Low-flow anaesthesia in paediatric patients

Editor—We were interested in the study regarding carbon monoxide (CO) rebreathing during low-flow anaesthesia (LFA) in paediatric patients. It is reassuring to note that modern anaesthetic circuits do not contribute to CO rebreathing in the context of LFA, as elegantly demonstrated by an in vitro control experiment.

Although the technique is becoming increasing popular, even in paediatric practice, the absence of a single definition of LFA hampers further enquiry and consistent study design. Meakin defined low fresh gas flow (FGF) as <1 litre min\(^{-1}\), and noted that when using modern circuits, the required flow is more dependent upon the circuit than patient weight, unless using basal flow.

In the in vivo limb of their experiment, the authors chose a liberal definition of an LFA, which is half of minute ventilation. We feel that, by choosing a relatively higher FGF, they reduced the likelihood of detecting a clinically significant accumulation of CO. They also did not state the absolute flow rates used in the study, which reduces the applicability of their findings to the practice of anaesthetists who use the definition of <1 litre min\(^{-1}\).

A further confounding factor to the study is the removal of 150 ml min\(^{-1}\) for the purpose of gas sampling. Although concentrations were recorded every 5 min, it is unclear if the sample stream was constant or intermittent. Additional information is required to enable the reader to critically appraise the impact of this methodology on the results.

The CO increase noted was small and, although statistically significant, the authors acknowledge that the clinical significance of such small changes is unknown. It would be interesting to determine what CO levels are reached at the kind of very low flows (FGF <1 litre min\(^{-1}\)) that are routinely practiced in children and relate these to critical levels of CO exposure known to produce clinical effects.

Conflict of interest
None declared.

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Reply from the authors
Editor—We thank Dr Hanison and colleagues for their comments. We agree that the broad definition of low-flow anaesthesia (LFA) can make interpretation of clinical studies challenging. Furthermore, lack of a singular definition also precludes clinicians from understanding how such findings may apply to their patients or their clinical practice.

It should be noted, however, that LFA has been defined previously in terms of fresh gas flow (FGF) rate in an absorber system based on the onset of rebreathing or a 50% rebreathing fraction. The key is that these definitions were in the context of using a CO\(_2\) absorber. Meakin, on the other hand, defined LFA in terms of FGF below the patient’s alveolar minute ventilation (Ve) such that CO\(_2\) elimination would be inadequate using a non-absorber system. Meakin went on to state that the major advantages of the low-flow technique are only achieved when flows are <1 litre min\(^{-1}\). The lower limit of FGF in a closed system with minimal leak is dependent upon patient oxygen and vapour consumption. Oxygen consumption, as Meakin states, can be calculated from body weight.

In the present study, we defined LFA as FGF:Ve=0.5. This is equivalent to a 50% rebreathing fraction. We chose this definition based on our prior work that demonstrated routine carbon monoxide (CO) detection in the inspiratory limb of the breathing circuit with FGF:Ve<1 and a resultant increase in COHb with FGF:Ve<0.68. In this first study, only the relationship between CO concentration and FGF:Ve achieved significance using longitudinal regression analysis. Thus, we did not report actual flow rates in the present study.

In the current study, the sample stream was intermittent. Sampling exhaled and inspired gas via this process could have removed some CO from the system. This limitation along with using FGF>1 litre min\(^{-1}\) probably means that the amount of inspired CO we detected does not represent the maximum possible when the lowest flow rates are utilized.

However, it should be noted that the peak inspired levels of CO we detected were 14 ppm. Since we used absorbent lacking sodium and potassium hydroxides, all of the CO in the system must have originated from endogenous patient sources. Thus, patients rebreathed up to 14 ppm CO during LFA. In the earlier study, we detected a peak of 18 ppm CO in the inspiratory limb during LFA using conventional CO\(_2\) absorbent. In that work, it was impossible to know if the CO detected was due to rebreathing exhaled gas or if CO was generated within the system. It should be stressed that volatile agents can be degraded by fresh conventional absorbent, producing CO. Up to 23 ppm, CO have been measured within in vitro breathing circuits with low FGF. So, practitioners should not be reassured that modern circuits do not contribute to CO rebreathing during LFA.
The levels of CO we detected in these two studies are not 'small'. In 1971, the US Environmental Protection Agency (EPA) disseminated the United States National Ambient Air Quality Standard for CO. The Standard defined the maximum CO exposure allowable as 9 ppm for 8 h and 35 ppm for 1 h. These recommendations were based on studies that demonstrated an increase in post-exposure COHb (2.9–5.9%) correlating with decreased time to the onset of angina during exercise in adults with coronary artery disease. The CO levels we have detected in the anaesthesia breathing circuit are in this potentially concerning range. However, they represent a subclinical CO exposure; meaning they do not result in obvious physiologic signs or symptoms in our patients. But, is such an exposure safe? The truth is that no one knows what effect a brief CO exposure of 14–18 ppm has on the brain when it is in a critical time of development. This is a key question that our field needs to address and answer before we deem LFA safe for infants and children. In the meantime, using a high-flow strategy and avoiding LFA would certainly limit the rebreathing of CO or any of the other potentially toxic components present in exhaled gas.

Conflict of interest

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