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# COMPARISON OF CHANGE IN LUNG COMPLIANCE ON PRESSURE CONTROL AND AIRWAY PRESSURE RELEASE VENTILATION – A RANDOMIZED CROSS-OVER TRIAL

*Original Research*

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## ABSTRACT

**Background:** Mechanical ventilation is a critical intervention in intensive care units, particularly for patients with impaired lung compliance. Optimizing ventilation requires careful adjustment of modes to preserve alveolar integrity, improve oxygenation, and minimize ventilator-associated injury. Airway Pressure Release Ventilation (APRV) and Pressure Control Ventilation (PCV) are widely used pressure-based strategies, yet their effects on lung compliance and oxygenation remain debated. Comparative evidence is limited, especially in crossover designs allowing within-patient evaluation of these modes.

**Objective:** The study aimed to assess changes in lung compliance and oxygenation indices following mechanical ventilation with APRV and PCV, using a randomized cross-over design.

**Methods:** This randomized cross-over trial was conducted in the Department of Anaesthesiology, Surgical ICU, Dr. Ruth K.M. Pfau Civil Hospital Karachi, Pakistan, from May to December 2021. A total of 70 patients aged 18–85 years requiring mechanical ventilation for >6 hours were included. Ventilation was initiated with Assist-Control Volume Control (AC-VC) mode for baseline measurements, followed by randomization to APRV or PCV in Phase I and cross-over to the alternate mode in Phase II. Data collected included dynamic lung compliance, oxygen index (OI), arterial blood gases, peak inspiratory pressure (PIP), mean airway pressure (MAP), and airway resistance.

**Results:** Baseline compliance in AC-VC mode was 45.5 mL/cm$H_2O$/kg (IQR: 32.8–64.2). In Phase I, compliance was significantly higher with APRV at 89.6 mL/cm$H_2O$/kg (IQR: 62.4–124.7) compared to PCV at 48.2 mL/cm$H_2O$/kg (IQR: 34.6–68.9). In Phase II, APRV maintained higher compliance at 76.4 mL/cm$H_2O$/kg (IQR: 55.2–108.6) compared with PCV at 68.3 mL/cm$H_2O$/kg (IQR: 49.5–92.1). Correlation analysis showed APRV weakly positive in Phase I ($r = 0.173$, $p = 0.322$) and Phase II ($r = 0.261$, $p = 0.131$), while PCV was moderately negative in Phase I ($r = -0.311$, $p = 0.069$) and very weakly negative in Phase II ($r = -0.065$, $p = 0.712$). Regression revealed a significant negative association for PCV in Phase I ($B = -1.998$, $p = 0.025$). Oxygen index analysis indicated significant improvements with both modes in Phase I, but only APRV sustained improvement in Phase II.

**Conclusion:** APRV demonstrated more consistent benefits in preserving lung compliance and sustaining oxygenation compared with PCV. These findings support the role of APRV in critically ill patients; however, larger multicenter studies are needed to confirm long-term outcomes and guide individualized ventilation strategies.

**Keywords:** Airway Pressure Release Ventilation; Blood Gas Analysis; Intensive Care Units; Lung Compliance; Oxygenation Index; Positive-Pressure Respiration; Respiratory Mechanics.

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## INTRODUCTION

Mechanical ventilation represents a cornerstone of intensive care medicine, serving as a life-sustaining intervention for patients with respiratory failure. Its therapeutic goals include improving oxygenation, ensuring effective ventilation, reducing the load on respiratory muscles, and maximizing alveolar recruitment to optimize gas exchange (1). Achieving these objectives requires careful adjustment of ventilatory settings, balancing the dynamic physiology of the lungs to meet metabolic demands. Importantly, patients in the intensive care unit (ICU) rarely present with normal lung compliance; rather, they often suffer from reduced compliance due to parenchymal disease such as pneumonia or acute respiratory distress syndrome, whereas conditions like emphysema may conversely increase compliance (2,3). In addition to underlying pathology, the ventilator itself can contribute to lung injury through mechanisms such as barotrauma, volutrauma, atelectrauma, and biotrauma, further complicating management and underscoring the importance of selecting appropriate ventilation modes (4,5). Among available strategies, Airway Pressure Release Ventilation (APRV) has been utilized for more than two decades in patients with compromised lungs. It applies a high continuous positive airway pressure (CPAP) with periodic releases, allowing for spontaneous breathing throughout the cycle (6,7). This mode promotes synchrony between patient and ventilator, reduces the need for heavy sedation or muscle relaxants, and maintains alveolar recruitment by limiting collapse and re-expansion (8). In contrast, Pressure Control Ventilation (PCV) delivers a preset inspiratory pressure during each breath, reducing peak inspiratory pressures and optimizing oxygen delivery through its flow pattern (9,10). Both modes have distinct physiological rationales, yet they aim to improve gas exchange while minimizing ventilator-associated injury.

Previous comparative studies suggest that APRV may improve patient-ventilator synchrony, decrease sedation requirements, and shorten the duration of ventilation (11). However, findings have been inconsistent, with some reports showing no significant differences between PCV and APRV in terms of cardiopulmonary outcomes or oxygenation (12,13). In fact, certain studies noted that $PaO_2$ values were higher in PCV compared to APRV (14-16). Despite these observations, there remains a paucity of evidence from cross-over trials directly comparing these two modes within the same patients, particularly in terms of their effect on dynamic lung compliance over time. This study was therefore designed to address this gap by evaluating changes in lung compliance at hourly intervals in ICU patients undergoing mechanical ventilation. By comparing PCV and APRV in a cross-over manner, it aims to provide clearer insights into how each mode influences lung mechanics, with the objective of guiding clinicians toward evidence-based ventilatory strategies for critically ill patients.

## METHODS

This randomized cross-over trial was conducted in the Department of Anaesthesiology, Surgical Intensive Care Unit, and Pain Management at Dr. Ruth K.M. Pfau Civil Hospital Karachi (CHK) between May and December 2021, following ethical approval from the Institutional Review Board (IRB) of Dow University of Health Sciences, Karachi, Pakistan [Ref: IRB-2021/DUHS/Approval/2021/861]. The study adhered to institutional guidelines for mechanical ventilation management in critically ill patients. Written informed consent was obtained from patients' attendants or next of kin prior to study enrolment, as participants were mechanically ventilated and unable to provide consent themselves. Confidentiality of patient data was strictly maintained, with no personal identifiers disclosed. Eligible participants included adult patients aged 18 to 85 years of either gender who were admitted to the surgical ICU and required mechanical ventilation for more than six hours using Hamilton S1 or C3 ventilators. Patients were excluded if they deteriorated during randomization, required inotropic support, or required ventilation modes other than Pressure Control Ventilation (PCV) or Airway Pressure Release Ventilation (APRV). Further exclusion criteria included pre-existing pulmonary pathology such as obstructive or restrictive lung disease, renal failure according to the RIFLE criteria, elevated intracranial pressure, or a requirement for positive end-expiratory pressure (PEEP) greater than 10 $cmH_2O$ to maintain mean airway pressure during the initial phase. A total of 70 patients meeting the inclusion criteria were recruited for analysis. The trial comprised three distinct phases. In Phase 0, all eligible patients were initially placed on Assist Control Volume Control (AC-VC) ventilation as per departmental protocol, with settings individualized to patient needs (9-11). Tidal volume was set according to predicted body weight, respiratory rate adjusted to achieve target minute ventilation, PEEP titrated to maintain oxygen saturation, and the fraction of inspired oxygen ($FiO_2$) initiated at 100% in line with ICU practice. At the end of one hour, baseline physiological and ventilatory parameters were recorded, including pH,

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$PaCO_2$, $HCO_3^-$, $PaO_2$, oxygen index, dynamic lung compliance, peak inspiratory pressure, mean airway pressure, and airway resistance. Patients whose clinical status deteriorated during this stage were excluded from subsequent phases.

In Phase 1, patients were randomly assigned into two groups using a simple randomization method. Group A received PCV with high PEEP, titrated to achieve the mean airway pressure observed during Phase 0. Group B received APRV, with P-high set at the mean airway pressure from Phase 0 plus 5 $cmH_2O$, P-low at 0 $cmH_2O$, Thigh adjusted between 4–6 seconds for comfort, and T-low set at 25–75% of peak expiratory flow. After one hour on the assigned ventilation mode, the same physiological and ventilatory parameters were measured and documented. In Phase 2, a cross-over was performed, with Group A shifted to APRV and Group B switched to PCV. Parameters were reassessed and recorded after three hours of ventilation in the new mode. This design allowed intra-patient comparison of both ventilatory strategies under controlled conditions. All data were collected using a structured proforma and entered into SPSS version 21.0 for analysis. Continuous variables were reported as means with standard deviations, while categorical variables were expressed as frequencies and percentages. The chi-square test was employed to compare categorical data, and a p-value of $<0.05$ was considered statistically significant at a 95% confidence interval.

## RESULTS

The study enrolled a total of 70 participants who were initially placed on Assist-Control Volume Control (AC-VC) ventilation in Phase 0, where all baseline measurements were recorded. Gender distribution across the study showed that males accounted for 67.14% of the cohort, whereas females represented 32.86%. In Phase 1, the APRV group included 12 females and 23 males, while the PCV group comprised 11 females and 24 males. The same gender distribution was maintained after cross-over in Phase 2. The mean age of participants was 32.7 years, with an average ideal body weight of 48.33 kg and a mean endotracheal tube size of 7.04. Baseline ventilatory parameters in Phase 0 demonstrated a mean compliance of 53.62 ± 32.53 mL/$cmH_2O$/kg, resistance of 11.89 ± 6.49 $cmH_2O$/L/s, mean airway pressure of 9.55 ± 2.06 $cmH_2O$, peak inspiratory pressure of 18.57 ± 4.56 $cmH_2O$, and oxygen index of 4.74 ± 2.73. Arterial blood gas analysis showed mean pH of 7.37 ± 0.13, $PaCO_2$ of 32.32 ± 8.26 mmHg, $PaO_2$ of 225.53 ± 97.87 mmHg, and bicarbonate of 20.13 ± 4.26 mmol/L.

During Phase 1, patients ventilated with APRV exhibited a mean compliance of 102.75 ± 71.98 mL/$cmH_2O$/kg compared to 56.54 ± 45.63 mL/$cmH_2O$/kg in the PCV group. In the same phase, APRV demonstrated lower peak pressures (16.14 ± 3.74 $cmH_2O$) compared to PCV (18.55 ± 3.35 $cmH_2O$), while mean airway pressure was higher in APRV (13.4 ± 2.46 $cmH_2O$) than PCV (10.38 ± 2.39 $cmH_2O$). The oxygen index was similar between APRV (4.3 ± 2.2) and PCV (3.92 ± 2.69). Arterial blood gases indicated mean $PaO_2$ of 187.91 ± 82.74 mmHg with APRV and 184.07 ± 87.83 mmHg with PCV. Following cross-over in Phase 2, patients on APRV maintained higher compliance at 88.59 ± 63.02 mL/$cmH_2O$/kg compared to 77.44 ± 49.48 mL/$cmH_2O$/kg in PCV. Mean airway pressure was also greater with APRV (14.55 ± 2.57 $cmH_2O$) than PCV (11.21 ± 2.92 $cmH_2O$). $PaO_2$ improved to 201.43 ± 63.4 mmHg in APRV, whereas PCV showed a lower mean $PaO_2$ of 163.75 ± 58.6 mmHg. Oxygen index values were equivalent for both modes at 3.54, though APRV sustained slightly higher oxygenation indices across phases. Correlation analysis revealed that APRV had a weak positive correlation with baseline compliance in both Phase 1 ($r = 0.173$, $p = 0.322$) and Phase 2 ($r = 0.261$, $p = 0.131$), whereas PCV demonstrated a moderate negative correlation in Phase 1 ($r = -0.311$, $p = 0.069$) and a very weak negative correlation in Phase 2 ($r = -0.065$, $p = 0.712$). Regression analysis indicated a significant negative relationship between PCV and baseline compliance in Phase 1 ($B = -1.998$, $p = 0.025$), while APRV did not show statistically significant associations in either phase. Scatter plot analysis demonstrated that APRV tended to maintain or slightly improve compliance, while PCV showed reductions, particularly in Phase 1. Outliers were present in all groups, highlighting variability in patient responses. In terms of oxygen index, both APRV and PCV showed significant improvements in Phase 1 compared to baseline, but only APRV maintained improvement in Phase 2, indicating better sustained oxygenation.

The findings suggest that APRV was generally associated with higher lung compliance and improved oxygenation indices compared to PCV across phases, though variability and lack of consistent statistical significance limit definitive conclusions. Analysis of compliance across phases demonstrated that APRV consistently achieved higher mean compliance values compared to PCV. In Phase I, compliance in APRV was 102.75 ± 71.98 mL/$cmH_2O$/kg, nearly double that of PCV at 56.54 ± 45.63 mL/$cmH_2O$/kg. After cross-over in Phase II, APRV maintained higher compliance (88.59 ± 63.02 mL/$cmH_2O$/kg) relative to PCV (77.44 ± 49.48 mL/$cmH_2O$/kg). Although this descriptive trend favored APRV, statistical testing revealed variability. Correlation analysis showed weak, non-significant positive associations between APRV and baseline compliance in both Phase I ($r = 0.173$, $p = 0.322$) and Phase II ($r = 0.261$, $p = 0.131$). In contrast, PCV demonstrated a moderate negative correlation in Phase I ($r = -0.311$, $p = 0.069$) and a very weak negative correlation in

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Phase II (r = -0.065, p = 0.712). Regression analysis further highlighted a significant reduction in compliance with PCV in Phase I (B = -1.998, p = 0.025), whereas APRV did not show statistically significant changes across phases. These findings suggest that while APRV was associated with higher mean compliance, the variability and lack of consistent significance limited the strength of the conclusion, and effect sizes were not uniformly reported for direct group comparisons.

**Table 1: Descriptive statistics of Mechanical Ventilation settings with respect to the randomization and Phase I and Phase II. Independent t-test applied.**

| | **PHASE 0** | | **PHASE I** | | | | **PHASE II** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ACVC Mode | | APRV | | PCV | | PCV | | APRV | |
| | Mean | S. D | Mean | S. D | Mean | S. D | Mean | S. D | Mean | S. D |
| Tidal volume | 399.59 | 48.39 | | | 481.83 | 129.66 | 470.37 | 94.64 | | |
| PEEP | 5.14 | 0.57 | | | 5.29 | 0.86 | 5.11 | 0.4 | | |
| FiO2 | 97.57 | 11.57 | 51.14 | 17.45 | 54.71 | 19.55 | 41.57 | 13.05 | 44.29 | 13.67 |
| Minute Ventilation | 7.88 | 1.62 | 6.8 | 2.35 | 8.6 | 2 | 8.29 | 1.59 | 5.84 | 1.8 |
| Compliance | 53.62 | 32.53 | 102.75 | 71.98 | 56.54 | 45.63 | 77.44 | 49.48 | 88.59 | 63.02 |
| Resistance | 11.89 | 6.49 | 9.94 | 7.91 | 13.23 | 7.15 | 11.29 | 5.29 | 10.37 | 4.89 |
| Peak Pressures | 18.57 | 4.56 | 16.14 | 3.74 | 18.55 | 3.35 | 18.54 | 3.62 | 15.94 | 3.73 |
| Mean Airway Pressure | 9.55 | 2.06 | 13.4 | 2.46 | 10.38 | 2.39 | 11.21 | 2.92 | 14.55 | 2.57 |
| SpO2 | 98.77 | 0.9 | 98.54 | 1.2 | 98.69 | 1.45 | 98.83 | 0.57 | 98.94 | 0.48 |
| SF Ratio | 101.49 | 31.69 | 210.87 | 63.81 | 202.17 | 68.05 | 249.21 | 57.37 | 238.66 | 55.35 |
| ABGs-PH | 7.37 | 0.13 | 7.34 | 0.1 | 7.4 | 0.09 | 7.39 | 0.09 | 7.42 | 0.09 |
| ABGs-PaCO2 | 32.32 | 8.26 | 33.97 | 8.91 | 31.15 | 8.26 | 32.33 | 7.49 | 30.59 | 8.13 |
| ABGs-PaO2 | 225.53 | 97.87 | 187.91 | 82.74 | 184.07 | 87.83 | 163.75 | 58.6 | 201.43 | 63.4 |
| ABGs-HCO3 | 20.13 | 4.26 | 19.01 | 3.59 | 21.14 | 4.95 | 20.5 | 4.08 | 21.56 | 3.82 |
| ABGs-BE | -5.18 | 5.64 | -6.38 | 4.8 | -3.94 | 6.35 | -5.79 | 5.69 | -2.95 | 4.93 |
| Oxygen Index | 4.74 | 2.73 | 4.3 | 2ss.2 | 3.92 | 2.69 | 3.54 | 3.01 | 3.54 | 2 |
| Pressure high | | | 16 | 2.73 | | | | | 15.77 | 2.56 |
| Pressure low | | | 0 | 0 | | | | | 0 | 0 |
| Time high | | | 5.11 | 0.35 | | | | | 5.27 | 0.39 |
| Time low | | | 0.75 | 0.96 | | | | | 0.79 | 1.26 |

**Table 2: Compliance correlation and regression analysis with randomization i.e., Phase 0**

| | **Correlation (r)** | **p** | **Regression (B)** | **S.E** | **p** |
|---|---|---|---|---|---|
| Phase I | | | | | |
| APRV | 0.173 | 0.322 | 0.139 | 0.08 | 0.093 |
| PCV | -0.311 | 0.069 | -1.998 | 0.846 | 0.025* |
| Phase II | | | | | |
| APRV | 0.261 | 0.131 | 0.206 | 0.114 | 0.079 |
| PCV | -0.065 | 0.712 | 0.034 | 0.094 | 0.717 |

*Significant

**Table 3: Comparison of Lung Compliance Across Ventilation Modes**

| **Phase** | **Mode** | **Mean Compliance (mL/cm$H_2O$/kg)** | **SD** | **Correlation (r)** | **p-value** | **Regression (B)** | **p-value** |
|---|---|---|---|---|---|---|---|
| Phase I | APRV | 102.75 | 71.98 | 0.173 | 0.322 | 0.139 | 0.093 |
| | PCV | 56.54 | 45.63 | -0.311 | 0.069 | -1.998 | 0.025* |
| Phase II | APRV | 88.59 | 63.02 | 0.261 | 0.131 | 0.206 | 0.079 |
| | PCV | 77.44 | 49.48 | -0.065 | 0.712 | 0.034 | 0.717 |

*Significant

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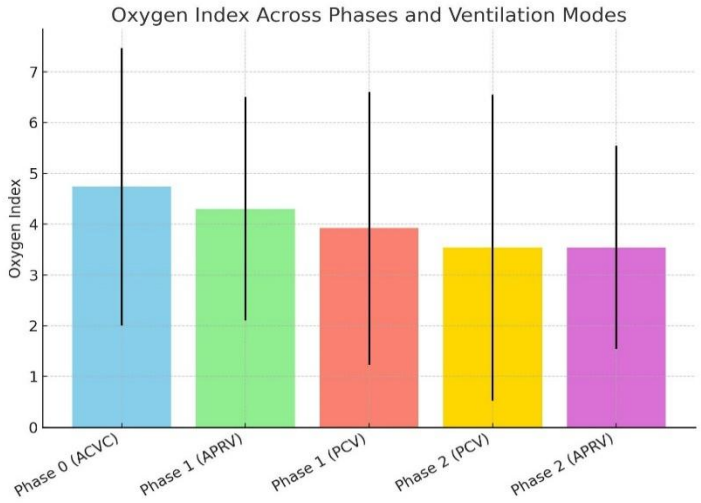


*Figure 1 Oxygen Index Across Phases and Ventilation Modes*

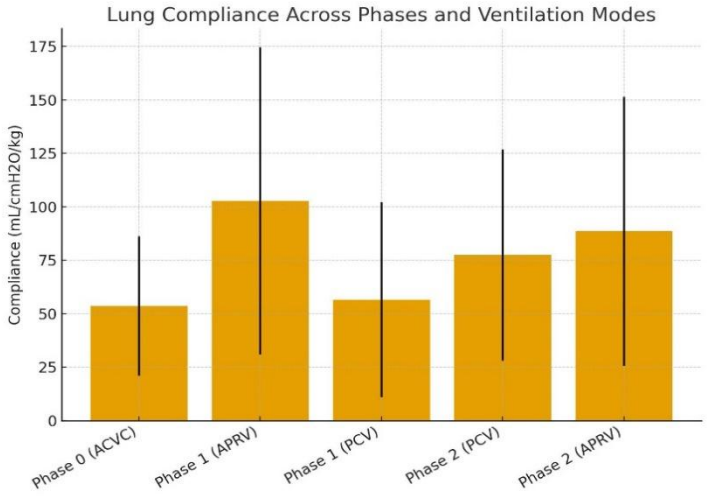


*Figure 2 Lung Compliance Across Phases and Ventilation Modes*

Partial Regression Plots of Compliance of APRV and PCV in Phase I and Phase II with randomization (Phase 0).

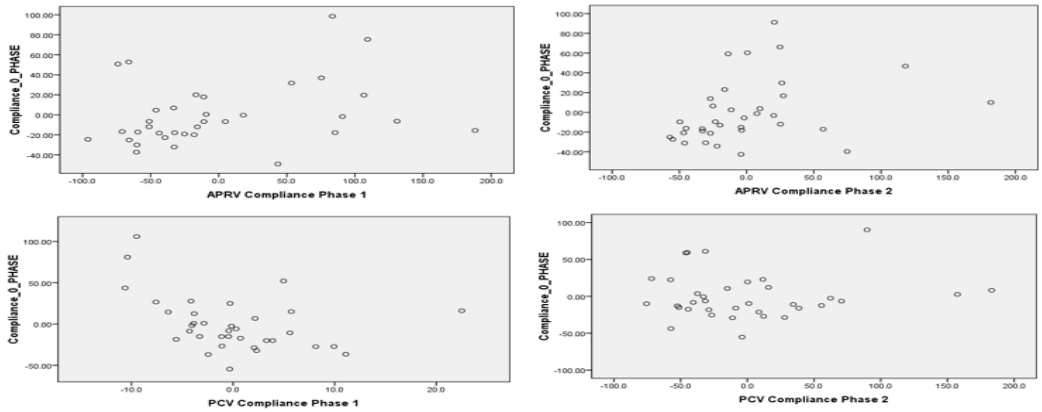


*Figure 3 Partial Regression Plots of Compliance of APRV and PCV in Phase I and II with Randomization (Phase 0)*

Pearson Correlation analysis on Oxygen Index of Phase 1 and Phase 2 with randomization (phase 0)

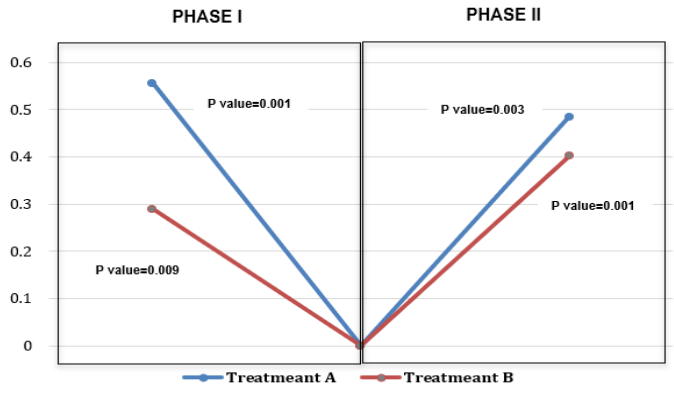


*Figure 4 Pearson Correlation Analysis on Oxygen Index of Phase 1 and Phase 2 with Randomization (Phase 0)*

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## DISCUSSION

The findings of this study demonstrated notable variability in lung compliance and oxygenation indices across the different phases of ventilation when comparing APRV with PCV. APRV consistently achieved higher compliance values than PCV, as reflected in both descriptive and median analyses. In Phase I, compliance under APRV was nearly double that of PCV, and although the difference narrowed after cross-over in Phase II, APRV maintained a higher trend in compliance. These observations are consistent with earlier research that documented improved patient-ventilator synchrony and enhanced lung mechanics with APRV (14,15). The sustained advantage of APRV in compliance may be attributed to its ability to maintain continuous positive airway pressure, minimizing alveolar collapse and reducing shear stress, thereby protecting the lung parenchyma (16-18). Regression analysis in the present study revealed a statistically significant negative association between PCV and compliance in Phase I, indicating that PCV could reduce lung compliance under certain conditions. This finding highlighted the variability of PCV performance, as scatter plots further showed outliers where PCV negatively impacted patient lung mechanics. Although some patients tolerated PCV without significant decline, others experienced reduced compliance, underscoring the need for individualized ventilatory strategies tailored to patient physiology. Oxygenation indices improved with both modes, yet APRV sustained these improvements more consistently across phases, which aligns with prior studies demonstrating the benefits of APRV in supporting oxygenation and reducing sedation requirements (19,20). While the results emphasize the potential benefits of APRV over PCV, important limitations must be acknowledged. The relatively small sample size of 70 patients limited the power of the study, particularly when compared with larger trials that included over 130 participants and reported stronger statistical outcomes (21,22). Furthermore, the absence of long-term follow-up restricted assessment of the sustained impact of ventilatory modes on clinical outcomes such as survival, weaning success, or long-term lung function. The strict exclusion criteria, including patients with underlying pulmonary pathology or those requiring higher levels of PEEP, restricted the applicability of the findings to the broader ICU population. This narrow selection improved internal validity but limited external generalizability, in contrast to other studies employing broader inclusion criteria and more heterogeneous patient samples (23).

Another methodological strength was the randomized cross-over design, which allowed within-patient comparison of both ventilatory modes and minimized inter-patient variability. Observer bias was also minimized by standardized protocols for data collection. However, the unequal duration of intervention phases—one hour for Phase I versus three hours for Phase II—may have influenced compliance measurements and introduced potential confounding effects. Moreover, while statistical correlations and regression analyses were reported, direct between-group comparisons of compliance with appropriate effect sizes were not consistently presented, limiting the robustness of conclusions. The findings of this study suggest that APRV may provide an advantage in maintaining higher lung compliance and more stable oxygenation in critically ill patients compared with PCV. Nevertheless, the variability in responses, particularly the negative impact of PCV observed in some cases, indicates the necessity for careful titration and patient-specific adjustments. Future research should address these limitations by conducting large-scale, multicenter randomized controlled trials with longer follow-up periods. Broader inclusion criteria that encompass patients with pulmonary comorbidities and higher ventilatory demands would enhance generalizability. Additionally, incorporating subgroup analyses based on demographic and clinical characteristics may identify which patients derive the most benefit from APRV or PCV. Strengthening statistical approaches with comprehensive reporting of effect sizes and clinically meaningful outcomes would further consolidate the evidence base. In summary, this study adds to the growing body of evidence that APRV may offer favorable outcomes in terms of lung compliance and oxygenation compared to PCV, but its benefits are not uniform across all patients. The variability in patient response highlights the importance of individualized ventilatory strategies, careful monitoring, and further rigorous research to establish optimal approaches for critically ill populations.

## CONCLUSION

This randomized cross-over trial concluded that both APRV and PCV demonstrated potential in supporting oxygenation and lung compliance, though their effects varied across different phases of ventilation. The study emphasized that while APRV appeared to offer more consistent benefits in maintaining compliance, PCV also contributed to improved oxygenation under certain conditions. These findings underscore the importance of tailoring ventilatory strategies to individual patient needs rather than relying on a single universal approach. By highlighting the strengths and limitations of each mode, this research contributes valuable insight into optimizing mechanical ventilation in critically ill patients. Future studies with larger and more diverse populations are warranted to confirm these observations and guide long-term ventilatory strategies that balance effectiveness with safety.

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## AUTHOR CONTRIBUTION

| Author | Contribution |
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| Iqra Abid | Substantial Contribution to study design, analysis, acquisition of Data<br>Manuscript Writing<br>Has given Final Approval of the version to be published |
| Imran Riasat | Substantial Contribution to study design, acquisition and interpretation of Data<br>Critical Review and Manuscript Writing<br>Has given Final Approval of the version to be published |
| Aneeha Alvi | Substantial Contribution to acquisition and interpretation of Data<br>Has given Final Approval of the version to be published |
| Surraya Shams* | Contributed to Data Collection and Analysis<br>Has given Final Approval of the version to be published |
| Omar Abousaad | Contributed to Data Collection and Analysis<br>Has given Final Approval of the version to be published |
| Malgorzata Sowa | Substantial Contribution to study design and Data Analysis<br>Has given Final Approval of the version to be published |
| Nadia Qureshi | Contributed to study concept and Data collection<br>Has given Final Approval of the version to be published |
| Hamza Irfan | Writing - Review & Editing, Assistance with Data Curation |
| Syed Farjad Sultan | Writing - Review & Editing, Assistance with Data Curation |

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