td>634</td>
</tr>
<tr>
<td>Failed</td>
<td>Mean Fresh Gas Flow (&lt;= 3.0 l/min)</td>
<td>7,902</td>
</tr>
<tr>
<td>Passed</td>
<td>Mean Fresh Gas Flow (&gt;= 3.0 l/min)</td>
<td>21,696</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70,007</td>
</tr>
</tbody>
</table>

Trend

Compliance by Institution

% Compliance

Anonymous Institutions

Courtesy Nirav Shah and Kathryn Buehler
Real-time decision support: AIMS alerts

- if FGFs exceed 1 L/min
- If Sevo, after 2 MAC-hours (between 1-2 L/min, then alert changes to 2 L/min
- Mean FGF reduction from 2.10 L/min to 1.59 L/min) (note: unclear inclusion/exclusion)
- Saved $105,000 in 2010

• What’s next for sustainability metrics?
  – Real-time FGF alerts
  – GHG emissions for inhaled anesthetics
  – GHG emissions for other drugs
  – Non-GHG emissions
  – Drug waste
  – Overdosing

• CMS pay-for-performance, accountability
WAG Treatment: don’t vent to the atmosphere!

- Charcoal: ultra short-term
  - Occupational exposure
    - Absorb and release
- Gas-capturing systems
  - Absorb and store
  - Potential reuse, storage issue
  - Volatiles only
- Gas destruction
  - N2O only
- ?? Efficiency
  - Only treat what is exhaled through circuit
  - ↑FFG= ↓efficiency
2020 Challenge! Reduce your facility inhaled anesthetic greenhouse gas emissions by 50%

1. Utilize low fresh gas flows
2. Avoid high impact inhaled anesthetics:
   ↓ Desflurane and Nitrous Oxide
3. Consider intravenous and regional techniques
4. Invest in WAG trapping or WAG destruction technology

https://publichealth.yale.edu/climate/research/conferences/challenge/
“Health professionals have a duty to care for current and future generations.”

ASA Mission: “Advancing the Practice and Securing the Future”

Thank you! Jodi.sherman@yale.edu