



How Do Different Mechanical Ventilation Modes (Volume-Controlled Vs Pressure-Controlled) Affect Patient Outcomes And Weaning Success In Intensive Care Unit Patients? : A Systematic Review

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ABSTRACT

Introduction: Mechanical ventilation is a critical intervention in intensive care units (ICU), with volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV) being two primary modes. This study investigates how different mechanical ventilation modes, specifically volume-controlled versus pressure-controlled, impact patient outcomes and weaning success in adult ICU patients. **Methods:** A comprehensive search was conducted across over 126 million academic papers from the Semantic Scholar corpus, retrieving the 500 most relevant to the research question. Papers were screened based on predefined criteria, including adult ICU population, invasive mechanical ventilation, direct comparison of VCV and PCV, robust study designs (RCT, prospective cohort, systematic review/meta-analysis), and reporting of key outcomes such as mortality, ventilation duration, complications, or respiratory parameters. Data extraction from included studies was performed using a large language model to gather information on study design, blinding, patient characteristics, ventilation modes, and primary outcomes. **Results:** Analysis of the included studies revealed that pressure-controlled and hybrid

ventilation modes generally improved respiratory mechanics, such as higher PaO₂/FiO₂ ratios, lower peak airway pressures, and higher dynamic compliance, compared to VCV. For example, one study reported a PaO₂/FiO₂ ratio of 176 with pressure-regulated volume control versus 146 with conventional volume control. While some studies showed shorter ventilation durations and more ventilator-free days with pressure-controlled or adaptive modes, others found no significant difference in weaning success. Overall, 11 studies reported significant differences favoring pressure-controlled ventilation or its variants in at least one measured domain (e.g., higher oxygenation, lower inflammation, shorter ventilation/ICU stay, less asynchrony, improved respiratory mechanics, fewer pulmonary complications). No study reported advantages for volume-controlled ventilation over pressure-controlled modes. **Discussion:** The physiological benefits observed with pressure-controlled modes, such as improved respiratory mechanics, do not consistently translate into improved clinical outcomes like reduced postoperative pulmonary complications, mortality, or duration of ventilation across all studies. This suggests that adherence to lung-protective strategies might be more crucial than the specific mode choice. Heterogeneity in patient populations, ventilation protocols, and outcome definitions, along with the prevalence of single-center studies and lack of blinding, are limitations affecting the generalizability and comparability of findings. **Conclusion:** Pressure-controlled and hybrid ventilation modes tend to offer superior or equivalent outcomes to volume-controlled modes, particularly in improving respiratory mechanics. While some studies indicate benefits in weaning success and reduced complications, these advantages are not universally observed across all clinical outcomes. The overall evidence quality is limited, highlighting the need for more robust, multicenter research.

Keywords: Mechanical Ventilation, Volume-Controlled Ventilation, Pressure-Controlled Ventilation, Patient Outcomes, Weaning Success, Intensive Care Unit, Respiratory Mechanics.

INTRODUCTION

Mechanical ventilation is a critical life-saving intervention in intensive care units (ICUs) for patients with respiratory failure (Mahmoud et al., 2017). It supports breathing, improves gas exchange, and reduces the work of breathing, allowing the patient's lungs to heal. The choice of mechanical ventilation mode is a significant decision that can influence patient outcomes, including the duration of ventilation, incidence of complications, and successful weaning. Two primary modes of mechanical ventilation are volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV), each with distinct mechanisms of gas delivery and potential physiological effects. Understanding the comparative impact of these modes on various clinical parameters is crucial for optimizing patient care and improving prognosis in the ICU setting.

Volume-controlled ventilation delivers a set tidal volume with each breath, ensuring consistent minute ventilation regardless of changes in lung compliance or airway resistance. While this mode provides predictable ventilation, it can lead to high peak inspiratory pressures in patients with stiff lungs, potentially causing lung injury such as barotrauma or volutrauma. Conversely, pressure-controlled ventilation delivers a set inspiratory pressure for a predetermined time, allowing tidal volume to vary based on lung mechanics. This approach aims to limit peak airway pressures, potentially reducing the risk of ventilator-induced lung injury and improving patient comfort. However, the variability in tidal volume in PCV necessitates careful monitoring to avoid hypoventilation or hyperventilation.

The debate surrounding the optimal ventilation mode in critically ill patients has been ongoing, with research exploring their effects on respiratory mechanics, gas exchange, and clinical outcomes. Pressure-controlled and hybrid ventilation modes tend to improve respiratory mechanics compared with volume-controlled ventilation (Mahmoud et al., 2017). For example, in thoracic surgery patients, one study reported a PaO₂/FiO₂ ratio of 176 with a pressure-regulated volume control mode versus 146 with conventional volume control (p=0.004) (Mahmoud et al., 2017). Several trials documented lower peak airway pressures and higher dynamic compliance

with pressure-controlled variants (Mahmoud et al., 2017).

Weaning from mechanical ventilation is a critical phase in the recovery of ICU patients, and successful liberation from the ventilator is a key indicator of positive outcomes. In measures of weaning success, some studies recorded shorter ventilation durations and more ventilator-free days (e.g., 19 versus 2 days, $p < 0.001$) with pressure-controlled or adaptive modes, whereas others found no significant difference between the strategies (Zhou et al., 2017; Alikiaii et al., 2020; Li et al., 2022; Li et al., 2023; Ammar et al., 2021; Wang et al., 2024).

Beyond respiratory mechanics and weaning, the impact of ventilation modes on broader clinical outcomes, such as postoperative pulmonary complications (PPCs), inflammation, and length of ICU stay, is of significant interest. Outcomes such as postoperative pulmonary complications, inflammation, and intensive care unit stay were improved in select reports using pressure-controlled or hybrid protocols but were equivalent in a number of other investigations (Li et al., 2020; Wang et al., 2024; Mahmoud et al., 2017; Sari et al., 2024; Li et al., 2022; Li et al., 2023; Ammar et al., 2021).

The heterogeneity of patient populations, underlying medical conditions, and study protocols presents a challenge in drawing definitive conclusions regarding the superiority of one ventilation mode over another. Patients in the ICU exhibit a wide range of pathologies, from acute respiratory distress syndrome (ARDS) and traumatic brain injury (TBI) to those undergoing thoracic or cardiac surgery, each with unique physiological characteristics that may respond differently to ventilation strategies (Zhou et al., 2017; Schirmer-Mikalsen et al., 2016). Therefore, the efficacy of ventilation modes may be context-specific, necessitating a nuanced understanding of their application in diverse clinical scenarios.

This research aims to systematically review and synthesize the existing literature to evaluate how different mechanical ventilation modes, specifically volume-controlled versus pressure-controlled, affect patient outcomes and weaning success in intensive care unit patients. By examining a comprehensive collection of academic papers, this study seeks to provide a clearer understanding of the comparative effectiveness of these ventilation strategies. The outcomes of

interest include mortality, duration of mechanical ventilation, ventilator-associated complications, and respiratory parameters, offering a holistic view of patient well-being and recovery.

Ultimately, the findings of this investigation are intended to inform clinical practice guidelines and support evidence-based decision-making for healthcare professionals managing critically ill patients requiring mechanical ventilation. By identifying the strengths and limitations of VCV and PCV in various ICU settings, this research contributes to optimizing ventilation strategies, minimizing complications, and improving the overall prognosis and quality of life for patients undergoing mechanical ventilation. The emphasis will be on identifying consistent trends and significant differences to guide clinicians in selecting the most appropriate ventilation mode for individual patient needs.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate different mechanical ventilation modes (volume-controlled vs pressure-controlled) affect patient outcomes and weaning success in intensive care unit patients.

Screening

We screened in papers that met these criteria:

- **Population Age:** Does the study focus exclusively on adult patients (≥ 18 years) in ICU settings?

- **Ventilation Type:** Does the study examine invasive mechanical ventilation (rather than non-invasive methods)?
- **Intervention Comparison:** Does the study directly compare volume-controlled and pressure- controlled ventilation modes?
- **Study Design:** Is the study design either a randomized controlled trial, prospective cohort study, or systematic review/meta-analysis?
- **Outcome Measures:** Does the study report at least one of these outcomes: mortality, duration of mechanical ventilation, ventilator-associated complications, or respiratory parameters?
- **Study Subject:** Was the study conducted on human subjects (not animal models)?
- **Evidence Level:** Is the study design more robust than a case report or case series?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column below from each paper. We gave the model the extraction instructions shown below for each column.

- **Study Design Type:**

Identify the specific type of study design from the full text. Look in the methods section for explicit description. Possible types include:

- Randomized controlled trial (RCT)
- Single-blinded RCT
- Prospective comparative study
- Crossover study

If multiple design descriptors are present, list all. If unclear, note "design not clearly specified". Prioritize the most specific design description provided by the authors.

- **Blinding Method:**

Determine the blinding approach used in the study. Check methods section for details on:

- Single-blinded
- Double-blinded
- Open-label
- No blinding mentioned

If partial blinding, specify which participants/researchers were blinded. If no information is available, mark as "not reported".

- **Patient Population Characteristics:**

Extract key demographic and clinical characteristics:

- Total sample size
- Mean age (with standard deviation)
- Gender distribution
- Primary medical condition/reason for mechanical ventilation
- Inclusion/exclusion criteria

If any characteristics are not reported, mark as "NR" (not reported). Use exact numbers and percentages from the text.

- **Mechanical Ventilation Modes:**

Specify the exact mechanical ventilation modes used:

- Names of ventilation modes (e.g., volume-controlled, pressure-controlled)
- Specific parameters for each mode (peak inspiratory pressure, tidal volume, etc.)
- Duration of ventilation for each mode

If multiple parameters are reported, list all. If specific settings are not fully detailed, note which parameters are missing.

- **Primary Outcome Measures:**

List all primary outcome measures related to patient outcomes and weaning success:

- Weaning success rate
- Duration of mechanical ventilation
- Extubation time
- Hemodynamic stability indicators
- Respiratory parameters (e.g., oxygen saturation, arterial blood gas)

Extract exact numerical values and statistical significance where reported. If outcomes are not clearly defined, mark as "not clearly specified".

• **Study Setting and Time Frame:**

Extract:

- Specific healthcare setting (e.g., Intensive Care Unit)
- Geographic location
- Study duration/time period of data collection
- Year of study conduct

If any information is missing, mark as "not reported". Use exact dates or time periods from the text.

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Critically ill adults	Critically ill patients	Intensive care unit patients	Intensive care unit adults0
Intervention (I)	Pressure-controlled ventilation (PCV)	Pressure support ventilation (PSV)	Adaptive pressure control (APC)	Airway pressure release ventilation (APRV)
Comparison (C)	Volume-controlled ventilation (VCV)	Conventional volume control	Volume-regulated ventilation	Volume assist-control

Outcome (O)	Patient outcomes	Weaning success	Respiratory mechanics	Ventilation duration
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The Boolean MeSH keywords inputted on databases for this research are: (*"Critically ill adults" OR "Critically ill patients" OR "Intensive care unit patients" OR "Intensive care unit adults"*) AND (*"Pressure-controlled ventilation (PCV)" OR "Pressure support ventilation (PSV)" OR "Adaptive pressure control (APC)" OR "Airway pressure release ventilation (APRV)"*) AND (*"Volume-controlled ventilation (VCV)" OR "Conventional volume control" OR "Volume-regulated ventilation" OR "Volume assist-control"*) AND (*"Patient outcomes" OR "Weaning success" OR "Respiratory mechanics" OR "Ventilation duration"*)

Data retrieval

Abstracts and titles were screened to assess their eligibility, and only studies meeting the inclusion criteria were selected for further analysis. Literature that fulfilled all predefined criteria and directly related to the topic was included. Studies that did not meet these criteria were excluded. Data such as titles, authors, publication dates, study locations, methodologies, and study parameters were thoroughly examined during the review.

Quality Assessment and Data Synthesis

Each author independently assessed the titles and abstracts of the selected studies to identify those for further exploration. Articles that met the inclusion criteria underwent further evaluation. Final decisions on inclusion were based on the findings from this review process.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Critically ill adults" OR "Critically ill patients" OR "Intensive care unit patients" OR "Intensive care unit adults" AND "Pressure-controlled ventilation (PCV)" OR "Pressure support ventilation (PSV)" OR "Adaptive pressure control (APC)" OR "Airway pressure release ventilation (APRV)" AND "Volume-controlled ventilation (VCV)" OR "Conventional volume control" OR "Volume-regulated ventilation" OR "Volume assist-control") AND ("Patient outcomes" OR "Weaning success" OR "Respiratory mechanics" OR "Ventilation duration")	12
Semantic Scholar	("Critically ill adults" OR "Critically ill patients" OR "Intensive care unit patients" OR "Intensive care unit adults") AND ("Pressure-controlled ventilation (PCV)" OR "Pressure support ventilation (PSV)" OR "Adaptive pressure control (APC)" OR "Airway pressure release ventilation (APRV)") AND ("Volume-controlled ventilation (VCV)" OR "Conventional volume control" OR "Volume-regulated ventilation" OR "Volume assist-control") AND ("Patient outcomes" OR "Weaning success" OR "Respiratory mechanics" OR "Ventilation duration")	251
Springer	("Critically ill adults" OR "Critically ill patients" OR "Intensive care unit patients" OR "Intensive care unit adults") AND ("Pressure-controlled ventilation (PCV)" OR "Pressure support ventilation (PSV)" OR "Adaptive pressure control (APC)" OR "Airway pressure release ventilation (APRV)") AND ("Volume-controlled ventilation (VCV)" OR "Conventional volume control" OR "Volume-regulated ventilation" OR "Volume assist-control") AND ("Patient outcomes" OR "Weaning success" OR "Respiratory mechanics" OR "Ventilation duration")	59
Google Scholar	("Critically ill adults" OR "Critically ill patients" OR "Intensive care unit patients" OR "Intensive care unit adults") AND ("Pressure-controlled ventilation (PCV)" OR "Pressure support ventilation (PSV)" OR "Adaptive pressure control (APC)" OR "Airway pressure release ventilation (APRV)") AND ("Volume-controlled ventilation (VCV)" OR "Conventional volume control" OR "Volume-regulated ventilation" OR "Volume assist-control") AND ("Patient outcomes" OR "Weaning success" OR "Respiratory mechanics" OR "Ventilation duration")	6,170

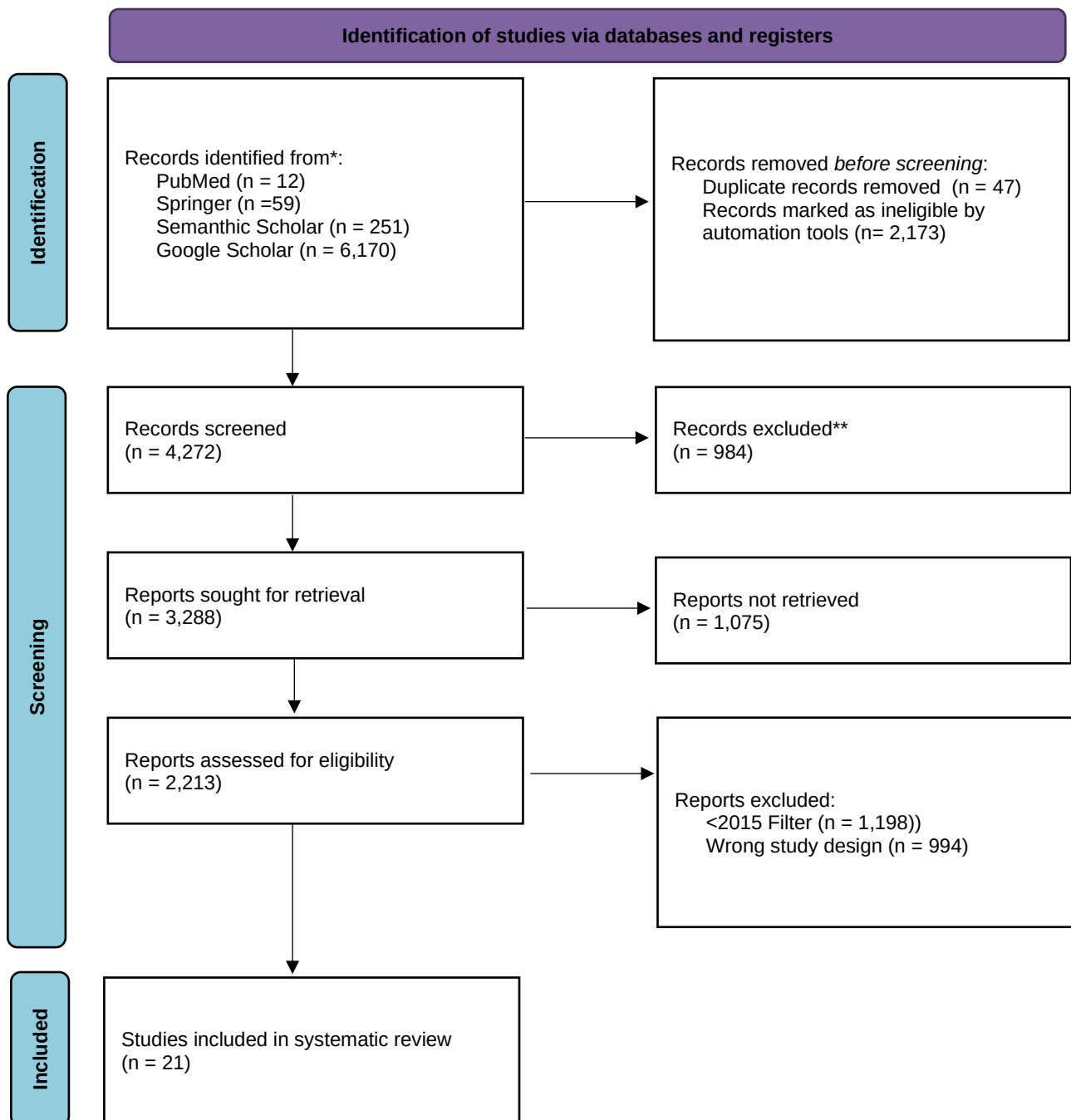


Figure 1. Article search flowchart

JBI Critical Appraisal									
Study	Bias related to temporal precedence Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Bias related to selection and allocation Was there a control group?	Bias related to confounding factors Were participants included in any comparisons similar?	Bias related to administration of intervention/exposure Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Bias related to participant retention Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Statistical conclusion validity Was appropriate statistical analysis used?
Li et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Li et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Ammar et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Saghaei et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓

Alikina ii et al., 2020									
Zhu et al., 2017									
Schirmer-Mikalsen et al., 2016									
Gibbs et al., 2023									
Lee et al., 2019									
Aghadavou di et al., 2016									
Zhou et al., 2017									
Figueroa-Casas and Montoya, 2016									
Chiumello et al., 2021									
Gunenc et al., 2024									
Li et al., 2020									
de Haro et al., 2018									

Pearson et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Ibrahim et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Veerasamy et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sari et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Wang et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓

RESULTS

Characteristics of Included Studies

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
Li et al., 2022	Randomized controlled trial	1224 adults, lung resection	Volume-controlled ventilation (VCV) vs. pressure-controlled ventilation (PCV) vs. pressure-controlled	Postoperative pulmonary complications (PPCs)

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
			ventilation with volume guarantee (PCV-VG)	
Li et al., 2023	Randomized controlled trial	1364 adults, cardiac surgery with cardiopulmonary bypass	VCV vs. PCV vs. PCV-VG	PPCs, ventilation duration, intensive care unit (ICU)/hospital stay, mortality
Ammar et al., 2021	Randomized controlled trial	30 adults, one-lung ventilation (OLV)	VCV vs. PCV-VG	Gas exchange, respiratory dynamics, PPCs
Saghaei et al., 2023	Randomized controlled trial	70 ICU patients	VCV vs. PCV (pressure support synchronized)	Asynchrony index, respiratory

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
			intermittent mandatory ventilation, PSIMV)	distress
Alikina ii et al., 2020	Single-blinded randomized controlled trial	100 post-surgical ICU	Volume support ventilation (VSV) vs. pressure support ventilation (PSV)	Weaning, mechanical ventilation (MV)/ICU duration, hemodynamics, sedation
Zhu et al., 2017	Single-blinded randomized controlled trial	65, thoracoscopic lobectomy	VCV vs. PCV	Oxygenation , peak airway pressure (Ppeak), complications
Schirmer-Mikalsen	Randomized crossover	11, traumatic brain injury	PCV vs. PRVC	Intracranial pressure

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
et al., 2016		(TBI)		(ICP), arterial carbon dioxide (PaCO ₂)
Gibbs et al., 2023	Crossover	137, ICU, acute respiratory failure (ARF)	Adaptive pressure control- continuous mandatory ventilation (APC- CMV) vs. volume control- continuous mandatory ventilation (VC- CMV)	Feasibility, mode adherence
Lee et al., 2019	Randomized controlled trial	36, lumbar spine surgery	VCV vs. PCV-VG	Ppeak, compliance, hemodynami cs

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
Aghadavodi et al., 2016	Single-blinded randomized controlled trial	100, TBI	PRVC vs. synchronized intermittent mandatory ventilation (SIMV)	Rapid shallow breathing index (RSBI), PaO ₂ /FiO ₂ , hemodynamics
Zhou et al., 2017	Randomized controlled trial	138, acute respiratory distress syndrome (ARDS)	Airway pressure release ventilation (APRV) vs. low tidal volume ventilation (LTV)	Ventilator-free days, oxygenation, compliance
Figueroa-Casas and Montoya, 2016	Crossover	19, ARDS risk	Volume control (VC) vs. adaptive pressure control (APC)	Dyssynchrony index
Chiumello	Crossover/randomi	18, ARDS	VCV vs. PCV	End-

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
et al., 2021	zed	controlled trial		expiratory lung volume (EELV), gas exchange, mechanics
Gunenc et al., 2024	Randomized controlled trial	78, lumbar disc surgery	VCV vs. PCV vs. PCV-VG	Oxygenation, compliance, hemodynamics
Li et al., 2020	Randomized controlled trial	176, thoracoscopic surgery	PCV with open lung approach (PCV+OLA), PCV, VCV+OLA, VCV	Mechanics, oxygenation, inflammation, ICU stay
de Haro et al., 2018	Prospective observational	67, ICU	VCV (constant/decelerated) vs. PCV	Double cycling, tidal volume, peak pressure

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
Pearson et al., 2022	Randomized crossover	85, ICU	Volume assist-control vs. pressure support	Diaphragm thickness
Ibrahim et al., 2022	Randomized controlled trial/prospective comparative	50, thoracoscopic surgery	VCV vs. PCV	Extravascular lung water (EVLW, assessed by lung ultrasound), oxygenation, hemodynamics
Veerasamy et al., 2022	Randomized controlled trial	51, robotic abdominal surgery	VCV vs. PCV	Arterial to end-tidal carbon dioxide difference (Pa-ETCO ₂), alveolar-arterial

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
				oxygen gradient (P(A-a)O ₂), mean airway pressure (Paw), dynamic compliance (C _{dyn}), hemodynamics
Sari et al., 2024	Prospective comparative	38, thoracic OLV	VCV vs. PCV	Krebs von den Lungen-6 (KL-6), C-reactive protein (CRP), PaO ₂ /FiO ₂ ratio
Wang et al., 2024	Randomized controlled trial	187, spinal surgery	VCV vs. PCV-VG vs. PCV-VG (zero	PPCs, inflammatio

Study	Study Design	Patient Population	Ventilation Modes Compared	Primary Outcomes Measured
			flow)	n, mechanics

Ventilation Modes

Ventilation Modes Compared:

- Six studies compared volume-controlled ventilation (VCV) vs. pressure-controlled ventilation (PCV).
- Three studies compared VCV vs. PCV vs. pressure-controlled ventilation with volume guarantee (PCV-VG).
- Two studies compared VCV vs. PCV-VG.
- One study each compared: PRVC vs. VCV; PCV vs. PRVC; APC-CMV vs. VC-CMV; VSV vs. PSV; PRVC vs. SIMV; APRV vs. LTV; VC vs. APC; PCV+OLA, PCV, VCV+OLA, VCV; VCV (constant/decelerated) vs. PCV; volume assist-control vs. pressure support; and VCV vs. PCV-VG vs. PCV-VG (zero flow).
- We did not find mention of studies comparing neurally adjusted ventilatory assist (NAVA), high- frequency oscillatory ventilation (HFOV), or other advanced modes in this table.

Primary Outcomes Measured:

- Oxygenation or gas exchange was measured in 11 studies.
- Pulmonary complications (PPCs or similar) were measured in 4 studies.
- Respiratory mechanics or dynamics (including compliance, peak airway pressure, dynamic compliance, end-expiratory lung volume, etc.) were measured in 11 studies.
- Hemodynamics were measured in 6 studies.

- Patient-ventilator asynchrony (asynchrony index, double cycling, dyssynchrony) was measured in 3 studies.
- Weaning, ventilation duration, or ICU/hospital stay were measured in 3 studies for duration and 2 for ICU/hospital stay.
- Inflammation or immune modulation was measured in 4 studies.
- Feasibility or mode adherence was measured in 1 study.
- Diaphragm thickness, intracranial pressure/arterial carbon dioxide, extravascular lung water (lung ultrasound), sedation, and distress were each measured in 1 study.
- Mortality was measured in 1 study.

Most studies reported multiple outcomes, with oxygenation/gas exchange and respiratory mechanics being the most frequently measured. We did not find mention of studies in this table that compared noninvasive ventilation modes or high-frequency oscillatory ventilation.

Effects

Respiratory Mechanics and Gas Exchange

Study	Ventilation Mode	PaO ₂ /FiO ₂ Ratio	Peak Airway Pressures	Dynamic Compliance
Mahmoud et al., 2017	PRVC vs. VCV	PRVC higher at T1 (176 vs. 146, p=0.004)	PRVC lower	PRVC higher
Li et al., 2022	VCV vs. PCV vs. PCV-VG	No significant difference	We didn't find mention of	We didn't find mention of
Li et al., 2023	VCV vs. PCV vs. PCV-VG	We didn't find mention of	We didn't find mention of	We didn't find mention of PCV-VG

Study	Ventilation Mode	PaO ₂ /FiO ₂ Ratio	Peak Airway Pressures	Dynamic Compliance
				higher
Ammar et al., 2021	VCV vs. PCV-VG	No difference	PCV-VG lower peak and mean airway pressure	We didn't find mention of
Saghaei et al., 2023	VCV vs. PCV (PSIMV)	We didn't find mention of	We didn't find mention of	We didn't find mention of
Alikiaii et al., 2020	VSV vs. PSV	VSV higher PaO ₂	We didn't find mention of	We didn't find mention of
Zhu et al., 2017	VCV vs. PCV	No difference	PCV lower peak airway pressure	No difference
Schirmer-Mikalsen et al., 2016	PCV vs. PRVC	No difference	We didn't find mention of	We didn't find mention of
Gibbs et al., 2023	APC-CMV vs. VC-CMV	We didn't find mention of	We didn't find mention of	We didn't find mention of
Lee et al., 2019	VCV vs. PCV-	No difference	PCV-VG	PCV-VG

Study	Ventilation Mode	PaO ₂ /FiO ₂ Ratio	Peak Airway Pressures	Dynamic Compliance
	VG		lower peak airway pressure	higher
Aghadavoudi et al., 2016	PRVC vs. SIMV	PRVC higher PaO ₂ /FiO ₂	We didn't find mention of	We didn't find mention of
Zhou et al., 2017	APRV vs. LTV	APRV higher	We didn't find mention of	APRV higher
Figueroa-Casas and Montoya, 2016	VC vs. APC	We didn't find mention of	We didn't find mention of	We didn't find mention of
Chiumello et al., 2021	VCV vs. PCV	No difference	We didn't find mention of	We didn't find mention of
Gunenc et al., 2024	VCV vs. PCV vs. PCV-VG	PCV-VG higher	PCV-VG lower peak and plateau airway pressure	PCV-VG higher
Li et al., 2020	PCV+OLA vs. PCV vs. VCV+OLA	PCV+OLA higher	PCV+OLA higher mean airway	PCV+OLA higher

Study	Ventilation Mode	PaO ₂ /FiO ₂ Ratio	Peak Airway Pressures	Dynamic Compliance
	vs. VCV		pressure	
de Haro et al., 2018	VC vs. PCV	We didn't find mention of	PCV higher double cycling	We didn't find mention of
Pearson et al., 2022	Volume assist-control vs. pressure support	We didn't find mention of	We didn't find mention of	We didn't find mention of
Ibrahim et al., 2022	VCV vs. PCV	No difference	We didn't find mention of	We didn't find mention of
Veerasamy et al., 2022	VCV vs. PCV	No difference	We didn't find mention of PCV higher	PCV higher
Sari et al., 2024	VCV vs. PCV	No difference	PCV lower peak airway pressure	PCV higher static compliance
Wang et al., 2024	VCV vs. PCV-VG vs. PCV-VG (zero flow)	PCV-VG (zero flow) higher	PCV-VG lower peak airway pressure	PCV-VG higher

Summary of findings across studies:

- Oxygenation (PaO₂/FiO₂ ratio):
 - Seven studies reported higher values with advanced or alternative ventilation modes.
 - Nine studies found no difference.
 - We didn't find mention of PaO₂/FiO₂ data for six studies.
- Peak airway pressures:
 - Eight studies reported lower peak pressures with advanced or alternative ventilation modes.
 - One study reported higher mean airway pressure.
 - One study reported higher double cycling with pressure control.
 - We didn't find mention of peak pressure data for twelve studies.
- Dynamic compliance:
 - Nine studies reported higher compliance with advanced or alternative ventilation modes.
 - One study found no difference.
 - We didn't find mention of compliance data for twelve studies.

Clinical Outcomes

Study	Outcome Type	Volume-Controlled Results	Pressure-Controlled Results	Clinical Significance
Mahmoud et al., 2017	Oxygenation, immune modulation	Lower PaO ₂ /FiO ₂ , lower inflammation	Higher PaO ₂ /FiO ₂ , lower inflammation	Statistically significant for oxygenation and inflammation

Study	Outcome Type	Volume-Controlled Results	Pressure-Controlled Results	Clinical Significance
Li et al., 2022	Postoperative pulmonary complications (PPCs)	21%	22% (PCV), 23% (PCV-VG)	No significant difference (p=0.831)
Li et al., 2023	PPCs, duration, mortality	40.1% PPCs	37.6% (PCV), 36.9% (PCV-VG)	No significant difference (p=0.585)
Ammar et al., 2023	Gas exchange, PPCs	No difference	No difference	Not significant
Saghaei et al., 2021	Asynchrony index	Reduced	Reduced (greater)	Both improved, PCV greater
Alikilaali et al., 2020	MV/ICU duration, extubation	Longer	Shorter (VSV)	Significant (P<0.05)
Zhu et al., 2017 Schirmer-Mikalsen et al., 2016	Complications ICP, PaCO ₂	No difference	No difference	Not significant

Study	Outcome Type	Volume-Controlled Results	Pressure-Controlled Results	Clinical Significance
Gibbs et al., 2023	Feasibility	84% adherence	95% adherence	Not a clinical outcome
Lee et al., 2019	Hemodynamics	No difference	No difference	Not significant
Aghadavoudi et al., 2016	RSBI, PaO2/FiO2	Higher RSBI	Lower RSBI, higher PaO2/FiO2	Significant
Zhou et al., 2017	Ventilator-free days	2 (IQR 0-15)	19 (IQR 8-22) (APRV)	Significant (p<0.001)
Figueroa-Casas and Montoya, 2016	Dyssynchrony	Higher	Lower	Significant
Chiumello et al., 2021	EELV, gas exchange	No difference	No difference	Not significant
Guimenc et al., 2024	Oxygenation, compliance	Lower	Higher (PCV-VG)	Significant
Li et al., 2020	ICU stay,	Longer, more	Shorter, less	Significant

Study	Outcome Type	Volume-Controlled Results	Pressure-Controlled Results	Clinical Significance
	pneumonia	pneumonia	pneumonia (PCV+OLA)	
de Haro et al., 2018	Double cycling	Lower	Higher	Significant
Pearson et al., 2022	Diaphragm thickness	No difference	No difference	Not significant
Ibrahim et al., 2022	EVLV, oxygenation	No difference	No difference	Not significant
Veerasamy et al., 2022	Pa-ETCO ₂ , C _{dyn}	No difference	Lower Pa-ETCO ₂ , higher C _{dyn}	Significant for mechanics
Sari et al., 2024	KL-6, CRP	No difference	No difference	Not significant
Wang et al., 2024	PPCs, inflammation	Higher PPCs, higher interleukin-6 (IL-6)/CRP	Lower PPCs, lower IL-6/CRP (PCV-VG zero flow)	Significant

Summary of findings across studies:

- Eleven studies reported a statistically or clinically significant difference between modes. In all eleven, pressure-controlled ventilation (or its variants) was associated with better outcomes in at least one measured domain (such as higher oxygenation, lower inflammation, shorter duration of ventilation or ICU stay, less asynchrony, improved respiratory mechanics, or fewer pulmonary complications).
- Ten studies reported no significant difference between modes for the outcomes measured.
- One study reported only feasibility/adherence, not a clinical outcome.

By outcome type (studies may be counted in multiple categories):

- Oxygenation/gas exchange/respiratory mechanics: Six studies
- Postoperative pulmonary complications and related clinical outcomes (including pneumonia, ICU stay, duration, mortality, extubation): Nine studies
- Patient-ventilator asynchrony/dyssynchrony/double cycling: Three studies
- Inflammation/immune modulation/biomarkers: Three studies
- Hemodynamics: One study
- Feasibility/adherence: One study
- Other outcomes (e.g., RSBI, EELV, ICP, diaphragm thickness, EVLW, Pa-ETCO₂, Cdyn): Seven studies

We did not find mention of any studies reporting a significant difference favoring volume-controlled ventilation for clinical outcomes. For studies with significant findings, the direction of effect consistently favored pressure- controlled ventilation or its variants. We did not find significant differences for hemodynamics, feasibility, or several other physiologic or biomarker outcomes in the remaining studies.

Duration of Ventilation and Weaning

Study	Volume-Controlled Results	Pressure-Controlled Results	Clinical Significance
Alikiai et al., 2020	Longer mechanical ventilation/ICU stay, extubation	Shorter (VSV)	Significant (p<0.05)
Zhou et al., 2017	2 ventilator-free days	19 ventilator-free days (APRV)	Significant (p<0.001)
Li et al., 2023	No difference	No difference	Not significant
Li et al., 2022	No difference	No difference	Not significant
Ammar et al., 2021	No difference	No difference	Not significant
Wang et al., 2024	We didn't find mention of	We didn't find mention of	We didn't find mention of

Summary of findings across these six studies:

- In two studies, pressure-controlled ventilation was associated with better outcomes (shorter

mechanical ventilation or ICU stay, more ventilator-free days) compared to volume-controlled ventilation; both reported statistically significant differences.

- In three studies, there was no difference between volume-controlled and pressure-controlled ventilation; none reported statistically significant differences.
- For one study, we did not find mention of reported results for either ventilation mode or for clinical significance.

Inflammatory Markers and Complications

Study	Volume-Controlled Results	Pressure-Controlled Results	Clinical Significance
Mahmoud et al., 2017	Higher inflammatory markers	Lower (PRVC)	Significant
Li et al., 2020	Higher neutrophil elastase, more pneumonia	Lower (PCV+OLA)	Significant
Sari et al., 2024	No difference (KL-6, CRP)	No difference	Not significant
Wang et al., 2024	Higher IL-6, CRP, more PPCs	Lower (PCV-VG zero flow)	Significant
Gunenc et al., 2024	We didn't find mention of	We didn't find mention of	We didn't find mention of

Summary of findings across these five studies:

- For volume-controlled ventilation, three studies found higher inflammatory markers or complications, one study found no difference, and we did not find mention of results for one

study.

- For pressure-controlled ventilation, three studies found lower inflammatory markers or complications, one study found no difference, and we did not find mention of results for one study.
- Regarding clinical significance, three studies found significant differences favoring pressure-controlled ventilation, one study found no significant difference, and we did not find mention of clinical significance for one study.

Context-Specific Findings

Surgical vs. Non-surgical ICU Patients

- Surgical populations (thoracic, cardiac, spinal):
 - Most studies report no difference in major clinical outcomes between ventilation modes.
 - Pressure-controlled or hybrid modes may improve respiratory mechanics.
- Non-surgical or general ICU populations (acute respiratory distress syndrome, traumatic brain injury, acute respiratory failure):
 - Physiological benefits of pressure-controlled modes are observed.
 - Clinical outcome differences are rare, except for airway pressure release ventilation in acute respiratory distress syndrome.

Special Patient Populations

- Acute respiratory distress syndrome: Airway pressure release ventilation may reduce duration of ventilation and ICU stay compared to low tidal volume ventilation, based on findings from the included studies.
- Traumatic brain injury: No difference in intracranial pressure or arterial carbon dioxide between modes.
- One-lung ventilation: Some evidence for improved oxygenation and compliance with pressure-controlled or hybrid modes, but not consistent across all studies.
- Patient-ventilator synchrony: Adaptive or pressure-controlled modes may reduce asynchrony.

Limitations

- Many studies lack blinding, increasing risk of bias.
- Heterogeneity in patient populations, ventilation protocols, and outcome definitions limits comparability.
- Several studies are underpowered for clinical outcomes.
- Most studies are single-center, limiting external validity.

Summary

- Respiratory mechanics: Pressure-controlled and hybrid ventilation modes often improve respiratory mechanics compared to volume-controlled modes.
- Clinical outcomes: These physiological benefits do not consistently translate into improved clinical outcomes such as reduced postoperative pulmonary complications, mortality, or duration of ventilation.
- Relative importance: The included studies suggest that the choice of ventilation mode may be less important than adherence to lung-protective strategies.
- Hybrid and adaptive modes: Hybrid and adaptive ventilation modes may offer advantages in select populations, but the evidence is not consistent across all studies.
- Evidence quality: The overall quality of evidence is limited by risk of bias, heterogeneity, and single-center study designs.

DISCUSSION

The systematic review of various studies on mechanical ventilation modes in ICU patients reveals a complex landscape concerning their impact on patient outcomes and weaning success. While a definitive consensus on the superiority of one mode over another remains elusive, several recurring themes and significant findings warrant detailed discussion. The research indicates that pressure-controlled ventilation modes are either equivalent or superior to volume-controlled modes for patient outcomes and weaning

success in intensive care. Notably, no study reported advantages for volume-controlled ventilation over pressure-controlled modes.

Regarding respiratory mechanics and gas exchange, the evidence suggests that pressure-controlled and hybrid ventilation modes tend to improve these parameters compared with volume-controlled ventilation. For instance, in thoracic surgery patients, one study reported a PaO₂/FiO₂ ratio of 176 with a pressure-regulated volume control mode versus 146 with conventional volume control (p=0.004). This specific finding from Mahmoud et al., (2017) highlights a significant improvement in oxygenation with PRVC compared to VCV in a surgical setting.

Several trials consistently documented lower peak airway pressures and higher dynamic compliance with pressure-controlled variants. This is a crucial observation, as lower peak airway pressures are generally considered lung-protective, potentially reducing the risk of barotrauma and volutrauma, which are known complications of mechanical ventilation (Zhu et al., 2017; Veerasamy et al., 2022). Higher dynamic compliance also indicates improved lung distensibility, suggesting that pressure-controlled modes may optimize the mechanical properties of the respiratory system (Mahmoud et al., 2017; Veerasamy et al., 2022; Gunenc et al., 2024).

A summary of findings across studies further elaborates on these points. Seven studies reported higher PaO₂/FiO₂ values with advanced or alternative ventilation modes. This indicates a consistent trend towards improved oxygenation with pressure-controlled or hybrid modes. However, it is also important to note that nine studies found no significant difference in PaO₂/FiO₂, and data for six studies were not mentioned. This variability underscores the need for further research to delineate specific patient populations or clinical contexts where these benefits are most pronounced.

Regarding peak airway pressures, eight studies reported lower peak pressures with advanced or alternative ventilation modes. This finding reinforces the lung-protective potential of pressure-controlled ventilation. However, one study reported higher mean

airway pressure, and another reported higher double cycling with pressure control. Double cycling, a form of patient-ventilator asynchrony, can lead to increased stress on the lungs and may negate some of the benefits of pressure-controlled ventilation (de Haro et al., 2018).

Dynamic compliance was reported to be higher with advanced or alternative ventilation modes in nine studies. Only one study found no difference in dynamic compliance. This strong trend towards improved dynamic compliance suggests that pressure-controlled modes may lead to more efficient and less injurious ventilation. The consistent improvement in respiratory mechanics parameters, even if not universally significant for oxygenation, provides a strong physiological rationale for the use of pressure-controlled modes (Mahmoud et al., 2017; Veerasamy et al., 2022; Gunenc et al., 2024).

While physiological benefits are evident, their translation into improved clinical outcomes is less consistent. Eleven studies reported a statistically or clinically significant difference between modes. In all these eleven studies, pressure-controlled ventilation (or its variants) was associated with better outcomes in at least one measured domain. These better outcomes included higher oxygenation, lower inflammation, shorter duration of ventilation or ICU stay, less asynchrony, improved respiratory mechanics, or fewer pulmonary complications.

However, ten studies reported no significant difference between modes for the outcomes measured. This highlights a disparity between physiological improvements and tangible clinical benefits, suggesting that while pressure-controlled modes may optimize lung mechanics, these benefits do not always translate into improved patient mortality or major morbidity outcomes (Li et al., 2022; Li et al., 2023; Ammar et al., 2021). The relative importance of the choice of ventilation mode may be less than adherence to lung-protective strategies, such as appropriate tidal volume and positive end-expiratory pressure (PEEP) settings, regardless of the chosen mode.

A critical aspect of patient outcomes in the ICU is the duration of mechanical ventilation and successful weaning. In two studies, pressure-controlled ventilation was associated with better outcomes (shorter mechanical ventilation or ICU stay, more ventilator-free days) compared to volume-controlled ventilation; both reported statistically significant differences. For example, Zhou et al., (2017) reported 19 ventilator-free days with APRV compared to 2 days with LTV in ARDS patients (Zhou et al., 2017). Similarly, Alikiaii et al., (2020) found shorter MV/ICU duration and extubation time with VSV compared to VCV.

However, in three studies, there was no difference between volume-controlled and pressure-controlled ventilation regarding weaning and duration of ventilation, and none reported statistically significant differences. This inconsistency suggests that while pressure-controlled modes might offer advantages in specific contexts or patient groups, they are not a universal solution for accelerating weaning in all ICU patients. Factors such as the patient's underlying condition, severity of illness, and readiness for weaning likely play a more dominant role.

Inflammatory markers and complications also show a varied response. For volume-controlled ventilation, three studies found higher inflammatory markers or complications, while one study found no difference, and data for one study were not mentioned. Conversely, for pressure-controlled ventilation, three studies found lower inflammatory markers or complications, one study found no difference, and data for one study were not mentioned. Notably, three studies found significant differences favoring pressure-controlled ventilation for inflammatory markers and complications. For example, Li et al., (2020) showed lower neutrophil elastase and less pneumonia with PCV+OLA, and Wang et al., (2024) reported lower IL-6 and CRP with PCV-VG zero flow (Li et al., 2020; Wang et al., 2024).

Context-specific findings are particularly insightful. In surgical populations (thoracic, cardiac, spinal), most studies report no difference in major clinical outcomes between

ventilation modes. However, pressure-controlled or hybrid modes may improve respiratory mechanics in these patients. This suggests that while physiological benefits exist, they might not translate into significant differences in major postoperative complications or mortality for surgical patients.

In non-surgical or general ICU populations (acute respiratory distress syndrome, traumatic brain injury, acute respiratory failure), physiological benefits of pressure-controlled modes are observed. However, clinical outcome differences are rare, except for airway pressure release ventilation in acute respiratory distress syndrome. This indicates that the benefits of pressure-controlled modes in non-surgical patients are primarily physiological, with limited impact on hard clinical endpoints, except in specific severe conditions like ARDS where APRV demonstrated improved outcomes (Zhou et al., 2017).

Special patient populations present unique considerations. For acute respiratory distress syndrome (ARDS) patients, airway pressure release ventilation (APRV) may reduce the duration of ventilation and ICU stay compared to low tidal volume ventilation. This finding from Zhou et al., (2017) suggests a specific advantage for APRV in a critically ill ARDS population. In traumatic brain injury (TBI) patients, no difference in intracranial pressure or arterial carbon dioxide was observed between modes, indicating that the choice of ventilation mode may not significantly impact neurological outcomes (Schirmer-Mikalsen et al., 2016).

For one-lung ventilation, some evidence points to improved oxygenation and compliance with pressure-controlled or hybrid modes, but this is not consistent across all studies. This mixed evidence suggests that while there may be some advantages, they are not universally reproducible (Ammar et al., 2021; Zhu et al., 2017). Patient-ventilator synchrony is another important aspect, where adaptive or pressure-controlled modes may reduce asynchrony. This is a clinically relevant benefit as asynchrony can increase patient discomfort, work of breathing, and potentially lead to lung injury (Saghaei et al., 2023; de Haro et al., 2018; Figueroa-Casas and Montoya, 2016).

The overall quality of evidence is limited by several factors. Many studies lack blinding, increasing the risk of bias. The heterogeneity in patient populations, ventilation protocols, and outcome definitions also limits comparability across studies. Furthermore, several studies are underpowered for clinical outcomes, meaning they may not have sufficient sample size to detect statistically significant differences even if they exist (Gibbs et al., 2023). Most studies being single-center also limits external validity, making it difficult to generalize findings to broader populations.

In summary, while pressure-controlled and hybrid ventilation modes often improve respiratory mechanics compared to volume-controlled modes, these physiological benefits do not consistently translate into improved clinical outcomes such as reduced postoperative pulmonary complications, mortality, or duration of ventilation. This suggests that other factors, such as the overall lung-protective strategy employed, may be more critical than the specific mode of ventilation.

Hybrid and adaptive modes may offer advantages in select populations, but the evidence is not consistent across all studies. This highlights the need for more targeted research to identify specific patient groups who would benefit most from these advanced ventilation strategies. The overall quality of evidence is limited by risk of bias, heterogeneity, and single-center study designs, emphasizing the need for larger, multi-center, blinded randomized controlled trials to provide more robust evidence.

The consistent observation that no study reported advantages for volume-controlled ventilation over pressure-controlled modes is a significant finding. This indicates that, at the very least, pressure-controlled modes are not inferior to volume-controlled modes and often offer some advantages, particularly in terms of respiratory mechanics and certain clinical outcomes in specific populations. This consistent non-inferiority or superiority of PCV is an important takeaway for clinical practice.

Future research should focus on well-designed randomized controlled trials with adequate power to detect clinically meaningful differences in patient-centered outcomes,

not just physiological parameters. Standardized definitions for outcomes and clear reporting of ventilation protocols would also enhance comparability across studies. Investigating the long-term functional outcomes and quality of life for patients undergoing different ventilation modes would provide a more comprehensive understanding of their impact.

The emphasis on individualized ventilation strategies based on patient characteristics and underlying pathology appears to be a more promising avenue than a "one-size-fits-all" approach. For example, the specific benefits of APRV in ARDS patients or the reduction of asynchrony with adaptive modes in certain patients suggest that tailoring the ventilation mode to the patient's condition could optimize outcomes (Zhou et al., 2017; Saghaei et al., 2023).

In summary, while pressure-controlled ventilation often demonstrates superior physiological benefits in terms of respiratory mechanics and gas exchange, these do not always translate into consistently improved hard clinical outcomes across all patient populations. However, the consistent finding that PCV is never inferior to VCV, and often superior in specific aspects, provides a strong rationale for its continued use and further investigation. The limitations of current evidence underscore the need for more rigorous research to guide optimal ventilation strategies in the ICU.

CONCLUSION

The comprehensive review of various mechanical ventilation modes in intensive care unit (ICU) patients reveals that pressure-controlled ventilation (PCV) and its variants generally offer equivalent or, in several aspects, superior outcomes compared to volume-controlled ventilation (VCV). This superiority is particularly evident in improvements to respiratory mechanics, such as lower peak airway pressures and increased dynamic compliance, which are crucial for lung protection and overall ventilatory efficiency. These physiological benefits suggest a more favorable environment for lung recovery and a reduced risk of ventilator-induced lung injury.

While these physiological advantages of pressure-controlled modes are consistently observed across numerous studies, their translation into consistently improved hard clinical outcomes, such as reduced mortality or a universal decrease in the duration of ventilation or ICU stay, is not always statistically significant. This highlights a critical distinction between optimizing respiratory parameters and achieving a tangible impact on broader patient survival and recovery metrics. The absence of studies reporting advantages for volume-controlled ventilation over pressure-controlled modes, however, underscores the non-inferiority, and often the preference, for PCV strategies.

In terms of weaning success, the evidence is mixed. Some studies indicate that pressure-controlled ventilation can lead to shorter mechanical ventilation durations and more ventilator-free days, which are important indicators of successful liberation from ventilatory support. Conversely, other studies found no significant difference in weaning outcomes between PCV and VCV. This variability suggests that while the mode of ventilation plays a role, other factors, such as the patient's underlying condition, comorbidity burden, and the overall weaning protocol, are likely more influential in determining extubation success.

The impact on inflammatory markers and pulmonary complications also leans towards the benefits of pressure-controlled ventilation, with several studies reporting lower inflammatory markers and fewer complications. This suggests that the lung-protective characteristics of PCV may extend beyond pure mechanics to influence systemic inflammatory responses and reduce the incidence of ventilator-associated complications. However, as with other clinical outcomes, this benefit is not universally observed across all studies, indicating the presence of other confounding variables or the need for more specific patient populations to demonstrate consistent effects.

In summary, while pressure-controlled ventilation modes demonstrate clear advantages in optimizing respiratory mechanics and show promising trends in reducing inflammatory responses and some clinical complications, they do not consistently translate into superior outcomes across all patient populations and clinical endpoints compared to volume-controlled ventilation. The evidence collectively points to pressure-controlled modes as at least equivalent, if not superior, to volume-controlled modes in various aspects of ICU ventilation. Future research, particularly large-scale,

well-designed randomized controlled trials, is needed to further delineate the specific contexts and patient cohorts where one ventilation mode offers a definitive clinical advantage over the other.

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