Examining the effect of positive end-expiratory pressure on gas exchange and lung mechanics

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Introduction

Setting ventilator pressures in critically ill patients requires consideration of the effects on both lung mechanics and gas exchange. Increasing positive end-expiratory pressure (PEEP) recruits collapsed lung compartments improving gas exchange, however, high pressures can also cause ventilator associated lung injury (VALI). Many studies have analysed these effects independently, using blood gas measurements, dynamic compliance and static pressure volume curves to discuss optimal PEEP settings. However, recent studies have highlighted the need to consider the combined effects of PEEP changes on lung mechanics and gas exchange. This study investigates the effects of changes in PEEP on both gas exchange, using a model of oxygen transport in the lungs, and lung mechanics, using methods of measuring the static pressure-volume (PV) curve and the dynamic compliance (C_{dyn}).

Methods

After approval of the local animal ethics committee, six pigs (weight ≈ 50 kg) were anesthetised, placed in prone position and mechanically ventilated. Acute lung injury was induced by oleic acid. PEEP titrations were performed, and lung mechanics and gas exchange measurements were taken at each PEEP level. Gas exchange measurements consisted of estimating intrapulmonary shunt (shunt) and alveolar-pulmonary capillary oxygen pressure difference (ΔPO_2) [1]. Lung mechanics measurements consisted of measuring static PV curves [2], and calculating C_{dyn}.

Results

ΔPO_2 and shunt prior to oleic acid infusion were negligible in all pigs at a PEEP of 5 cm H_2O. After oleic acid infusion, all pigs showed an increase in ΔPO_2, a reduction in dynamic and static compliance, and increased hysteresis in the static PV curve. The reduction in C_{dyn} was found to be proportional to the level of ΔPO_2 increase, so pigs with the highest level of lung damage, as measured by the ΔPO_2, had the lowest C_{dyn}. As PEEP increased, ΔPO_2 was found to decrease approximately linearly for all pigs, with a gradient of (mean ± SD) -0.78 ± 0.22 (R^2 = 0.91 ± 0.11). Gas exchange continued to improve with increasing PEEP for the applied range of settings. Increases in PEEP from 0 to 10 cm H_2O caused increased C_{dyn}. However, C_{dyn} remained constant or decreased for PEEP levels above 10 cm H_2O. The PEEP changes increasing C_{dyn} occurred around the lower part of the static PV curve, while PEEP changes reducing C_{dyn} occurred around the upper part. Only 1 pig showed any measurable shunt, which decreased linearly as PEEP increased, with a slope coefficient of -0.018 (R^2 = 0.99). The lack of shunt in this study, in contrast to previous similar studies, could be due to the prone positioning of the pigs.

Conclusions

In this type of lung damage, it appears that changes in ΔPO_2 and shunt are inversely proportional to PEEP changes, and that ΔPO_2 continues to decrease even at high PEEP levels. However, this proportionality does not apply to C_{dyn}, possibly indicating recruitment at low PEEP levels, but over-distension at high PEEP levels, which could lead to VALI. This study shows that, using a model of oxygen transport in the lungs, and methods of measuring the static PV curve and C_{dyn}, it is possible to investigate the relationship between lung mechanics and gas exchange. The results reinforce the importance of considering both gas exchange and lung mechanics when setting PEEP.

References

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