PLAN FOR ACTION

ACTION

Decrease greenhouse gas pollution in anaesthesia

WHAT IS THE PROBLEM	Anaesthesia is a carbon-intensive specialty, involving the routine use of inhaled drugs which are potent greenhouse gases. After patient use, these gases are exhausted directly to the environment, where they accumulate in the atmosphere contributing to global warming. Such inhaled anaesthetic drugs are volatile halogenated organic compounds (sevoflurane, desflurane, isoflurane, halothane) and nitrous oxide (N_2O). The environmental impacts of desflurane and N_2O are several times greater than the other inhaled anaesthetics, making them an even higher mitigation priority. Volatile anaesthetic agents have been estimated to be responsible for 0.01 – 0.1% of total global CO2 equivalent (CO2e) emissions contributing to global warming; and based on atmospheric sampling of volatile agents, their accumulation is increasing (particularly desflurane). Whilst a seemingly small contribution to total global emissions, inhaled anaesthetics frequently account for 5% of acute hospital CO_2e emissions, and 50% of perioperative department emissions (in high income countries). Their use is directly within the control of anaesthesia providers and thus, their stewardship is an important opportunity for greenhouse gas mitigation and leadership in healthcare environmental sustainability.
WHAT IS THE ACTION	Anaesthesia practitioners to exercise stewardship in the use of volatile anaesthetic agents, when clinically safe to do so. Actions to reduce inhaled anaesthetic atmospheric waste include: 1. Use lowest fresh gas flow rates during all stages of anaesthesia (e.g. <1L/minute during maintenance). 2. Avoid high impact inhaled anaesthetics: desflurane, nitrous oxide. 3. Decommission N2O central piping, and switch to portable tanks that remain closed between uses. 4. Consider intravenous and regional techniques, when safe to do so. 5. Measure inhaled anaesthetic greenhouse gas emissions at an institutional and provider level to support education, practice improvement and set targets for mitigation. N.B. More research is needed before investing in waste anaesthetic gas (WAG) trapping (for volatiles only) or WAG destroying (N_2O only) technology. While such technology appears promising, only a fraction of WAG is captured/re-processable for potential reuse. Further, reuse requires regulatory approval, and thus storage of reprocessed volatiles is presently required. Avoidance of these inhaled anaesthetics and reduction of fresh gas flows (FGFs) are much higher priorities.

ACTION

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MEASURE

Conduct a baseline audit of volatile anaesthetic and N2O consumption within your hospital, and track progress over time:

1. Provide education to your department about the environmental impact of anaesthesia practice, including institutional performance and provide strategies to reduce emissions.

- Refer to WFSA Consensus Statement and the Environmental Sustainability Checklists, above.

2. Engage in specific interventions – e.g.:

- Desflurane intervention: have desflurane vaporizers removed from the anaesthetic machines and make available 'upon request only' based on agreed clinical indications, or have desflurane removed from drug formulary entirely.
- Nitrous oxide intervention: for existing infrastructure, decommission central nitrous distribution in favour of portable tanks; for new construction, do not build nitrous oxide central piping. Substitute portable tanks, and ensure they are closed between each use.
- Fresh gas flow waste reduction intervention: for electronic health records, insert a real-time high fresh gas flow alert, e.g., when above one litre per minute for over 10 minutes.

3. Gather information pre and post intervention:

- Request procurement data from pharmacy on quantities of volatile drugs purchased on an annual basis, to track progress.
- Request procurement data from the medical gas department on quantity of N2O purchased on an annual basis, to track progress.
- Where electronic health record data are available, track department and provider average FGFs, inhaled drug types, quantities consumed, and numbers of hours of anaesthetic performed, on a monthly basis.

4. Consolidate:

- Convert procured inhaled anaesthetic drugs into CO2e and equivalent miles or kilometres driven, to track progress and educate providers about their impact. Free calculators available in resources above.

5. Sharing successes, lessons, crowdsourcing results and practice improvement strategies

- Present departmental, and individual performance reports (where EHRs exist,) on a regular basis (e.g. quarterly.)
- Share results, and lessons learned, through symposia, newsletters, and case reports.
- Share results and lessons through the CODA website, to accelerate and amplify actions

ACTION

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SUCCESS STORIES

1. Desflurane, which has a global warming potential over 100 years of 2540 CO2 equivalents (CO_2e), was eliminated from the Yale New Haven Health System formulary in 2013 in favor of sevoflurane, saving an estimated US$1.2 million and 1.6 million kg CO2e (the equivalent of 360 passenger vehicles) annually from the flagship hospital alone.

2. In Australia and New Zealand, a network of anaesthesia trainees has formed a group to drive research and other initiatives around environmental sustainability in anaesthesia (TRA2SH – Trainee-led Research and Audit in Anaesthesia for Sustainability in Healthcare). This group has promoted an online pledge to encourage anaesthesia departments to immediately reduce their use of desflurane and remove it from their hospital formulary by 2025. Several large institutions, including The Alfred, Western Health and Fiona Stanley Hospital, have already removed desflurane from their formulary, along with many others who have pledged to do so prior to 2025 (Link).

   At the Fiona Stanley Hospital in Perth, the removal of desflurane from their formulary has saved approximately AUD$90 000 and approximately 300 tonnes CO2e per year (equivalent of 60 return flights from Perth to London). At Western Health
   in Melbourne, this same action has saved AUD$30 000 and reduced emissions by 140 tonnes per year (the equivalent of 36 return flights from Melbourne to London). Following their action in 2021, The Alfred Hospital reported only positive, supportive departmental feedback (Link).

3. After labelling on environmental impact at the point of use, desflurane use at the University of Wisconsin was reduced by 55% in favour of sevoflurane. This resulted in a saving of $25,000/month in 2015, and an average reduction of per anaesthetic case emissions from 163kg CO_2e pre-intervention to 58kg CO_2e post-intervention. (Link)

4. The University of California San Francisco implemented an electronic clinical decision support tool, aimed at nudging providers to reduce FGFs in real-time. The electronic health record tool alerts providers if FGFs > 0.7 L/min for desflurane, and >1 L/min for sevoflurane, during maintenance anaesthesia. In 2018, researchers demonstrated reductions in mean FGFs by 0.6 L/min for sevoflurane and 0.2 L/min for desflurane.

5. The primary driver of N_2O emissions is loss of gas in the facility infrastructure. In 2019, Providence St. Vincent hospital in Portland, Oregon, USA, procured 991 metric tons of N_2O. Investigators discovered infrastructure leak rates, ranging from <0.1 L/min to >3.5 L/min, resulting in use efficiency of 5-40%. Central piped N_2O was subsequently decommissioned, and portable e-cylinders substituted, saving 958 metric tonnes of CO_2e of N2O annually, equivalent to 2,407,644 fewer car miles driven, and $12,000 in procurement costs.

6. In 2020, Lothian NHS Scotland demonstrated system losses from 3 centrally piped N2O systems across two hospital sites, of approximately 790,000 and 685,000 litres, respectively. Mitigation activities, including fully decommissioning centrally piped N2O, eliminated the equivalent of 806 tonnes CO2e per annum. The national Nitrous Oxide Project was subsequently launched in January 2021. By the end of March 2021, 16 hospitals across the NHS reported an annual system loss of 13,770,000 litres, 95% of total procured N2O. This is equivalent to 7,219 tonnes CO2e, comparable to 7,600 flights from Paris to New York.

ACTION

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SUPPORTING INFO/ RESOURCES

Below is further information to support individuals in taking action

Supporting consensus guideline from the World Federation of Societies of Anaesthesiologists (WFSA):

- White et al. (2021), **'Principles of environmentally-sustainable anaesthesia: a global consensus statement from the World Federation of Societies of Anaesthesiologists'**, *Anaesthesia*, 77(2), 201-212 (Link)

Comprehensive review of basic science and anaesthesia sustainability literature:

- McGain, Muret, Lawson & Sherman (2020), **'Environmental Sustainability in Anaesthesia and Critical Care'**, *British Journal of Anaesthesia*, 125(5):680-692 (Link)

Checklists to improve environmental sustainability in perioperative environments:

- **The ASA Sustainability Checklist**: (Link)
- **The ANZCA Environmental Sustainability Audit Tool**: (Link)

Calculate the comparative CO2e emissions associated with different anaesthesia methods:

- **Yale Gassing Greener App** (free), provider educational calculator: (Link)
- **American Society of Anesthesiologists** (free), institutional calculator: (Link)
- **AAGBI Anaesthetic Impact Calculator** (free), provider calculator: available as an app (Link) or spreadsheet (Link)

Further information and resources about the comparative environmental impact of desflurane and N_2O:

Desflurane:

The greenhouse gas emissions (CO_2e) for desflurane as clinically used are approximately 50 times that of sevoflurane and isoflurane over a 100-year period. Desflurane is also significantly more costly and lacks evidence of improved clinical outcomes over alternative anaesthetics.

Resources:

- Sherman, Le, Lamers & Eckelman. (2012) **Life Cycle Greenhouse Gas Emissions of Anaesthetic Drugs**, *Anaesthesia and Analgesia*, 114(5), 1086-90 (Link)
- Sherman, Feldman, Chesebro (2020), **'Inhaled Anesthetic 2020 Challenge: Reduce your Inhaled Carbon Emissions by 50%!'**, *ASA Monitor*, 84, 14-17: (Link)
- Sherman & Berkow (2019), **'Scaling Up Inhaled Anesthetic Practice Improvement: The Role of Environmental Sustainability Metrics'**, *Anaesthesia and Analgesia*, 128(6), 1060-1062, (Link)
- McGain et al. **Why be sustainable?** The ANZCA Professional Document PS64: Statement on Environmental Sustainability in Anaesthesia and Pain Medicine. *Anaesth Intens Care* 2019 Sep;47(5):413-422 (Link)

N_2O:

N_2O is less potent and must be used in high concentrations (typically 50%) and has a very long atmospheric lifetime (114 years). Therefore, its warming impacts are similar to desflurane in clinically relevant doses.

ACTION

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SUPPORTING INFO/ RESOURCES (continued)

Resources:

- Sherman, Le, Lamers & Eckelman. (2012) **'Life Cycle Greenhouse Gas Emissions of Anaesthetic Drugs'**, *Anaesthesia and Analgesia, 114(5), 1086-90* (Link)
- **Association of Anaesthetists 'Nitrous Oxide Project**': (Link)
- Seglenieks R et al. (2022) '**Discrepancy between procurement and clinical use of nitrous oxide: waste not, want not'**, *British Journal of Anaesthesia, 128(1):e32-e34* (Link)

Further information about low flow anaesthesia:

There have been historical concerns about a theoretical risk of renal injury associated with 'compound A' production when sevoflurane is used with low FGFs. There is no clinical evidence of harm associated with compound A in humans and it is advised that sevoflurane can safely be used with low FGFs to minimise its environmental impact. It is recommended to use CO_2 absorbers which contain low or no sodium hydroxide (NaOH) during low FGF anaesthesia with sevoflurane.

Resources:

- Feldman (2012), **'Managing fresh gas flow to reduce environmental contamination'**, *Anaesthesia and Analgesia, 114(5):1093-101* (Link)
- Sondekoppam et al. (2020), '**The impact of sevoflurane anesthesia on postoperative renal function: a systematic review and meta-analysis of randomized-controlled trials'**, *Canadian Journal of Anaesthesia, 67(11):1595-1623* (Link)

Environmental impact and use of total intravenous anaesthesia (TIVA):

The environmental impact of TIVA is substantially less than volatile anaesthesia, even when consumables and the carbon cost of production is factored in.

Resources:

- Sherman and Barrick (2019), **'Total Intravenous Anesthetic Versus Inhaled Anesthetic: Pick Your Poison'**, *Anesthesia and Analgesia, 128(1):13-15.* (Link)

Environmental impact of regional anaesthesia:

The use of regional anaesthesia is not a default low carbon alternative and consideration needs to be given to minimising O2 flows, reducing single use plastics and sources of energy generation, to minimise its impact.

Resources:

- McGain et al. (2021), **'Carbon Footprint of General, Regional, and Combined Anesthesia for Total Knee Replacements'**, *Anaesthesiology, 135(6):976-991* (Link)

ACTION

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MOST IMPORTANT LESSONS

1. Resource stewardship is an opportunity for leadership and environmental action that acknowledges limited resources, the impact of the health care sector on climate change, and the impact of climate change on health. Anaesthesia professionals are well placed to lead.

2. Desflurane has a disproportionately high climate impact and little evidence of clinical benefit that justifies its use. This agent can safely be removed from routine anaesthesia practice to reduce our environmental impact.

3. Most N2O is lost through the manifold and central piping, which should be decommissioned in existing infrastructure and avoided in new construction. Portable tanks should be substituted, and these should be closed between uses to avert losses.

4. If inhaled anaesthetics are used, lowest possible FGF rates should be used during all stages of anaesthesia (e.g. < 1 L/min during maintenance). To speed induction, low flows can be combined with high concentrations. However, lowering flows will result in faster consumption of traditional CO2 absorbers.

5. Regional and Total Intravenous Anaesthesia (TIVA) are alternatives with fewer environmental emissions, even when other pollutants are considered. Procurement costs may be higher, however. Care should be taken to avoid unnecessary high flow O2 in regional anaesthesia as this can add considerably to the resultant GHG emissions.

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