Fresh gas flow during total intravenous anaesthesia and marginal gains in sustainable healthcare. Comment on *Br J Anaesth* 2020; 125: 773-8

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Editor—The British cycling team won eight gold medals at the 2012 London Olympics. This success, it has been suggested, was attributable, 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 the paper by Zhong and colleagues[2] on the environmental and financial impacts of different fresh gas flow (FGF) rates during non-inhaled anaesthesia. 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 about two-thirds of general anaesthetics (internal data). Here we present the results of our audit and consider whether higher FGF rates may have a lower environmental impact than Zhong and colleagues[2] suggest in countries with lower-carbon electricity generation.

We analysed 58 consecutive TIVA cases during a departmental sprint audit conducted in the Department of Anaesthesia at Wythenshawe Hospital, Manchester, UK, from October 16 to October 22, 2020. In 26% of cases the FGF used was $\leq$1 L min^{-1}, with higher flows used with progressively lower frequency (Fig 1). The median FGF (used as a measure of central tendency because of 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 UK cost data associated with Dräger CLIC™ absorbers (as used at our institution) at FGF rates of 1–6 L min^{-1}, taken from Zhong and colleagues'[3] supplementary materials. Using the resulting equation, we calculated a running cost of £0.87 h^{-1} at our median FGF rate of 2.5 L min^{-1}. Based on an estimated annual provision of 11 000 h of TIVA (11 operating theatres, 6 h day^{-1}, 250 days yr^{--1}, 2/3 of cases with TIVA), we calculated our annual cost associated with FGF and CO_2 absorbers to be £9570. Assuming that our audit data are representative of our typical workload, there would be scope for a cost reduction of more than £8000 yr^{--1} 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 and colleagues[2] showed clear potential for financial benefit, and patient care is unlikely to be affected by FGF rates of 1–6 L min^{-1} if a heat and moisture exchanging filter is used.[6] From an environmental standpoint, Zhong and colleagues[2] state that the climate change impacts of different FGF rates within this range is 'minimal' (e.g. a 28 g h^{-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 noted, there is a marked difference in the carbon intensity of electricity generation in different countries.[7] In Australia (where Zhong and colleagues'[2] 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 kWh^{-1} of electricity.[7] In the UK, where our institution is located, electricity is generated using a combination of fossil fuel, nuclear, and renewable sources with 0.28 kg CO_2e emitted per kWh.[8]

In order to investigate the generalisability of their findings, Zhong and colleagues[2,3] modelled the effect of altering FGF rates on global warming impacts in the USA and UK, and 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] It would be helpful for Zhong and colleagues[2] to clarify whether country-specific emissions of electricity generation were taken into account in their modelling.

Whereas 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 coronavirus disease 2019 (COVID-19) pandemic or in institutions without robust oxygen supply chains, practical rationing of oxygen usage may be required.[9] We do note, however, that the oxygen flow rates examined by Zhong and colleagues[2] are relatively modest in comparison to those recommended

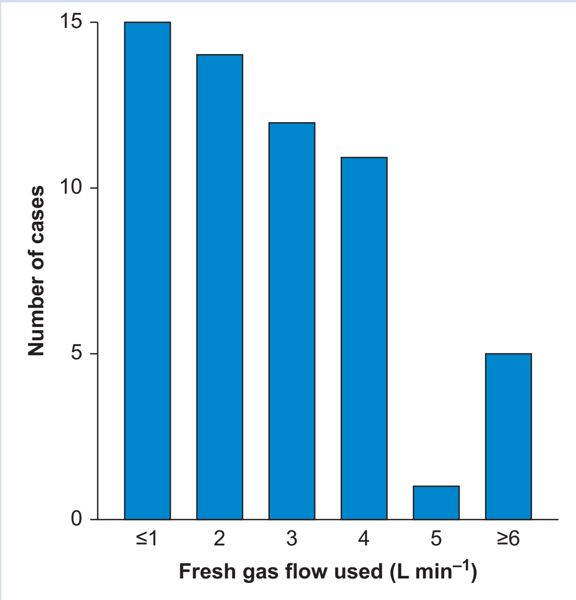

Fig 1. Sprint audit data showing the variation in fresh gas flow rates when using TIVA at our institution.

for routinely-used techniques such as nasal high-flow oxygen (20–60 L min^{-1}) or non-rebreather oxygen masks (15 L min^{-1}).

As much as 5% of the carbon footprint of UK acute care hospitals is attributable to inhaled anaesthetic agents that 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 at Wythenshawe Hospital has already taken steps to address this by removing desflurane vaporisers and nitrous oxide cylinders from our anaesthetic machines and minimising use of inhalation anaesthesia. With most of our general anaesthetics now conducted using TIVA, we are actively seeking 'marginal gains' in sustainable anaesthetic practice. We commend Zhong and colleagues[2] for identifying one such potential gain; it is important 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.

Declarations of interest

CS is a former member of the editorial board of *BJA Education*. The authors declare no other competing interests.

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Radial artery catheterisation pressure monitoring with a closed intravascular catheter system and ultrasound-guided dynamic needle tip positioning technique

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