Fresh gas flow during total intravenous anaesthesia: marginal gains in sustainable healthcare

M Back[1*], A Al-Attar[1], R Sutton[1], C Shelton[1,2]

[1]Manchester, UK
[2]Lancaster, UK

* Email: morganback@gmail.com

Editor –

The British Cycling Team won eight gold medals at the 2012 London Olympics. This success, it has been suggested, was due in part to the philosophy of 'the aggregation of marginal gains': small improvements every day, everywhere and anywhere, that have a compound effect. This concept has gained traction in clinical anaesthesia and perioperative medicine; we believe that it should likewise be applied in sustainable healthcare.[1]

With this in mind we enjoyed reading Zhong and colleagues' paper on the environmental and financial impacts of different fresh gas flow (FGF) rates during non-volatile anaesthesia.[2] Drawing on their work, we audited the FGF rates when using total intravenous anaesthesia (TIVA) at our institution, a large UK teaching hospital in which TIVA is the technique used in approximately two-thirds of general anaesthetics (internal data). In this letter, we present the results of our audit and consider whether higher FGF rates may have a lower environmental impact than Zhong and colleagues suggest in countries with lower-carbon electricity generation.

Fifty-eight consecutive TIVA cases were analysed during a departmental sprint audit conducted from 16th to 22nd October 2020. We found that in 26% of cases ≤ 1 $L.min^{-1}$ of FGF was used, with higher flows used with progressively lower frequency (Figure 1). The median FGF (used as a measure of central tendency due to the positive skew of the data) in our audit was 2.5 $L.min^{-1}$.

Our current financial costs were approximated by undertaking a linear regression of the UK cost data associated with Dräger CLIC™ absorbers (as used at our institution) at FGF rates between 1 and 6 $l.min^{-1}$, from Zhong and colleagues' supplementary materials.[3] Using the resulting equation, we calculated a running cost of £0.87 per hour at our median FGF rate of 2.5 $l.min^{-1}$. Based on an estimated annual provision of 11,000 hours of TIVA (11 operating theatres, 6 $h.day^{-1}$, 250 $days.year^{-1}$, 2/3 of cases with TIVA), we calculate our annual cost associated with FGF and CO_2 absorbers to be £9,570. Assuming that our audit data is representative of our typical workload, there would be scope for a cost reduction of over £8,000 per year if FGF rates were uniformly set to 6 $L.min^{-1}$ (£1430 annually, based on an hourly running cost of £0.13).[3]

Sustainability can be conceptualised using the 'triple bottom line' model, incorporating financial, social, and environmental considerations.[4,5] Zhong's work indicates clear potential for financial benefit, and patient care is unlikely to be affected by FGF rates within the range of 1-6 $l.min^{-1}$ if a heat and moisture exchanging filter is used.[6] From an environmental standpoint, Zhong and colleagues state that the climate change impacts of different FGF rates within this range is 'minimal' (e.g. a 28 $g.hr^{-1}$ reduction in CO_2e by increasing FGF from 1 $L.min^{-1}$ to 4 $L.min^{-1}$). This appears to be because the reduced use of CO_2 absorbent canisters is offset by the production of greater volumes of gases.[2,3] However as we have previously noted, there is a marked difference in the carbon intensity of electricity generation in different countries.[7] In Australia (where Zhong and colleagues' study was conducted) electricity generation is predominantly coal-fired and is amongst the most carbon-intensive in the world, emitting 0.9 kg CO_2e per kWh of electricity.[7] In the UK, where our institution is located, electricity is generated using a combination of fossil fuel, nuclear and renewable sources; 0.28 kg CO_2e is emitted per kWh.[8]

In order to investigate the generalisability of their findings, Zhong and colleagues modelled the effect of altering FGF rates on global warming impacts in the USA and UK, as well as Australia, in their supplementary materials, finding little difference in carbon emissions. However, it appears that this modelling only takes into account the (minimal) impact of the international shipping of CO_2 absorbers and not the carbon-intensity of electricity generation methods used in different countries.[3] Considering this variation, and that medical gases are typically produced in the country of use, we question whether the impact of altering FGF rates is indeed 'minimal' internationally. Based on our prior work, we suspect that higher FGF rates would have lower environmental impacts in countries with lower carbon electricity production.[7] We would therefore like to invite Zhong and colleagues to clarify whether the country-specific emissions of electricity generation were taken into account in their modelling.[3]

Whilst increasing FGF rates may make economic and environmental sense, it does of course demand a greater supply of oxygen. In some circumstances, such as during 'surges' of the COVID-19 pandemic or in institutions without robust oxygen supply chains, practical rationing of oxygen usage may be required as suggested by Hall and Chakladar.[9] We do note, however, that the oxygen flow rates examined by Zhong and colleagues are relatively modest in comparison to those recommended for routinely-used techniques such as nasal high flow oxygen (20-60 $L.min^{-1}$) or non-rebreathe oxygen masks (15 $L.min^{-1}$).

As much as 5% of the carbon footprint of UK acute hospitals is attributable to inhaled anaesthetic agents which are potent 'greenhouse gases', with desflurane and nitrous oxide having the greatest environmental effects yet little evidence of clinical benefit.[4,10] Our anaesthetic department has already taken steps to address this by removing desflurane vaporisers and nitrous oxide cylinders from our anaesthetic machines and minimising the use of inhalational anaesthesia. With most of our general anaesthetics now conducted using TIVA, we are actively seeking 'marginal gains' in sustainable anaesthetic practice. We commend Zhong et al for identifying one such potential gain, and would be interested to know if, when the carbon intensity of electricity production is accounted for, the potential for environmental gains is actually greater than they have calculated.

Declaration of Interest

C.S. is a former member of the editorial board of *BJA Education.* The authors declare no other competing interests. No funding received.

References

1. Schonborn JL, Anderson H. Perioperative medicine: a changing model of care. *BJA Education* 2019; 19: 27-33.
2. Zhong G, Abbas A, Jones J, Kong S, McCulloch T. Environmental and economic impact of using increased fresh gas flow to reduce carbon dioxide absorbent consumption in the absence of inhalational anaesthetics. *Br J Anaes* 2020; 125: 773-8.
3. Zhong G, Abbas A, Jones J, Kong S, McCulloch T. Supplementary Materials [Internet]. 2020. https://bjanaesthesia.org/cms/10.1016/j.bja.2020.07.043/attachment/f2e4618f-87f3-415c-bd44-942797435279/mmc1.docx Date accessed: November 4th, 2020.
4. Shelton CL, Sutton R, White SM. Desflurane in modern anaesthetic practice: walking on thin ice(caps)? *Br J Anaes* 2020; doi: 10.1016/j.bja.2020.09.013.
5. McGain F, Muret J, Lawson C, Sherman JD. Environmental sustainability within anaesthesia and critical care. *Br J Anaesth* 2020; doi: 10.1016/j.bja.2020.06.055.
6. Thomas R. Fresh gas flows, filters, heat and moisture exchangers, and humidification. Comment on Br J Anaesth 2020; 125: 773–778. *Br J Anaes* 2020; doi: 10.1016/j.bja.2020.09.027.
7. Court MW, McAllister S, Pierce JMT, Sutton R. Converting gas-driven ventilators from oxygen to air: environmental implications. *Anaesthesia*. 2020; doi: 10.1111/anae.15214
8. Carbonfootprint.com. 2019 Grid Electricity Emissions Factors v1.0 [Internet]. 2019. https://www.carbonfootprint.com/docs/2019_06_emissions_factors_sources_for_2019_electricity.pdf Date accessed: November 4th, 2020.
9. Hall A, Chakladar A. High fresh gas flow during non-inhalational anaesthesia during the COVID-19 pandemic. Comment on *Br J Anaesth* 2020; 125: 773-778. *Br J Anaesth* 2020; doi: 10.1016/j.bja.2020.09.033.
10. UK Sustainable Development Unit. Carbon Footprint from Anaesthetic Gas Use [Internet]. 2013. https://www.sduhealth.org.uk/documents/publications/Anaesthetic_gases_research_v1.pdf Date accessed: November 4th, 2020.

Caption for figure

Figure 1: Sprint audit data showing the variation in Fresh Gas Flows (FGF) when using TIVA at our institution.