Response: Rebreathing of carbon dioxide during noninvasive ventilation. Is PEEP the final solution?

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Dear Editor,

We would like to thank you for the opportunity to respond to Dr. Dhar et al. and provide clarity to issues of concern with our recent paper, "Potential rebreathing of carbon dioxide during noninvasive ventilation provided by critical care ventilator" [1].

While unlikely that noninvasive ventilation (NIV) would be used clinically at a low level of positive end-expiratory pressure (PEEP), the concern is that a lack of a leak at any level of PEEP may result in CO_2 rebreathing. A leak occurred at all PEEP levels in this study because a cannula was placed in the participants' noses to measure CO_2. Without that cannula, CO_2 rebreathing could be higher.

Regarding Dhar et al.'s comment about our paper's primary objective, this pilot study aimed to determine if CO_2 rebreathing existed in a dual limb circuit and, if so, the amount of PEEP needed to flush the CO_2 from the mask. The finding that increasing the PEEP level significantly lowered CO_2 rebreathing was important, as it indicates a low probability that our results are due to chance. We did not perform a sample size calculation due to this study's exploratory (pilot) nature. We agree that more extended experiments might have answered more questions, but that was beyond this pilot study's scope. We feel strongly that our findings should be tested in clinical settings.

Regarding comments about our methodology, we agree that mask fit is important. All masks were sized and secured appropriately for study volunteers. As in the clinical setting, masks were secured but not overtightened. The volunteer in figure 1 notably does have a light beard [1]. We did not consider this an issue as the critical care ventilator normally triggered and cycled with all participants, which indicated the leak was acceptable [2]. Regarding the washout period between the PEEP and masks, we felt it was more important to allow a washout between the masks than between the PEEP levels. It is important to consider volunteers' time and willingness to volunteer if the time commitment was longer. Every mask started at zero PEEP and increased to 5 cm H_2O, and as observed, CO_2 rebreathing significantly decreased. These are normal volunteers, so regardless of the baseline CO_2 at each PEEP level, it appears that 5 min is enough time to clear CO_2 at higher levels of PEEP, which is evident in figures 2 and 3 [1].

Regarding Dhar et al.'s comment, there were no significant differences in minute ventilation between the PEEP levels. This finding can likely be explained by the leak compensation feature on the ventilator. The ventilator used in the pilot study was a PB980 (Covidien USA, Medtronic, Minneapolis, MN) with leak compensation software. We agree that leak compensation should have been added to the paper's methods section.

Dhar et al. suggest that no or minimal leak is essential for essential ventilation and PEEP maintenance, citing a study from 2011 that demonstrated that a NIV performed better than critical care ventilators [3]. Others have shown that critical care ventilators with leak compensation can synchronize well with various simulated leaks [4]. Neither of these studies tested the ventilator used in our pilot project. Clinically, it is common to have leaks during NIV, and mask overtightening should be avoided to decrease the likelihood of skin breakdown [5]. Regarding leaks, we think ventilator synchronization with the patient is more important than a slight decrease in pressure noted in the bench study [3]. Ventilator pressures can be adjusted to achieve clinical goals.

Our pilot project intended to determine if CO_2 rebreathing occurred during NIV with a dual limb circuit and critical care ventilator. We also sought to understand if CO_2 clearance changes with increasing PEEP. Our findings demonstrated that CO_2 rebreathing does occur during NIV with a dual limb circuit, and PEEP did impact CO_2 clearance from the masks. We also found that leaks increased as PEEP increased. While our findings are interesting and thought-provoking, clinical studies are needed to determine if this occurs clinically and its clinical significance, if any.

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