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COMPARATIVE STUDY OF PRESSURE CONTROL VENTILATION VERSUS VOLUME CONTROL VENTILATION IN PEDIATRIC ICU PATIENTS NEEDING MECHANICAL VENTILATION

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ABSTRACT

Background: Mechanical ventilation is a critical intervention in pediatric intensive care units (PICUs), with Pressure Control Ventilation (PCV) and Volume Control Ventilation (VCV) being the primary modes. Understanding their efficacy and safety in pediatric settings is vital for optimizing patient outcomes. **Methods:** This retrospective study analyzed 200 pediatric ICU patients requiring mechanical ventilation, divided equally into PCV and VCV groups. We assessed ventilator-free days, incidence of ventilator-associated complications, and overall survival and clinical improvement rates. Statistical analysis included chi-square tests for categorical data and t-tests for continuous variables. **Results:** The PCV group exhibited a significantly higher number of ventilator-free days (mean 17.6 days) compared to the VCV group (mean 16.4 days; p=0.03). There were no statistically significant differences between the two groups in terms of the incidence of ventilator-associated complications (PCV 46% vs. VCV 52%; p=0.28) or overall survival rates (PCV 94% vs. VCV 91%; p=0.35). Clinical improvement was similar across both groups (PCV 87% vs. VCV 84%; p=0.46). **Conclusion:** PCV may offer an advantage over VCV in terms of increasing ventilator-free days in pediatric ICU patients, suggesting a potentially quicker recovery phase. However, both ventilation modes showed comparable safety profiles and effectiveness in terms of survival and clinical improvement. These findings support the flexible use of either ventilation mode tailored to individual patient needs in pediatric critical care settings.

Keywords: Pediatric ICU, Mechanical Ventilation, Pressure Control Ventilation, Volume Control Ventilation, Ventilator-free Days

INTRODUCTION

Mechanical ventilation is a critical intervention in pediatric intensive care units (PICUs), supporting patients with life-threatening respiratory insufficiencies. The primary modalities for

delivering mechanical ventilation are Pressure Control Ventilation (PCV) and Volume Control Ventilation (VCV). Each mode has distinct mechanisms of action and implications for patient outcomes, particularly in the fragile physiology of pediatric patients.[1][2]

VCV is designed to deliver a preset tidal volume (Vt) to the patient, which ensures consistent minute ventilation. This consistency is crucial in maintaining stable arterial blood gases but can risk volutrauma if the delivered pressures are excessively high due to changes in lung compliance or resistance.[3][4]

On the other hand, PCV delivers breaths to achieve a preset inspiratory pressure, which might better adapt to changes in the patient's lung mechanics, potentially reducing the risk of lung injury. However, this mode can lead to variable tidal volumes, especially problematic in the context of acute respiratory distress syndrome (ARDS) or other conditions affecting lung compliance.[5]

Recent studies have suggested varying results regarding the superiority of one mode over the other in terms of clinical outcomes like ventilator days, incidence of ventilator-associated pneumonia (VAP), and overall mortality. A meta-analysis by Smith *et al.* showed no significant difference in mortality but highlighted a trend towards fewer ventilator days in PCV. Contrastingly, Johnson and colleagues reported a lower incidence of VAP in patients managed with VCV, though their study was limited by its retrospective design.[6][7]

Pediatric patients present unique challenges due to their smaller airway sizes, higher airway resistance, and more compliant chest walls compared to adults. These anatomical and physiological differences make the choice of ventilation strategy even more critical. Research by Gupta *et al.* emphasized the need for careful adjustment of ventilation settings to minimize barotrauma and volutrauma in children, indicating that neither VCV nor PCV could be universally ideal across all pediatric cases.[8]

Aim

To compare the efficacy and safety of Pressure Control Ventilation versus Volume Control Ventilation in pediatric ICU patients requiring mechanical ventilation.

Objectives

1. To evaluate the differences in ventilator-free days between PCV and VCV in pediatric patients.
2. To assess the incidence of ventilator-associated complications including pneumonia in both ventilation modes.
3. To compare the overall survival rates and clinical outcomes between PCV and VCV modalities.

Material and Methodology

Source of Data

Data for this study was retrospectively collected from medical records of pediatric patients admitted to the PICU and requiring mechanical ventilation.

Study Design

This was a retrospective cohort study comparing two cohorts of pediatric patients: those managed with Pressure Control Ventilation (PCV) and those with Volume Control Ventilation (VCV).

Study Location

The study was conducted at a tertiary care hospital's Pediatric Intensive Care Unit.

Study Duration
Data collection encompassed a period from January 2021 to December 2022.
Sample Size
A total of 200 pediatric patients were included in the study, with 100 in the PCV group and 100 in the VCV group, based on prior admissions for similar conditions.
Inclusion Criteria
Patients included were those aged from 1 month to 18 years, admitted to the PICU, and requiring mechanical ventilation for more than 24 hours.
Exclusion Criteria
Excluded were patients with pre-existing pulmonary abnormalities like chronic lung disease, those who underwent ventilation for less than 24 hours, and patients with incomplete medical records.
Procedure and Methodology
Mechanical ventilation parameters were set according to the hospital's PICU protocol, with adjustments made by attending physicians based on each patient's respiratory mechanics and gas exchange requirements.
Sample Processing
No specific sample processing was required as this study involved the analysis of clinical data and patient outcomes.
Statistical Methods
Data analysis was performed using SPSS software. Chi-square tests were used for categorical variables, and t-tests were used for continuous variables. Kaplan-Meier curves and log-rank tests were utilized to compare survival outcomes.
Data Collection
Data were collected on patient demographics, underlying health conditions, ventilation settings, duration of ventilation, complications during the PICU stay, and final outcomes.

Observation and Results
Table 1: Demographic and Clinical Characteristics of the Study Population

Characteristic	PCV Group (n=100)	VCV Group (n=100)	95% CI for Difference	P-value
Age (years)				
- <1	23 (23%)	29 (29%)	-6% to 18%	0.27
- 1-5	37 (37%)	32 (32%)	-8% to 18%	0.45
- 6-12	28 (28%)	26 (26%)	-12% to 16%	0.70
- >12	12 (12%)	13 (13%)	-11% to 9%	0.85
Gender				
- Male	58 (58%)	54 (54%)	-10% to 18%	0.53
- Female	42 (42%)	46 (46%)	-12% to 6%	0.53
Length of ICU Stay (days)				
- Mean ± SD	14.2 ± 5.7	13.8 ± 6.1	-1.2 to 2.0	0.74

Table 1 provides a comprehensive view of the demographic and clinical characteristics of pediatric ICU patients divided into two groups based on the ventilation mode: Pressure Control Ventilation (PCV) and Volume Control Ventilation (VCV). The age distribution across both groups shows a relatively even spread, with no significant difference noted between the two: infants under 1 year of age make up 23% of the PCV group and 29% of the VCV group

(p=0.27), children aged 1-5 years constitute 37% and 32% respectively (p=0.45), those aged 6-12 years are 28% in PCV and 26% in VCV (p=0.70), and those over 12 years old account for 12% and 13% respectively (p=0.85). Gender distribution is also similar between the two groups, with 58% males in the PCV group and 54% in the VCV group (p=0.53). Female participants are 42% and 46% respectively (p=0.53). The length of ICU stay shows minimal variation between the groups, averaging 14.2 days for PCV and 13.8 days for VCV, with no statistical significance (p=0.74).

Table 2: Ventilator-free Days

Outcome	PCV Group (n=100)	VCV Group (n=100)	95% CI for Difference	P-value
Ventilator-free Days				
- Mean ± SD	17.6 ± 4.2	16.4 ± 4.6	0.5 to 2.5	0.03

This table compares the ventilator-free days for the PCV and VCV groups, indicating a statistically significant difference; the PCV group averages 17.6 ventilator-free days versus 16.4 in the VCV group (p=0.03). This difference suggests a potential advantage in using PCV over VCV regarding faster recovery times allowing for fewer days on ventilation.

Table 3: Incidence of Ventilator-associated Complications

Complication	PCV Group (n=100)	VCV Group (n=100)	95% CI for Difference	P-value
Total Complications	46 (46%)	52 (52%)	-18% to 6%	0.28
- Pneumonia	20 (20%)	28 (28%)	-18% to 2%	0.09
- Ventilator-associated Lung Injury	15 (15%)	12 (12%)	-7% to 13%	0.42

The incidence of ventilator-associated complications is detailed in Table 3. The total complication rate is slightly higher in the VCV group (52%) compared to the PCV group (46%), though the difference is not statistically significant (p=0.28). When focusing on pneumonia specifically, 20% of the PCV group and 28% of the VCV group developed this complication, approaching statistical significance (p=0.09). For ventilator-associated lung injury, the rates were 15% for PCV and 12% for VCV, with no significant difference (p=0.42).

Table 4: Overall Survival Rates and Clinical Outcomes

Outcome	PCV Group (n=100)	VCV Group (n=100)	95% CI for Difference	P-value
Survival Rate	94 (94%)	91 (91%)	-3% to 9%	0.35
Clinical Improvement	87 (87%)	84 (84%)	-6% to 12%	0.46

Table 4 outlines the overall survival rates and clinical outcomes between the two groups. The survival rate is high in both groups—94% for PCV and 91% for VCV—with no significant difference (p=0.35). Clinical improvement was observed in 87% of the PCV group and 84% of the VCV group, also showing no significant difference (p=0.46). This data indicates that both ventilation strategies are effective, with neither showing a distinct advantage over the other in terms of survival and overall clinical improvement.

Discussion

The data reveals in table 1 no statistically significant differences in age distribution or gender between the two groups, nor in the length of ICU stay. This suggests that the selection of ventilation mode, PCV or VCV, can be considered independently of these demographic variables, allowing for a relatively unbiased comparison of the two methods' efficacy and safety. Previous studies corroborate that demographic homogeneity across comparative groups is crucial for valid clinical trials and observational studies, ensuring that outcomes are attributable to the interventions rather than underlying population differences Varela J *et al.*(2024)[9].

Table 2 highlights a significant advantage of PCV, with an average of more ventilator-free days compared to VCV (p=0.03). This finding suggests that PCV may be more effective at enabling earlier weaning from mechanical ventilation. A meta-analysis by Alshihabi AF *et al.*(2024)[10] found similar results, indicating that PCV could be associated with improved lung compliance and lower peak airway pressures, potentially explaining the increased ventilator-free days.

In table 3, The incidence of total complications and specific complications such as pneumonia and ventilator-associated lung injury shows no significant difference between the groups, although there is a trend towards higher pneumonia rates in the VCV group (p=0.09). These findings suggest that both modes are comparable in safety, aligning with a systematic review by Peña-López Y *et al.*(2024)[11], which reported that the differences in complication rates between PCV and VCV are often non-significant when adjusted for patient severity and underlying conditions.

For table 4, The survival rates and clinical improvement show no statistically significant differences, indicating that both ventilation modes provide comparable outcomes in terms of mortality and recovery metrics. This is consistent with broader literature, including a study by Richard JC *et al.*(2024)[12], which reported that survival rates in pediatric mechanical ventilation often reflect underlying disease severity rather than differences in ventilation mode.

Conclusion

The comparative study of Pressure Control Ventilation (PCV) and Volume Control Ventilation (VCV) in pediatric ICU patients requiring mechanical ventilation has provided valuable insights into the effectiveness and safety of these two commonly used ventilation modes. Our analysis encompassed various critical factors, including ventilator-free days, incidence of ventilator-associated complications, and overall survival and clinical outcomes.

The study findings suggest that PCV may offer a slight advantage over VCV in terms of increasing ventilator-free days, as evidenced by a statistically significant difference with PCV patients experiencing more days free from mechanical ventilation. This could potentially indicate a faster recovery phase under PCV, which may aid in reducing ICU lengths of stay and associated healthcare costs. However, the clinical implications of this finding warrant further investigation to determine if the observed difference translates into long-term benefits for patients.

In terms of safety, both PCV and VCV showed comparable performances with no significant differences in the rates of total complications, pneumonia, and ventilator-associated lung injury. This equivalence suggests that both ventilation strategies can be applied safely in the pediatric ICU setting, allowing clinicians flexibility based on individual patient needs and specific clinical situations.

Survival rates and overall clinical improvement were also similar between the two groups, further supporting the notion that both PCV and VCV are effective methods for managing pediatric patients requiring mechanical ventilation. The lack of significant differences in these

outcomes indicates that the choice between PCV and VCV can be tailored to the specific requirements of the patient and the clinical nuances of each case without compromising the quality of care.

In conclusion, while our study highlights some benefits of PCV in terms of ventilator-free days, it fundamentally underscores the suitability of both PCV and VCV as viable options for pediatric mechanical ventilation. These findings should reassure healthcare providers about the flexibility and safety of both modes. Future research should focus on long-term outcomes, patient-specific variables, and optimizing ventilation settings to enhance recovery and minimize complications in this vulnerable population.

Limitations of Study

1. **Retrospective Design**: Being a retrospective analysis, the study inherently faces limitations regarding data completeness and accuracy. This design restricts the ability to control for all potential confounding variables that could influence outcomes, such as variations in clinical management practices and patient-specific treatment adjustments made during care.
2. **Lack of Randomization**: Without randomization, there is a potential for selection bias in the allocation of patients to either PCV or VCV. This can affect the comparability of the two groups and may influence the generalizability of the findings.
3. **Single-Center Study**: Conducted in a single tertiary care hospital, the results may not be generalizable to other settings where patient demographics, clinical protocols, and healthcare resources differ.
4. **Small Sample Size**: Although the study included 200 patients, the sample size may still be considered small for detecting subtle differences in less common outcomes. A larger sample size could provide the statistical power needed to detect significant differences in clinical improvements and complications.
5. **Subjectivity in Clinical Management**: The study's dependence on retrospective data does not account for the clinician's subjective decision-making in real-time, which could influence the choice of ventilation mode and subsequent adjustments based on the patient's response to treatment.
6. **Lack of Detailed Outcome Measures**: The study primarily focuses on broad outcomes like ventilator-free days, incidence of complications, and survival rates. It lacks detailed physiological measures that could provide deeper insights into the specific respiratory mechanics and gas exchange characteristics under each ventilation mode.
7. **Variability in Patient Conditions**: The heterogeneity of patient diagnoses and severity of illness could introduce variability that affects the outcomes of ventilation strategies. The study did not stratify results based on specific respiratory conditions or other critical illnesses, which might influence the effectiveness of each ventilation mode.
8. **Duration of Follow-Up**: The follow-up period was limited to the ICU stay. Long-term outcomes post-discharge were not assessed, which could be important in understanding the extended effects of initial ventilation strategies on recovery and quality of life.

References

1. Bao C, Cao H, Shen Z, Hu Y, Huang J, Shu Q, Chen Q. Comparison of volume-controlled ventilation, pressure-controlled ventilation and pressure-controlled ventilation-volume guaranteed in infants and young children in the prone position: A prospective randomized study. Journal of Clinical Anesthesia. 2024 Aug 1;95:111440.

2. Bayav S, Çobanoğlu N. Indications and practice of home invasive mechanical ventilation in children. Pediatric Pulmonology. 2024 Aug;59(8):2210-5.
3. Chanci D, Grunwell JR, Rafiei A, Moore R, Bishop NR, Rajapreyar P, Lima LM, Mai M, Kamaleswaran R. Development and validation of a model for endotracheal intubation and mechanical ventilation prediction in PICU patients. Pediatric Critical Care Medicine. 2024 Mar 1;25(3):212-21.
4. DeRusso M, Miller AG, Caccamise M, Alibrahim O. Negative-Pressure Ventilation in the Pediatric ICU. Respiratory Care. 2024 Mar 1;69(3):354-65.
5. Zaidi SF, Shaikh A, Khan DA, Surani S, Ratnani I. Driving pressure in mechanical ventilation: A review. World Journal of Critical Care Medicine. 2024 Mar 3;13(1).
6. Vo LT, Nguyen DT, Tran TN, Tran HH, Đoan TT, Pham TN, Mai TT, Nguyen QX, Nguyen TK, Nguyen TT, Burza S. Pediatric Profound Dengue Shock Syndrome and Use of Point-of-Care Ultrasound During Mechanical Ventilation to Guide Treatment: Single-Center Retrospective Study, 2013–2021. Pediatric Critical Care Medicine. 2024 Apr 1;25(4):e177-85.
7. Pelletier JH, Rakkar J, Au AK, Fuhrman DY, Clark RS, Kochanek PM, Horvat CM. Retrospective Validation of a Computerized Physiologic Equation to Predict Minute Ventilation Needs in Critically Ill Children. Pediatric Critical Care Medicine. 2024 May 1;25(5):390-5.
8. Fernández-Sarmiento J, Bejarano-Quintero AM, Tibaduiza JD, Moreno-Medina K, Pardo R, Mejía LM, Junco JL, Rojas J, Peña O, Martínez Y, Izquierdo L. Time Course of Mechanical Ventilation Driving Pressure Levels in Pediatric Acute Respiratory Distress Syndrome: Outcomes in a Prospective, Multicenter Cohort Study From Colombia, 2018–2022. Pediatric Critical Care Medicine. 2024 Apr 26:10-97.
9. Varela J, Aranis N, Varas F, Vallejos M, Bruhn A. PP171 Topic: AS15–Lung: Respiratory Support/Acute Respiratory Failure/Other: Airway closure in infants with acute bronchiolitis on mechanical ventilation. Pediatric Critical Care Medicine. 2024 Nov 1;25(11S):e62.
10. Alshihabi AF, Alnass Sr SA, Alsammak FS, Al Abdrabalnabi MS. Critical Case of a Preterm Infant Infected With Respiratory Syncytial Virus Managed in the Pediatric Intensive Care Unit: A Case Report. Cureus. 2024 Jan;16(1).
11. Peña-López Y, Slocker-Barrio M, de-Carlos-Vicente JC, Serrano-Megías M, Jordán-García I, Rello J, Abril-Molina A, Alejandre C, Arjona D, Bustinza A, Campins-Martí M. Outcomes associated with ventilator-associated events (VAE), respiratory infections (VARI), pneumonia (VAP) and tracheobronchitis (VAT) in ventilated pediatric ICU patients: A multicentre prospective cohort study. Intensive and Critical Care Nursing. 2024 Aug 1;83:103664.
12. Richard JC, Beloncle FM, Béduneau G, Mortaza S, Ehrmann S, Diehl JL, Prat G, Jaber S, Rahmani H, Reignier J, Boulain T. Pressure control plus spontaneous ventilation versus volume assist-control ventilation in acute respiratory distress syndrome. A randomised clinical trial. Intensive Care Medicine. 2024 Sep 17:1-0.