Commentary

Does perfluorocarbon deoxygenate during partial liquid ventilation?

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Abstract

Perfluorocarbons accumulate in the dependent regions of the lungs, which may result in regional hypoxia if ventilation with oxygen is insufficient to oxygenate the dependent perfluorocarbon-filled alveoli. In this issue of *Critical Care*, Max *et al* present data that demonstrate a decrease in arterial oxygen tension (PaO_2) at 30 min compared to that observed at 5 min after administration of FC 3280. These data suggest failure of on-going ventilation/oxygenation to support the initial increase in PaO_2 attributed to the oxygen dissolved in the administered perfluorocarbon. Studies such as this one demonstrate that development of the optimal partial liquid ventilation (PLV) technique is ongoing.

Keywords: acute lung injury, partial liquid ventilation, perfluorocarbon

PLV has piqued the fascination of critical care practitioners since it was described in 1991 [1]. It was proposed to enhance gas exchange in the setting of the acute respiratory distress syndrome, and laboratory studies quickly demonstrated that alveolar recruitment and redistribution of pulmonary blood flow, presumably due to the presence of the high-density perfluorocarbons in the dependent regions of the lungs, contributed to the observed improvement in gas exchange [2–4]. It was also noted, both in the laboratory and the clinical settings, that perfluorocarbons accumulated predominately in the dependent regions of the lungs [5,6]. This observation led to the concern that areas of relative hypoxia might exist if ventilation with oxygen was insufficient to oxygenate the perfluorocarbon-filled alveoli in these regions. It is worthwhile to note that oxygenation of the perfluorocarbon-filled alveolus is likely dependent on convection, rather than diffusion, because the diffusion of oxygen in a liquid is several orders of magnitude less than that in a gas. Whether this dependent hypoxic phenomenon occurs has not been defined. Tutuncu *et al* [7] demonstrated a reduction in oxygenation in normal rabbits in which pulmonary perfluorocarbon was administered. That ventilation–perfusion matching may be compromised in these normal animals suggests that oxygenation of the liquid-filled alveolus may be incomplete.

In this issue of *Critical Care*, Max *et al* [8] examine the time course of changes in arterial oxygenation after administration of 7.5 ml/kg of the perfluorocarbon FC 3280 into the lungs of saline lavage lung-injured pigs. Specifically, the authors measured PaO_2 and other physiologic parameters at 5 and 30 min after perfluorocarbon instillation, with the hypothesis that a time-dependent decrease in PaO_2 would suggest failure of ongoing ventilation–oxygenation to support the initial increase in PaO_2 attributed to the oxygen dissolved in the administered perfluorocarbon. Indeed, the authors observed two important findings: first, a dose-dependent increase in PaO_2 was observed;

PaO_2 = arterial oxygen tension; PLV = partial liquid ventilation.

and second, PaO_2 at 30 min was significantly less than that observed at 5 min after administration of 22.5 and 30 ml/kg FC 3280. The latter is an intriguing observation that suggests that oxygenation of the perfluorocarbon may be insufficient after initial administration. There are, however, a number of issues that need to be considered in the interpretation of these findings. One premise of the derived conclusions is that the administered perfluorocarbon was sufficiently oxygenated so as to have a substantial impact on PaO_2. We have no information on the oxygenation status of the perfluorocarbon at the time of administration, however. Even so, the theoretic amount of oxygen contributed by fully saturated FC 3280 would be fairly small (approximately 3 ml O_2/kg).

One enhancement to the study by Max *et al* [8] might be to assess the effect of hyperoxygenated, room air, and deoxygenated perfluorocarbon on pulmonary gas transport at 5 min and 30 min after dosing. These data would provide more convincing evidence that an increase in oxygenation at 5 min and the subsequent decrease at 30 min were due to changes in perfluorocarbon oxygen content. Other confounding variables that may affect the difference in PaO_2 between 5 and 30 min include evaporation of FC 3280 and changes in other physiologic variables, such as cardiac output, which might independently affect PaO_2. For instance, oxygen delivery, probably the most important parameter of oxygen dynamics, is not significantly different between the 5-min and 30-min time periods in the study.

Studies such as that by Max *et al* [8] contribute toward refining the PLV technique; these data might suggest that application of higher levels of peak inspiratory pressure or positive end-expiratory pressure could enhance gas distribution and minimize the effects observed. The technique of perfluorocarbon administration and the amount dosed may need to be altered. It would be intriguing to consider whether similar findings would be observed in newborn animals in which the relatively small height of the chest is less likely to provide regional differences in perfluorocarbon and gas distribution.

A randomized, controlled, multicentered study evaluating PLV in adults with the acute respiratory distress syndrome is underway. However, the pilot study preceding that trial [9] failed to demonstrate an enhancement in parameters of oxygenation in the PLV group when compared with the conventional mechanical ventilation group. We have much to learn about PLV and, even though it is currently undergoing clinical trials, we are still defining the optimal application of this technique.

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