(ie, esophagectomy, open lobectomy, and pneumonectomy). This may also suggest that centers that specialize in minimally invasive lung surgery may employ other modern perioperative, intraoperative, and postoperative measures as previously described, which combine to minimize risk of acute lung injury from OLV.

References

1. Lohser J, Slinger P. Lung injury after one-lung ventilation: a review of the pathophysiologic mechanisms affecting the ventilated and the collapsed lung. *Anesth Analg*. 2015;121:302-18.
2. Brassard CL, Lohser J, Donati F, Bussières JS. Step-by-step clinical management of one-lung ventilation: continuing professional development. *Can J Anaesth*. 2014;61:1103-21.
3. The Acute Respiratory Distress Syndrome Network. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *N Engl J Med*. 2000;342:1301-8.
4. Peel J, Funk D, Slinger P, Srinathan S, Kidane B. Tidal volume during 1-lung ventilations: a systematic review and meta-analysis. *J Thorac Cardiovasc Surg*. 2022;163:1573-85.e1.
5. Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, Brunelli A, Cerfolio RJ, Gonzalez M, et al. Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS) Society and the European Society of Thoracic Surgeons (ESTS). *Eur J Cardiothorac Surg*. 2019;55:91-115.

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Commentary: The tid(al)s are turning toward lower volumes

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Previous literature has largely supported the use of lung protective ventilation (LPV) with lower tidal volumes in patients with acute respiratory distress syndrome (ARDS), finding that LPV with lower tidal volumes is associated with lower postoperative morbidity and mortality, likely through reduced stretch-induced lung injury and decreased release of inflammatory mediators.^{1,2}

However, literature supporting the use of LPV with low tidal volumes in patients without ARDS during intraoperative 1-lung ventilation has lagged behind the ARDS literature. This may be a result of greater emphasis placed on sustaining normal pH and arterial carbon dioxide partial pressure rather than protecting the lung from injurious stretch in patients without ARDS.^{1,3} Recently, though, an increasing body of evidence shows that patients without

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CENTRAL MESSAGE

In this meta-analysis by Peel and colleagues, low tidal volume ventilation was not associated with worsened oxygenation or compliance and was associated with reduced postoperative pulmonary complications.

ARDS are susceptible to ventilator-induced lung injury and may benefit from LPV with lower tidal volumes.⁴⁻⁶

In this issue of the *Journal*, Peel and colleagues⁷ report a well-designed systematic review and random-effects meta-analysis of 18 studies to assess the effect of low tidal volume on perioperative outcomes. In total, 3963 patients who underwent pulmonary resection or esophagectomy with 1-lung ventilation were included. Of note, patients with severe preoperative pulmonary or cardiopulmonary disease were excluded. When compared with conventional tidal volumes (8.1 ± 3.1 mL/kg), low tidal volumes (5.6 ± 0.9 mL/kg) were associated with a decreased risk of developing postoperative pulmonary complications

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(pooled odds ratio, 0.40 [0.29-0.57]; $P < .0001$). There were also no significant differences found in oxygenation, compliance, length of stay, or mortality between conventional and low tidal volume approaches. The finding that low tidal volume is associated with lower postoperative morbidity has considerable significance. No heterogeneity was observed in this comparison ($I^2 = 0\%$, $P = .94$), further strengthening the significance of the observed lower morbidity among patients with low tidal ventilation.

The majority of studies included in the analysis involved low tidal volume with positive end-expiratory pressure (PEEP). As a result, the effect of low-tidal volume on perioperative outcomes could not be assessed independently from PEEP. The co-administration of low tidal volumes with PEEP is likely due to their synergistic effect: Low tidal volumes minimize alveolar distension and barotrauma, whereas PEEP minimizes atelectotrauma.^{8,9} Blank and colleagues¹⁰ reported that low tidal volumes without PEEP increased the risk of pulmonary morbidity. Thus, it is possible that the reduction in postoperative morbidity in the present study is a result of the combined effect of low tidal volume and PEEP. In accordance with these observations, the authors recommended a 1-lung ventilation strategy of low tidal volumes no greater than 6 mL/kg with PEEP of at least 5 cmH₂O and lung recruitment.

Although well designed, there were some limitations in this meta-analysis, and these were adequately addressed by the authors. Peel and colleagues⁷ appropriately addressed the ways in which heterogeneity could have affected the results. Importantly, the heterogeneity of the analysis evaluating the impact of conventional versus low tidal volume strategy on postoperative morbidity was low at 0% and is one of the strengths of the meta-analysis. The authors acknowledged that variation in practice (eg, differences in anesthetic choice, use of PEEP, lung recruitment, ventilation mode, intravenous fluid administration, and differences in the timing of measurement) can affect heterogeneity. Of note, variation in lung protective strategies is a major challenge for knowledge translation in this field. This is why robust data synthesis is needed and why

this study by Peel and colleagues⁷ is a welcome addition to the literature.¹¹

The findings of this study are important contributions to improving patient safety in thoracic surgery. Peel and colleagues⁷ should be congratulated for their efforts, pushing the frontier to better understand how low tidal volume should be used in thoracic surgery to protect against perioperative ventilator-induced lung injury. Although further research must be done to understand the ideal protective ventilation strategy during thoracic surgery with 1-lung ventilation, it is clear: Low tidal volumes should be a part of it.

References

1. Brower RG, Matthay MA, Morris A, Schoenfeld D, Thompson BT, Wheeler A. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *N Engl J Med*. 2000;342:1301-8.
2. Brower RG, Lanken PN, MacIntyre N, Matthay MA, Morris A, Ancukiewicz M, et al. Higher versus lower positive end-expiratory pressures in patients with the acute respiratory distress syndrome. *N Engl J Med*. 2004;351:327-36.
3. Grune J, Tabuchi A, Kuebler WM. Alveolar dynamics during mechanical ventilation in the healthy and injured lung. *Intensive Care Med Exp*. 2019;7(Suppl 1):34.
4. Wolthuis EK, Vlaar APJ, Choi G, Roelofs JJTH, Juffermans NP, Schultz MJ. Mechanical ventilation using non-injurious ventilation settings causes lung injury in the absence of pre-existing lung injury in healthy mice. *Crit Care*. 2009;13:R1.
5. Rackley CR, MacIntyre NR. Low tidal volumes for everyone? *Chest*. 2019;156:783-91.
6. Hu X-Y, Du B. Lung-protective ventilation during one-lung ventilation: known knowns, and known unknowns. *J Thorac Dis*. 2019;11(Suppl 3):S237-40.
7. Peel JK, Funk DJ, Slinger P, Srinathan S, Kidane B. Tidal volume during 1-lung ventilation: a systematic review and meta-analysis. *J Thorac Cardiovasc Surg*. 2022;163:1573-85.e1.
8. Halter JM, Steinberg JM, Gatto LA, DiRocco JD, Pavone LA, Schiller HJ, et al. Effect of positive end-expiratory pressure and tidal volume on lung injury induced by alveolar instability. *Crit Care*. 2007;11:R20.
9. Chu EK, Whitehead T, Slutsky AS. Effects of cyclic opening and closing at low- and high-volume ventilation on bronchoalveolar lavage cytokines. *Crit Care Med*. 2004;32:168-74.
10. Blank RS, Colquhoun DA, Durieux ME, Kozower BD, McMurphy TL, Bender SP, et al. Management of one-lung ventilation: impact of tidal volume on complications after thoracic surgery. *Anesthesiology*. 2016;124:1286-95.
11. Kidane B, Choi S, Fortin D, O'Hare T, Nicolaou G, Badner NH, et al. Use of lung-protective strategies during one-lung ventilation surgery: a multi-institutional survey. *Ann Transl Med*. 2018;6:269.