How do we “green” health care?

Ann Kurth, PhD, CNM, MPH
• "Leveraging Universities for Planetary Health-Smart Systems,"

Matthew Eckelman, PhD @MJEckelman
• Tracking Health Care Sector Emissions at National and International Scales

Cassandra Thiel, PhD @CassandraLThiel
• Ophthalmology Around the World: Using Life Cycle Assessment to Measure and Mitigate Health Care Pollution

Jodi Sherman, MD @GreeningDoc
• Integrating Environmental Emissions, Resource Utilization, and Clinical Outcomes to Guide Healthcare Pollution Prevention

Julie Zimmerman, PhD
• Green Engineering and Green Design of Medical Devices and Pharmaceuticals

Q&A

#ClinicalSustainability #CleanMed
Healthcare Pollution Prevention: 
A Clinical Perspective

Jodi Sherman, MD
Associate Professor of Anesthesiology, 
and Epidemiology (Environmental Health Sciences) 
Yale Schools of Medicine, and Public Health

#ClinicalSustainability  #CleanMed
Intravenous drug management: Learning Objectives

1. Describe pharmaceutical pollution
2. Identify causes of IV drug waste
3. Discuss barriers to waste reduction
4. Identify waste reduction solutions
Why sustainability in health care?

• Pollution a leading cause of morbidity/mortality globally: 9 million (16%) premature deaths annually
• Health care itself is a leading emitter of environmental pollutants
• Reducing health care pollution can improve the triple bottom line
• Means to engage health professions around pollution prevention, key for public policy and societal transformation
Life expectancy vs. health expenditure, 1970 to 2015

Health financing is reported as the annual per capita health expenditure and is adjusted for inflation and price level differences between countries (measured in 2010 international dollars).

OurWorldInData.org/the-link-between-life-expectancy-and-health-spending-us-focus • CC BY
Relative National GHG emissions from pharmaceuticals

Fig 1. Relative contributions of expenditure categories to health care sector GHG emissions, 2014, Canada-USA-Australia.

Eckelman, Sherman, MacNeill, PLoS Med 2018
The global relevance of pharmaceuticals in the environment

Figure 3: Global occurrence of pharmaceuticals: Pharmaceuticals have been found in the environment in all UN regional groups (IWW 2014).

German Environment Agency-UBA
Anesthesiology
Drug waste is common

- Multiple studies, overall volume of anesthesia prepared drug waste ranges from 30-80%
- Problems/solutions apply to all IV drug locations

<table>
<thead>
<tr>
<th>Drug</th>
<th>Total ML Opened</th>
<th>Total ML Used</th>
<th>Total ML Wasted</th>
<th>% Wasted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propofol</td>
<td>9900</td>
<td>7198.2</td>
<td>2701.8</td>
<td>27.29%</td>
</tr>
<tr>
<td>Neostigmine</td>
<td>2190</td>
<td>830</td>
<td>1360</td>
<td>62.10%</td>
</tr>
<tr>
<td>Ketamine</td>
<td>660</td>
<td>122</td>
<td>538</td>
<td>81.52%</td>
</tr>
<tr>
<td>Rocuronium</td>
<td>2425</td>
<td>1943.1</td>
<td>481.9</td>
<td>19.87%</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>800</td>
<td>322.25</td>
<td>477.75</td>
<td>59.72%</td>
</tr>
<tr>
<td>Zofran</td>
<td>790</td>
<td>786.5</td>
<td>3.5</td>
<td>0.44%</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>2195</td>
<td>1455.1</td>
<td>739.9</td>
<td>33.71%</td>
</tr>
<tr>
<td>Glycopyrrolate</td>
<td>1235</td>
<td>880</td>
<td>355</td>
<td>28.74%</td>
</tr>
<tr>
<td>Midazolam</td>
<td>558</td>
<td>537</td>
<td>21</td>
<td>3.76%</td>
</tr>
<tr>
<td>Midazolam</td>
<td>185</td>
<td>78</td>
<td>107</td>
<td>57.84%</td>
</tr>
<tr>
<td>Succinylcholine</td>
<td>850</td>
<td>392.5</td>
<td>457.5</td>
<td>53.82%</td>
</tr>
<tr>
<td>Toradol</td>
<td>57</td>
<td>51.9</td>
<td>5.1</td>
<td>8.95%</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>1785</td>
<td>1368.9</td>
<td>416.1</td>
<td>23.31%</td>
</tr>
<tr>
<td>Ephedrine (diluted)</td>
<td>1200</td>
<td>347.4</td>
<td>852.6</td>
<td>71.05%</td>
</tr>
<tr>
<td>Labetalol</td>
<td>1380</td>
<td>303</td>
<td>1077</td>
<td>78.04%</td>
</tr>
<tr>
<td>Hydromorphone (diluted)</td>
<td>2420</td>
<td>945</td>
<td>1475</td>
<td>60.95%</td>
</tr>
<tr>
<td>Phenylephrine (diluted)</td>
<td>14400</td>
<td>523.3</td>
<td>13876.7</td>
<td>96.37%</td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td><strong>24945.85</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Life Cycle Inventory (LCI) Assessment
“Cradle-to-Gate”

<table>
<thead>
<tr>
<th>Pharmaceutical Drugs</th>
<th>GWP100a kg CO2 eq./kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydromorphone</td>
<td>4361</td>
</tr>
<tr>
<td>Dexmedetomidine</td>
<td>3704</td>
</tr>
<tr>
<td>Morphine</td>
<td>1318</td>
</tr>
<tr>
<td>Midazolam</td>
<td>455</td>
</tr>
<tr>
<td>Phenylephrine HCl</td>
<td>200</td>
</tr>
<tr>
<td>Rocuronium Bromide</td>
<td>159</td>
</tr>
<tr>
<td>Ketamine</td>
<td>130</td>
</tr>
<tr>
<td>Remifentanil</td>
<td>119</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>99</td>
</tr>
<tr>
<td>Ephedrine HCl</td>
<td>93</td>
</tr>
<tr>
<td>Ropivacaine base</td>
<td>68</td>
</tr>
<tr>
<td>Succinylcholine</td>
<td>52</td>
</tr>
<tr>
<td>Bupivacaine HCl</td>
<td>40</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>39</td>
</tr>
<tr>
<td>Glycopyrrolate</td>
<td>39</td>
</tr>
<tr>
<td>Ondansetron</td>
<td>35</td>
</tr>
<tr>
<td>Neostigmine methylsulfate</td>
<td>15</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>12</td>
</tr>
<tr>
<td>Morphine (from opium)</td>
<td>7</td>
</tr>
<tr>
<td>Sugammadex</td>
<td>3</td>
</tr>
</tbody>
</table>

OR drug waste

- YNHH, 20 common OR drugs
- $1.2 million wasted annually
- conservatively estimated at 22,514 kg CO2 equivalents
- Similar to 54,778 miles driven
  (Earth circumference = 24,901 miles)
Waste AND critical drug shortages

1/3 of US drugs manufactured in Puerto Rico

Figure 1. Median duration in days of shortage for anesthesia drugs by class that were listed on the American Society of Health-System Pharmacists (ASHP) website\(^2\) during the year 2010.

Oliveira, et al., A&A 113(6), 2011
Global insulin unmet needs

Demand for insulin is growing, and the current need is unmet

<table>
<thead>
<tr>
<th>Year</th>
<th>Use Insulin</th>
<th>Need Insulin</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>30 million</td>
<td>63 million</td>
</tr>
<tr>
<td>2030</td>
<td>38</td>
<td>79</td>
</tr>
</tbody>
</table>

Data: Basu et al., 2018

Insulin patient costs

- Insulin isolated in 1921, Nobel prize
- Patent sold for $3
- Average patient incurred costs (same product)
  - $2,864 in 2012
  - $5,705 in 2016
- 1 in 4 diabetic patients report rationing due to costs, few of which are uninsured
- Lethal self-rationing
- GoFundMe crowdsourcing
Why so much drug waste?

- Over-sized vials
- Regulation
- Contamination
- Over-preparation
- Expiration

We routinely waste 97-99% of insulin in the OR
Overspending driven by oversized single dose vials of cancer drugs

*BMJ* 2016;352:i788 doi: 10.1136/bmj.i788 (Published 1 March 2016)

Waste in Cancer Drugs Costs $3 Billion a Year, a Study Says

By GARDINER HARRIS
MARCH 1, 2016
Why is there drug waste?
Regulation and Expiration

• Multi-dose v. Single dose, CDC regulations

• How prepared?
  – OR/wards ➔ 60 minutes (non-sterile)
  – pharmacy ➔ 9 days refrigerated, 12 hours without

• Stability testing? ➔ weeks

• What container?

FDA expands warning on Becton-Dickinson (BD) syringes being used to store compounded or repackaged drugs
Why is there drug waste?
Gross contamination
Why is there drug waste?
Over-preparation

- Dynamic patient care environment
- Emergency drugs
- Academic environment
- Habit
- Candy store culture
Reduce waste:
Split vials into “pre-filled” syringes

Original manufacturer
“emergency drugs” $$$
Longest shelf life

Third-party vendor
splits vials $$
Medium shelf life

In-house pharmacy
splits vials $
Shorter shelf life
Do pre-filled syringes reduce waste?
Predicting pre-filled syringe requirements

- Data-driven management
- Integration of electronic health records and procurement records
- Predictive modeling to guide pharmacy manufacturing for greatest efficiency
Performance reports and behavior change

<table>
<thead>
<tr>
<th>Medication Name</th>
<th>Surgical Cases</th>
<th>Packages Opened</th>
<th>% Waste</th>
<th>Expense Wasted</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHENYLEPHRINE 10 MG/ML INJECTION SOLUTION</td>
<td>45</td>
<td>46</td>
<td>99.9%</td>
<td>$162</td>
</tr>
<tr>
<td>DIPHENHYDRAMINE 50 MG/ML INJECTION SOLUTION</td>
<td>8</td>
<td>8</td>
<td>98.3%</td>
<td>$5</td>
</tr>
<tr>
<td>EPINEPHRINE 1 MG/ML INJECTION SOLUTION</td>
<td>1</td>
<td>1</td>
<td>98.0%</td>
<td>$496</td>
</tr>
<tr>
<td>DEXMEDETOMIDINE 100 MCG/ML INTRAVENOUS SOLUTION</td>
<td>22</td>
<td>24</td>
<td>97.7%</td>
<td>$165</td>
</tr>
<tr>
<td>EPEDRINE SULFATE 50 MG/ML INTRAVENOUS SOLUTION</td>
<td>35</td>
<td>35</td>
<td>97.0%</td>
<td>$969</td>
</tr>
<tr>
<td>ATROPINE 1 MG/ML INJECTION SOLUTION</td>
<td>1</td>
<td>1</td>
<td>96.8%</td>
<td>$215</td>
</tr>
<tr>
<td>KETOROLAC 30 MG/ML (1 ML) INJECTION SOLUTION</td>
<td>95</td>
<td>95</td>
<td>96.0%</td>
<td>$1</td>
</tr>
<tr>
<td>FUROSEMIde 10 MG/ML INJECTION SOLUTION</td>
<td>1</td>
<td>1</td>
<td>96.0%</td>
<td>$1</td>
</tr>
<tr>
<td>METRONIDAZOLE 500 MG/100 ML SODIUM CHLORIDE(ISO) INTRAVE…</td>
<td>1</td>
<td>1</td>
<td>96.0%</td>
<td>$1</td>
</tr>
<tr>
<td>MIDAZOLAM (PF) 5 MG/ML INJECTION SOLUTION</td>
<td>1</td>
<td>1</td>
<td>96.0%</td>
<td>$1</td>
</tr>
<tr>
<td>CLORPHETHALIN 250 MG/100 ML IN 5% Dextrose INTRAVENOUS DI</td>
<td>1</td>
<td>1</td>
<td>94.8%</td>
<td>$10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service (All)</th>
<th>400</th>
<th>6,816</th>
<th>33.8%</th>
<th>$9,095</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL (All Services)</td>
<td>400</td>
<td>6,816</td>
<td>33.8%</td>
<td>$9,095</td>
</tr>
</tbody>
</table>
What happens to inhaled anesthetic drugs?

- 95% vented out the roof of the hospital
- Destroy ozone layer
- Greenhouse gases
- Emissions not controlled
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)
Yale Gassing Greener
Smart phone calculator

Anesthesia Provider Calculator

Inputs

Sevoflurane % (Scroll to the Bottom for Live Results):

Isoflurane %:

Desflurane %: 6.4

Halothane %:

Nitrous Oxide Flow (L/min):

Oxygen Flow (L/min): 10

Carbon Dioxide Equivalent (Kg of CO2 Produced per Hour):

681.776640

Driving Equivalent (Miles Driven per Hour):

1,658.823942

Driving Equivalent (Kilometers Driven per Hour):

2,673.633882

Share current values:

Courtesy L. Lipana
Gassing Greener
Smart phone calculator

Patient Weight (Kg):
Propofol Infusion Dose (mcg/kg/minute):
Remifentanyl Infusion Dose (mcg/kg/minute):
Dexmedetomidine Infusion Dose (mcg/kg/hour):
Ketamine Dose (mg):
Lidcaine Dose (mg):
Bupivacaine Dose (mg):

Outputs
Approximate Cost of All Anesthetics (from www.drugs.com) and Nitrous Oxide and Oxygen (from e-cylinders purchased from Lawson Medical):
U.S. $35.63

Enter Your Own Drug Prices in Our Cost Calculator (copy and paste link below):
https://jcalc.io/calc/do45B0JrVzXMaEGC

Carbon Dioxide Equivalent (Kg of CO2 Produced per Hour):
0.008863

Driving Equivalent (Miles Driven per Hour):
0.021565

Driving Equivalent (Kilometers Driven per Hour):
0.034758

Share current values:

Courtesy L. Lipana
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.


Changes in use of desflurane and sevoflurane and carbon emissions

Alexander, et al. CJA 2018
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.
Where do we go from here?

- Quantify pollutants for ALL clinical activities
- Include resource utilization, pollution impacts, total cost of ownership, and outcomes as part of overall decision-making
- Frame public health as a matter of patient safety, quality and value of care
- Accountability: pay-for-performance

\[
\text{VALUE} = \frac{\text{Outcomes for Patients \& Populations}}{\text{Environmental + Social + Financial Costs}}
\]
Reducing health care waste, and least polluting care choices can help close the gap.

“Health professionals have a duty to care for current and future generations.”