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CORRESPONDENCE

Environmental sustainability in anaesthesia and critical care. Response to *Br J Anaesth* 2021; 126: e195–e197

Jodi D. Sherman[1,2], Mads P. Sulbaek Andersen[3], James Renwick[4] and Forbes McGain[5,6,7,*]

[1]Department of Anesthesiology, Yale School of Medicine, Yale University, New Haven, CT, USA, [2]Department of Epidemiology (Environmental Health Sciences), Yale School of Public Health, Yale University, New Haven, CT, USA, [3]Department of Chemistry and Biochemistry, California State University Northridge, Northridge, CA, USA, [4]Department of Physical Geography, School of Geography, Environmental and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand, [5]Western Health, Footscray, Victoria, Australia, [6]School of Public Health, University of Sydney, Sydney, Australia and [7]Centre for Integrated Critical Care, University of Melbourne, Melbourne, Australia

*Corresponding author. E-mail: forbes.mcgain@wh.org.au

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Editor—In their comment to the recent review article, 'Environmental sustainability in anaesthesia and critical care',[1] Slingo and Slingo[2] attempt to downplay calls to reduce inhaled anaesthetic pollution in clinical practice, citing low atmospheric concentrations and short lifetimes of volatile drugs, and suggest that climate change mitigation efforts should instead focus on aggressive reductions of CO_2 emissions (though they offer no recommended actions). Although we do not disagree that the impact of CO_2 on climate vastly overshadows that of the inhaled anaesthetics, we believe Slingo and Slingo represent a misleading oversimplification of the issue.

Inhaled anaesthetic agents in common clinical use globally include halogenated ethers (mainly isoflurane, desflurane, and sevoflurane) and N_2O. Slingo and Slingo[2] argue that as there is only a miniscule quantity of the flurane anaesthetics in the atmosphere, that is parts per trillion (ppt) levels, concerns about any contribution of these compounds to the radiative forcing of climate are unfounded. They provide a comparison of the concentrations of the fluranes to those of three of the main individual greenhouse gases (GHSs)- CO_2, CH_4, and N_2O – showing a difference in concentration scale that encompasses many orders of magnitude, for example the current average global atmospheric CO_2 level is >400 parts per million (ppm).

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Halogenated volatile compounds constitute a group of GHGs that have accounted for ~11% of the observed historical warming of the climate.[3] These compounds are measured in the atmosphere in mixing ratios ranging from 20 parts per quadrillion (ppq) (CFC-216ca) to 515.9 ppt (CFC-12).[4] The fluranes belong to this group and in terms of concentrations in the atmosphere, levels of fluranes are comparable with many of the other halogenated compounds, for which international mitigation efforts have been impactful, providing an appropriate benchmark from a comparative policy standpoint. Furthermore, although desflurane's atmospheric lifetime is only 11 yr, this is similar to that of methane. Short-lived greenhouse gases such as methane and high global warming potential (GWP) gases are rightly being mitigated by our wider society. As anaesthesia is by far the dominant source of volatile anaesthetics in the atmosphere, it is most germane to consider these gases in connection to the profession's contribution to the radiative forcing of climate.

Slingo and Slingo critique the GWP metric (the standard adopted by national and international policy agreements, for example the United Nations Framework Convention on Climate Change (UNFCCC) Kyoto Protocol, and state that '1 kg of desflurane does not 'equal' the climate impacts of 2540 kg of CO_2, because they are fundamentally dissimilar gases present at hugely different concentrations in the atmosphere and with very different residence times'. Although CO_2 has complicated long-term feedback processes in its geochemical cycle, the GWP metric *does* take into account the atmospheric residence time of the climate forcer. It is indeed true that forcing of climate caused by a pulse of 1 kg desflurane to the atmosphere can be said to be equivalent to the pulse of 2540 kg of CO_2, when integrated over a 100 yr time horizon using the GWP100 metric. Of the inhaled anaesthetics, desflurane is the most potent from a GWP perspective. Indeed, all of the inhaled anaesthetics are several-fold higher in life cycle carbon dioxide equivalent emissions in clinically relevant doses compared with intravenously administered propofol, even when including plastic syringes, tubing, and energy to run intravenous drug delivery pumps.[5] Thus, it is reasonable to suggest avoiding desflurane (and N_2O) in particular, when clinically safe to do so, and emissions of inhaled anaesthetics in general.

Slingo and Slingo[2] cite a 2010 letter in the *British Journal of Anaesthesia* by Shine,[6] noting that volatile anaesthetics are responsible for 'only minor contributions' to global emissions (0.02%). Firstly, this is a significant number considering it stems from a small profession in the global context. Secondly, the original source estimate (Sulbaek Andersen and colleagues[7]) was extrapolated from one institution that did not use desflurane (unusual), and neglected to account for N_2O. These two drugs often account for the vast majority of a health system's inhaled anaesthetic footprint,[8–11] suggesting that Sulbaek Andersen and Shine[7] significantly underestimated anaesthesia's global carbon footprint.[12]

Importantly, direct atmospheric emissions from inhaled anaesthetics make up a sizeable fraction of healthcare's total climate footprint. Waste anaesthetic gases account for 2.5–3.0% of total carbon emissions of the UK's National Health Service[10] and Kaiser Permanente,[11] 5% of an acute care organisation's footprint,[10] and can be more than 50% of perioperative services carbon emissions.[13] This significant climate footprint gives anaesthetists urgency and agency to mitigate such atmospheric emissions through clinical practice choices and technological improvements.

Slingo and Slingo reiterate that a significant proportion of N_2O use occurs outside of the operating room (analgesia for maternity, emergency room, and ambulance care). The fraction used in operating rooms is unknown, but one single-hospital report suggested that 50% is used outside perioperative services.[14] Furthermore, we believe significant N_2O quantities may be lost through leaks in aging building manifolds. However, Slingo and Slingo imply that emissions occurring outside perioperative services are someone else's problem. Healthcare organisations must account for all their life cycle emissions and cannot abrogate responsibility. Anaesthetists should serve as leaders.

Mitigation of anaesthetic atmospheric pollution offers immediate opportunities to reduce the carbon footprint of the healthcare sector and contribute to the global effort in reducing the radiative forcing of climate. Several initiatives have already demonstrated significant reductions in facility-level GHG emissions, achieved simply through: (1) substituting sevoflurane for desflurane,[8,9,11] (2) reducing fresh gas flow rates, and (3) avoiding N_2O usage.[9] Such changes are easy to implement and lead to significant wins at the health system scale. To prevent surpassing the 1.5°C warming limit suggested by the Intergovernmental Panel on Climate Change (IPCC) to avoid the worst consequences to civilization,[5] worldwide greenhouse gas emissions must fall by 7.5% each year for this decade.[15] Globally, healthcare contributes 4.6% of total global greenhouse gas emissions (CO_2 equivalents).[11] Striving towards net zero emissions requires focus on both short-term and long-term opportunities. It will take collective action to *bend the climate change curve*.[16]

Declarations of interest

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Climate impacts of anaesthesia

Mary E. Slingo[1,*] and Julia M. Slingo[2,3]

[1]Department of Anaesthesia, Hampshire Hospitals NHS Trust, Winchester, UK, [2]Cabot Institute for the Environment, University of Bristol, Bristol, UK and [3]Met Office, Exeter, UK

*Corresponding author. E-mail: maryslingo@doctors.org.uk

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Editor—We congratulate McGain and colleagues[1] on a thorough review of environmental sustainability in anaesthesia and critical care. We wish to place the discussion of volatile anaesthetic agents within the science of climate change, and argue that a move away from the use of these agents cannot be justified based solely on their global warming potential (GWP).

The authors state that the atmospheric concentration of desflurane is increasing and that, because of its high GWP, this is a cause for concern.[2] Although levels are indeed rising, the concentrations of volatile anaesthetic agents, in comparison with the major greenhouse gases, are exceptionally small. Furthermore, their lifetimes are short and their impacts on Earth's energy budget (i.e. radiative forcing) are minute (see Table 1 based on Vollmer and colleagues,[2] Hodnebrog and colleagues,[3] and IPCC.[4]

Much has been made of the high GWP of volatile anaesthetic gases,[2] but this is deeply misleading. Global warming potential was designed for multi-gas climate policies (such as the Kyoto Protocol), where emissions of different compounds need to be placed on a common scale to aid international agreements. It has subsequently been taken up very widely as a simple proxy for the climate impact of a greenhouse gas and for converting emissions of that gas to equivalent carbon dioxide (CO_2) emissions.

This is problematic in several ways. Global warming potential represents the time-integrated radiative forcing (usually over 100 yr) attributable to a single burst of a gas, a pulse

Table 1 Atmospheric concentrations, lifetimes, and radiative forcing values for the three main greenhouse gases and the three main volatile anaesthetic agents.[2–4] Radiative forcing (a change in Earth's energy budget)=radiative efficiency ($W\ m^{-2}\ ppb^{-1}$) multiplied by atmospheric concentration, based on a radiative efficiency of 0.4 $W\ m^{-2}\ ppb^{-1}$ for volatile anaesthetic agents.[2–4] Thus, the percentage contribution of volatile anaesthetic agents, compared with the radiative effect that results from anthropogenic CO_2 emissions=(0.00021/1.68)*100, that is, 0.01%. Radiative forcing is the fundamental driver of climate change, not GWP. It avoids the issue of varying lifetimes, which confounds GWP (and its derivative, CO_2 equivalence), and depends only on the present-day accumulation of anthropogenic greenhouse gases, as measured by atmospheric concentrations. *National Oceanic and Atmospheric Administration Global Monitoring Laboratory. †Sum of atmospheric concentrations for sevoflurane/desflurane/isoflurane). CO_2, carbon dioxide; GWP, global warming potential.

Gas	Atmospheric concentration (parts per trillion)	Atmospheric lifetime	Radiative forcing ($W\ m^{-2}$)	
CO_2	411 000 000*	Centuries–millennia[4]	1.68[4]	The three main volatile agents contribute only 0.01% of the climate effect that results from the increases in CO_2 attributable to human activity.
Methane	1 870 000*	12.4 yr[4]	0.97[4]	
Nitrous oxide	323 000*	121 yr[4]	0.17[4]	
Sevoflurane	0.13[2]	1.1 yr[2]	0.00005	
Desflurane	0.30[2]	14 yr[2]	0.00014	
Isoflurane	0.097[2]	3.2 yr[2]	0.00004	
Total volatile anaesthetics†	0.53	—	0.00021	