Recognizing & Reducing the Greenhouse Gas Impacts from Anesthesia

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Environmental Impact – Volatile Anesthetics

Did you know... that anesthetic gases were also potent greenhouse gases?
### TABLE 1
**Physical characteristics of anesthetic gases in the atmosphere**

<table>
<thead>
<tr>
<th>AGENT</th>
<th>GWP$_{100}$</th>
<th>ATMOSPHERIC LIFETIME (YEARS)</th>
<th>MAC IN DOGS (%)</th>
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<td>Desflurane</td>
<td>2540</td>
<td>10</td>
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GWP$_{100}$ – Global warming potential over 100 years; MAC – Minimum alveolar concentration
What is the Overall Impact?

• Anesthetic gases
  • Small but important part of healthcare system's carbon footprint
Scopes of Greenhouse Gas Emissions:

**Scope 1: Direct Emissions**
Emissions coming from a generator owned and used by the healthcare facility.

**Scope 2: Indirect Emissions**
Emissions coming from electric, gas, and other utilities paid for by the facility.

**Scope 3: All Other Emissions**
Emissions from manufacturing and shipping medical supplies to the facility, and emissions from patients traveling to and from the facility.

+ anesthetic gases
+ mobile vehicles
What is the Overall Impact?

• Anesthetic gases
  • Small but important part of healthcare system's carbon footprint
  • But very large part of internally or individually controlled carbon footprint
    • 20-50% or more!
### Some perspective

<table>
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<tr>
<th>VOLATILE ANESTHETIC</th>
<th>VEHICLE (KM EQUIVALENT) PER HOUR ANESTHESIA</th>
<th>PER DAY - 4 HRS (KM)</th>
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<td>Isoflurane</td>
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<th>VOLATILE ANESTHETIC</th>
<th>CO2 EQUIVALENT (KG) PER HOUR ANESTHESIA</th>
<th>PER DAY - 4 HRS (KG)</th>
<th>PER YEAR – 1040 HRS (KG)</th>
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<tr>
<td>Isoflurane</td>
<td>7.9</td>
<td>31.6</td>
<td>8200</td>
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**AVERAGE ANNUAL CARBON FOOTPRINT/PERSON**
- Canadian - 15500 kg
- European - 6800 kg
- Worldwide - 4790 kg
Anesthetic gases are potent greenhouse gases (GHG)
Reducing your anesthetic carbon footprint

• Reduce amount of inhalant
  1. **Use less**
     • Proper premedication
     • Locoregional techniques
     • Partial or total intravenous anesthesia
  2. **Waste less**
     • Lower fresh gas flow (FGF)
  3. **Capture**
     • Recycle
     • Destroy

• Select lowest carbon inhalant
  • (sevo vs. iso)

• Proper selection & use of consumables
  • Circuits, ETT, syringes, etc.
REDUCING CARBON EMMISIONS IN VETERINARY ANESTHESIA

Use Less
Reducing use

• Proper premedication (10-50%)
  • Acepromazine vs dexmedetomidine
  • Opioids
Reducing use

- Proper premedication (10-50%)
  - Acepromazine vs dexmedetomidine
  - Opioids
- Locoregional techniques (20-50%)
  - Dental blocks, epidural, nerve blocks
  - Lidocaine, bupivacaine
- Partial or total intravenous infusion (20-100%)
  - Propofol, alfaxalone, ketamine
  - Dexmedetomidine
  - Opioids

Overall improved quality of anesthesia
Reducing use

**PROS**
- Significant reductions possible (50-100%?)
- But ... further research needed, upstream manufacturing, equipment/consumables

**CONS**
- Precision equipment & consumables needed
- Different training for a different style of anesthesia, educational investment
- Licensing & species limitations with currently available drugs
- Concerns about biodiversity impacts of residual pharmaceuticals in environment
REDUCING CARBON EMISSIONS IN VETERINARY ANESTHESIA

Waste Less
Selecting *fresh gas flows* (FGF)

- Decrease FGF will waste proportionately less anesthetic & lower GHG
  - Decrease flow rate by 25%, decreases GHG by ~25%

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<th>VOLATILE ANESTHETIC DOSE</th>
<th>FLOW RATE</th>
<th>VEHICLE (KM EQUIVALENT) PER HOUR ANESTHESIA</th>
<th>KM EQUIVALENT (4 H/DAY)</th>
<th>KM EQUIVALENT (H/YR)</th>
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<tr>
<td>Isoflurane</td>
<td>2 l/min</td>
<td>38</td>
<td>152</td>
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<tr>
<td>~50%</td>
<td>1 l/min</td>
<td>19</td>
<td>71</td>
<td>19750</td>
</tr>
<tr>
<td>~75%</td>
<td>1 l/min q 15 min, 0.5 l/min</td>
<td>9.5</td>
<td>38</td>
<td>9875</td>
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How low can you go?
Sufficient oxygen delivery

• Metabolic oxygen consumption 3-5 ml/kg/min

• 20 kg dog
  • 100 ml/min is all the oxygen required to meet metabolic oxygen consumption

BUT.....
Sufficient inhalant delivery

- Oxygen or oxygen combination is carrier for inhalant delivery
- Amount inhalant delivered not always same as vaporizer setting

- **Rebreathing flow rates**, recirculated gas DILUTES amount being delivered from the vaporizer, LOWER FLOWS MORE DILUTION

- **Non-rebreathing flow rates**, amount delivered from vaporizer is what patient is breathing in, NO DILUTION
No/minimal rebreathing of CO₂

**REBREATHEING SYSTEM**

- One-way valves (unidirectional flow), CO₂ absorbent
- Flow independent

**NON-REBREATHEING SYSTEM**

- Flow rate dependent, minimum flow rates required (200 mL/kg/min)
- Factors – flow rate, respiratory rate, expiratory pause, depth of respiration
How low can you go?

REBREATHEING SYSTEM
• 500 ml/min rebreathing system
• Min patient size 3 kg
  • Consider dead-space, low volume circuit?/ETCO2 adapters
  • Resistance to breathing??

NON-REBREATHEING SYSTEM
• 1 L/min non-rebreathing system
• Max patient size 5 kg
  • 200 ml/kg/min often needed to prevent rebreathing
Lowering fresh gas flow – final comments

Accuracy

• Modern variable bypass vaporizers clinically accurate delivery (0.25 – 15 L/min)
  • Output may decrease slightly outside limits
  • Anesthetic dose largely based on clinical assessment (not %)

Toxicity

• Sevoflurane – Compound A production (nephrotoxicity)
  • Identified as potential concern when using low flow anesthesia
Lowering fresh gas flows

**PROS**
- Reductions possible (25-75%)
- Lower cost, actually saves money

**CONS**
- Change in anesthetic delivery characteristics – depth and plane changes
- Investment
  - Education/training
  - Equipment costs (improved monitoring)
REDUCING CARBON EMISSIONS IN VETERINARY ANESTHESIA

Capture and recycle or destroy
Capture technology

• Technology & commercial model to capture, redistill, & redeliver volatile anesthetics available

• Licensed recaptured product not yet available:
  • Sagetech (UK)
  • ZeoSys/Baxter (GER)
  • BlueZone (CDN)
Capture technology

**PROS**

- Large reductions possible (70%)
- Simple change to anesthetic practices (does not impact delivery patterns)
- Reduced cost of recaptured product?
- True circular economy

**CONS**

- Need to choose one recaptured drug
- Requires R&D including licensing of a recaptured product
- Logistics need to be tied into current supplier networks
Capture and incinerate

• Incinerating full large charcoal absorber (200g isoflurane) as pharmaceutical waste will release about 1.5kgCO₂e

• Releasing same amount (200g) of isoflurane into the atmosphere gives around 100kgCO₂e

• Full lifecycle, including manufacture/transport has NOT been evaluated
Capture and incinerate

**PROS**
- Easy to install
- Large and rapid reduction in emissions (?-99%)

**CONS**
- Cost of waste disposal
- Unintended consequences (i.e., H&S occupational exposure if canisters are not replaced when full)
- Incorrect handling could release volatiles into the atmosphere
- Relies on a supply chain of canisters
- Would ‘feel’ like a backwards step to many Associates
Switching to **sevoflurane**

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Switching to sevoflurane

- Reduce GHG by about 50%
- Expensive (relative to isoflurane):
  - $64 vs $20 for 250 mL bottle and use 2x as much
  - Increase drug cost by ~6x
- Compound A production, potentially nephrotoxic?
  - Result of interaction with strong base in carbon dioxide absorbents
  - No clinical evidence of toxicity in humans or animals
  - Unfortunately label in several countries recommend minimum fresh gas flow rates (> 2 L/min)
  - Largely avoided by using CO2 absorbents with no or minimal (<2.5%) strong base (KOH and NaOH)
Switching to sevoflurane

**PROS**
- Large reductions possible (50%)
- Minimal ‘effort’, easy switch clinically

**CONS**
- Large cost, replacement of vaporizers and higher cost drug
- Licensing concerns in some regions?
- Potential concern about nephrotoxicity/compound A
What else can you do **tomorrow**?

• Travel - staff and patients
• Single use vs. reusable
  • Drapes, gowns, instruments. etc.
• Plastics
  • Biodegradable medical grade plastics?
• Purchase renewable sources of electricity
• Minimize hospital stays
• Eliminate “excessive” preoperative testing
  • Use should be evidence based
Thank You