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ORIGINAL RESEARCH

Manual vs. Mechanical Ventilation in Respiratory Parameters of intubated Patients During cardiopulmonary Resuscitation; a Randomized Clinical Trial

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Abstract: Introduction: Ventilation and oxygen delivery during cardiopulmonary resuscitation (CPR) is of paramount importance. This study aimed to compare the effects of manual and mechanical ventilation on respiratory parameters of intubated patients during CPR. **Methods:** This randomized controlled clinical trial was conducted in 2024 on 61 intubated patients with neurological disorders admitted to the ICU of educational hospitals. Participants were allocated to either the intervention or the control group using block randomization with a block size of six. The intervention group received mechanical ventilation, while the control group received manual ventilation using bag valve mask (BVM). The effects of manual versus mechanical ventilation during CPR on key physiological and respiratory parameters, including venous blood gases (VBG), end tidal Co2 ($ETCO_2$), and peripheral oxygen saturation (SpO_2) were compared between groups. Statistical analyses were performed using SPSS version 21. **Results:** The study findings indicated no statistically significant differences between the manual and mechanical ventilation groups in terms of venous blood pH levels ($P = 0.38$), PCO_2 ($P = 0.65$), and HCO_3 levels ($P = 0.47$) changes. However, PO_2 ($P < 0.001$), $ETCO_2$ ($P < 0.05$). and SpO_2 ($P < 0.001$) were more stable and consistently higher in patients receiving mechanical ventilation. **Conclusion:** These findings suggest that while pH, PCO_2, and HCO_3 levels did not significantly differ between the two ventilation methods, mechanical ventilation demonstrated superior efficacy in optimizing oxygenation (PO_2 and SpO_2) and regulating $ETCO_2$ levels.

Keywords: Cardiopulmonary resuscitation; Ventilation; Blood Gas Analysis; Carbon Dioxide; Oxygen Saturation

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1. Introduction

Cardiac arrest is the third leading cause of mortality worldwide (1), contributing to an estimated 275,000 to 420,000 deaths annually in the United States and Europe (2). Cardiopulmonary resuscitation (CPR) is a life-saving intervention that can sustain 10% to 30% of normal cardiac output and 30% to 40% of normal cerebral blood flow (3). Chest compressions and ventilation constitute the core components of advanced cardiac life support (ACLS) and have been standard practice in cardiac arrest management for over four decades (4). Each of these interventions is critically important (5), and effective airway management and ventilation are essential for successful resuscitation (6). Despite their significance, current resuscitation guidelines offer limited recommendations regarding optimal ventilation strategies (7). Ventilation method, rate, and tidal volume significantly influence CPR outcomes (8), as appropriate ventilation not only ensures adequate oxygenation but also facilitates carbon dioxide elimination and enhances cellular metabolism (7). Positive-pressure ventilation can be delivered either manually using a bag-valve mask (BVM) or mechanically through a ventilator (6). Each technique has its own advantages and limitations, with ongoing debate among clinicians regarding their effectiveness (9). Manual ventilation with a BVM, one of the earliest resuscitative tools, remains widely utilized in both emergency and clinical settings (10). However, even experienced healthcare providers may encounter challenges such as inadequate alveolar ventilation or inadvertent hyperventilation (11). Excessive ventilation rates can lead to increased intrathoracic pressure, reduced venous return, and decreased cardiac output, ultimately impairing hemodynamic stability (12). A study conducted across 438 hospitals in China found that only 51.4% of healthcare providers adhered to the recommended venti-

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lation rate of 10 breaths per minute during CPR (5).
Similarly, another study reported that 18% of clinicians interrupted chest compressions while delivering breaths with a BVM, and 39% exceeded the recommended 10 breaths per minute, both representing deviations from international CPR guidelines (13). Furthermore, certain BVMs may fail to deliver adequate oxygenation during resuscitation (10). Conversely, mechanical ventilation is widely recognized as the standard of care in critical settings (14), yet its effectiveness during CPR remains underexplored (4). Some evidence suggests that mechanical ventilation enhances CPR quality by minimizing human error and ensuring consistent ventilation rates (6, 15). However, modern ventilators may misinterpret chest compressions as spontaneous patient breathing, leading to increased ventilation rates if not properly adjusted (12). Optimizing ventilator settings can mitigate these challenges (16).
Monitoring end tidal Co2 ($ETCO_2$) and arterial blood gas (ABG) parameters during CPR is crucial for assessing ventilation adequacy and perfusion status. Capnography serves as an essential tool in evaluating ventilation effectiveness and pulmonary perfusion (4), while $ETCO_2$ levels correlate with chest compression quality and optimal ventilation (17). Additionally, ABG analysis provides insights into tissue hypoxia and cellular ischemia, informing decisions regarding more aggressive resuscitation strategies (18, 19). Given that ventilation techniques can significantly impact patient survival during cardiac arrest (13), optimizing ventilation strategies is essential. Current international guidelines recommend delivering positive-pressure ventilation without interrupting chest compressions once an advanced airway is secured (6). However, the most effective ventilation strategy for CPR remains unclear (20), leading to inconsistencies in clinical practice (13). While mechanical ventilation is typically initiated following intubation during CPR, limited studies have evaluated its efficacy in this context (4). Notably, only one randomized clinical trial has investigated the comparative effectiveness of mechanical versus manual ventilation on arterial oxygen pressure in a hospital setting (21).
This gap highlights the need for further research to develop evidence-based ventilation protocols during CPR. This study aimed to compare the effects of manual and mechanical ventilation on respiratory parameters of intubated patients during CPR.

2. Methods

2.1. Study design and setting

This randomized controlled clinical trial was conducted in 2024 on 61 intubated and mechanically ventilated patients with neurological disorders admitted to the ICU of educational hospitals in Mashhad (Qaem and Imam Reza Hospitals), Iran, who experienced cardiopulmonary arrest. Participants were allocated to either the intervention or the control group using block randomization with a block size of six, generated via the website www.sealedenvelop.com, resulting in ten blocks with six patients each. The primary objective of this study was to compare the effects of manual versus mechanical ventilation during CPR on key physiological and respiratory parameters, including venous blood gases (VBG), $ETCO_2$, and peripheral oxygen saturation (SpO_2) in intubated patients with a neurological disorder during CPR in ICU.
The study was approved by the Ethics Committee of Mashhad University of Medical Sciences (code: IR.MUMS.NURSE.REC.1402-133) and registered in the Iranian Registry of Clinical Trials (IRCT20240106060630N1). Patient confidentiality was strictly maintained. Given the patients' unconscious state and intubation, written informed consent was obtained from their legal guardians prior to cardiac arrest (pre-arrest phase). Consent was proactively obtained from legal representatives of these patients, anticipating potential resuscitation needs.

2.2. Participants

Eligibility criteria included patients aged 18 years or older with a confirmed diagnosis of cardiopulmonary arrest (defined by unresponsiveness, absence of carotid pulse, and apnea), a primary admission diagnosis of a neurological disorder, and the presence of a central venous catheter. Neurological disorders were classified based on the attending physician's clinical diagnosis, supported by imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) scans, along with other relevant diagnostic evaluations when necessary. Since some neurological conditions (e.g., brainstem strokes) can involve respiratory or cardiac complications, patients with significant pre-existing cardiopulmonary conditions were excluded to minimize potential confounding effects on ventilation and resuscitation outcomes. Patient wards were classified into Neurology 1, 2, and 3 based on care needs: Neurology 1 for acute conditions requiring intensive monitoring, Neurology 2 for stable or chronic disorders, and Neurology 3 for post-acute rehabilitation. This system optimized patient management according to clinical severity.
Exclusion criteria included cardiac arrest resulting from trauma, evidence of irreversible death, pregnancy, suspected COVID-19 infection, suspected pneumothorax, return of spontaneous circulation (ROSC) prior to intervention, physician-directed withdrawal from the study, thromboembolism, anemia, cold extremities, congestive heart failure (CHF), CPR initiation before hospital admission, and cases in which initial VBG samples could not be obtained within two minutes of CPR initiation.

2.3. Intervention

This study employed a double-blind design, ensuring that neither the patients nor the statistician was aware of the assigned intervention or control group. Patients in the intervention group received mechanical ventilation with pre-

specified settings, including volume-controlled ventilation (VCV) with a tidal volume of 6-7 mL/kg)ideal body weight; 500 mL for men, 400 mL for women if weight was unspecified), zero positive end-expiratory pressure (PEEP), respiratory rate of 10 breaths per minute, inspiratory time of one second, I:E ratio of 1:5, FiO_2 of 1.0, maximum inspiratory pressure alarm (Pimax) of 60 cmH_2O, and trigger sensitivity set at -20 cmH_2O. In cases where SpO_2 levels dropped during CPR or ventilator alarms indicated excessive airway pressure, ventilation was switched to manual at the discretion of the physician.
Patients in the control group received manual ventilation using a BVM equipped with a reservoir bag (1.5 L Ambu bag) connected to an oxygen flow of at least 15 L/min.
The healthcare provider administering manual ventilation remained blinded to the study, while the research team monitored respiratory rate and tidal volume using a respirometer. Capnography and pulse oximetry were utilized similarly in the intervention group, with data collection occurring every two minutes. If a sufficient number of trained personnel were unavailable during CPR, ventilation was transitioned to mechanical ventilation at the physician's discretion.
In both groups, capnography and pulse oximetry readings were collected and documented at two-minute intervals during CPR. The initial VBG sample was obtained at the onset of CPR, while the second sample was drawn 1 minute after ROSC through the patient's central venous catheter.
Venous blood sampling was selected over arterial sampling due to its practicality during resuscitation. Arterial access can be technically challenging and time-consuming during CPR because of peripheral vasoconstriction and poor circulation. In contrast, venous sampling is easier, faster, less invasive, and does not interrupt chest compressions, enabling timely assessment of blood gas parameters. Furthermore, VBG parameters—particularly pH and PCO_2—have demonstrated sufficient correlation with arterial values during resuscitation, making venous sampling a reliable and efficient choice in emergency settings.
To ensure the comparability of CPR quality between the two groups and to minimize potential sources of bias, multiple measures were implemented to standardize and objectively evaluate chest compression quality. The Laerdal CPR Meter, a validated device, was used to continuously monitor and record critical CPR quality indicators, including compression depth, compression rate, and chest recoil. Prior to the study, all resuscitation team members underwent standardized training to reduce operator-related variability. The CPR quality data collected from both groups were statistically analyzed, revealing no significant differences in these key quality metrics. This rigorous approach ensured that any differences in study outcomes could be attributed to the ventilation method rather than variations in CPR quality.
As seen in supplementary table 1, a comparative overview of manual ventilation with BVM and mechanical ventilation highlights the advantages and disadvantages of each method. This table provides a clearer understanding of the clinical context and operational challenges associated with both techniques.

2.4. Data gathering

Demographic data as well as data of capnography, VBG analysis, RESMED mechanical ventilator, pulse oximeter, respirometer, and CPR meter were collected for each patient using a predesigned checklist. The data collection process was carried out by a nursing PhD supervisor and a medical student.
1. Capnography device:
$ETCO_2$ levels during CPR were monitored using a portable sidestream capnography device (Comdek MD-660P, Taiwan, 2005). Its reliability was verified by cross-referencing with a validated capnography system and arterial blood gas (ABG) analysis. $ETCO_2$ values were recorded at two-minute intervals throughout the resuscitation process.
2. VBG analysis:
VBG were measured using the GEM 2000 blood gas analyzer (USA). To ensure accuracy, the device underwent internal calibration according to manufacturer guidelines. Blood samples were collected immediately at the start of CPR and one minute after the ROSC.
3. Mechanical ventilator:
Mechanical ventilation during CPR was delivered using a RESMED ventilator, approved by the FDA. The device's validity and reliability were ensured through internal calibration procedures.
4. Pulse oximeter:
SpO_2 was assessed using the SP-20 pulse oximeter (Germany, 2019). Measurements were taken every two minutes, with internal calibration validating the device's precision.
5. Exhalometer:
Tidal volume was measured using a GALEMED exhalometer (Taiwan). Device reliability was confirmed through routine internal calibration.
6. CPR meter:
The Laerdal CPR Meter (Norway) was used to evaluate chest compression quality during CPR. The device measured key parameters, including compression depth, rate, and chest recoil, at two-minute intervals. To ensure data accuracy and consistency, the device underwent internal calibration prior to data collection. The use of this device helped minimize potential operator-related variability in chest compression quality. Pre-arrest patients were identified based on the first link of the American Heart Association (AHA) 2020 Chain of Survival (early recognition and prevention) using the following criteria:
1. Clinical deterioration indicating a high risk of cardiac arrest (e.g., severe hypotension, bradycardia, progressive respiratory failure)
2. Activation of rapid response teams due to acute clinical worsening
3. Abnormal early warning scores (EWS) suggestive of im-

pending cardiac arrest
4. Refractory hypoxia despite optimal ventilatory support
5. Documented arrhythmias with high arrest potential

2.5. Outcomes

The primary outcome of study was comparing VBG (PaO_2, pH, $PaCo_2$, and HCO), $ETCO_2$, and SpO_2 between the two groups. $ETCO_2$ and SpO_2 were recorded every two minutes, while VBG samples were collected immediately at the start of CPR and one minute after the ROSC. The secondary outcome was to assess the variations in perfusion index across CPR cycles in both studied groups.

2.6. Statistical Analysis

The sample size calculation was based on Johannigman et al.'s study (9), which reported a mean PO_2 of 210 ± 100 mmHg. Assuming a type I error of 0.05, a power of 80%, and a minimum detectable difference of 80 mmHg between groups, the required sample size was determined to be 26 patients per group. Allowing for a 20% dropout rate, the final sample size was set at 33 patients per group.
Quantitative data were expressed as mean ± standard deviation (SD), while categorical variables were reported as frequencies (percentages). The normality of quantitative variables was evaluated using the Shapiro-Wilk test. For comparisons between the mechanical ventilation and manual ventilation groups, categorical variables were analyzed using the Chi-square test. Within-group comparisons of data from the first and last cycles were performed using the paired t-test. For quantitative variables that deviated from a normal distribution, the Wilcoxon signed-rank test was utilized. Comparisons between two independent groups were conducted using the independent t-test for normally distributed variables, while the non-parametric Mann-Whitney U test was applied for variables with non-normal distributions. All statistical analyses were performed using IBM SPSS software, version 28, with a significance level (alpha) set at 0.05. To address potential bias related to varying durations of mechanical ventilation among different neurological diagnoses, multivariate regression analyses were performed, adjusting for the length of ventilation prior to cardiac arrest.

3. Results

3.1. Baseline characteristics of studied patients

The study enrolled a total of 61 patients who required ventilation during CPR (figure 1). Of these, 38 patients (62.0%) were male, and 23 (38.0%) were female. The participants were patients with neurologic problems who had been intubated and placed on mechanical ventilation during their hospitalization in the ICU. The analysis revealed no statistically significant differences in CPR quality between male and female providers. Comprehensive team training and adherence to standardized protocols ensured consistency in key CPR parameters, including compression depth (p=0.67), compression rate (p=0.98), and chest recoil (p=0.83), regardless of the provider's gender.
Table 1 compares the baseline characteristics of patients in the mechanical ventilation and manual ventilation groups. Patient characteristics, CPR quality, and the profiles of rescuers exhibited no statistically significant differences between the 2 groups, confirming the homogeneity of the groups.

3.2. Respiratory parameter changes

Table 2 and figure 2 compare the studied respiratory parameters between the two groups at the initiation of CPR and after the ROSC. At baseline, there were no significant differences between the groups in pH (P = 0.04), PCO_2 (P = 0.25), PO_2 (P = 0.056), HCO (P = 0.43), $ETCO_2$ (P = 0.39), tidal volume (P = 0.051), respiratory rate (P = 0.32), minute ventilation (P = 0.07), heart rate (P = 0.63), and SpO_2 (P = 0.26), confirming the homogeneity of the groups in these variables before the intervention.

3.2.1 pH

The pH showed a significant reduction in both groups, with a change of -0.34 ± 0.09 (P < 0.001) in the mechanical ventilation group and -0.29 ± 0.15 (P < 0.001) in the manual ventilation group. However, the magnitude of pH decline did not differ significantly between the two groups (P = 0.052).

3.2.2 PCO_2

Both groups exhibited a significant increase in PCO_2, with changes of 28.65 ± 16.11 (P < 0.001) in the Mechanical Ventilation group and 17.75 ± 26.31 (P = 0.002) in the manual ventilation group. Nonetheless, the increase in PCO_2 was not significantly greater in the manual ventilation group compared to the mechanical ventilation group (P = 0.055).

3.2.3 PO_2

A significant reduction in PO_2 was observed in both groups, with a change of -5.16 ± 9.97 (P < 0.001) in the mechanical ventilation group and -15.22 ± 10.15 (P < 0.001) in the manual ventilation group. However, the decrease in PO_2 was significantly greater in the manual ventilation group (P < 0.001), indicating a more pronounced decline in oxygenation with manual ventilation.

3.2.4 HCO

Both groups experienced a significant reduction in HCO, with changes of -5.97 ± 5.5 (P < 0.001) in the mechanical ventilation group and -5.1 ± 3.72 (P < 0.001) in the manual ventilation group. However, the magnitude of decrease in HCO did not differ significantly between the two groups (P = 0.47).

3.2.5 $ETCO_2$

In the mechanical ventilation group, $ETCO_2$ remained relatively stable (1 ± 7.18, P = 0.50), whereas a significant reduction was observed in the manual ventilation group (-3.03 ± 7.33, P = 0.003). The decrease in $ETCO_2$ was significantly greater in the manual ventilation group compared to the mechanical ventilation group (P = 0.008).

3.2.6 Tidal volume

No significant change in tidal volume was observed in either the mechanical ventilation group (2.58 ± 10.64, P = 0.14) or the manual ventilation group (-38.67 ± 115.39, P = 0.07). However, the reduction in tidal volume was more pronounced in the manual ventilation group compared to the mechanical ventilation group (P = 0.14).

3.2.7 Respiratory rate

A significant change in respiratory rate was noted in the mechanical ventilation group (0.32 ± 0.75, P = 0.03), while the change in the manual ventilation group (-0.57 ± 2.53, P = 0.19) was not statistically significant. However, the decline in respiratory rate was significantly greater in the manual ventilation group compared to the mechanical ventilation group (P = 0.04).

3.2.8 SpO_2

A significant reduction in SpO_2 was observed in both the mechanical ventilation group (-1.58 ± 6.47, P = 0.009) and the manual ventilation group (-4 ± 4.9, P < 0.001). However, the decrease in SpO_2 was not significantly greater in the mechanical ventilation group (P < 0.20).

3.3. Perfusion index

Table 2 and figure 2 show the changes in perfusion index between the two groups over time. The change in perfusion index was not statistically significant within either the mechanical ventilation group (0.13 ± 0.54, P = 0.18) or the manual ventilation group (-38.67 ± 115.39, P = 0.13) (both P > 0.05). However, the reduction in Perfusion Index was greater in the manual ventilation group compared to the mechanical ventilation group (P = 0.06).

4. Discussion

These findings suggest that while pH, PCO_2, and HCO_3 levels did not significantly differ between the two ventilation methods, mechanical ventilation demonstrated superior efficacy in optimizing oxygenation (PO_2 and SpO_2) and regulating $ETCO_2$ levels.

This study aimed to compare the effects of manual and mechanical ventilation on respiratory parameters in mechanically ventilated patients with neurological disorders undergoing CPR. VBG parameters, including pH, $PaCo_2$, PaO_2, and HCO_3 levels, are widely recognized as key indicators of tissue hypoxia and the extent of hypoperfusion during CPR. These variables offer essential insights into the efficacy of resuscitation efforts and potential patient outcomes.

The study demonstrated that both manual and mechanical ventilation had comparable effects on blood pH during CPR. Specifically, the mean pH decreased from 7.25 to 6.91 in the mechanical ventilation group and from 7.17 to 6.88 in the manual ventilation group. This reduction in pH across both groups indicates the occurrence of acidosis during CPR. However, the difference in pH levels between the two groups was not statistically significant (P ≤ 0.38). These findings are consistent with retrospective analyses of out-of-hospital CPR, which report pH values in the range of 7 to 7.1 in similar clinical settings (22). The results suggest that both ventilation methods, particularly when CPR is accompanied by hypoxia and hypoperfusion, may contribute to acidosis. Nevertheless, no significant difference in pH levels was observed between manual and mechanical ventilation.

The effects of both ventilation strategies on bicarbonate levels were similar, indicating that both contributed to a decrease in HCO and the development of metabolic acidosis. This decline is likely attributable to increased lactate production under conditions of hypoxia and hypoperfusion during CPR. Additionally, although $PaCo_2$ levels were marginally lower in the manual ventilation group, the difference was not statistically significant.

Partial pressure of oxygen (PaO_2), a critical indicator of tissue oxygenation, was significantly higher in the mechanical ventilation group than in the manual ventilation group. The mean PaO_2 was 75.11 ± 61.91 mmHg in the mechanical ventilation group and 55.35 ± 15.11 mmHg in the manual ventilation group. While PaO_2 levels declined in both groups following intervention, the reduction was significantly greater in the manual ventilation group (P ≤ 0.001). These findings align with the results of the study titled 'The effects of mechanical versus BVM on gas exchange during CPR in emergency department patients' (2023), which investigated the effects of mechanical ventilation versus BVM ventilation on gas exchange during CPR in emergency department patients. The study reported no significant differences in blood gas parameters—including PaO_2, pH, $PaCo_2$, and HCO—between manual and mechanical ventilation groups (P = 0.879) (21). Similar to our study and the trial mentioned, PaO_2 levels remained below 60 mmHg, reflecting severe hypoxemia in both ventilation methods. This suggests that neither method was entirely effective in optimizing blood oxygenation. However, despite these low PaO_2 levels, patients in this study achieved return of spontaneous circulation (ROSC). This contrasts with findings from previous studies (2018, 2016), which demonstrated that higher arterial oxygen levels (PaO_2 > 75-90 mmHg) during CPR were associated with an increased likelihood of ROSC (23, 24). These discrepancies may be attributed to variations in patient demographics, disease severity, CPR duration, or ventilation and oxygenation management strategies.

$ETCO_2$ monitoring serves as a non-invasive tool providing critical insights into cardiac output, ventilation, and tissue oxygenation during CPR (25). Previous studies have established that higher $ETCO_2$ levels are predictive of ROSC (26), survival to hospital discharge (27), and improved neurological outcomes (28). However, even with high-quality CPR, $ETCO_2$ values below 10 mmHg have been reported in some cases (26), indicating that additional factors may influence $ETCO_2$ levels. Ventilation parameters, particularly tidal volume and respiratory rate, play a significant role in determining $ETCO_2$ levels. Hyperventilation can reduce $ETCO_2$ by increasing intrathoracic pressure, thereby decreasing venous return and cardiac output (29). A 2020 study demonstrated that a rise in respiratory rate was associated with a decline in $ETCO_2$, with the most pronounced effects observed at rates below 10 breaths per minute (30). In the current study, mechanical ventilation maintained a stable respiratory rate and tidal volume, effectively preventing hyperventilation and sustaining significantly higher $ETCO_2$ levels compared to manual ventilation. These findings suggest that mechanical ventilation during CPR may mitigate fluctuations in ventilation parameters and support improved CPR outcomes by maintaining optimal $ETCO_2$ levels.

Mechanical ventilation was found to provide greater stability in tidal volume and respiratory rate compared to manual ventilation. Although tidal volume was slightly higher in the mechanical ventilation group, relative to the manual ventilation group, the difference was not statistically significant. These results are consistent with previous studies, which reported that the actual delivered tidal volume during mechanical ventilation may be lower than the preset ventilator values (31-33).

The mean SaO was significantly higher in the mechanical ventilation group (90.03 ± 3.11%) than in the manual ventilation group (86.73 ± 5.43%) (P = 0.03), indicating that mechanical ventilation was more effective in maintaining oxygen saturation during the later stages of CPR. Although pulse oximetry is not considered a life-saving measure during CPR, it can offer valuable physiological data when applied appropriately. Continuous monitoring of heart rate and oxygen saturation facilitates the adjustment of oxygen delivery, thereby minimizing the risk of both hypoxia and hyperoxia (34, 35). However, further investigation is warranted to assess the role of pulse oximetry in enhancing CPR quality and improving patient outcomes (36).

The findings of this study may help inform clinical guidelines by clarifying whether mechanical or manual ventilation during CPR leads to better physiological outcomes in ICU patients. Improved understanding of ventilation strategies could optimize resuscitation protocols, enhance patient survival rates, and reduce post-resuscitation complications.

In this study, the decrease in Perfusion Index (PI) was greater in the manual ventilation group compared to the mechanical ventilation group, suggesting that mechanical ventilation may better preserve peripheral perfusion during CPR. These findings are consistent with previous research that highlighted the value of PI and $ETCO_2$ in hemodynamic monitoring during resuscitation. Such results may influence the choice of ventilation strategy in critical care settings (37).

5. Strengths and limitations

This study has several limitations that should be considered. First, the relatively small sample size may limit the generalizability of the findings to larger populations. Second, the exclusion of patients with diverse underlying conditions that could influence CPR outcomes introduces a potential bias. Third, the lack of long-term follow-up data restricts our ability to assess the sustained impact of the different ventilation methods on patient outcomes.

Despite these limitations, the study has notable strengths. Its innovative approach stands out, and to the best of our knowledge, it is the first clinical trial in Iran to investigate different ventilation methods during CPR. This pioneering aspect contributes valuable insights to the existing body of research and can serve as a foundation for future multicenter studies with larger sample sizes and longer follow-up periods.

6. Conclusions

The mechanical ventilation, delivering a specific tidal volume and respiratory rate, prevents hyperventilation and helps mitigate the risk of reduced coronary and cerebral perfusion pressure. While manual ventilation carries the risk of delivering excessive tidal volumes, newer ventilator models with feedback mechanisms have significantly improved this issue. In addition, the use of mechanical ventilation during CPR allows one member of the medical team to be freed up to perform other critical medical tasks.

7. Declarations

7.1. Acknowledgments

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7.2. Conflict of interest

The authors have no conflicts of interest to declare

7.3. Funding

We did not receive any funding for this work.

7.4. Availability of data

The data that support the findings of this study are available on request from the corresponding author.

7.5. Ethical considerations

This study received approval from the Ethics Committee of Mashhad University of Medical Sciences (code: IR.MUMS.NURSE.REC.1402-133) and was registered with the Iranian Registry of Clinical Trials (code: IRCT20240106060630N1). Patient information remained confidential, and written informed consent was obtained from all patients' guardians.

7.6. Authors' contributions

NL, RF, ABM, and HN have contributed to the study on conception and design, drafting the article, revising it critically for important intellectual content, and final approval of the version to be published. NL, RF, ABM, and HN are in agreement with the content of the manuscript. This manuscript has been read and approved by all the above authors.

7.7. Using artificial intelligence chatbots

During the preparation of this work, the authors used AI in order to check the grammar and improve readability. After using this tool, the authors reviewed and edited the manuscript as needed and take full responsibility for the content of the publication.

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Table 1: Comparing the baseline characteristics between manual and mechanical ventilation groups

Variables	Ventilation method		P
	Mechanical (n=31)	Manual (n=30)	
Age (year)			
Mean ± SD	68.9 ± 15.57	69.6 ± 14.87	0.85
Sex			
Male	21 (0.68)	17 (0.57)	0.37
Female	10 (0.32)	13 (0.43)	
Number of hospitalized days			
Mean ± SD	19.58 ± 11.8	16.67 ± 8.87	0.44
BMI (kg/m2)			
Mean ± SD	23.44 ± 3.1	23.44 ± 3.19	0.99
SOFA			
Mean ± SD	13.54 ± 0.99	13.60 ± 1.06	0.86
Medical diagnosis			
CVA	9 (0.29)	10 (0.33)	0.97
ICH+IVH	10 (0.32)	8 (0.27)	
CVA+ICH	2 (0.06)	2 (0.07)	
Infraction	10 (0.32)	10 (0.33)	
Inpatient ward			
Neurology 1	12 (0.39)	13 (0.43)	0.90
Neurology 2	12 (0.39)	10 (0.33)	
Neurology 3	7 (0.23)	7 (0.23)	
Rescuer sex			
Male	16 (0.52)	14 (0.47)	0.70
Female	15 (0.48)	16 (0.53)	
Rescuer CPR experience (yeas)			
Mean ± SD	4.97 ± 2.61	5.00 ± 2.65	0.99
Rescuer age (years)			
Mean ± SD	29.94 ± 3.35	29.6 ± 3.36	0.70
Rescuer work experience			
Mean ± SD	7.26 ± 3.14	6.93 ± 3.18	0.99

Data are presented as mean ± standard deviation (SD) or frequency (%).BMI: Body mass index; SOFA: Sequential Organ Failure Assessment, CVA: Cerebrovascular accident; ICH: Intracranial hemorrhage; IVH: Intraventricular hemorrhage; CPR: Cardiopulmonary Resuscitation.

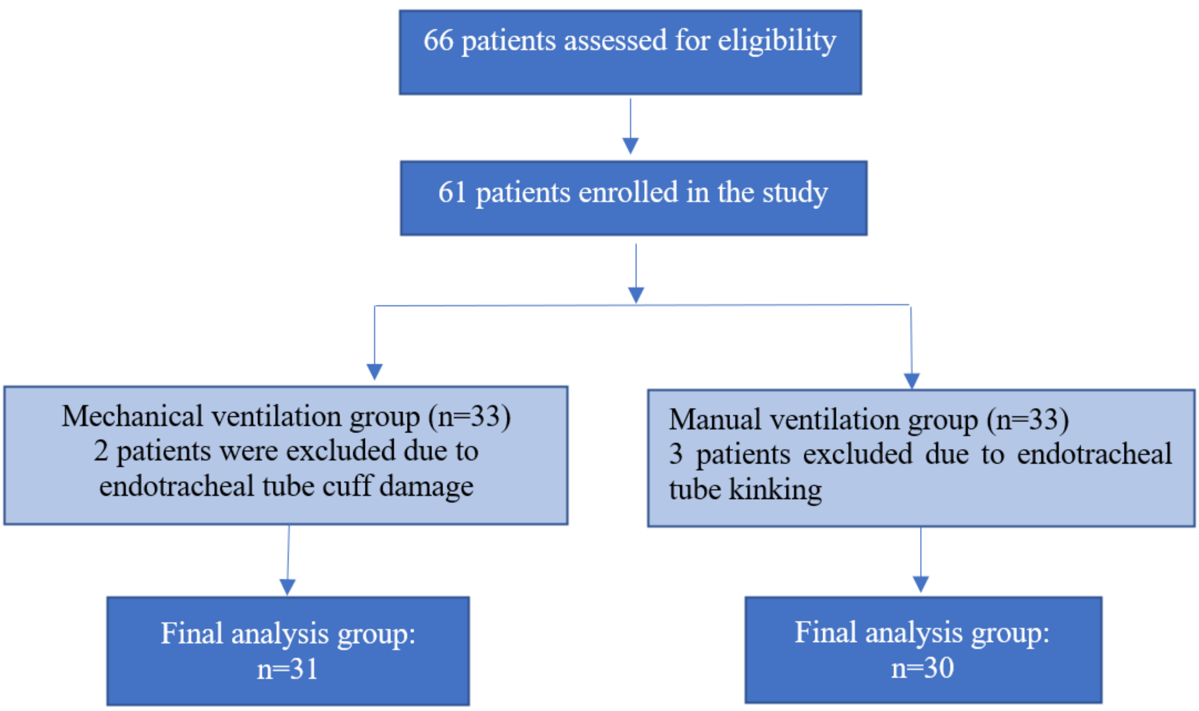

Figure 1: The flowchart of study

Table 2: Comparing the respiratory parameters between manual and mechanical ventilation and groups

Variables	Ventilation method		P
	Mechanical (n=31)	Manual (n=30)	
pH			
Primary	7.25 ± 0.16	7.17 ± 0.21	0.051
ROSC	6.91 ± 0.16	6.88 ± 0.13	0.38
Difference	-0.34 ± 0.09	-0.29 ± 0.15	0.052
Within group	<0.001	<0.001	
PCO_2 (mmHg)			
Primary	45.01 ± 16.31	49.9 ± 15.48	0.25
ROSC	73.65 ± 23.17	67.65 ± 32.46	0.65
Difference	28.65 ± 16.11	17.75 ± 26.31	0.055
Within group	<0.001	0.002	
PO_2 (mmHg)			
Primary	61.91 ± 11.75	55.11 ± 15.35	0.056
ROSC	56.75 ± 10.74	39.89 ± 14.98	< 0.001
Difference	-5.16 ± 9.97	-15.22 ± 10.15	< 0.001
Within group	<0.001	<0.001	
HCO_3 (mEq/L)			
Primary	18.21 ± 7.85	16.65 ± 7.53	0.43
ROSC	12.24 ± 4.85	11.55 ± 5.94	0.90
Difference	-5.97 ± 5.5	-5.1 ± 3.72	0.47
Within group	<0.001	<0.001	
$ETCO_2$ (mmHg)			
First cycle	15.65 ± 5.27	14.5 ± 5.22	0.051
Last cycle	16.65 ± 5.45	11.47 ± 6.11	< 0.001
Difference	1 ± 7.18	7 -3.03 ± 7.33	0.008
Within group	0.50	0.003	
Tidal volume (L)			
First cycle	467.1 ± 47.69	499.33 ± 129.35	0.051
Last cycle	469.68 ± 48.34	460.67 ± 107.57	0.99
Difference	2.58 ± 10.64	-38.67 ± 115.39	0.14
Within group	0.14	0.07	
Respiratory rate (bpm)			
First cycle	10.1 ± 0.3	10.87 ± 2.61	0.32
Last cycle	10.42 ± 0.72	10.3 ± 3.01	0.79
Difference	0.32 ± 0.75	-0.57 ± 2.53	0.04
Within group	0.19	0.03	
Minute ventilation (L/min)			
First cycle	4.68 ± 0.48	5.55 ± 2.21	0.07
Last cycle	4.89 ± 0.63	4.81 ± 2.12	0.45
Difference	0.22 ± 0.34	-0.73 ± 2.03	0.07
Within group	0.14	0.001	
Heart rate(/minute)			
First cycle	111.26 ± 5.76	111.93 ± 5.3	0.63
Last cycle	110.26 ± 6.12	110.23 ± 6.21	0.98
Difference	-1 ± 7.62	-1.7 ± 8.08	0.73
Within group	0.47	0.25	
SpO_2 (%)			
First cycle	91.61 ± 6.16	90.73 ± 4.97	0.26
Last cycle	90.03 ± 3.11	86.73 ± 5.43	0.03
Difference	-1.58 ± 6.47	-4.0 ± 4.9	0.20
Within group	0.009	< 0.001	
Perfusion index			
First cycle	1.07 ± 0.43	1.13 ± 0.53	0.78
Last cycle	1.19 ± 0.04	0.96 ± 0.39	0.02
Difference	0.13 ± 0.54	-0.16 ± 0.61	0.06
Within group	0.18	0.13	

Data are presented as mean ± standard deviation. ROSC: return of spontaneous circulation; PCO_2: partial pressure of carbon dioxide; PO_2: partial pressure of carbon dioxide; HCO_3: Bicarbonate; $ETCO_2$: End-tidal Carbon Dioxide; SpO_2: Peripheral oxygen saturation.

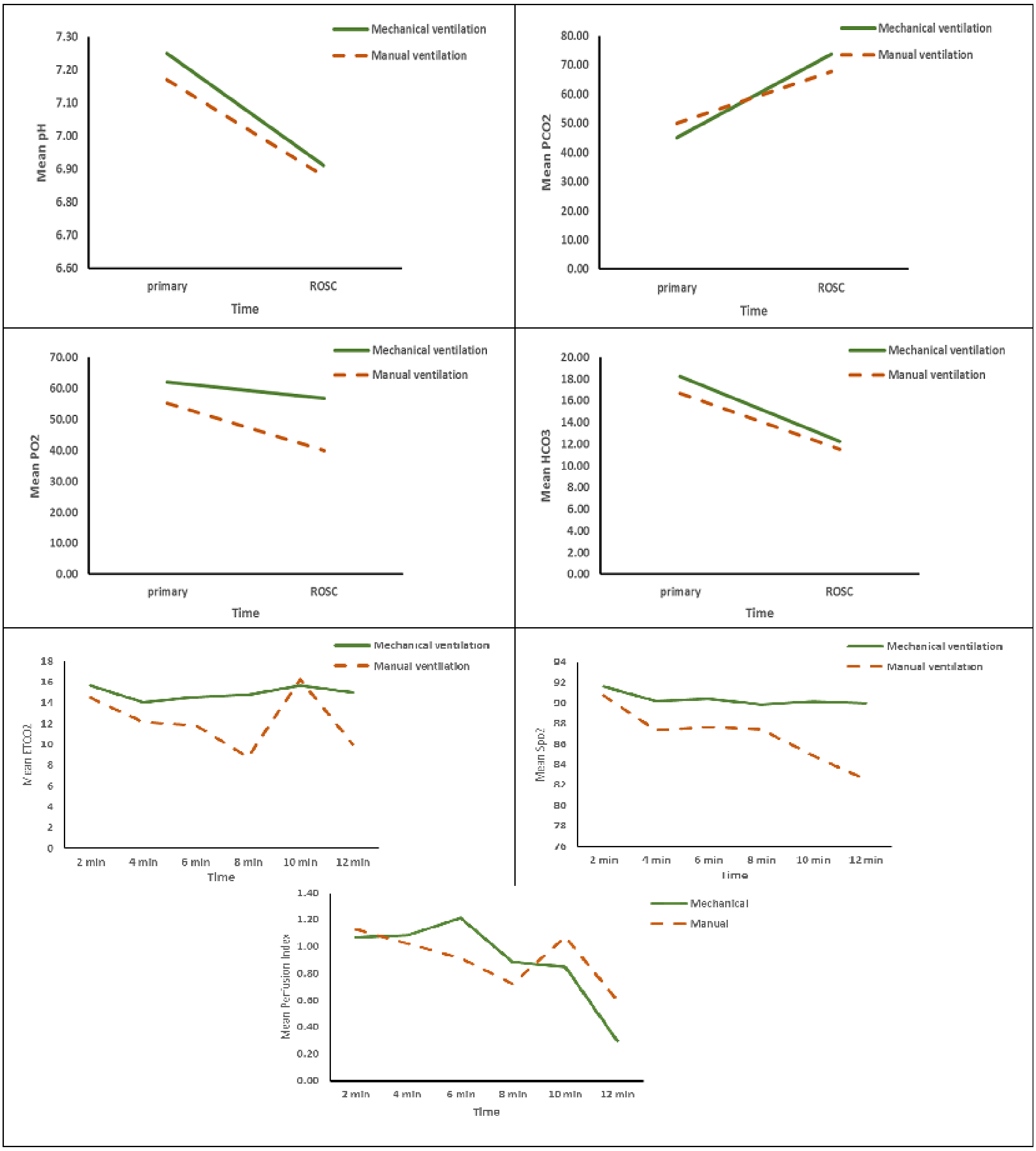

Figure 2: Respiratory parameters and perfusion index changes in patients who underwent manual and mechanical ventilation. ROSC: return of spontaneous circulation; PCO_2: partial pressure of carbon dioxide; PO_2: partial pressure of carbon dioxide; HCO_3: Bicarbonate; $ETCO_2$: End-tidal Carbon Dioxide; SpO_2: Peripheral oxygen saturation.

Supplementary table 1: Comparison of manual and mechanical ventilation methods

Aspect	Manual Ventilation (BVM)	Mechanical Ventilation
Ease of Use	Requires skill and experience from the provider	Requires less hands-on involvement once set
Ventilation Rate Control	Difficult to maintain consistent rate	Consistent rate, adjustable settings
Human Error	Higher risk of over/under-ventilation	Minimizes human error if set correctly
Hemodynamic Impact	Can increase intrathoracic pressure, impair circulation	Less impact on hemodynamics if properly adjusted
Oxygenation Quality	Can be insufficient if technique is incorrect	Consistent oxygenation, but can misinterpret chest compressions
Application in CPR	Common in emergency situations	Standard in ICU and advanced care settings