BeSARPP (Belgian Society of Anesthesiology, Resuscitation, Perioperative medicine and Pain management) recommendations on responsible and sustainable use of inhaled anesthetics: NO time TO WASTE

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Unstructured abstract

Following up on the successful BeSARPP annual meeting on sustainability in anesthesia held on November 2022, the Board Members of BeSARPP met to draft recommendations regarding the use of inhaled anesthetics, that would help anesthesiologists decrease the professional environmental impact of their daily practice in the operating room. This manuscript discusses the rationale for these recommendations. The major premise was none of these should compromise patient safety or the level of care we provide to our patients. For measures beyond those addressing the use of inhaled anesthetics, the reader is referred to other recommendations that can decrease the environmental footprint of anesthesia and perioperative care in general[1].

Main text

Climate change and global warming have become a poignant reality and are considered the biggest health threats facing humanity[2,3]. Ironically, the healthcare delivery system itself contributes to environmental pollution at an estimated proportion of 1 – 5%[4]. In this context, anesthesia, and the operating room environment play an important role. Out of many contributing factors, inhaled anesthetics deserve particular attention because they are potent greenhouse gases (GHGs) just like carbon dioxide (CO_2)[5].

The temperature on the earth depends on the balance between radiation energy captured from

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the sun and radiation energy reflected to space by earth. Once sun light reaches earth, it is absorbed and its energy is partly re-emitted into space by waves within the infrared light spectrum. This process prevents excessive heating of our planet. Unfortunately, human made GHG's absorb this infrared light and radiate it back again to the earth's surface, causing the earth's surface and lower atmosphere to warm up (https://www.epa.gov/climatechange-science/basics-climate-change). GHG's thus directly contribute to the warming of the earth.

The various inhaled anesthetics differ in their greenhouse effect, which is expressed by their global warming potential (GWP)[5]. The GWP of inhaled anesthetics is referenced to the effect of CO_2, which has been assigned reference value 1[6]. Therefore the "carbon dioxide equivalent" of a gas or "CO_2e" is the amount of CO_2 that would have the equivalent global warming impact.

While generally expressed over a 100-year period (GWP100), several authors argue the GWP of inhaled anesthetics should be expressed over a 20-year time horizon (GWP_{20}) because this better reflects the drastic imminent consequences of their use.

Table I illustrates the GWP_{20} and GWP_{100} of currently used inhaled anesthetics based on the 2021 official report from the United Nations Intergovernmental Panel on Climate Change (IPCC) (sixth assessment report)[7]. Desflurane has the highest GWP_{100}. But besides the GWP, other factors need to be considered to properly determine the environmental impact of inhaled anesthetics.

First, the atmospheric half-life of inhaled anesthetics differs between different agents, varying from 1 year to more than a hundred years for nitrous oxide (N_2O)[6,7]. *Second*, N_2O also causes ozone depletion[8]. *Third*, the MAC (minimum alveolar concentration) of different agents differs. With a MAC value (for a 40-year-old patient) of 6% desflurane and 2% sevoflurane, this implies that approximately 3 times more desflurane molecules are needed than sevoflurane to achieve the same clinical effect at the same fresh-gas flow (FGF) settings. N_2O has an even lower anesthetic potency (MAC of 104%), requiring it to be used at high concentrations (50 - 70%).

A *fourth* factor to consider are the agents' relative clinical advantages. Although time to recovery from desflurane anesthesia is approximately 3 minutes shorter compared to e.g. sevoflurane, a meta-analysis showed that there is no clinically significant reduction in time spent in post-anesthesia care unit when compared to sevoflurane[9]. Also in the morbidly obese patient this effect remains relatively small[6].

Table I. — Atmospheric lifetimes in years (y) and 20-year and 100-year horizon global warming potential (GWP) values for different inhaled anesthetics.

Compound	Lifetime (y)	GWP_{20}	GWP_{100}
Carbon dioxide		1	1
Sevoflurane	1.1	702	195
Desflurane	14	7020	2590
Isoflurane	3.5	1930	539
Nitrous oxide	114	273	273

The vast majority of atmospheric N_2O results from microbial processes in the soil, the use of fertilizers containing nitrogen and burning of biomass. However, one study showed that the use of N_2O in anesthesia contributes with 3% to the total N_2O emission of the United States, accounting for 3500 tons of N_2O or 956000 tons of CO_2e[10]. While clinicians may still perceive the use of N_2O to offer clinical advantages in e.g. the pediatric setting, one needs to consider that the majority of N_2O pollution is caused by leaks in the central distribution systems of N_2O[11-13]. So merely banning the use of N_2O in the operating theatre does not deal with the persistent leak from the central distribution system and piping of N_2O. The crucial initial step in reducing pollution by N_2O therefore is decommissioning existing infrastructure and avoiding the installation of central piping in new medical facilities[13]. Where N_2O is still required, portable canisters should be used, and these should be closed between uses to avoid continuous leaks.

A final factor affecting the environmental impact of inhaled agents is the FGF. This factor (besides agent selection) is under the direct control of the clinician. Rational reduction of FGF is the daily responsibility of every individual anesthesiologist. The effect of lowering FGF may differ depending on clinical circumstances. In one study, reducing FGF from 2 L/min to 0.5 L/min decreased sevoflurane consumption by 60%[14]. It is well-known that with appropriate monitoring, low FGF (< 1L/min) and even ultra-low FGF (< 0.5 L/min) can be safely administered at all stages of anesthesia[15-18]. While low FGFs result in a higher consumption of traditional CO_2 absorbers[19], preliminary data indicate that both the combined environmental and financial cost of agent and CO_2 absorbent use decrease as FGF is decreased[20]. High FGFs with simultaneous administration of sevoflurane, typically during manual ventilation before tracheal intubation, should strictly be kept as short as possible[21]. Low FGF can also be adopted during mask-induction in pediatric cases[22], and in adult patients with specific needs. Minimal flow anesthesia can be safely and ergonomically ensured with modern workstations.

The above considerations explain that both agent selection and the FGF at which the agent is delivered need to be considered when calculating an agent's environmental impact. This environmental impact can be expressed in kg CO_2e/h, which is the effect equivalent to the amount of CO_2 per hour of use of a product. For example, delivering 6% desflurane with a 1L/min FGF results in a carbon footprint equivalent of 176.5 kg of CO_2 per hour. The equivalent carbon footprint for an equipotent sevoflurane concentration (2%) is 7 kg of CO_2 per hour. Adding 60% N_2O at a FGF of 1L/min generates an additional 18 kg CO_2e per hour (Addendum 1).

BeSARPP empowers responsible and sustainable use of inhaled anesthetics in an effort to minimize the environmental impact of our professional activities. The above review formed the basis for BeSARPP to come up with the following recommendations. These recommendations have no adverse effect on patient safety or quality of perioperative care:

1. BeSARPP recommends stopping the use of desflurane in all Belgian hospitals.
2. BeSARPP recommends decommissioning central N_2O piping. N_2O should be delivered from portable tanks that should be closed after use. BeSARPP recommends to only use N_2O in specific cases and whenever no other alternatives are feasible or available.
3. BeSARPP recommends minimizing FGF to the safest feasible extent whenever inhaled agents are used. Whenever available, the use of automatic computer controlled FGF is encouraged. In cases where an intravenous induction is not feasible and mask induction with inhaled anesthetics is required, minimizing FGF should also be encouraged. In all other cases, the administration of inhaled anesthetics should only be initiated after having secured the airway.

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Addendum 1 — Detailed calculation of CO_2-equivalents of the global warming effect of inhaled anesthetics.

Molecular weight desflurane = 168 g/mol
Molecular weight sevoflurane = 200 g/mol
Molecular weight N_2O = 44 g/mol
1 mol of a gas at 20°C and 1 atmosphere = 24.06 litre.
GWP_{20} of desflurane = 7020 [7]
GWP_{20} of sevoflurane = 702 [7]
GWP_{20} of N_2O = 273 [7]
CO_2 emissions from burning 1 litre of gasoline: 2.3 kg.

How much CO_2e is emitted when using desflurane 6% at a FGF of 1L/min?

1L/min with an inspiratory volume percent concentration of 6% → 0.06 Liter desflurane vapor /minute.
[0.06 liter/min] / [24.06 liter/mol] = 0.00249 mol/min
[0.00249 mol/min] x [168 g/mol] = 0.41895 g/min
[0.41895 g desflurane/min] x [7020 g CO_2e/g desflurane] = 2941 g CO_2e/min
[2941 g CO_2e/min] x [60 min/h] = 176463 g CO_2e/h = 176.5 kg CO_2e/h
→ 1 hour of desflurane 6% administration at 1L FGF emits the equivalent of 176,5 kg CO_2, which equals the emission of burning 76 litres of gasoline.

How much CO_2e is emitted when using N_2O 60% at a FGF of 1L/min?

60% N_2O at 1L/min → 0.6 L N_2O /min
[0.6 liter N_2O/min] / [24.06 liter/mol] = 0.0249 mol/min
[0.0249 mol/min] x [44 g/mol] = 1.1 g/min
[1.1 g N_2O /min] x [273 g CO_2e/g N_2O] = 300 g CO_2e/min
[300 g CO_2e/min] x [60 min/h] = 18 kg CO_2e/h, or burning 7,8 litres of gasoline

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