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Mechanical Ventilation Errors and Patient Safety: A Narrative Review

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ABSTRACT

Mechanical ventilation is a life-saving intervention in critical care and emergency medicine, yet it remains a high-risk therapy because outcomes depend on correct configuration of ventilator settings, continuous monitoring, timely troubleshooting, and reliable teamwork. Mechanical ventilation–related errors occur at initiation, during ongoing titration, and during weaning and extubation. Common errors include inaccurate tidal volume selection (often not based on predicted body weight), failure to measure and limit plateau or driving pressure, inappropriate positive end-expiratory pressure (PEEP) application, inadequate alarm configuration and response, delayed recognition of patient–ventilator asynchrony, and unsafe sedation and liberation practices. These errors can precipitate ventilator-induced lung injury (VILI), hemodynamic compromise, prolonged mechanical ventilation, ventilator-associated complications, longer intensive care unit (ICU) length of stay, and increased mortality. This narrative review synthesizes key evidence and translates it into a patient safety framework. We classify ventilation errors into setting-related, monitoring/alarm-related, and human/system-related domains, describe mechanisms linking errors to harm, and summarize evidence-based prevention strategies. Practical tools are provided, including tables that map errors to consequences and a daily ventilator safety checklist that can be embedded into ICU workflows. A systems approach combining lung-protective ventilation, structured monitoring, standardized handover, competency-based education, and continuous quality improvement is essential to reduce preventable harm in mechanically ventilated patients.

KEYWORDS: Mechanical Ventilation; Patient Safety; Icu; Ventilator-Induced Lung Injury; Errors; Alarms; Asynchrony; Sedation; Weaning.

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INTRODUCTION

Mechanical ventilation supports patients with acute respiratory failure due to pneumonia, sepsis, trauma, postoperative complications, and neurologic disease. Despite advances in ventilator technology and guideline recommendations, mechanical ventilation remains a complex intervention in which small deviations in practice can lead to major adverse events. Patient safety risks arise from inappropriate ventilator settings, delayed recognition of deterioration, failure to respond to alarms, and inconsistent application of evidence-based protocols. A key safety principle is that mechanical ventilation can worsen lung injury when applied with excessive stress and strain. Ventilator-induced lung injury (VILI) includes volutrauma, barotrauma, atelectrauma, and biotrauma, and it is particularly relevant in acute respiratory distress syndrome (ARDS) where lung tissue is heterogeneous and vulnerable. Landmark evidence demonstrated that lower tidal volume ventilation improves survival compared with traditional higher tidal volumes [3]. Subsequent analyses highlighted driving pressure as an important physiologic marker associated with outcomes in ARDS [4]. International clinical practice guidelines emphasize lung-protective ventilation, careful monitoring of pressures, and individualized PEEP strategies [5]. However, implementation is variable, and errors occur across all ICU settings. Importantly, ventilation safety is not limited to numeric targets. Patient–ventilator asynchrony, sedation depth, delirium, immobility, secretion management, and weaning processes all influence duration of ventilation and complications. ICU safety bundles that integrate spontaneous awakening and breathing trials and structured delirium/mobility care can reduce time on the ventilator and improve outcomes [10,11]. Therefore, preventing ventilation-related harm requires a systems approach that accounts for human factors, workflows, and culture. This narrative review provides a structured synthesis of common mechanical ventilation errors and their patient safety implications, and it offers practical prevention strategies that can be operationalized through protocols, checklists, training, and quality improvement.

PROBLEM STATEMENT

Despite strong evidence supporting lung-protective ventilation, preventable ventilation-related errors remain common. Contributing factors include inconsistent clinician training, workload and staffing pressures, lack of standardized ventilator protocols, communication failures during handovers and transports, and alarm fatigue. These system and human-factor issues allow unsafe settings to persist, delay corrective actions, and contribute to avoidable VILI, hemodynamic compromise, prolonged mechanical ventilation, ventilator-associated complications, and increased mortality [2,3,6]. A safety-focused synthesis is needed to support standardization, clarify high-yield prevention targets, and provide practical tools for ICU teams.

AIM AND OBJECTIVES

3.1 Aim

To review common mechanical ventilation errors and evaluate their implications for patient safety and clinical outcomes.

3.2 Objectives

- Classify ventilation errors into setting-related, monitoring/alarm-related, and human/system-related domains.
- Summarize mechanisms linking common errors to patient harm (VILI, hemodynamic instability, prolonged ventilation, complications).
- Highlight evidence-based strategies to prevent errors (protocols, checklists, education, bundles, and quality improvement).
- Provide tables and a daily ventilator safety checklist suitable for ICU implementation.

METHODS (NARRATIVE REVIEW APPROACH)

This narrative review synthesizes widely cited evidence from critical care literature, including landmark ARDS ventilation trials, clinical practice guidelines, and studies addressing patient–ventilator interaction, sedation and weaning strategies, and ICU safety bundles [3–11]. The goal is to translate evidence into a practical patient safety framework rather than perform a formal systematic review with meta-analysis. References are provided in Vancouver format.

CLASSIFICATION OF MECHANICAL VENTILATION ERRORS (SAFETY FRAMEWORK)

Mechanical ventilation errors can be grouped into three interacting domains: (1) ventilator setting–related errors, (2) monitoring and alarm–related errors, and (3) human and system–related errors. This classification supports targeted prevention by linking each domain to its primary mechanisms of harm and practical mitigation steps.

Table 1. High-yield classification of mechanical ventilation errors.

Domain	Common error examples	Primary harm mechanism	Typical consequences
Settings-related	High tidal volume; high plateau/driving pressure; inappropriate PEEP; excessive FiO_2; wrong mode/trigger	VILI and hemodynamic compromise	Pneumothorax; refractory hypoxemia; hypotension; increased mortality
Monitoring/alarm	Alarm fatigue; inadequate waveform review; delayed ABG review; missed auto-PEEP; missed asynchrony	Delayed recognition of deterioration	Prolonged ventilation; delayed rescue; worsening gas exchange
Human/system	Training gaps; poor handover; lack of protocols; workload; unclear responsibility	Inconsistent delivery of evidence-based care	Persistent errors; higher complications; delayed weaning

VENTILATOR SETTING–RELATED ERRORS (DIRECT CAUSES OF HARM)

6.1 Incorrect Tidal Volume Selection (VT not based on Predicted Body Weight)

A frequent and high-impact error is selecting tidal volume based on actual body weight or default ventilator settings instead of predicted body weight (PBW). Because PBW reflects lung size more accurately than actual weight, PBW-based tidal volume is essential to avoid overdistension. Higher tidal volumes increase lung stress and inflammatory mediator release, contributing to VILI [2,3]. The ARDS Network trial demonstrated improved survival with lower tidal volume ventilation (approximately 6 mL/kg PBW) compared with traditional higher tidal volumes [3]. Even outside ARDS, lower tidal volumes have been associated with better clinical outcomes and reduced pulmonary complications [6].

- High-risk moments for VT errors:
  - Initial ventilator setup after emergency intubation (height not measured; PBW not calculated).
  - Transport or post-procedure reconnection (settings reset to defaults).
  - Shift handover (settings drift without documentation of rationale).
- Safety actions:
  - Measure and document patient height; calculate PBW and record it on the ventilator chart.
  - Target VT ≈ 6 mL/kg PBW in ARDS, and avoid unnecessarily high VT in other ventilated patients unless clinically justified [3,5,6].
  - Reassess VT after clinical changes (e.g., worsening compliance, initiation of prone positioning, or sedation changes).

6.2 Failure to Measure and Limit Plateau Pressure and Driving Pressure

Plateau pressure (Pplat) reflects alveolar pressure during an inspiratory hold and is central to preventing barotrauma and volutrauma. A common error is failing to perform inspiratory hold maneuvers or failing to act on elevated Pplat. Guidelines commonly recommend limiting Pplat to ≤30 cmH_2O in ARDS [5]. Driving pressure (ΔP = Pplat − PEEP) has been associated

with mortality in ARDS, emphasizing the importance of minimizing excessive ΔP when feasible [4]. Elevated pressures may arise from high VT, reduced compliance, patient–ventilator asynchrony, bronchospasm, secretions, or circuit problems.

- Safety actions:
  - Measure Pplat at least daily and after any major clinical change (e.g., sudden hypoxemia, rising airway pressures).
  - If Pplat exceeds safe targets, reduce VT, optimize sedation/asynchrony management, and reassess PEEP strategy [3–5].
  - Trend ΔP over time; rising ΔP may indicate worsening compliance or injurious settings requiring reassessment [4].

6.3 Inappropriate PEEP Selection (Too Low or Too High)

PEEP helps prevent alveolar collapse and reduces atelectrauma, but both insufficient and excessive PEEP can be harmful. Too low PEEP promotes cyclic collapse and reopening of unstable lung units, worsening oxygenation and inflammation. Excessive PEEP can overdistend compliant regions, increase pulmonary vascular resistance, reduce venous return, and cause hypotension or barotrauma [5,7]. Large trials have evaluated recruitment and PEEP titration strategies with mixed results, underscoring the need for individualized approaches and careful hemodynamic monitoring [7].

- Safety actions:
  - Use structured approaches to PEEP selection (e.g., guideline-based PEEP–FiO_2 tables where appropriate) and reassess response [3,5].
  - After PEEP adjustments, reassess oxygenation, compliance, and hemodynamics; avoid treating hypoxemia solely by increasing PEEP without considering circulatory effects.
  - Consider adjunct strategies such as prone positioning in severe ARDS to improve oxygenation and reduce injurious stress distribution [8].

6.4 Excessive FiO_2 and Failure to Wean Oxygen

Prolonged exposure to high fractions of inspired oxygen (FiO_2) can contribute to oxygen toxicity and absorption atelectasis. In practice, a common error is failing to down-titrate FiO_2 after stabilization or relying on high FiO_2 instead of optimizing PEEP and lung recruitment strategies. Target oxygenation ranges should be guided by unit policy and patient context, with prompt FiO_2 reduction when safe [5].

- Safety actions:
  - Reassess FiO_2 frequently and reduce it when SpO_2/PaO_2 exceeds target range.
  - Optimize PEEP and positioning to maintain oxygenation rather than maintaining unnecessarily high FiO_2 for prolonged periods [5,8].

6.5 Mode/Trigger Errors and Patient–Ventilator Asynchrony

Patient–ventilator asynchrony is common during assisted ventilation and may be under-recognized if clinicians focus only on numeric values rather than waveforms. Asynchrony increases work of breathing, discomfort, and may contribute to prolonged ventilation and potentially injurious swings in transpulmonary pressure. Errors include inappropriate trigger sensitivity, incorrect inspiratory time, excessive mandatory rate, and failure to address auto-PEEP. Waveform analysis is essential for detection and correction [9].

- Safety actions:
  - Review ventilator waveforms routinely (flow-time, pressure-time) to identify trigger delay, double-triggering, ineffective efforts, and flow starvation.
  - Adjust trigger sensitivity, inspiratory flow, and cycling criteria based on patient effort; address reversible causes such as secretions, bronchospasm, or tube obstruction.
  - Treat auto-PEEP by reducing respiratory rate, increasing expiratory time, and addressing airflow limitation [9].

Table 2. Common ventilator setting–related errors and clinical consequences.

Error	Description	Patient safety impact
High tidal volume	>8 mL/kg PBW or VT not PBW-based	Volutrauma; increased inflammation; worse outcomes (especially ARDS)
High plateau pressure	Pplat > 30 cmH_2O or not measured	Barotrauma; VILI; increased mortality risk
High driving pressure	Rising ΔP trend	Marker of injurious stress; associated with worse survival in ARDS
Inappropriate PEEP	Too low or excessive	Atelectrauma or hemodynamic compromise/barotrauma
Excessive FiO_2	High FiO_2 maintained unnecessarily	Oxygen toxicity risk; absorption atelectasis
Mode/trigger mismatch	Poor trigger/cycling; missed auto-PEEP	Asynchrony; failed weaning; increased work of breathing

MONITORING AND ALARM–RELATED ERRORS

7.1 Alarm Fatigue and Inadequate Alarm Configuration

Alarm fatigue is a recognized patient safety risk in critical care. When alarms are frequent and non-actionable, staff may become desensitized, increasing the risk that true deterioration is missed. Ventilator-related alarm errors include leaving default alarm thresholds unchanged, silencing alarms without addressing the cause, and failing to individualize alarm limits after clinical changes. Because ventilator alarms provide early warning of disconnections, high airway pressures, apnea, or low tidal volume delivery, reliable alarm management is essential for safety.

- Safety actions:
  - Individualize alarm limits for high pressure, low exhaled volume, apnea, and oxygenation thresholds at initiation and after changes.
  - Establish unit policies that discourage inappropriate alarm silencing and emphasize root-cause correction.
  - Use structured response algorithms for common alarms (e.g., high pressure, low minute ventilation).

7.2 Delayed Assessment of Gas Exchange and Ventilation

Delayed review of arterial blood gases (ABGs), capnography, ventilator waveforms, and hemodynamic status can postpone recognition of hypoventilation, hypercapnia, worsening oxygenation, or evolving shock. Post-intubation and post-transport periods are particularly high-risk for missed problems such as tube malposition, circuit disconnection, or acute compliance changes. Timely ABG assessment and waveform capnography can enhance safety, especially immediately after intubation and during transport.

- Safety actions:
  - Standardize a post-intubation safety bundle: confirm tube position clinically and with capnography; reassess ventilator settings; obtain ABG within a defined timeframe per policy.
  - Incorporate waveform review into routine ventilator rounds rather than relying only on SpO_2 and numeric ventilator values.
  - Use structured documentation of key parameters (mode, VT, RR, PEEP, FiO_2, Pplat/ΔP when available).

7.3 Failure to Detect Acute Complications Early

Acute complications such as pneumothorax, mucus plugging, endotracheal tube obstruction, bronchospasm, or circuit disconnection may present as sudden changes in airway pressures, delivered tidal volume, oxygenation, or capnography. A safety error occurs when rising airway pressures or sudden loss of tidal volume is not investigated promptly. Bedside teams require a simple, shared troubleshooting model to rapidly evaluate likely causes and implement immediate rescue steps.

- Safety actions:
  - Use a rapid differential diagnosis for acute deterioration (e.g., DOPES: Displacement, Obstruction, Pneumothorax, Equipment, Stacked breaths).
  - Ensure staff competency in immediate ventilator troubleshooting and bag-valve-mask backup ventilation.
  - Escalate promptly when alarms persist or patient status worsens.

Table 3. Monitoring and alarm-related errors and mitigation strategies.

Error	Why it happens	Mitigation
Alarm fatigue	Too many non-actionable alarms; default thresholds	Customize limits; alarm policy; structured response algorithms
Missed waveform abnormalities	Focus on numbers rather than waveforms	Routine waveform review; education on asynchrony patterns
Delayed ABG review	Workflow delays; unclear responsibility	Post-intubation bundle; scheduled reassessments
Unrecognized acute complications	No shared troubleshooting model	DOPES approach; rapid response training; backup ventilation readiness

HUMAN FACTORS AND SYSTEM-RELATED ERRORS

8.1 Training and Competency Gaps

Mechanical ventilation requires proficiency in respiratory mechanics, waveform interpretation, mode selection, and troubleshooting. Errors increase when staff lack structured training or when there is frequent rotation of personnel without competency assessment. Competency gaps contribute to unsafe settings, delayed recognition of asynchrony, inconsistent adherence to lung-protective principles, and inadequate alarm management. A safety strategy must therefore include standardized training and ongoing competency validation.

- Safety actions:
  - Implement competency-based education with simulation and supervised bedside practice.
  - Use quick-reference tools for PBW calculation, lung-protective targets, and alarm response.
  - Provide structured refresher training for high-risk scenarios (e.g., ARDS, obstructive physiology, transport ventilation).

8.2 Handover and Communication Failures

Handover is a high-risk period for ventilation errors. Settings may change during procedures, bronchoscopy, imaging, transport, or resuscitation, and rationale may not be communicated clearly. Without standardized handover, teams may miss trends such as

rising driving pressure, increasing oxygen requirement, or repeated asynchrony. Communication failures also occur between disciplines, for example when sedation changes are made without anticipating ventilatory consequences.

- Safety actions:
  - Use a standardized ventilator handover checklist (mode, VT, RR, PEEP, FiO_2, Pplat/ΔP, recent ABG targets, sedation plan, and weaning plan).
  - Apply closed-loop communication for critical changes, including readback of new settings and goals.
  - Document the reason for any deviation from lung-protective targets.

8.3 Workload, Staffing, and Safety Culture

High workload and insufficient staffing increase missed assessments, delayed responses to alarms, and reduced opportunity for proactive ventilator optimization. In high-reliability settings, safety culture encourages early escalation, routine cross-checks, and non-punitive reporting of near-misses. Ventilation safety improves when teams adopt shared goals and standard work, supported by leadership and continuous quality improvement.

Table 4. Human factors that drive ventilation errors and practical fixes.

Contributing factor	Typical error outcome	Practical fix
Inadequate training	Wrong VT/PEEP; missed asynchrony	Competency program; simulation; bedside coaching
Poor handover	Settings drift; missed trends	Ventilator handoff checklist; closed-loop communication
High workload	Missed alarms; delayed reassessment	Scheduled vent checks; staffing support; clear roles
No protocol	High variability in settings	Lung-protective protocol; audit/feedback

PATIENT SAFETY CONSEQUENCES AND CLINICAL OUTCOMES

9.1 Ventilator-Induced Lung Injury (VILI)

VILI is a central pathway linking ventilation errors to harm. Excessive VT, high pressures, and cyclic collapse amplify lung injury through mechanical disruption and inflammation [2]. Lung-protective ventilation reduces mortality in ARDS, demonstrating that injury from settings is clinically meaningful and preventable [3,5]. Driving pressure has emerged as an important marker associated with survival, reinforcing the need to monitor mechanical stress [4].

9.2 Prolonged Mechanical Ventilation and Ventilator-Associated Complications

Errors that increase sedation depth, worsen asynchrony, or delay recognition of readiness for liberation can prolong mechanical ventilation. Longer ventilation increases the risk of ventilator-associated pneumonia, ICU-acquired weakness, and delirium. Clinical trials have shown that coordinated sedation interruption and spontaneous breathing trials can reduce time on the ventilator and improve outcomes [10].

9.3 Hemodynamic Instability and Organ Dysfunction

Ventilator settings influence cardiovascular function. Excessive intrathoracic pressure from high PEEP or high mean airway pressure can reduce venous return and cardiac output, contributing to hypotension and impaired organ perfusion. Therefore, ventilator adjustments should be paired with hemodynamic assessment, particularly in shock states [5].

Table 5. Error-to-harm map (clinical linkage).

Error	Direct harm	Downstream harm
High VT / high Pplat	Volutrauma/barotrauma	VILI; increased mortality; longer ventilation
Inappropriate PEEP	Atelectrauma or hypotension	Worsened hypoxemia; shock; organ dysfunction
Missed asynchrony	Increased work of breathing	Failed weaning; prolonged ventilation
Alarm fatigue	Missed deterioration	Delayed rescue; cardiac arrest risk
Over-sedation	Delayed liberation	Delirium; ICU weakness; longer ICU stay

PREVENTION STRATEGIES (EVIDENCE-BASED SAFETY BUNDLE)

10.1 Protocolized Lung-Protective Ventilation

Protocols reduce variability and improve reliability of lung-protective ventilation. Core elements include PBW-based VT, regular Pplat assessment, and structured PEEP and FiO_2 titration [3,5]. Protocols should define reassessment triggers (e.g., changes in oxygenation, compliance, hemodynamics) and provide guidance for common scenarios such as severe ARDS, obstructive physiology, and transport.

10.2 Daily Ventilator Safety Checklist

Checklists convert expert knowledge into routine practice. A daily checklist can be completed during rounds and at handover, ensuring that key parameters, alarms, sedation plans, and weaning readiness are consistently reviewed.

Table 6. Daily ventilator safety checklist.

Item	Target / Action	Done
PBW documented	Height measured; PBW calculated and recorded	☐
Tidal volume	ARDS: ~6 mL/kg PBW (adjust pr protocol)	☐
Plateau pressure	Measure inspiratory hold; aim ≤30 cmH_2O when applicable	☐
Driving pressure	Trend ΔP (Pplat−PEEP); reassess if rising	☐
PEEP/FiO_2	Titrate per protocol + hemodynamic tolerance	☐
Waveforms	Assess for asynchrony/auto-PEEP/flow starvation	☐
Alarms	Individualize limits; avoid non-actionable alarm burden	☐
Sedation	Use lightest effective; consider daily awakening trial if appropriate	☐
Weaning readiness	Evaluate SBT criteria and plan	☐
VAP prevention	Head-of-bed elevation; oral care; secretion plan	☐

The "Done" column is intended for real-time bedside documentation when the checklist is used clinically

10.3 Sedation, Delirium, and Early Mobility Bundles

Excessive sedation contributes to delirium, immobility, and prolonged ventilation. Bundle-based approaches that coordinate analgesia, spontaneous awakening trials, spontaneous breathing trials, delirium monitoring, and early mobility can reduce time on ventilation and improve outcomes [10,11]. These practices support safety by reducing oversedation-related complications and promoting earlier liberation.

10.4 Weaning Protocols and Spontaneous Breathing Trials

Delayed identification of readiness for liberation is a common system failure. Protocolized spontaneous breathing trials (SBTs) and coordinated daily evaluation reduce unnecessary ventilation days and associated complications [10]. Successful weaning requires attention to sedation depth, secretion management, hemodynamic stability, and patient–ventilator synchrony.

10.5 Audit, Feedback, and Ventilator Dashboards

Continuous quality improvement can track adherence to PBW-based VT, frequency of Pplat measurements, alarm event rates, and duration of ventilation. Audit and feedback help identify unit-specific barriers, support targeted education, and reinforce standard work.

FUTURE DIRECTIONS

- Decision-support systems that prompt PBW-based VT selection, plateau pressure checks, and alarm optimization.
- Automated waveform analytics to detect asynchrony and auto-PEEP in real time.
- Embedding ventilator safety metrics into ICU dashboards and safety huddles.
- Standardizing minimum ventilation competencies across disciplines working with ventilated patients.

LIMITATIONS

As a narrative review, this paper prioritizes practical synthesis and translation to safety tools rather than exhaustive systematic search and meta-analysis. Evidence strength varies by topic; while lung-protective ventilation has strong trial support in ARDS, other safety domains (e.g., alarm fatigue interventions) may rely more on observational and implementation evidence. Nevertheless, the framework and tools presented are intended to be actionable for ICU teams.

CONCLUSION

Mechanical ventilation saves lives but carries significant patient safety risks when settings, monitoring, and team processes are unreliable. Common errors—such as excessive tidal volumes, failure to limit plateau/driving pressure, inappropriate PEEP, missed asynchrony, and poor alarm management—can precipitate VILI, hemodynamic compromise, prolonged ventilation, and increased mortality. Patient safety improves when ICUs implement protocolized lung-protective ventilation, daily ventilator checklists, structured handover, competency-based training, and integrated sedation/weaning bundles. A systems approach combining evidence-based ventilation strategies with human factors principles is essential to reduce preventable harm in mechanically ventilated patients.

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