Eun-Ho Lee, M.D., In-Cheol Choi, M.D. University of Ulsan College of Medicine, Seoul, Korea (I.-C.C.). icchoi@amc.seoul.kr

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Complications of One-lung Ventilation: Is It the Blood Flow or the Ventilation?

To the Editor:

The results of the study of management of one-lung ventilation by Blank *et al.*[1] suggest that adequate positive end-expiratory pressure (PEEP) is an important factor in reducing pulmonary complications. Blank *et al.*[1] provide an excellent discussion of the mechanical mechanisms and implications. I suggest an alternative or additional possible explanation of the beneficial effects of PEEP. The ventilated lung is subjected to increased blood flow, and this hyperemia may create additional shear stress, resulting in damage to the endothelial glycocalyx, which can then result in clinically significant respiratory complications.[2–4] Studies support the concept that increased pulmonary blood flow may induce lung injury or aggravate a preexisting injury state.[5–9] PEEP to the ventilated lung may reduce this hyperemia and hence reduce complications. Lower tidal volumes and the resultant reduced inspiratory pressure may result in more hyperemia, thus offsetting any potential beneficial effect of the expected reduced volutrauma. If we find a way to protect the glycocalyx or otherwise reduce the hyperemia to the ventilated lung, it is possible that lower tidal volumes may have a net beneficial effect. Larger tidal volumes to the ventilated lung may increase inspiratory pressure, resulting in less hyperemia and less damage to the glycocalyx, but damage from volutrauma could still occur.

Unfortunately, this hypothesis creates a clinical dilemma. Reducing blood flow by the application of PEEP to the ventilated lung may result in a greater shunt with potential desaturation. Applying continuous positive airway pressure (CPAP) to the operative lung to treat desaturation may not be as much of a problem. While the percentage of blood flow to the ventilated lung may increase, thus reducing shunt, it is unclear if there is an absolute increased blood flow to the ventilated lung as a result of the CPAP; the CPAP may just reduce blood flow to the operative lung with no change in blood flow to the ventilated lung.

This hypothesis is consistent with their results. Blank *et al.*[1] found that low tidal volume and low PEEP, conditions that would be expected to increase blood flow to the ventilated lung, are associated with increased pulmonary complications. In the presence of PEEP, which would be expected to decrease blood flow to the operative lung, low tidal volume ventilation is protective.

The concept of pulmonary hyperemia being a cause of pulmonary complications is also consistent with the observations that pulmonary complication rates increase with increased amounts of pulmonary resection. For a given cardiac output, hyperemia may occur because of the reduced pulmonary vascular bed. In the most extreme case of a pneumonectomy, hyperemia would be expected to be maximal and complication rates are the highest; pulmonary edema may result from hyperemia-induced damage to the glycocalyx.

Further studies that incorporate measures of pulmonary blood flow would be helpful. Additional studies should also evaluate carbon dioxide management. Hypercarbia causes pulmonary artery vasoconstriction, which may reduce hyperemia, would require less minute ventilation, thus reducing the risk of volu- or barotrauma while trying to normalize the partial pressure of carbon dioxide, and may by itself be pneumoprotective. Permissive hypercarbia also permits lower respiratory rates, thus reducing the risk of potentially damaging air trapping.

Competing Interests

The author declares no competing interests.

Jonathan V. Roth, M.D. Department of Anesthesiology, Albert Einstein Medical Center, Philadelphia, Pennsylvania. rothj@einstein.edu

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This letter was sent to the author of the original article referenced above, who declined to respond.— Evan D. Kharasch, M.D., Ph.D., Editor-in-Chief.

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Selecting the Level of Positive End-expiratory Pressure for One-lung Ventilation: "By Formula" or "By Feel"?

To the Editor:

Blank *et al.*[1] confirm that one-lung ventilation (OLV) is not without risk, but I have grave doubts about whether it is reasonable to conclude that "advances in our understanding of protective ventilation during OLV are likely to derive from well-designed randomized trials controlling for variables of inherent pathophysiologic significance." The latter proviso, "controlling for variables of inherent pathophysiologic significance," identifies the difficulties presented by the wide variety of respiratory pathophysiology seen in thoracic surgical patients, as has recently been pointed out in relation to another, unrelated issue of OLV.[2]

Perhaps the quest for optimal protective ventilation should be directed more toward basic physiologic issues such as those identifiable in the now largely disregarded "art" of OLV. This particular "art" relied on three key aspects of two-handed manual ventilation with the adjustable "pressure relief valve" carefully adjusted to ensure that ventilation does not result in the standard adult 2-l reservoir bag progressively emptying or overfilling. First, judiciously applied manual ventilation enables the lung to be ventilated at the perceived optimal respiratory system dynamic compliance, as assessed by the ease with which gas is squeezed into it. (Incidentally, in the era before fiberoptic bronchoscopy was in clinical use for OLV, the clinical assessment of compliance [of both the ventilated lung and the "operated" lung] was invaluable for the optimal placement of a double-lumen tube.)

Second, the rate at which gas vents from the lung can also be readily assessed "by feel." (A delay in venting [from either the ventilated or the "operated" lung] could be caused by pathophysiology as varied as chronic airway obstruction or emphysema, by bronchospasm or secretions, or by a bronchial cuff partially obstructing gas flow.) This assessment of the "expiratory gas flow rate" can be facilitated by temporarily reducing the "fresh gas flow" into the ventilating "system/circuit" to say 0.5 to 1.0 l/min, whereupon the gas returning to the reservoir bag during the expiratory phase of manual ventilation is coming predominantly from the lung. Where the "expiratory gas flow rate" as assessed is low, a lesser level or no positive end-expiratory pressure (PEEP) is likely to be indicated.

Third, the "inspiratory gas flow rate" can also be usefully assessed. To me, manual ventilation during OLV has always felt intuitively most satisfying (easiest) when generated with a "square wave" airway pressure; and because a monitored "square wave" airway pressure can be generated instantaneously by conscientious two-handed manual ventilation, the rate at which gas empties from the reservoir bag enables the specific assessment of the well-accepted "physiologic" decelerating pattern of inspiratory gas flow. Furthermore, when manually ventilating (with an *instantaneously* applied "square wave" airway pressure) at a relevant predetermined respiratory rate and a suitably low tidal volume for a given patient (and with the monitored tidal volume maintained at a *constant* level), I believe that it is possible to identify a level of applied (extrinsic) PEEP at which the delivery of the "decelerating gas flow" into the ventilated lung is easiest. (Such a level of PEEP will be expected in those patients with an initial "flat" component of the static compliance plot.) But does this perceived ease of delivering gas from a 2-l reservoir bag (at a decelerating pattern of flow) correlate with a high *initial* (peak) inspiratory gas flow rate? Would it not, therefore, be both interesting and potentially clinically relevant to undertake a study plotting the level of applied PEEP against the *initial* (peak) inspiratory gas flow rate (as accurately recorded at the airway) in patients with differing respiratory pathophysiologies?

Many years of varied thoracic surgical experience has led me to believe that the greater the respiratory pathophysiology, the more important is carefully monitored, conscientiously performed manual ventilation in determining the initial settings for the mechanical ventilator, as described in just one interesting case report.[3]

To me, it seems most unlikely, considering the wide variety of respiratory pathophysiology seen in thoracic surgical

This letter was sent to the author of the original article referenced above, who declined to respond.—Evan D. Kharasch, M.D., Ph.D., Editor-in-Chief.