Reducing our carbon footprint:
The impact of efficient use of fresh gas flow with inhaled anesthetics
and other **GREEN** initiatives in the OR

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Global warming is already having significant and costly effects:

- More Frequent and Intense Heat Waves
- Loss of Snowpack
- Longer and More Damaging Wildfire Seasons
- Reductions in the quality and quantity of agricultural products
- Health Impacts
  - increased air pollution
  - longer and more intense allergy season.
Healthcare sector represents 8% of US Carbon Footprint

History of anesthetic gases

1844
Dentist Horace Wells attends a demonstration of nitrous oxide inhalation at an exhibition by Gardner Quincy Colton.

Colton administers nitrous oxide to Wells while another dentist, Dr. John M. Riggs, extracted one of Well's teeth.

1845
Horace Wells attempts to demonstrate anaesthetic properties of nitrous oxide at Massachusetts General Hospital. The anaesthetic was incomplete and judged a failure.

"Gentlemen, this is no humbug"
Dr John Collins Warren, 17 October 1846
Inhaled anesthetics and nitrous oxide are potent environmentally deleterious greenhouse gases (GHGs)

Eger et al. (2002). The Pharmacology of Inhaled anesthetics

Numerous reagents developed, 4 utilized currently in US

<table>
<thead>
<tr>
<th>Gas</th>
<th>Lifetime (years)</th>
<th>Global warming potential (time horizon, years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GWP20</td>
</tr>
<tr>
<td><strong>Carbon dioxide</strong></td>
<td>variable</td>
<td>1</td>
</tr>
<tr>
<td><strong>Methane</strong></td>
<td>12</td>
<td>72</td>
</tr>
<tr>
<td><strong>Nitrous oxide</strong></td>
<td>114</td>
<td>289</td>
</tr>
<tr>
<td><strong>Isoflurane</strong></td>
<td>2.6</td>
<td>1230</td>
</tr>
<tr>
<td><strong>Sevoflurane</strong></td>
<td>5.2</td>
<td>1980</td>
</tr>
<tr>
<td><strong>Desflurane</strong></td>
<td>2.6</td>
<td>1230</td>
</tr>
<tr>
<td><strong>Sulfur hexafluoride</strong></td>
<td>3200</td>
<td>16300</td>
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How does volatile gas get into the environment?
What is the primary determinant of how much volatile gas gets into the environment?

Fresh gas flow (FGF)
• The Anesthesia Quality Institute estimates 65 million anesthetic cases were performed in 2013 and approximately half of these used inhalational anesthetics.

• At UCSF, we utilize > 1200 L of inhalational agents annually, and produce ~4700 carbon dioxide (CO₂) equivalents via inhaled anesthetic agents.

• The total fresh gas flow (FGF) used to administer anesthetic gases primarily determines the volume of anesthetic utilized and thus proportion of inhaled gases that enter the atmosphere.
How does one decide how much FGF to use?

- Extrapolated FGFs for sevoflurane to desflurane and isoflurane, resulting in higher than necessary FGFs.
- At UCSF, current CO$_2$ absorbent (Litholyme) containing primarily calcium hydroxide is used which does not produce compound A or carbon monoxide, thus safely allowing the utilization of lower FGFs with sevoflurane and other inhalational gases.
- At SFGH the absorber is Amsorb
- AT SF VA the absorber is…??

| Compound A = nephrotoxic in rodents |

Current guidelines on lowest acceptable FGFs

<table>
<thead>
<tr>
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<th>Sevoflurane</th>
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<tr>
<td>&lt; 2 MAC hours</td>
<td>0.5 L/min</td>
<td>0.5 L/min</td>
<td>1 L/min</td>
</tr>
<tr>
<td>&gt; 2 MAC hours</td>
<td>0.5 L/min</td>
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## Current guidelines on lowest acceptable FGFs

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![Bar graph showing mean FGF (L/min) for SEVO, ISO, and DES](image)

- **SEVO**: 2.4 ± 1.5
- **ISO**: 1.4 ± 0.6
- **DES**: 1.7 ± 0.8

n=372
Practice patterns assessed via survey

During maintenance of anesthesia, what is your estimate of FGF (in L/min) of gas that you utilize or would utilize for the vapors listed below?

- Desflurane
- Isoflurane
- Sevoflurane

% Residents

L/min

<0.5
0.5-0.99
1.0-1.49
1.5-1.99
2.0-2.5
>2.5
### Table 1. Order of Magnitude Estimation of Anesthetic Drug Used per Case and Over a 35-Year Career When 2 L/min or 1 L/min is Used for the Maintenance Phase of Anesthesia

<table>
<thead>
<tr>
<th>Technique</th>
<th>Delivered isoflurane per patient (L)</th>
<th>Delivered isoflurane, career (L)</th>
<th>Isoflurane uptake per patient (L)</th>
<th>Isoflurane uptake, career (L)</th>
<th>Total career isoflurane waste/contamination (L)</th>
<th>Career efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-min induction</td>
<td>2.4</td>
<td>42,000</td>
<td>0.35</td>
<td>6125</td>
<td>35,875</td>
<td>15%</td>
</tr>
<tr>
<td>2 L/min maintenance</td>
<td>5.4</td>
<td>94,500</td>
<td>1.3</td>
<td>22,750</td>
<td>71,750</td>
<td>24%</td>
</tr>
<tr>
<td>1 L/min maintenance</td>
<td>4.28</td>
<td>74,900</td>
<td>1.26</td>
<td>22,050</td>
<td>52,850</td>
<td>29%</td>
</tr>
<tr>
<td>Technique difference, maintenance only</td>
<td>1.12</td>
<td>19,600</td>
<td>0.04</td>
<td>700</td>
<td>18,900</td>
<td></td>
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Career anesthesiologists modeled 500 annual inhaled anesthetics over 35 years. GASman simulation used to calculate total anesthetic vapor delivered and total taken up. Model assumes a 90-minute isoflurane anesthetic for a 70-kg adult with a goal of 1 minimum alveolar concentration. Fresh gas flow is 8 L/min for the first 15 minutes then either 2 or 1 L/min for the remaining 75 minutes. Differences in isoflurane uptake between 2 L/min and 1 L/min models are attributable to less rebreathing in the 2 L/min model and therefore slightly larger inspired and alveolar anesthetic concentrations.

**Desflurane**
- $160 / 240 ml bottle

**Isoflurane**
- $51 / 250 ml bottle

**Sevoflurane**
- $136 / 250 ml bottle
Goals

• Incorporate FGFs and mLs inhaled anesthetic used per case into UCSF Medical Center Electronic Medical Record (EMR)

• Assess current FGFs utilized by UCSF anesthesia providers in Moffitt-Long operating rooms

• Understand practice habits to improve resource utilization & costs

• Encourage behavioral change and efficient and mindful use of FGF
Other strategies to **GREEN** the OR

- Turn off the lights
- Recycling
- Reuse
Modifications to the anesthesia machine

Figure 1. The Dräger Apollo main display with the 3 possible Low Flow Wizard recommendations demonstrated.
The future of **GREEN** anesthetics

**RECYCLED ANESTHETICS**

**Dynamic Gas Scavenging System** (Vanderbilt University Medical Center)
- collects and reuses 99% of anesthetic gases without chemically altering them in the process.

**Deltasorb** (Blue-Zone Technologies)
- captures the inhalation anesthetics before they enter the atmosphere through a filtration process, drugs are extracted and used a to produce bulk anesthetic drugs.

John Pappas - Mazetti
Thanks