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Immediate Effects of Early Chest Physiotherapy on Hemodynamic and Ventilatory Parameters in Mechanically Ventilated Adult Patients: A Quasi-Experimental Study

Dinkar Sharma[1], Vijay Pratap Singh[2]

Abstract

Background: Mechanical ventilation is a life-saving intervention in intensive care units (ICUs); however, prolonged ventilation increases the risk of ventilator-associated complications. Early chest physiotherapy (CPT) has been suggested to improve lung compliance, secretion clearance, and hemodynamic stability in patients on mechanical ventilation. However, few studies have evaluated their immediate effects. **Objective:** The objective is to determine the immediate effects of early CPT on hemodynamic and ventilatory parameters in mechanically ventilated adult patients. **Methods:** A quasi-experimental pre–post study was conducted on 50 mechanically ventilated adults admitted to the ICU. Participants received early CPT, including manual percussion, vibration, manual hyperinflation, and endotracheal suctioning, for 3 consecutive days. Hemodynamic (heart rate, respiratory rate, mean arterial pressure, SpO_2) and ventilatory (compliance, resistance, and peak inspiratory pressure [PIP]) parameters were recorded pre- and post-intervention each day. Statistical analysis was performed using Statistical Package for the Social Sciences v20 with repeated measures analysis of variance. **Results:** Early CPT significantly improved ventilatory parameters, including compliance ($P < 0.05$), reduced resistance ($P < 0.05$), and PIP ($P < 0.05$). SpO_2 showed a significant increase post-CPT, whereas the respiratory rate significantly decreased. No adverse events were reported. **Conclusion:** Early CPT leads to immediate improvements in lung dynamics and hemodynamic stability in mechanically ventilated adults, without causing adverse effects. These findings highlight the importance of early physiotherapy interventions in ICUs.

Keywords: Chest physiotherapy, Intensive care units, Lung compliance, Mechanical ventilation, Ventilatory parameters

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Introduction

Mechanical ventilation constitutes a critical intervention for the management of patients with respiratory failure in intensive care units (ICUs).[1-4] Internationally, a substantial proportion of ICU admissions necessitate mechanical ventilation, with research indicating that approximately 40–60% of ICU patients require ventilatory support during their hospitalization.[2-6] Although this intervention is lifesaving, extended use of mechanical ventilation is linked to complications such as ventilator-associated pneumonia, atelectasis, barotrauma, and diaphragmatic dysfunction, all of which contribute to increased morbidity, prolonged hospital stays, and elevated healthcare costs.[7-10] Chest physiotherapy (CPT) has emerged as a vital non-pharmacological intervention in reducing these risks. Techniques within CPT, such as manual hyperinflation (MHI), percussion, vibration, and endotracheal suctioning, have been demonstrated to facilitate secretion clearance, prevent atelectasis, and enhance lung compliance and gas exchange.[11] In contrast to pharmacological treatments, CPT provides a proactive method to improve pulmonary function without increasing medication burden or the risk of systemic side effects. Despite its potential advantages, there is a paucity of studies investigating the immediate physiological effects of CPT, particularly concerning its impact on hemodynamic stability and ventilatory mechanics.[12-14] Understanding these acute responses is essential, particularly when determining the optimal timing and frequency of interventions in critically ill patients. Given the prevalence of ventilator dependence and its associated complications, investigating the impact of early physiotherapy could provide valuable insights for ICU protocols aimed at enhancing patient outcomes and reducing weaning time. This study seeks to evaluate the immediate effects of early CPT on lung compliance, airway resistance, peak inspiratory pressure, and hemodynamic parameters in mechanically ventilated adult patients.

[1]Department of Physiotherapy, Heritage Institute of Medical Sciences College of Physiotherapy, Bhadawar, Uttar Pradesh, India.

[2]Department of Physiotherapy, Manipal College of Physiotherapy, Manipal Academy of Higher Education, Mangaluru, Karnataka, India.

Corresponding Author: Dinkar Sharma, Assistant Professor, Department of Physiotherapy, Heritage Institute of Medical Sciences College of Physiotherapy, Varanasi, Uttar Pradesh, India

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Methods

The study was conducted in the Medicine and Surgical ICUs of the Central Referral Hospital, Gangtok, India. Following approval from the Institutional Ethical Committee (IEC/522/19–16), the study adhered to ethical guidelines and patient safety protocols. This study aimed to assess the immediate effects of early CPT on ventilatory and hemodynamic parameters in mechanically ventilated adults. The study population comprised mechanically ventilated adults aged ≥18 years who were referred for CPT. The participants were required to be under sedation with a stable hemodynamic status to ensure the safe administration of the intervention. Patients with unstable

cardiovascular conditions, chest trauma, recent thoracic surgery, or contraindications to physiotherapy were excluded from the study. The sample size of 50 was determined through a power analysis conducted using G Power, with the assumptions of an effect size of 0.35, a significance level of 0.05, and a power of 0.80 for repeated measures analysis of variance (ANOVA). The analysis calculated a minimum requirement of 44 participants, and the sample size was increased to 50 to account for potential dropouts. Participants were selected via convenience sampling from the Medicine and Surgical ICUs of Central Referral Hospital, Gangtok, Sikkim. The study encompassed adult patients aged 18 years and older who were mechanically ventilated and referred for CPT in the ICU. All participants were sedated and maintained stable hemodynamic status, ensuring the safe administration of the intervention. Eligibility for inclusion required that patients had no contraindications to physiotherapy and were expected to remain on mechanical ventilation for at least 72 h to complete the 3-day intervention protocol. Exclusion criteria included unstable cardiovascular conditions, active chest trauma, recent thoracic or abdominal surgery, or any neurological instability. In addition, individuals with a history of rib fractures, elevated intracranial pressure, or diagnosed conditions where manual techniques were contraindicated were excluded to ensure patient safety and consistency in intervention outcomes. These participants underwent early CPT for 3 consecutive days, which comprised four principal physiotherapy techniques. Manual percussion was employed as a rhythmic force applied to the chest wall to mobilize secretions and enhance airway clearance (Figure 1). Manual vibrations, characterized by rapid oscillations over the chest, have been utilized to facilitate mucociliary clearance and improve pulmonary function (Figure 2). MHI was administered using an artificial manual breathing unit bag, with inflation pressure maintained at approximately 40 cm H_2O, to enhance lung compliance and alveolar recruitment. Endotracheal suctioning was conducted using a standard suction catheter (14 French gauge) to effectively remove airway secretions (Figure 3). Each physiotherapy session was conducted for 15–20 min. The pre- and post-intervention parameters were documented daily, with post-intervention measurements obtained 30 min after therapy to assess immediate effects. This study focused on both ventilatory and hemodynamic parameters as outcome measures. Primary ventilatory parameters included lung compliance (measured in mL/cm H_2O), airway resistance (measured in cm H_2O/L/s), and peak inspiratory pressure (PIP) (measured in cm H_2O). These indicators offer insights into pulmonary mechanics and the efficacy of CPT in enhancing lung function. The secondary outcome measures evaluated were hemodynamic stability, including heart rate (beats per minute), respiratory rate (breaths per minute), mean arterial pressure (measured in mmHg), and peripheral oxygen saturation (SpO_2, measured as a percentage). These parameters were documented to ascertain whether CPT interventions affected cardiovascular responses and oxygenation in patients on mechanical ventilation. The collected data were subsequently analyzed to determine the statistical significance of the changes observed pre- and post-intervention. Data analysis was conducted using Statistical Package for the Social Sciences v20.0, and the means and standard deviations were calculated. Repeated measures ANOVA was employed to compare pre-and post-intervention effects, with $p < 0.05$ considered statistically significant.

Figure 1: Manual vibration

Figure 2: Manual percussion

Results

In this study, 50 mechanically ventilated patients (mean age: 48.68 ± 12.83 years) were enrolled, with primary diagnoses predominantly comprising sepsis (n = 15), chronic obstructive pulmonary disease (n = 9), and lower respiratory tract infections (n = 7). The findings revealed significant enhancements in ventilatory and hemodynamic parameters after early implementation of CPT. Notably, lung compliance exhibited a significant increase over the 3-day intervention period ($P < 0.05$), indicative of improved lung expansion and respiratory mechanics. Furthermore, there was a marked reduction in airway resistance and PIP, suggesting enhanced airway function and diminished respiratory effort. The peripheral oxygen saturation (SpO_2) levels increased following CPT, reflecting improved oxygenation and gas exchange. In addition, a significant decrease in respiratory rate was observed, contributing to enhanced respiratory stability and reduced ventilatory demand in critically ill patients (Table 1).

Discussion

This study demonstrated that early CPT significantly enhanced ventilatory compliance, reduced airway resistance, and improved oxygenation in mechanically ventilated patients. The observed increase in lung compliance and decrease in PIP suggest enhanced alveolar recruitment and diminished airway obstruction. These results are consistent with those of existing studies, indicating that

Figure 3: Endo-tracheal suctioning

Table 1: Comparison of pre- and post-intervention effects (day 1 to day 3)

Parameter	*Day 1 pre*	*Day 3 post*	*P-value*
Compliance (mL/cmH_2O)	38.93±8.98	41.66±8.41	0.000*
Resistance (cmH_2O/L/s)	19.54±3.17	16.78±1.87	0.000*
PIP (cmH_2O)	24.80±6.99	19.41±3.47	0.000*
Heart rate (bpm)	86.16±13.52	83.16±8.24	0.000*
Respiratory rate (breaths/min)	21.10±3.92	17.04±1.48	0.000*
MAP (mmHg)	90.26±5.24	91.42±3.35	0.000*
SpO_2 (%)	92.14±2.53	113.62±127.78	0.000*

MAP: Mean arterial pressure, Statistically significant difference between Day 1 and Day 3 values ($p < 0.05$)

MHI and endotracheal suctioning facilitate secretion clearance and prevent atelectasis. The present findings corroborate those of Castro *et al*. (2013), who emphasized that CPT contributes to reduced pulmonary infection rates and improved lung mechanics.[3] Similarly, Unoki *et al*. (2005) reported that rib cage compression enhances secretion clearance and oxygenation in ICU patients, thereby corroborating the present findings.[13] Contrary to previous research that identified potential risks such as transient hypoxemia or hypotension (Branson, 2007), this study observed no adverse hemodynamic effects, thereby reinforcing the safety of early CPT interventions.[15] The notable reduction in respiratory rate following the intervention indicates improved ventilatory efficiency, which may be attributed to enhanced gas exchange and reduced workload on the respiratory muscles. Furthermore, the increase in SpO_2 levels post-therapy suggests improved oxygenation, which is a critical factor in weaning patients from mechanical ventilation. Despite these promising results, this study had certain limitations. The relatively small sample size and absence of a control group constrain the ability to draw causal inferences. Moreover, the study exclusively evaluated the immediate effects of CPT and lacked long-term follow-up to assess sustained benefits or potential risks. Furthermore, sex-specific differences were not examined because of the emphasis on overall efficacy. Future research should incorporate a larger sample size and control group to derive more robust conclusions. Longitudinal studies investigating the long-term effects of CPT on weaning success, hospital stay duration, and overall mortality are necessary. In addition, a sex-based analysis may offer insights into whether the effectiveness of CPT differs between male and female patients. The integration of advanced imaging and biomarkers could further elucidate the physiological mechanisms underlying the observed improvements.

Conclusion

Early CPT in mechanically ventilated adults significantly improves ventilatory function, hemodynamic stability, and oxygenation, without adverse effects. These findings support the routine inclusion of CPT in ICU management to enhance respiratory function and facilitate weaning from mechanical ventilation. Nevertheless, this study is subject to certain limitations. The small sample size, absence of a control group, and exclusive focus on immediate effects constrain the generalizability and the ability to draw causal inferences. Furthermore, the study did not stratify outcomes based on the underlying diagnosis or the severity of the illness. Future research should prioritize the implementation of randomized controlled trials involving larger and more diverse patient cohorts to improve the generalizability of the results. Longitudinal studies are necessary to investigate the long-term effects of early CPT on clinical outcomes, including the duration of mechanical ventilation, length of ICU stay, incidence of ventilator-associated complications, and overall patient mortality. Furthermore, the integration of objective imaging modalities and pulmonary biomarkers could yield deeper insights into the physiological mechanisms responsible for the observed enhancements in lung compliance and oxygenation. Additional research should also consider sex-specific responses to CPT and evaluate its efficacy in comparison to alternative respiratory interventions, such as mechanical insufflation–exsufflation and high-frequency chest wall oscillation. Investigating the cost-effectiveness and feasibility of incorporating early physiotherapy protocols into routine ICU care could facilitate widespread clinical adoption and standardization of care.

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