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Moving towards green anaesthesia: Strategies for reducing environmental impact

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Abstract
According to the World Health Organization, the change in climate stands as the foremost health risk confronting humanity. In addition to endanger the accessibility of clean drinking water and clean air, it also entails the capability to negate centuries of progress in public health and advancement. Given the urgency of the circumstance, enlightened media sources have incorporated the phrase 'climate crisis' to underscore the existential risk posed by this critical issue.
The provision of healthcare services needs significant resources. The acute healthcare system is identified as the sector with the second-highest carbon intensity, following closely behind food service setups. It entails the consumption of considerable resources, encompassing disposable items and medical apparatus, necessitating substantial energy input for their manufacture. Healthcare operations independently responsible for 8% of United States-based Greenhouse Gas (GHG) emissions. Particularly, surgical theatres used 3 to 6 times the energy than the entirety of hospitals.
The administration of anaesthesia acts a significant component in climate change, attributed not only to the pharmaceuticals used, but also the significant amount of waste generated in our professional environment daily. As healthcare practitioners, we are dedicated to the principle of prioritizing the safety and health of patients; yet, by producing excessive waste in our clinical endeavours, we have inadvertently influenced the overall health of the public. Estimates recommend that life-cycle Greenhouse Gas (GHG) emissions associated with the healthcare and medical in the US will result in up to 381,000 extra disability-adjusted lifespan yearly.
In our roles as anaesthesiologists, we are entrusted with welfare and safety of the patients; similarly, we also carry ethical commitments towards environmental preservation, as it impacts the well-being of the general public. It is fundamental to highlight that climate emergency is not limited to "safeguarding the earth" but rather capability for healthy human cohabitation.

Keywords: TIVA, Green anesthesia, greenhouse gas, environmental impact from anesthesia gases, volatile anesthetics

Introduction
According to the World Health Organization, the change in climate stands as the foremost health risk confronting humanity. In addition to endanger the accessibility of clean drinking water and clean air, it also entails the capability to negate centuries of progress in public health and advancement [1]. Given the urgency of the circumstance, enlightened media sources have incorporated the phrase 'climate crisis' to underscore the existential risk posed by this critical issue. The provision of healthcare services needs significant resources. The acute healthcare system is identified as the sector with the second-highest carbon intensity, following closely behind food service setups [2]. It entails the consumption of considerable resources, encompassing disposable items and medical apparatus, necessitating substantial energy input for their manufacture. Healthcare operations independently responsible for 8% of United States-based Greenhouse Gas (GHG) emissions. Particularly, surgical theatres used 3 to 6 times the energy than the entirety of hospitals [3].
The administration of anaesthesia acts a significant component in climate change, attributed not only to the pharmaceuticals used, but also the significant amount of waste generated in our professional environment daily. As healthcare practitioners, we are dedicated to the principle of prioritizing the safety and health of patients; yet, by producing excessive waste in our clinical endeavours, we have inadvertently influenced the overall health of the public. Estimates recommend that life-cycle greenhouse gas (GHG) emissions associated with the healthcare and medical in the US will result in up to 381,000 extra disability-adjusted lifespan yearly [4].

In our roles as anaesthesiologists, we are entrusted with welfare and safety of the patients; similarly, we also carry ethical commitments towards environmental preservation, as it impacts the well-being of the general public. It is fundamental to highlight that climate emergency is not limited to "safeguarding the earth" but rather capability for healthy human cohabitation.

The environmental influence of volatile anaesthetics

Anaesthesiology presents a significant environmental impact due to the regular utilization of volatile agents recognized for their considerable greenhouse gas potency. These volatile gases are discharged directly into the environment, magnifies their effects of global warming. Estimates recommend that volatile anaesthetic agents constitute around 0.01% - 0.10% of the cumulative carbon dioxide equivalent (CO2e) emissions on a global scale, thus playing a role in global warming. The outflow from atmospheric sampling shows progressive rise in the accumulation of volatile anaesthetics. Within high-income settings, acute hospital carbon dioxide equivalent (CO2e) emissions account for 5% of the overall sum, with perioperative setting comprising 50% of the comprehensive total.

The important inhaled volatile anaesthetics administered consists of isoflurane, desflurane, halothane, sevoflurane and nitrous oxide. In the domain of environmental issues, it is significant to assess the ecological effects of agents including nitrous oxide and desflurane, which demonstrate notably elevated environmental repercussions at clinically relevant concentrations. The potential of desflurane global warming, factored in by clinical efficiency, is approximately 40-50 times greater than isoflurane and sevoflurane over a 100-year span. Desflurane presents a notably greater cost, in contrast to other inhaled anaesthetics, with limited evidence of clinical benefit to support its utilization, and refraining from its use may result in cost-saving benefits. Relative to other volatile anaesthetics, nitrous oxide showed decreased potency, requiring its use in concentrated dosage, and its extended atmospheric presence leads to global warming which impacts similar to desflurane in clinically significant quantities [5].

Practical recommendations

The subsequent part of this review proposes a set of implementable recommendations to diminish the environmental burden of the operating theatre. We intentionally chose not to offer a comprehensive approach, instead emphasizing on evidence-backed suggestions that are comparatively easy to execute and provide significant potential benefits.

1. Utilize total intravenous anaesthesia instead of inhalation-based anaesthesia

   For the pioneering introduction of general anaesthesia, utilized on October 16, 1846, by the medical professional William Morto [6], the utilization of gaseous and volatile compounds for anaesthesia purpose has endured from the onset of diethyl ether inhalation from a saturated cloth by anaesthetists. In recent times, this technique has faced intensified scrutiny regarding its environmental effects. The present series of halogenated anaesthetics exhibit chemical characteristic analogous to those of greenhouse gases displaying their efficacy. In terms of the GWP20 or 20-year Global Warming Potential, sevoflurane emits equal to 440 kilograms of carbon dioxide production per kilogram, while desflurane emits approximately 6810 kilograms of carbon dioxide per kilogram [7]. The majority of these substances undergo minimal metabolic transformation, are emitted into the environment following their use, with lifetimes spanning from 1.1-14 years. A research study scrutinized the atmospheric prevalence of anaesthetics in the Swiss Alps, Antarctic and Northern Pacific territories, showcasing a progressive increase in levels within these exceedingly distant expanses. Instead of volatile anaesthetics, intravenous anaesthesia (total) emerges as an alternative method with minimal greenhouse gas (GHG) outcomes, notably showed by propofol, which primarily arise from the energy expenditure of only a syringe pump [8-10].

   Life cycle assessment demonstrated a notable divergence in the carbon emissions associated with anaesthesia options for hysterectomy, showing a range of 0.001 kg carbon dioxide -equivalent emissions of propofol in contrast to 505 kilograms of carbon dioxide equivalent for desflurane. Despite notable differences in carbon footprint, outcomes showed no noticeable distinction among the cohorts. Recent years have highlighted the notion that the selection of anaesthesia might exert only a slight impact on patient outcomes, as demonstrated by significant randomized controlled investigations failed to illustrate any substantial impact on the rate of mortality post cancer recurrence [11] or cardiac procedures [12].

2. Employ ultra-low fresh gas flow for volatile anaesthesia and use higher flows during total intravenous anaesthesia.

   The association between the emission of inhaled anaesthetics and FGF or fresh gas flows utilized highlights the necessity of decreasing FGF to the most attainable level. A study demonstrated that lowering FGF rate from 2.0 L/min down to 0.5 L/min resulted in a 60% decrease in the usage of sevoflurane [13]. In regions where guidelines restrict the application of ultra-low fresh gas flows (FGF) throughout anaesthesia initiated by sevoflurane-associated anaesthesia, a different CO_2 absorber may be used to fulfil this requirement. Reduced fresh gas flow (FGF) could also be used during the process of mask induction as per a particular low-flow protocol in an investigation, resulting in the consumption of half sevoflurane without affecting the duration of induction or outcomes to airway manipulation in paediatrics [14]. Regarding Total Intravenous Anaesthesia (TIVA), the appropriate FGF is associated with considering the environmental implications and cost of CO_2 absorber depletion compared to the consumption of energy for manufacturing different medical gases including oxygen. An LCA carried out in Australia indicates that expenditures may be reduced by approximately 93% by switching from 1-6 litres per minute, with minor effect on the emissions of carbon [15] nevertheless, as contended by other [16], the production of energy in Australia is mainly coal-dependent and is considered the most carbon-intensive globally. In areas with highly favourable energy assortments, heightened FGF produces not only financial benefits but also ecological

advantages.

3. The effectiveness of anaesthetic gas capturing model remains highly unproven and might provide limited environmental advantages, while also elevating expenses.

   Various techniques have been developed and investigated to hinder the emission of gaseous anaesthetics into the atmosphere. The majority of commercial equipment consists of proprietary components that have not been documented in scientific publications. In general, the chemical principle governing these particular devices is the process of binding to zeolite, activated carbon, silica gel and molecular sieves. An *in vitro* investigation contrast to different substances and acceptable maximal adsorption potency isoflurane (93%), desflurane (77%), while sevoflurane (89%), it is worth noticing that desflurane (principal greenhouse gas), showed limited efficacy [17]. Adsorption is known as a reversible mechanism and provides the capability to retrieve the substance for subsequent reuse. The single technology analysed in an *in-vivo* study documented in a well-known journal assessed the efficacy of adsorption in 80 consecutive general anaesthetic procedures employing desflurane. Among the complete 6902 grams of used desflurane, only 2509 gm were assimilated by the charcoal (Zeocys, Contra Fluran, and Germany) and finally 1727 grams could be reclaimed for reuse, resulting in around 25%. Recapture proportion [18]. The efficacy demonstrated so far cannot justify investment in this new technology, particularly due to the unknown environmental impact of the entire procedure and the lack of authorization from regulatory entities for the reutilization of reclaimed medication [19]. Within the clinical context, the use of epidural or IV analgesia is suggested over the gaseous anaesthesia, nitrous oxide for pain relief during labor. A number of alternatives are accessible for labor analgesia, among which the primary methods are epidural analgesia, intravenous or intramuscular delivery of opioids, and inhalation of nitrous oxide (N_2O).

The accessibility of these choices exhibits substantial diversity across nations and medical settings. Within the United Kingdom, it is suggested that nitrous oxide (N_2O) be available across all birthing environments, resulting in 30% of total GHG emissions from anaesthetic services due to its administration during labor [54]. A recent analysis assessed the overall carbon emissions measured CO_2-equivalents during 4-hour durations for distinct techniques to labor pain management. The findings demonstrated that the use of nitrous oxide generates 237 kg carbon dioxide--equivalents in contrast to epidural bupivacaine and 0.75 kg carbon dioxide-equivalents for remifentanil PC [20]. Given that both remifentanil and epidural provide greater pain relief in contrast to N_2O [21], with a significantly reduced ecological footprint, they should be favoured for managing labor pain in clinical settings.

Next Areas of Focus

- Re-ordering of reusable laryngoscope blades and handles.
- Increase use of low fresh gas flow anesthesia; working with Epic team to develop an intelligent reminder to decrease gas flows when appropriate.
- Reusable ECG Leads.
- Reduction of redundant or unnecessary blue drape waste.
- PVC-free IV tubing/fluid bags.
- Reducing unnecessary mepilex use.

Conclusion

The substantial expansion of the medical sector has given rise to an industry that contributes substantially to world's ecological pollution. This is inconsistent with the medical industry's aspiration of enhancing health, motivating us to evolve healthcare into a more sustainable field. Within this review, a number of recommendations are given to aid anaesthesiologists in enhancing the ecological sustainability. Formation of an OR committee dedicated to ecological initiatives can provide a significant opportunity to improve health care's impact on the environment and save money. Teaching and research are also the potential means to create a generation of doctors who can inculcate sustainable practices in their day-to-day life, so that the future progeny can breathe clean air. We, as anaesthesiologists, should also be conscious about the long-term effects of our own specialty and should lead the way by adopting sustainable and environment-friendly practices.

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