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Research Article

Practices to Lower the Mortality Rate and Duration of Invasive Mechanical Ventilation in Patients Suffering from Acute Respiratory Distress Syndrome; Systematic Review

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Abstract

Background: Acute Respiratory Distress Syndrome characterized by Refractory hypoxemia, inflammation, and alveolar destruction, which necessitates mechanical ventilation. In order to minimize ventilator-induced lung damage and lower mortality, ventilatory methods must be used. This systematic review aims to assess various ventilation methods utilized in intensive care units for critically sick patients to lower death rates and ventilation time.

Method: This study was conducted according to The PRISMA statement. We conducted a search of electronic databases (PubMed, Scopus, and Google scholar) for articles on mortality rate and duration of invasive mechanical ventilation in patients suffering from acute respiratory distress syndrome published in the period from 2016 to 2024. We include randomized controlled trials, prospective and retrospective cohort studies, and observational studies.

Result and Conclusion: We include 7 articles in this review, the included studies discussed different ventilation strategies and their effect on mortality rates and mechanical ventilation duration in critically ill patients. The findings from the included studies show the role of lung-protective ventilation, prone positioning, high-frequency oscillatory ventilation, extracorporeal membrane oxygenation, oxygenation targets, and spontaneous breathing trials in the improvement of patient outcomes. We found that lung-protective strategies, early mobilization, and adjunctive interventions were needed to reduce mortality and ventilation duration in critically ill patients. LTVV, prone positioning, HFOV, ECMO, and oxygenation target optimization emerged as an important strategies to improve outcomes.

Keywords: Mortality Rate; Duration of Invasive Mechanical Ventilation; Acute Respiratory Distress Syndrome

Abbreviation

ARDS: Acute Respiratory Distress Syndrome; IMV: Invasive Mechanical Ventilation; VILI: Ventilator-Induced Lung Injury; APRV: Airway Pressure Release Ventilation; ECMO: Extracorporeal Membrane Oxygenation; PEEP: Positive End-Expiratory Pressure; HFOV: High-Frequency Oscillatory Ventilation; CMV: Conventional Mechanical Ventilation; LTVV: Low Tidal Volume Ventilation; NOS: Newcastle-Ottawa Scale; RoB: Risk of Bias; ICU: Intensive Care Unit; MV: Mechanical Ventilation; VAP: Ventilator-Associated Pneumonia; FiO_2: Fraction of Inspired Oxygen; PaO_2: Partial Pressure of Arterial Oxygen; SBT: Spontaneous Breathing Trial; NIV: Non-Invasive Ventilation; ESICM: European Society of Intensive Care Medicine; ATS: American Thoracic Society; RCT: Randomized Controlled Trial; LRM: Lung Recruitment Maneuver; UPV: Ultraprotective Ventilation

Introduction

Acute Respiratory Distress Syndrome (ARDS) is characterized by refractory hypoxemia, inflammation, and alveolar damage, and required mechanical ventilation. The mortality rate remains high, ranging from 30–45%, despite advancements in critical care [1]. Use of ventilatory strategies is important to reducing mortality and minimizing ventilator-induced lung injury (VILI). Different approaches were explored, which include airway pressure release ventilation (APRV) [2,3], prone positioning before ECMO [4], and individualized PEEP strategies [5], all approaches can improve lung recruitment and gas exchange. Studies indicted the risks of hyperoxia [6,7], and the need for careful oxygen titration to prevent complications.

Positive end-expiratory pressure (PEEP) is the a mainstay in the treatment of patients with ARDS who are on mechanical ventilation. PEEP enhances ventilation distribution and may reduce VILI as part of a lung protective ventilation strategy. Randomized clinical trials have assessed many approaches to titrate PEEP based on respiratory mechanics and oxygenation, but the best course of action to enhance clinical results is still unknown [8,9].

PEEP titration based on respiratory mechanics as opposed to oxygenation, or greater vs lower oxygenation-based PEEP, is not recommended by the current European Society of Intensive Care Medicine (ESICM) guideline on ARDS [10]. In contrast, the American Thoracic Society (ATS) guideline on ARDS care supports using greater rather than lower PEEP in patients with moderate to severe ARDS [11] based on two meta-analyses revealing a link between higher PEEP and increased survival in this ARDS subpopulation [12,13].

Aim of the Study

The aim of this systematic review is to evaluate different ventilation strategies used in IMV for critically ill patients, to reduce mortality rates and ventilation duration.

Method

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Figure 1).

Search strategy

We conducted a literature search using PubMed, Scopus, and Google Scholar. The search targeted publications from January 2016 to February 2024. Keywords and Medical Subject Headings (MeSH) used in various combinations included: “Acute Respiratory Distress Syndrome,” “ARDS,” “invasive mechanical ventilation,” “ventilation strategies,” “mortality,” “duration,” “HFOV,” “LTVV,” “ECMO,” “prone positioning,” “PEEP,” and “oxygen therapy.” Boolean operators (AND/OR) were applied to narrow or broaden the search. We also reviewed the reference lists of key articles to identify additional eligible studies.

Inclusion criteria

We include studies published between 2016 and 2024; English-language articles; Randomized Controlled Trials (RCTs), cohort studies (prospective or retrospective), and observational studies; Studies involving adult or neonatal patients diagnosed with ARDS or respiratory failure, received invasive mechanical ventilation (IMV); Studies comparing standard mechanical ventilation strategies (e.g., CMV, SIMV, PSV) with alternative approaches (e.g., HFOV, LTVV, ECMO, prone positioning, etc.); Studies reporting outcomes related to mortality rates and/or duration of IMV.

Exclusion criteria

We exclude case reports, case series, editorials, expert opinions, or narrative reviews; studies lacking comparative data or not focused on ventilation strategies; non-English publications or those not accessible in full text.

Study selection and data extraction

Two reviewers independently screened titles, abstracts, and full-text articles. Any discrepancies were resolved by consensus with a third reviewer. Studies identified in different databases were de-duplicated using reference management software. A standardized Google Form was used for data extraction, including; citation, study type, sample size, patient demographics, interventions, comparator strategies, and key outcomes.

Risk of bias assessment

Newcastle-Ottawa Scale (NOS) was used to assess the quality of 5 studies [1,2,4,6,7], the total score of ≥7 points (High Quality), 5-6 points (Moderate Quality) and ≤4 points (Low Quality), while two studies [3,5] were assessed according to Risk of Bias (RoB 2) (Table 1).

Study	Selection (0-4)	Comparability (0-2)	Outcome (0-3)	Total Score (0-9)	Quality Rating
Lim., et al.	4	2	3	9	High
Tyagi., et al.	3	1	2	6	Moderate
Page., et al.	3	1	2	6	Moderate
Kim., et al.	4	2	3	9	High
Weiss., et al.	3	1	2	6	Moderate

Table 1: Quality assessment according to Newcastle-Ottawa Scale (NOS).

Study	Bias Due to Randomization	Bias Due to Deviations from Intended Intervention	Bias Due to Missing Outcome Data	Bias in Measurement of Outcomes	Bias in Selection of Reported Results	Overall Bias Judgment
Boesing., *et al.*	Low	Low	Some concerns	Low	Low	Low
Zhou., *et al.*	Some concerns	Low	Low	Low	Some concerns	Some concerns

Table 2: Quality assessment according to Risk of Bias (RoB 2).

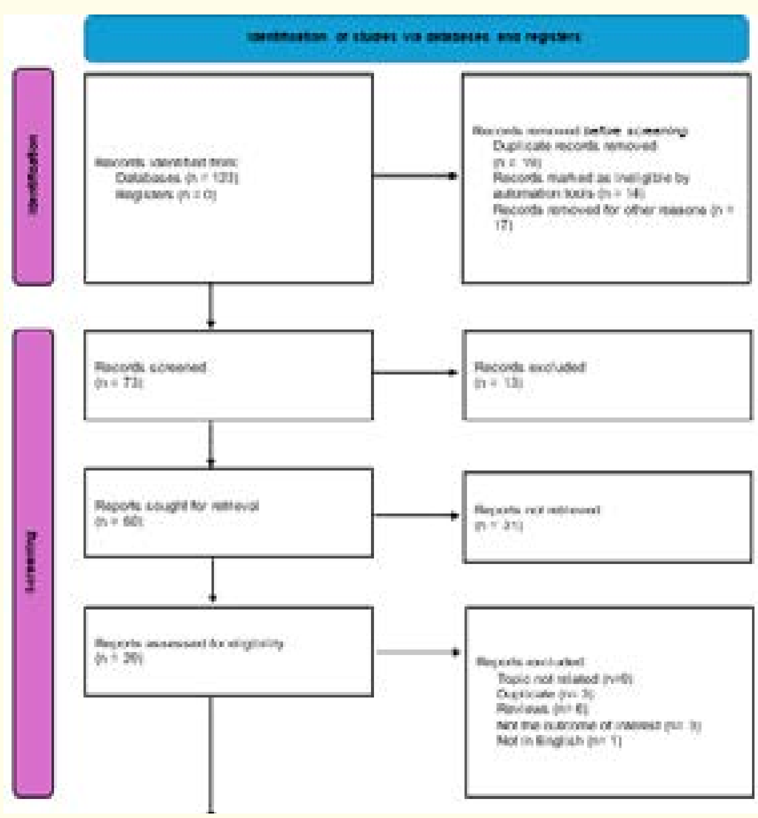

Figure 1: PRISMA consort chart of selected studies.

Results

The included studies discussed different ventilation strategies and their effect on mortality rates and mechanical ventilation duration in critically ill patients (ARDS, respiratory failure, and neonatal respiratory distress). The findings from the included studies show the role of lung-protective ventilation, prone positioning, high-frequency oscillatory ventilation (HFOV), extracorporeal membrane oxygenation (ECMO), oxygenation targets, and spontaneous breathing trials (SBTs) in the improvement of patient outcomes.

Lim., *et al*. [2] and Weiss., *et al*. [1] studied the effect of low tidal volume ventilation (LTVV) on ARDS outcomes. LTVV (4–6 mL/kg predicted body weight) associated with decreased VILI and lower mortality rates in relation to conventional tidal volumes. Lim., *et al*. found that LTVV led to a shorter duration of IMV by the prevention lung overdistension and reduce the need for prolonged sedation. Weiss., *et al*. reported that adoption rates of LTVV remained low due to clinical variations in ventilator management.

Kim., *et al*. studied the effect of prone positioning in patients with severe ARDS on ECMO. They found that prone positioning improved oxygenation, improve lung recruitment, and decrease the risk of ventilator-associated pneumonia (VAP). No statistical significance difference was reached regarding its effect to lower mortality rate. Patients in the prone positioning group had a higher number of ventilator-free days [4].

Zhou., *et al*. and Salvo., *et al*. compared HFOV to conventional mechanical ventilation (CMV) in neonates with respiratory distress syndrome (RDS). HFOV reduced ventilator dependency, decreased the need for reintubation, and shortened hospital stays in neonates. Early initiation of HFOV led to better oxygenation and improved lung compliance, making it a good strategy in preterm infants with severe hypoxemic respiratory failure, but the effects of HFOV on long-term neurodevelopmental outcomes remain uncertain [3]. Boesing., *et al*. tested the outcomes of ultraprotective ventilation (UPV) in combination with ECMO for patients with severe ARDS. Using lower ventilatory pressures with ECMO decrease lung injury and increase survival rates. Patients treated with UPV and ECMO had shorter ventilation duration. Combining extracorporeal oxygenation with lung-protective ventilation decrease mechanical ventilation dependency [5]. Tyagi., *et al*. and Page., *et al*. tested the effects of hyperoxia on mechanically ventilated patients. Both studies found that severe hyperoxia (>200 mmHg) increase mortality rate and ventilation duration. Emergency department patients who were exposed to hyperoxia need longer durations of invasive ventilation [6,7].

Study	Study Aim	Methodology	Participants Characteristics	Demographics	Outcome
Lim., *et al*.	Assess the impact of LTVV on ARDS outcomes	Retrospective cohort study analyzing patient outcomes based on ventilation strategy	ARDS patients requiring mechanical ventilation	Adult ICU patients with ARDS (Median age: 55, 60% male)	LTVV was associated with improved survival and shorter ventilation duration
Tyagi., *et al*.	Evaluate the effect of oxygen targeting strategies on mechanically ventilated patients	Retrospective cohort study evaluating oxygenation targets and mortality rates	Mechanically ventilated adult ICU patients	Critically ill adult patients (Age: 45-70, Male: 65%)	Severe hyperoxia increased mortality and prolonged ventilation duration
Page., *et al*.	Investigate the relationship between emergency department hyperoxia and mortality	Observational cohort study examining hyperoxia exposure in the emergency setting	Patients receiving emergency mechanical ventilation	Emergency department patients requiring intubation (Age: 50-75)	Hyperoxia in the emergency department was associated with higher mortality
Kim., *et al*.	Analyze the effects of prone positioning in ECMO-supported ARDS patients	Prospective observational study analyzing prone positioning impact in ECMO patients	ARDS patients requiring ECMO support	Severe ARDS patients receiving ECMO (Median age: 50, 70% male)	Prone positioning improved oxygenation and trended towards reduced mortality

Boesing., *et al*.	Assess the benefits of ultraprotective ventilation with ECMO in ARDS	Experimental study testing ultraprotective ventilation protocols with ECMO	Patients with severe ARDS receiving ECMO	ARDS patients with ECMO support (Age: 40-65, Male: 60%)	Ultraprotective ventilation with ECMO improved survival and reduced lung injury
Zhou., *et al*.	Compare HFOV vs. CMV in neonatal respiratory distress	Randomized controlled trial comparing HFOV and CMV in neonatal patients	Neonates diagnosed with respiratory distress syndrome (RDS)	Preterm and term neonates with RDS (Gestational age 28-40 weeks)	HFOV improved survival rates and reduced ventilation duration compared to CMV
Weiss., *et al*.	Evaluate the adoption and clinical impact of LTVV in ARDS management	Retrospective cross-sectional study assessing LTVV adoption in ARDS patients	Patients diagnosed with ARDS requiring mechanical ventilation	Adult patients with ARDS on mechanical ventilation (Age: 50-70)	LTVV adoption remained low despite evidence of its benefits

Table 3: Study aim and outcome of included studies.

Discussion

ARDS is a significant issue in critical care, it result in high mortality rates and prolonged durations of IMV. Recent research focused on optimizing mechanical ventilation strategies to improve patient outcomes. Our systematic review discussed practices aimed at reducing mortality and ventilation duration in ARDS patients.

Prone positioning is one of the most effective interventions for ARDS patients, it improves oxygenation and lung compliance by decreasing dorsal lung collapse and improve ventilation-perfusion matching. That prone positioning before ECMO was associated with lower mortality rates and improved ECMO weaning success [4,14]. Proper PEEP titration is important to prevent lung injury and improve oxygenation. Individualized PEEP titration based on esophageal pressure measurements resulted in lower mortality for patients with lower multiorgan dysfunction severity [15]. Electrical impedance tomography (EIT)-guided PEEP showed improved lung compliance and reduced mortality [16]. The response to increased PEEP predicted mortality, reinforcing the importance of individualized PEEP titration based on patient-specific lung mechanics [17].

Lung recruitment maneuvers (LRMs) in combination with LTVV reduced VILI. Gattinoni., *et al*. adviced set PEEP to prevent alveolar collapse because of variation in lung recruitability [18]. Included studies found that protective ventilation with lower driving pressures and tailored recruitment maneuvers can shorten mechanical ventilation duration and lower mortality.

According to Page., *et al*. and Tyagi., *et al*. investigations, the early exposure to high oxygen levels in mechanically ventilated patients increased mortality. The avoidance of excessive oxygen supplementation and targeting normoxia (PaO_2 60–120 mmHg) is crucial in preventing oxygen toxicity and the improvement of patient outcomes [6,7]. Lim., *et al*. and Zhou., *et al*. studied APRV as a rescue strategy for ARDS patients. APRV improved oxygenation, decrease the need for ECMO, and shortened mechanical ventilation duration in select patients. APRV serve as an alternative to conventional volume-controlled ventilation, in refractory cases [2,3].

Several studies, including those by Boesing., *et al*. and Weiss., *et al*., indicated the need for individualized ventilation strategies, which include monitoring lung mechanics, dynamic compliance, and oxygenation response to tailor interventions. Personalized approaches that integrate prone positioning, optimized PEEP, and lung recruitment can increase survival rates and reduce the duration of IMV [1,5].

Early weaning from mechanical ventilation is needed to prevent ventilator-associated complications. The studies indicate that protocolized weaning, including spontaneous breathing trials (SBTs) and early identification of extubation, can reduce ventilation duration. Early mobilization and non-invasive ventilation (NIV) post-extubation prevent reintubation and further complications.

The findings of our systematic review align with previous reviews on ventilatory management strategies in Acute Respiratory Distress Syndrome (ARDS). Our study converge on the importance of lung-protective ventilation, low tidal volume ventilation (LTVV), in reducing mortality and the duration of invasive mechanical ventilation (IMV).

Wang., *et al*. (2016) [19] meta-analysis involved 36 randomized trials and found that LTVV combined with FiO_2-guided higher PEEP and prone positioning is the most effective strategy for lowering mortality. Their hazard ratio for this combination strategy show a significant survival benefit, same as our findings, as we found that LTVV and prone positioning are consistently associated with improved outcomes. However, Wang's study show that permissive hypercapnia and recruitment maneuvers were less effective, and our study noted utility of recruitment maneuvers in conjunction with ECMO or pressure-controlled strategies.

Liaqat., *et al*. (2022) study, [20] found that LTVV lower mortality and identified plateau pressure control, individualized PEEP, and driving pressure optimization as important factors in ARDS management. Our review discussed the benefits of these strategies, through studies utilizing esophageal pressure-guided ventilation, Liaqat's work provided more mechanistic context, strengthening the physiological rationale for these practices. Coleman and Aldrich (2021) [21] found that prone positioning is effective rescue method for severe ARDS. Our study supported these findings, with prone positioning improving oxygenation and reducing ventilator dependency.

Limitations

Our study had some limitations, as some studies show the adverse effects of hyperoxia, highlights oxygen-related complications but does not explore strategies to optimize oxygenation in ARDS patients. Two studies focus on low tidal volume ventilation and prone positioning before ECMO, but the review lacks randomized trials comparing these techniques to alternative management strategies. The reliance on observational studies limits the ability to draw strong conclusions, and reduce the generalizability of findings across diverse ARDS populations.

Conclusion

The included studies indicate the importance of lung-protective strategies, early mobilization, and adjunctive interventions to reduce mortality and ventilation duration in critically ill patients. LTVV, HFOV, prone positioning, ECMO, and oxygenation target optimization emerged as an important strategies to improve outcomes. Further research is needed to refine patient selection criteria and optimize long-term benefits.

Bibliography

1. Weiss CH., *et al*. "Low Tidal Volume Ventilation Use in Acute Respiratory Distress Syndrome". *Critical Care Medicine* 44.8 (2016): 1515-1522.
2. Lim J., *et al*. "Characteristics and outcomes of patients treated with airway pressure release ventilation for acute respiratory distress syndrome: A retrospective observational study". *Journal of Critical Care* 34 (2016): 154-159.
3. Zhou C., *et al*. "Digital material fabrication using mask-image-projection-based stereolithography". *Rapid Prototype Journal* 19.3 (2013): 153-165.
4. Kim WY., *et al*. "Prone positioning before extracorporeal membrane oxygenation for severe acute respiratory distress syndrome: A retrospective multicenter study". *Medical Intensiva* 43.7 (2019): 402-409.
5. Boesing C., *et al*. "Positive end-expiratory pressure management in patients with severe ARDS: implications of prone positioning and extracorporeal membrane oxygenation". *Critical Care* 28.1 (2024): 277.
6. Page D., *et al*. "Emergency department hyperoxia is associated with increased mortality in mechanically ventilated patients: a cohort study". *Critical Care* 22.1 (2018): 9.
7. Tyagi S., *et al*. "Outcomes and Predictors of Severe Hyperoxemia in Patients Receiving Mechanical Ventilation: A Single-Center Cohort Study". *Annals of the American Thoracic Society* 19.8 (2022): 1338-1345.
8. Slutsky AS and Ranieri VM. "Ventilator-Induced Lung Injury". *The New England Journal of Medicine* 369.22 (2013): 2126-2136.

9. Gattinoni L and Marini JJ. "In search of the Holy Grail: identifying the best PEEP in ventilated patients". *Intensive Care Medicine* 48.6 (2022): 728-731.

10. Qadir N., *et al*. "An Update on Management of Adult Patients with Acute Respiratory Distress Syndrome: An Official American Thoracic Society Clinical Practice Guideline". *American Journal of Respiratory and Critical Care Medicine* 209.1 (2024): 24-36.

11. Briel M., *et al*. "Higher vs Lower Positive End-Expiratory Pressure in Patients With Acute Lung Injury and Acute Respiratory Distress Syndrome". *JAMA* 303.9 (2010): 865.

12. Dianti J., *et al*. "Association of Positive End-Expiratory Pressure and Lung Recruitment Selection Strategies with Mortality in Acute Respiratory Distress Syndrome: A Systematic Review and Network Meta-analysis". *American Journal of Respiratory and Critical Care Medicine* 205.11 (2022): 1300-1310.

13. Grasselli G., *et al*. "ESICM guidelines on acute respiratory distress syndrome: definition, phenotyping and respiratory support strategies". *Intensive Care Medicine* 49.7 (2023): 727-759.

14. Keenan JC., *et al*. "PEEP titration: the effect of prone position and abdominal pressure in an ARDS model". *Intensive Care Medicine Experimental* 6.1 (2018): 3.

15. Sarge T., *et al*. "Effect of Esophageal Pressure-guided Positive End-Expiratory Pressure on Survival from Acute Respiratory Distress Syndrome: A Risk-based and Mechanistic Reanalysis of the EPVent-2 Trial". *American Journal of Respiratory and Critical Care Medicine* 204.10 (2021): 1153-1163.

16. Songsangvorn N., *et al*. "Electrical impedance tomography-guided positive end-expiratory pressure titration in ARDS: a systematic review and meta-analysis". *Intensive Care Medicine* 50.5 (2024): 617-631.

17. Goligher EC., *et al*. "Oxygenation Response to Positive End-Expiratory Pressure Predicts Mortality in Acute Respiratory Distress Syndrome. A Secondary Analysis of the LOVS and ExPress Trials". *American Journal of Respiratory and Critical Care Medicine* 190.1 (2014): 70-76.

18. Gattinoni L., *et al*. "Assessing lung recruitability: does it help with PEEP settings?" *Intensive Care Medicine* 50.5 (2024): 749-751.

19. Wang C., *et al*. "Lung ventilation strategies for acute respiratory distress syndrome: a systematic review and network meta-analysis". *Scientific Repport* 6.1 (2019): 22855.

20. Liaqat A., *et al*. "Evidence-Based Mechanical Ventilatory Strategies in ARDS". *Journal of Clinical Medicine* 11.2 (2022): 319.

21. Coleman MH and Aldrich JM. "Acute Respiratory Distress Syndrome". *Critical Care Clinics* 37.4 (2021): 851-866.