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Translating evidence into practice in ARDS: teamwork, clinical decision support, and behavioral economic interventions

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Abstract

Purpose of the review—While the treatment of the Acute Respiratory Distress Syndrome (ARDS) with low tidal volume (LTV) mechanical ventilation improves mortality, it is not consistently administered in clinical practice. This review examines strategies to improve LTV and other evidence-based therapies for patients with ARDS.

Recent findings—Despite the well-established role of LTV in the treatment of ARDS, a recent multi-national study suggests it is under-utilized in clinical practice. Strategies to improve LTV include audit and feedback, provider education, protocol development, interventions to improve ICU teamwork, computer decision support, and behavioral economic interventions such as making LTV the default ventilator setting. These strategies typically target all patients receiving invasive mechanical ventilation, effectively avoiding the problem of poor ARDS recognition in clinical practice. To more effectively administer advanced ARDS therapies, such as prone positioning, better approaches for ARDS recognition will also be required.

Summary—Multiple strategies can be utilized to improve adherence to low tidal volume ventilation in ARDS patients.

Keywords

Acute Lung Injury; Quality Improvement; Behavioral Economics

Introduction

The Acute Respiratory Distress Syndrome (ARDS) is a critical illness syndrome with high mortality affecting 23% of patients requiring invasive mechanical ventilation (1). While multiple evidence-based therapies can improve outcomes in ARDS, the most well-established is the provision of low tidal volumes (LTV) during invasive mechanical ventilation (2). Yet, a recent multi-national study of 3022 ARDS patients published in 2016 suggests that ARDS is infrequently recognized in clinical practice and ARDS patients do not receive LTV despite its strong evidence basis (1). Other work has demonstrated that in ARDS patients who receive LTV, it is frequently delayed (3). This review describes

strategies to improve care for ARDS patients, with a key focus on the delivery of LTV. It discusses the relevance of these strategies to other ARDS therapies such as prone positioning, and highlights the use of team-based approaches, electronic health record (EHR) decision support, and behavioral economic principles to improve ARDS care.

How well has low tidal volume ventilation been adopted in clinical practice for ARDS patients?

Two clinical trials published in 1998 (4) and 2000 (5) provide strong evidence for the mortality benefit of LTV in patients with ARDS. The second, a multi-center ARDSnet investigation of 861 patients demonstrated an 8.8% absolute decrease in mortality when patients were randomized to tidal volumes of 6 versus 12 ml/kg ideal body weight (IBW). Based on this evidence, a recent multi-society clinical practice guideline confirmed the importance of LTV in managing ARDS patients and strongly recommended that ARDS patients receive mechanical ventilation with strategies that limit tidal volumes (4–8 ml/kg IBW) and inspiratory pressure (plateau pressure <30 cm H₂O) (2).

In the 15 years since publication of the ARDSnet investigation, multiple studies have highlighted the persistently poor adherence to LTV in clinical practice. The first, published two years after ARDSnet, found that average tidal volumes declined from 11.2 ml/kg to 10.1 ml/kg IBW in three teaching hospitals after study publication, well above the 6 ml/kg IBW trial target (6). Subsequent studies have confirmed an ongoing poor adherence to LTV in clinical practice (7–11). The most recent and comprehensive, the LUNG-SAFE study, enrolled patients receiving mechanical ventilation in 459 Intensive care units from 50 countries (1). While 3022 patients fulfilled ARDS Berlin criteria, clinicians recognized patients with ARDS only 34% of the time on the day they fulfilled all ARDS clinical criteria, and only 60% during the hospital stay. In addition, while the mean tidal volume of ARDS patients was 7.6 ml/kg IBW, 35% of patients with ARDS received tidal volumes > 8 ml/kg IBW. This seminal study's main conclusion was that clinicians frequently fail to recognize patients with ARDS, and do not consistently administer LTV ventilation to these patients.

What are the barriers and facilitators to LTV administration?

Low adherence to LTV mechanical ventilation prompted research to examine barriers and facilitators of LTV administration. Early work began by looking at providers. In a 2004 survey, nurses and respiratory therapists identified physician unwillingness to relinquish ventilator control, physician under-recognition of ARDS, and physician perceptions of contraindications to LTV as the major barriers to initiating this therapy (12). Participants identified concerns regarding patient discomfort, tachypnea, and hypercapnia as barriers to continuing LTV ventilation. Techniques for overcoming these barriers included having specific ventilator protocol recommendations, clinician education, and tools to assess patient discomfort. A 2007 survey also identified knowledge deficits in the goals of LTV delivery the relative contra-indications as another major barrier to its delivery (13). Evaluation of physician documentation found that uncertainty in an ARDS diagnosis and concerns regarding metabolic acidosis contributed lower LTV adherence (14). In the same study,

physicians sometimes believed LTV was being administered based on their clinical documentation, even though it was not actually getting administered, suggesting that poor communication and coordination between multi-disciplinary ICU teams could also be contributing.

Specific organizational factors are also associated with low LTV use. For example, the presence of a written protocol for the delivery of LTV ventilation was found to be associated with increased use of this therapy (15). In addition, patients are more likely to receive LTV ventilation when their care was directed by an ICU team or when consultation from a board-certified intensivist was mandatory (16). Under-recognition of ARDS among providers is also frequently cited as reason for low LTV adherence across multiple studies (1, 8, 10, 17). These insights on the barriers and facilitators of LTV delivery help to inform strategies to improve LTV adherence.

What are effective strategies to improve low tidal volume ventilation adherence?

Multiple strategies have been shown to improve adherence to low tidal volume ventilation (Table). For pragmatic reasons, efforts to improve LTV ventilation generally target all mechanically ventilated patients, not just those with ARDS. This approach circumvents the well-known problem of poor clinician recognition of ARDS (25, 26). Evidence also suggests that LTV ventilation may be beneficial to all patients and does not cause harm (27). The trade-off in targeting all patients is that clinicians may have a higher tolerance for non-compliance. For example, if a practice audit demonstrated that 20% of patients in an ICU received more than 8 mL/kg IBW, this might be an acceptable level of non-compliance among providers. Knowing the specific level of LTV non-compliance in ARDS patients might still be useful, as tolerance for LTV non-compliance in ARDS patients should be lower. Yet by targeting all patients, the specific effect of these strategies on ARDS patients is usually unknown.

Audit, feedback and educational interventions

Most interventions to improve the use of LTV ventilation begin with an educational activity coupled with audit and feedback to providers on current LTV adherence. In one of the first studies to demonstrate LTV improvement after intervention, Wolthuis *et al* audited current use of LTV ventilation in three ICUs, and then provided ICU physicians education and feedback on their current use of LTV ventilation (18). The education consisted of discussing LTV studies, the need to calculate IBW to determine appropriate tidal volume, and possible reasons not to use low tidal volumes. ICU nurses also participated at two of three centers. After the intervention, average tidal volumes significantly decreased from 9.7 to 8.0 mL/kg IBW ($p < 0.01$). In the single center where a follow-up evaluation was performed at 1 year, tidal volumes remained consistently lower.

Protocol Development

A ICU protocol for LTV administration may also improve the consistency of tidal volume delivery and LTV adherence. Rolling out a new protocol at an individual ICU or

organization can be effective when performed concurrently with an educational initiative. For example, Yilmaz *et al* reported large reductions in tidal volumes after performing a staged quality improvement intervention that included both provider education and new ventilator protocol (19). Tidal volumes significantly declined from a median of 10.6 to 8.7 ml/kg IBW ($p < 0.01$) after the educational initiative of didactic and web-based teaching to physicians, nurses and respiratory therapists, and then declined significantly more to 7.7 ml/kg ($p < 0.01$) after institution of the respiratory therapy protocol. The protocol consisted of limiting tidal volumes to < 10 ml/kg IBW for all patients, and recommended 6–8 ml/kg IBW for any patient felt to be at risk for ARDS. Despite evidence that LTV protocols improve compliance with this therapy, a recent survey of United States ICU nurse managers in Pennsylvania found that less than half had a specific LTV ventilation protocol (28).

Team-based interventions

Because ICU patients are managed by a multi-disciplinary team of providers, and physicians, nurses, and respiratory therapists are all involved in the delivery of LTV ventilation, team based interventions can also improve LTV adherence. A large cluster randomized trial of Brazilian ICUs published in 2016 demonstrated the effectiveness of team-based interventions for multiple ICU processes of care (20). This intervention was performed in ICUs that had not previously performed multi-disciplinary rounding, and included the institution of daily multi-disciplinary rounds that included the use of checklists to evaluate adherence to ICU processes of care, and daily goal setting among team members. In addition, a nurse prompted the team later in the day to ensure follow-through with checklist adherence. The intervention lead to improvement in adherence to LTV ventilation from 58.9% to 67.5%, but was underpowered to detect whether this further translated into mortality benefits (29).

Integrated decision support in electronic health records

Clinical decision support systems in EHR systems can also improve LTV adherence, although the usability and acceptability of these tools to clinicians have not been carefully examined. Eslami *et al*. developed a simple pop-up window that displayed patient-specific tidal volume recommendations at the time the respiratory data page was viewed on patients receiving mechanical ventilation (21). After implementation, tidal volumes > 6 ml/kg IBW decreased by 10% for patients receiving mechanical ventilation for > 24 hours ($p = 0.01$). In a follow-up study, they found the pop-up window was less effective when it only displayed on patients who were receiving high tidal volumes, and they also found that LTV adherence declined when the CDS was turned off (30). Evaluating the effect of a CDS during computer order entry, Bagga *et al*. developed a pop-up tidal volume recommender at the time of initiation or change of a ventilator order, which had to be clicked closed prior to order completion (22). After implementation, average initial tidal volumes declined significantly from 8.9 ml/kg to 8.1 ml/kg IBW ($p < 0.01$), and the number of patients who were given initial tidal volumes > 10 ml/kg IBW declined from 20% to 4% ($p < 0.01$).

A comprehensive EHR ARDS alert system notifying providers by text page if ARDS patients were receiving higher ventilator settings was evaluated by Herasevich *et al*. in 2011 (23). The system identified ARDS patients utilizing a previously validated algorithm that

searched for patients with a $\text{PaO}_2/\text{FiO}_2 < 300$ and (“bilateral” AND “infiltrates”) OR “edema” on a portable chest x-ray report (9). Pulmonary fellows and respiratory therapists were alerted if ARDS patients received injurious tidal volumes for more than one hour. To minimize alerts, the algorithm only alerted providers about a patient once per 24 hours, and only during the patient’s first 3 hospital days. After implementation, the quantity of time patients with ARDS were exposed to potentially injurious tidal volumes significantly decreased from 40 to 27 hours ($p < 0.01$). In a post-study usability survey of 40 respiratory therapists, 19% felt the algorithm sent false alarms which were “common and annoying,” and 19% felt the alert was not useful.

Behavioral economic strategies

Because human behavior is often influenced by cognitive, social, and emotional factors, there is increasing interest in capitalizing on these behavioral patterns to nudge patient or physician decision-making, while still preserving choice (31). In a 2016 study, investigators evaluated two behavioral economic strategies to improve compliance with LTV (24). In the first, ventilators were configured so tidal volumes would default to 6 ml/kg IBW at the start of invasive mechanical ventilation, unless manually overridden by a clinician. Because of the extra effort required to delivered higher settings, tidal volumes were significantly lower when the default was set to 6 ml/kg IBW. In the second, two electronic dashboards were mounted in the ICU displaying tidal volume settings for all ventilated patients. Patients receiving tidal volumes > 8 ml/kg IBW were highlighted in red, providing an efficient visual cue to clinicians of the elevated settings. Introduction of the dashboard to also significantly reduced tidal volumes after during the study period.

Delivery of advanced ARDS therapies: higher PEEP, prone positing, neuromuscular blockade

While strategies to improve LTV adherence have targeted all patients, this approach would not be feasible or appropriate for other evidence-based ARDS therapies, given their inherent risks. A recently published multi-society guideline included a strong recommendation for prone positioning of more than 12 hours per day in patients with severe ARDS, and a conditional recommendation for the use of a higher PEEP strategy in patients with moderate to severe ARDS (2). No recommendation was made for or against extracorporeal membrane oxygenation (ECMO), nor did the guideline address the use of neuromuscular blockade (32), although another multi-center clinical trial is still ongoing (33). Intervention studies to increase use of a high PEEP are limited, and it is not clear whether targeting all patients receiving invasive mechanical ventilation would be acceptable to physicians. The specific amount of PEEP recommended for each level of FiO_2 is not well defined in current guidelines, so operationalizing this recommendation is also difficult. Adopting the PEEP ladder from one of the high PEEP clinical trials is likely appropriate (34–36), with additional caution that plateau pressures should be monitored and remain < 30 cm Hg (2).

It would not be acceptable to utilize prone-positioning for more than 12 hours in all patients to ensure its administration to patients with severe ARDS patients. While this therapy has been shown to improve mortality in severe ARDS patients (37), it also requires higher levels

of sedation and is associated with increased risk of endotracheal obstruction, pressure sores, and requires an increased level ICU resources to safely administer, including multiple ICU staff members to turn patients. Any attempt to improve utilization of prone positioning will need to address the ongoing challenge of ARDS recognition. Similar approaches will be necessary if neuromuscular blockade or ECMO become more well established in ARDS. Here automated systems to help clinicians synthesize electronic health data and alert clinicians to patients developing severe ARDS may be useful to ensure timely administration of therapies (11).

Conclusion

Despite the well-established role of LTV in the treatment of ARDS, recent evidence suggests it remains under-utilized in clinical practice. Strategies to improve LTV include audit and feedback, provider education, protocol development, ICU team based interventions, computer decision support, and default LTV ventilator settings. Most strategies generally target all patients receiving invasive mechanical ventilation, circumventing the problem of poor ARDS recognition. To more effectively administer advanced ARDS therapies, such as prone positioning, or to ensure high-level LTV compliance in ARDS patients, better approaches for ARDS recognition may also be required.

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References

- **1. Bellani G, Laffey JG, Pham T, Fan E, Brochard L, Esteban A, et al. Epidemiology, Patterns of Care, and Mortality for Patients With Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries. *JAMA: the journal of the American Medical Association*. 2016; 315(8): 788–800. The lung safe study was a large, multi-national prospective cohort study of patients receiving mechanical ventilation. Its primary finding was that clinicians frequently failed to recognize patients with ARDS, and ARDS patients were not consistently given low tidal volume ventilation. [PubMed: 26903337]
- **2. Fan E, Del Sorbo L, Goligher EC, Hodgson CL, Munshi L, Walkey AJ, et al. An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: Mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome. *American journal of respiratory and critical care medicine*. 2017; 195(9):1253–63. This is a multi-society guideline statement for the mechanical ventilation in patients with ARDS. Recommendations include: 1) low tidal volume ventilation in all ARDS patients (strong recommendation), 2) Prone position in severe ARDS (strong recommendation), 3) High PEEP strategy (conditional recommendation), 4) Recruitment maneuvers (conditional recommendation). [PubMed: 28459336]
3. Needham DM, Colantuoni E, Mendez-Tellez PA, Dinglas VD, Sevransky JE, Dennison Himmelfarb CR, et al. Lung protective mechanical ventilation and two year survival in patients with acute lung injury: prospective cohort study. *BMJ (Clinical research ed)*. 2012; 344:e2124.

4. Amato MB, Barbas CS, Medeiros DM, Magaldi RB, Schettino GP, Lorenzi-Filho G, et al. Effect of a protective-ventilation strategy on mortality in the acute respiratory distress syndrome. *The New England journal of medicine*. 1998; 338(6):347–54. [PubMed: 9449727]
5. 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. *The New England journal of medicine*. 2000; 342(18):1301–8. [PubMed: 10793162]
6. Weinert CR, Gross CR, Marinelli WA. Impact of randomized trial results on acute lung injury ventilator therapy in teaching hospitals. *American journal of respiratory and critical care medicine*. 2003; 167(10):1304–9. [PubMed: 12574072]
7. Young MP, Manning HL, Wilson DL, Mette SA, Riker RR, Leiter JC, et al. Ventilation of patients with acute lung injury and acute respiratory distress syndrome: has new evidence changed clinical practice? *Critical care medicine*. 2004; 32(6):1260–5. [PubMed: 15187503]
- *8. Weiss CH, Baker DW, Weiner S, Bechel M, Ragland M, Rademaker A, et al. Low Tidal Volume Ventilation Use in Acute Respiratory Distress Syndrome. *Critical care medicine*. 2016 This was a retrospective study of ventilator practice at three US hospitals, including two non-academic hospitals. It found there was poor compliance with low-tidal volume ventilation in ARDS patients.
9. Herasevich V, Yilmaz M, Khan H, Hubmayr RD, Gajic O. Validation of an electronic surveillance system for acute lung injury. *Intensive care medicine*. 2009; 35(6):1018–23. [PubMed: 19280175]
10. Kalhan R, Mikkelsen M, Dedhiya P, Christie J, Gaughan C, Lanken PN, et al. Underuse of lung protective ventilation: analysis of potential factors to explain physician behavior. *Critical care medicine*. 2006; 34(2):300–6. [PubMed: 16424706]
11. Sjoding MW, Hyzy RC. Recognition and Appropriate Treatment of the Acute Respiratory Distress Syndrome Remains Unacceptably Low. *Critical care medicine*. 2016; 44(8):1611–2. [PubMed: 27428124]
12. Rubenfeld GD, Cooper C, Carter G, Thompson BT, Hudson LD. Barriers to providing lung-protective ventilation to patients with acute lung injury. *Critical care medicine*. 2004; 32(6):1289–93. [PubMed: 15187508]
13. Dennison CR, Mendez-Tellez PA, Wang W, Pronovost PJ, Needham DM. Barriers to low tidal volume ventilation in acute respiratory distress syndrome: survey development, validation, and results. *Critical care medicine*. 2007; 35(12):2747–54. [PubMed: 17901838]
14. Mikkelsen ME, Dedhiya PM, Kalhan R, Gallop RJ, Lanken PN, Fuchs BD. Potential reasons why physicians underuse lung-protective ventilation: a retrospective cohort study using physician documentation. *Respiratory care*. 2008; 53(4):455–61. [PubMed: 18364057]
15. Umoh NJ, Fan E, Mendez-Tellez PA, Sevransky JE, Dennison CR, Shanholtz C, et al. Patient and intensive care unit organizational factors associated with low tidal volume ventilation in acute lung injury. *Critical care medicine*. 2008; 36(5):1463–8. [PubMed: 18434907]
16. Cooke CR, Watkins TR, Kahn JM, Treggiari MM, Caldwell E, Hudson LD, et al. The effect of an intensive care unit staffing model on tidal volume in patients with acute lung injury. *Critical care (London, England)*. 2008; 12(6):R134.
17. Ferguson ND, Frutos-Vivar F, Esteban A, Fernandez-Segoviano P, Aramburu JA, Najera L, et al. Acute respiratory distress syndrome: underrecognition by clinicians and diagnostic accuracy of three clinical definitions. *Critical care medicine*. 2005; 33(10):2228–34. [PubMed: 16215375]
18. Wolthuis EK, Korevaar JC, Spronk P, Kuiper MA, Dzoljic M, Vroom MB, et al. Feedback and education improve physician compliance in use of lung-protective mechanical ventilation. *Intensive care medicine*. 2005; 31(4):540–6. [PubMed: 15731892]
19. Yilmaz M, Keegan MT, Iscimen R, Afessa B, Buck CF, Hubmayr RD, et al. Toward the prevention of acute lung injury: protocol-guided limitation of large tidal volume ventilation and inappropriate transfusion. *Critical care medicine*. 2007; 35(7):1660–6. [PubMed: 17507824]
- **20. Cavalcanti AB, Bozza FA, Machado FR, Salluh JI, Campagnucci VP, Vendramim P, et al. Effect of a Quality Improvement Intervention With Daily Round Checklists, Goal Setting, and Clinician Prompting on Mortality of Critically Ill Patients: A Randomized Clinical Trial. *JAMA: the journal of the American Medical Association*. 2016; 315(14):1480–90. This cluster randomized trial of 118 Brazilian ICUs tested an intervention that included multi-disciplinary rounding with

checklists and daily goal-setting on 11 ICU processes of care. Although no reduction in mortality was seen, there was improvement in some ICU processes of care including low tidal volume ventilation. [PubMed: 27115264]

21. Eslami S, de Keizer NF, Abu-Hanna A, de Jonge E, Schultz MJ. Effect of a clinical decision support system on adherence to a lower tidal volume mechanical ventilation strategy. *Journal of critical care*. 2009; 24(4):523–9. [PubMed: 19327326]
22. Bagga S, Paluzzi DE, Chen CY, Riggio JM, Nagaraja M, Marik PE, et al. Better ventilator settings using a computerized clinical tool. *Respiratory care*. 2014; 59(8):1172–7. [PubMed: 24327745]
23. Herasevich V, Tsapenko M, Kojicic M, Ahmed A, Kashyap R, Venkata C, et al. Limiting ventilator-induced lung injury through individual electronic medical record surveillance. *Critical care medicine*. 2011; 39(1):34–9. [PubMed: 20959788]
- **24. Bourdeaux CP, Thomas MJ, Gould TH, Malhotra G, Jarvstad A, Jones T, et al. Increasing compliance with low tidal volume ventilation in the ICU with two nudge-based interventions: evaluation through intervention time-series analyses. *BMJ open*. 2016; 6(5):e010129. This study tested two behavioral economic interventions to lower tidal volumes in a single ICU: 1) making low tidal volumes the default ventilator setting and 2) creating a large ventilator dash-board to clearly display excessive tidal volumes. Both interventions reduced tidal volumes in mechanically ventilated patients.
25. Laffey JG, Pham T, Bellani G. Continued under-recognition of acute respiratory distress syndrome after the Berlin definition: what is the solution? *Current opinion in critical care*. 2017; 23(1):10–7. [PubMed: 27922845]
26. Sjoding MW, Cooke CR, Iwashyna TJ, Hofer TP. Acute Respiratory Distress Syndrome Measurement Error: Potential Effect on Clinical Study Results. *Annals of the American Thoracic Society*. 2016
27. Serpa Neto A, Cardoso SO, Manetta JA, Pereira VG, Esposito DC, de Pasqualucci MO, et al. Association between use of lung-protective ventilation with lower tidal volumes and clinical outcomes among patients without acute respiratory distress syndrome: a meta-analysis. *JAMA: the journal of the American Medical Association*. 2012; 308(16):1651–9. [PubMed: 23093163]
- *28. Kohn R, Madden V, Kahn JM, Asch DA, Barnato AE, Halpern SD, et al. Diffusion of Evidence-based Intensive Care Unit Organizational Practices. A State-Wide Analysis. *Annals of the American Thoracic Society*. 2017; 14(2):254–61. This study provides the results of a survey of ICU nurse managers in the State of Pennsylvania on organizational practices, and found there was limited use of some evidence-based management practices, such as protocols for low tidal volume mechanical ventilation or prone positioning in ARDS. [PubMed: 28076685]
29. Sjoding M, Iwashyna TJ. Care for ARDS in 2016: room to improve. *The Lancet Respiratory medicine*. 2016; 4(12):936–7. [PubMed: 27890497]
30. Eslami S, Abu-Hanna A, Schultz MJ, de Jonge E, de Keizer NF. Evaluation of consulting and critiquing decision support systems: effect on adherence to a lower tidal volume mechanical ventilation strategy. *Journal of critical care*. 2012; 27(4):425e1–8.
31. Loewenstein G, Brennan T, Volpp KG. Asymmetric paternalism to improve health behaviors. *JAMA: the journal of the American Medical Association*. 2007; 298(20):2415–7. [PubMed: 18042920]
32. Papazian L, Forel JM, Gacouin A, Penot-Ragon C, Perrin G, Loundou A, et al. Neuromuscular blockers in early acute respiratory distress syndrome. *The New England journal of medicine*. 2010; 363(12):1107–16. [PubMed: 20843245]
33. Huang DT, Angus DC, Moss M, Thompson BT, Ferguson ND, Ginde A, et al. Design and Rationale of the Reevaluation of Systemic Early Neuromuscular Blockade Trial for Acute Respiratory Distress Syndrome. *Annals of the American Thoracic Society*. 2017; 14(1):124–33. [PubMed: 27779896]
34. 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. *The New England journal of medicine*. 2004; 351(4):327–36. [PubMed: 15269312]
35. Meade MO, Cook DJ, Guyatt GH, Slutsky AS, Arabi YM, Cooper DJ, et al. Ventilation strategy using low tidal volumes, recruitment maneuvers, and high positive end-expiratory pressure for

- acute lung injury and acute respiratory distress syndrome: a randomized controlled trial. JAMA: the journal of the American Medical Association. 2008; 299(6):637–45. [PubMed: 18270352]
36. Mercat A, Richard JC, Vielle B, Jaber S, Osman D, Diehl JL, et al. Positive end-expiratory pressure setting in adults with acute lung injury and acute respiratory distress syndrome: a randomized controlled trial. JAMA: the journal of the American Medical Association. 2008; 299(6):646–55. [PubMed: 18270353]
37. Guerin C, Reignier J, Richard JC, Beuret P, Gacouin A, Boulain T, et al. Prone positioning in severe acute respiratory distress syndrome. The New England journal of medicine. 2013; 368(23): 2159–68. [PubMed: 23688302]

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Key points

- Despite the well-established role of low tidal volume mechanical ventilation in ARDS patients, the therapy remains underutilized in clinical practice
- Strategies to lower tidal volumes generally target all patients receiving mechanical ventilation and include audit and feedback, provider education, protocol development, and team-based interventions.
- Electronic health records are an effective platform for improving compliance with low tidal volume ventilation when reminders are displayed during computer order entry or during respiratory data review.
- When low tidal volume ventilation is the default option, it makes providers more likely to administer this therapy without limiting their ability choose an alternative.
- Strategies to increase use of advanced therapies (e.g. prone positioning) for severe ARDS will need to also address the problem of poor ARDS recognition in clinical practice.

Table

Strategies to improve compliance with low tidal volume mechanical ventilation

Strategy	Description and rationale	Example Citations
Audit and feedback	Critical for assessing current compliance, provides intrinsic motivation to improve, and is also necessary for evaluating the effect of any quality improvement intervention	Wolthuis <i>et al</i> (18)
Provider education	In-person activity or online module to remind providers of low tidal volume benefits, the importance of setting volumes based on ideal body weight, and to address concerns regarding perceived harms and contraindications	Wolthuis <i>et al</i> (18), Yilmaz <i>et al</i> (19)
Written ventilator protocol	Increase consistency of the tidal volumes administered and ensure settings are determined based on ideal body weight	Yilmaz <i>et al</i> (19)
Multi-disciplinary rounding with checklists, goal setting	Teams of providers are involved in ventilator management decisions (physicians, nurses, and respiratory therapists) and should have shared tidal volume goals for each patient	Cavalcanti <i>et al</i> (20)
Clinical decision support in electronic health records	Customize electronic health records to provide low tidal volume ventilation reminders at convenient times	Eslami <i>et al</i> (21), Bagga <i>et al</i> (22), Herasevich <i>et al</i> (23)
Default low tidal volume ventilator settings	Make 6 – 8 ml/kg ideal body weight the default tidal volume while still allowing providers to choose alternative settings	Bourdeaux <i>et al</i> (24)