Resident Journal Review

Mechanical Ventilation in the Emergency Department

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Introduction

Patients with respiratory failure are commonly encountered in the emergency department (ED), and many of these patients progress to require endotracheal intubation and mechanical ventilation. Mechanical ventilation strategies were the focus on a recent Annals of Emergency Medicine Clinical Controversy. Since its publication, there have been a number of newer studies suggesting that perhaps ventilation with low tidal volume can improve outcomes for many ED patients with respiratory failure, not just those with the acute respiratory distress syndrome (ARDS). This “Resident Journal Review” goes through the pertinent recent literature on low tidal volume ventilation.

We begin with an investigation regarding the use of low tidal volume ventilation in the ED among patients with and without ARDS. The investigators found that low tidal volumes are infrequently used in both scenarios. The impact of this becomes clearer, as the following three articles note a variety of improvements in patients ventilated with lower tidal volumes. There is a suggestion that even a 1mL/kg difference from a lung-protective strategy can worsen clinical outcomes.


This is a retrospective, observational cohort study of ED patients who required intubation and met criteria for severe sepsis or septic shock. The primary outcome was development of acute lung injury (ALI) within the first five days of admission to the ICU. ALI was defined using the American-European consensus definition of ARDS, which includes the presence of bilateral alveolar infiltrates on chest x-ray, PaO_{2}/FiO_{2} ratio <300, and absence of any clinical evidence of left atrial hypertension. The authors evaluated the number of ED patients ventilated with “lung-protective” ventilation (defined as <8mL/kg ideal body weight (IBW)), whether patients already meeting criteria for ALI were more likely to be put on lung-protective ventilation, and risk factors for development of ALI.

The authors found that 27.5% of patients developed ALI in the hospital. Higher BMI (adjusted odds ratio 1.09, IQR 1.03-1.14, p<0.001), Sequential Organ Failure Assessment (SOFA) score (aOR 1.13, IQR 1.03-1.25, p<0.03) and need for vasopressor use (aOR 2.80, IQR 1.16-7.20, p<0.02) were the only statistically significant risk factors associated with development of ALI. Interestingly, high tidal volume ventilation was not associated with the development of ALI, but the study was not powered to find such a difference.

The findings characterizing the types of ventilation strategies used in the ED were revealing. Lung-protective ventilation was used in only 27.1% of patients in the ED. Furthermore, patients who met criteria for ALI at time of ED admission (8.8%) were no more likely to be placed on lung-protective ventilation settings than those without ALI at presentation (9.0mL/kg IBW compared with 8.7mL/kg IBW, p=0.40). The authors also note that ventilator settings were changed and plateau pressures were checked in the ED only 30% of the time.

Overall, this study suggests that patients with ALI, and those at-risk for developing it, are uncommonly placed on lung-protective ventilation strategies in the ED. This particular study found no correlation between higher tidal volumes and the development of ARDS, but that brings us to our next study.


This study examines the effect of lung-protective mechanical ventilation in patients who do not have ARDS. Current evidence has shown that lung-protective mechanical ventilation decreases morbidity and mortality in patients with ARDS, but whether there is any benefit in patients who do not have ARDS is less clear. This meta-analysis attempts to

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determine if in fact higher or lower tidal volumes are associated with lung injury, mortality, pulmonary infection, and atelectasis in patients on mechanical ventilation who have no pre-existing evidence of lung injury.

Articles were included in the analysis if they evaluated two different ventilation strategies in patients without ARDS at the onset of mechanical ventilation. Both randomized trials and observational studies were included, without restrictions on language or whether patients were evaluated in the ICU or the operating room. The GRADE approach was used to summarize the quality of evidence for each outcome. Development of lung injury was the primary end point. Secondary end points included overall survival, incidence of pulmonary infection and atelectasis, ICU and hospital length of stay, time to extubation, change in PaCO₂, arterial pH, and change in the ratio of PaO₂ to fraction of inspired oxygen (FiO₂).

Twenty articles met the inclusion criteria and data on 2,822 patients were analyzed. Of the articles included, 15 were observational studies and five were randomized controlled trials. Forty-seven of the 1,113 (4.2%) patients in the lung-protective ventilation group developed lung injury during follow-up while 138 of 1,090 (12.7%) developed lung injury in the conventional ventilation group (RR 0.33; 95% CI (0.23-0.47): NNT, 11).

Overall, mortality was lower in patients receiving lung-protective ventilation (RR 0.64; 95% CI 0.46-0.89: NNT 26). There was also a decreased incidence of pulmonary infection and atelectasis with lower tidal volume ventilation (RR 0.45; 95% CI 0.22-0.92: NNT 26 and RR 0.62; 95% CI 0.41-0.95, respectively). Protective ventilation was associated with shorter mean hospital stay (6.91 vs 8.87 days, 95% CI 0.20-0.82) and showed no difference in ICU stay or time of mechanical ventilation (3.63 vs 4.64 days, 95% CI -0.53-1.27 and 51.07 vs 47.12 hours, 95% CI -0.27-1.23).

The authors encourage the interpretation of these results within the context of the articles included. Publication bias may exaggerate the conclusions, as negative studies may have less chance of being published. Also, it is important to note that the majority of studies included patients ventilated for a short duration. Fifteen of the included studies had scheduled surgery as the indication for mechanical ventilation. This makes it difficult to extrapolate the results to patients intubated for different indications or who are ventilated for longer durations.

Overall, there is some reasonable evidence that low tidal volume ventilation in patients without ARDS results in improved outcomes.

**Fuller BM, Mohr NM, Drewry AM, Carpenter CR. Lower tidal volume at initiation of mechanical ventilation may reduce progression to acute respiratory distress syndrome: A systematic review. Crit Care. 2013,17:R11.**

While, as discussed above, it has become accepted practice to use low tidal volume settings in patients who meet criteria for ARDS, the effect of “lung-protective” ventilation strategies on patients prior to the onset of ARDS has been less clear. In light of this conflict, Fuller et al., set out to examine the existing literature, specifically looking at high versus low tidal volumes and their effect on the development of ARDS.

Authors included 13 out of 1,704 studies found via a search of MEDLINE, EMBASE, CINAHL, the Cochrane Library, ClinicalTrials.gov, and a manual search of unpublished clinical studies. Studies were included only if tidal volume for intubated patients was independently studied as a predictor of ARDS development. They excluded studies that did not objectively define ARDS, and in which tidal volume was not the only variable manipulated to examine effect. Appropriate studies for inclusion were agreed upon by independent review of two investigators, with disagreements settled by a third.

The 13 studies consisted of one RCT and 12 observational studies conducted between 2004 and 2011. The investigators reported that they were only able to assess the quality of the one RCT, as none of the observational studies commented on their adherence to STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. There was a great deal of variation between the methods and populations included in each study, as well as the underlying illnesses contributing to respiratory failure requiring ventilation, and the actual definition of ARDS used by the studies themselves. For this reason, the investigators felt it was inappropriate to perform a meta-analysis of all of the included data.

The RCT by Determann et al., found a 10.9% decrease in absolute risk for developing ARDS with tidal volumes of 6mL/kg predicted body weight, as compared to 10mL/kg. One of the three studies set in the operating room (OR) found an association between tidal volume and development of ARDS, but its two variable groups were not significantly different in terms of tidal volume. Six of nine ICU studies found that tidal volume was an independent predictor of ARDS development, and five studies demonstrated a dose-response relationship between increasing tidal volumes and incidence of ARDS.

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Overall, ARDS occurred early after intubation (primarily within four days), less often in OR patients compared to ICU patients (an average of ~1% vs. up to 44%, respectively), and corresponded to increased morbidity (length of stay, days ventilated, organ failure) and mortality. While not the focal point of this review, other factors such as presence of restrictive lung disease or transfusion of blood products also correlated with ARDS development, indicating that a multimodal approach is likely to be the most beneficial in preventing ARDS.

The authors of this review correctly concluded that they could not offer a definitive recommendation on the best tidal volume strategy for patients at risk of developing ARDS. The majority of their data came from observational studies, and there were too many inherent differences between the studies to equalize them with a meta-analysis, precluding any strengthening of the data by increased power (n).

Overall, the current evidence seems to point to a link between higher tidal volumes and development of ARDS, especially for patients at greater risk based on other factors.


Patients with acute lung injury requiring mechanical ventilation have high rates of mortality after hospital discharge. Lung-protective ventilation has been shown to reduce short-term mortality in these patients by nearly 10%. Needham and colleagues’ 2012 publication suggests that long-term mortality can also be reduced with greater use of lung-protective ventilation strategies in ICU patients with acute lung injury. This prospective cohort study followed patients who were mechanically ventilated with acute lung injury for a total of 24 months after hospital discharge. The primary outcome was overall mortality. The authors reviewed patient data from a total of 13 individual ICUs in Baltimore, Maryland. Germaine to the authors’ review was not only whether or not a patient was mechanically ventilated and their long-term mortality, but the specific ventilator settings and if these settings were lung-protective. Adherence to lung-protective ventilator settings was defined as a tidal volume less than or equal to 6.5mL/kg predicted body weight as well as a plateau pressure of less than or equal to 30cm of water.

A total of 485 patients were included in this study, with 85% of these patients coming from medical ICUs. A total of 41% of these patients had ventilator settings considered to be lung-protective. The authors concluded that lung-protective ventilation strategies were associated with a statistically significant decrease in two year mortality of 3% (HR 0.97, 95% CI 0.95 to 0.99, p=.002). Further analysis of the data showed that, when compared to patients with no adherence to lung-protective ventilation, patients with 50% adherence had an absolute risk reduction of mortality over two years of 4.0% (0.8% to 7.2%, p=0.012) and patients with 100% adherence had a 7.8% reduction (1.6% to 14.0%, p=0.011). Also, for every increase of average tidal volume by 1mL/kg of predicted body weight, there was an 18% relative increase in mortality.

The most significant limitation of this study is the observational aspect; so although there is correlation, causation cannot be proven. However, given that the ARDS Network has established the short-term mortality benefit in lung-protective ventilation strategies, a randomized controlled trial looking at long-term mortality benefit would not be ethical. The study was also only conducted in one geographic area and only at academic medical centers, which may limit its generalizability.

Despite these limitations, the study’s results suggest that lung-protective ventilation is associated with an increase in long-term survival in patients with acute lung injury. This builds upon the conclusions of the ARDS Network study that showed a benefit to short-term survival. The results further emphasize that many patients with acute lung injury (59% in this study) may actually not be receiving lung-protective ventilation at all. Given this, there stands to be further improvement in overall post-ICU mortality if these parameters were more consistently applied in clinical practice.

Overall, adherence to lung-protective ventilator settings decreases overall mortality in patients with acute lung injury up to 24 months after hospital discharge. Increases of just 1 ml/kg above lung-protective settings increase long-term mortality.

Conclusions

- Patients with ARDS are often not started on low tidal volumes in the ED.
- Low tidal volume ventilation in patients without ARDS may result in improved outcomes.
- In at-risk patients, higher tidal volumes are associated with the development of ARDS.
- Lung-protective ventilation decreases long-term mortality in patients with ARDS.
- Increases of just 1mL/kg above lung-protective settings increase long-term mortality.

Additional References