Capnodynamic Estimation of Lung Volumes: Teething Issues of a Potential Early Warning System

To the Editor:

I would like to commend Albu *et al.*[1] for their well-designed study evaluating the correlation between effective lung volume (ELV) and end-expiratory lung volume (EELV) in healthy and surfactant-depleted rabbit lungs with various levels of positive end-expiratory pressure.

The results have indicated that the correlation between ELV and EELV improves with higher positive end-expiratory pressure, and is best in surfactant-depleted lungs, with the ELV being an overestimate of ELV in healthy lungs by as much as 150 ± 13% at 0 cm H_2O. The authors have hypothesized that this is due to carbon dioxide being an intrinsic gas and the ELV/EELV difference is affected by changes in pulmonary capillary volume and ventilation–perfusion mismatch. There are other methodological factors that may affect this correlation, but no method is able to satisfactorily correct for those, and any attempt may potentially require a more complicated set-up than the elegant one Albu *et al.* propose.[2]

However, for neonatal patients (whom a rabbit model is supposed to simulate), lung injury is on a continuum from healthy to surfactant-depleted. Generally a surfactant-depleted state is avoided by the following two interventions—antenatal glucocorticoid therapy and the instillation of exogenous surfactant into the neonatal lung. Therefore, most neonates requiring ventilator support for perioperative or critical care will be somewhere in the middle—having neither healthy nor surfactant-depleted lungs. The lack of demonstrable reliability of ELV in this gray zone undermines the utility of its absolute value as an estimation of the EELV in this setting.

The authors imply that trending the change in ELV would be more useful than the absolute value. I would be concerned however that the percentage change in ELV and EELV postlavage differs significantly between different positive end-expiratory pressure values. The difference is greatest at 0 and 9 cm H_2O, but this mitigates the issue somewhat because an optimal and protective lung ventilation strategy in neonates is unlikely to be at these extremes. Nevertheless, it may be difficult to estimate the degree of change in actual lung volumes after a decrease in ELV, and may lead a provider to utilize an overly aggressive recruitment strategy that could potentially result in barotrauma.

It should be noted that the sensitivity of ELV to changes to effectiveness in ventilation and as a rough measure of physiological dead space could be useful when paired with other indices that together may indicate lung dysfunction.[3] For example, a decreasing ELV with increasing airway resistance and pressures can serve as a preliminary warning before an appreciable increase in ET_{CO_2} or a suboptimal arterial blood gas result. At present, such dysfunction is only detected after an arterial blood gas result, and there is no simple, continuous and noninvasive method to detect lung atelectasis and institute recruitment measures early.

I believe the greatest value of this study is that the method they describe can be easily implemented as part of an early warning protocol for recruitment manoeuvres, and then a gauge of the effectiveness of the intervention.[3] Further studies and modification of the algorithm should be done to improve the accuracy of ELV as an estimate of EELV in various lung states and ventilator settings. This may then allow its potential to be realized as a simple yet powerful tool currently absent from the arsenal available to modern anesthesiologists and intensivists.

Competing Interests

The author declares no competing interests.

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In Reply:

We thank Dr. Zeng for the thoughtful comments regarding our article. We totally agree that estimating effective lung volume (ELV) by the capnodynamic method may offer an early detector for loss in lung volume. In the lavage-depleted lung model, we mimic a heterogeneous lung, a condition that is often encountered in pediatric clinical practice. Although we agree that neonates have a continuum state between normal and surfactant-depleted lungs, we still face a heterogeneous condition with regional differences in ventilation distribution. This condition was well demonstrated recently by our research group[1] and is confirmed by the significant increase in lung clearance index observed in the current study.[2]