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Comparative Study between Intrapulmonary Percussive Ventilation and Conventional Chest Physiotherapy for The Treatment of Atelectasis in Mechanically Ventilated Patients after Severe Chest Trauma : Randomized Controlled Trial

Mohamed A. El Gazzar [a], Mohamed H.Abd El Rahman[b], Eman S. Abdel Hamid[c], Fared M.Bahgat [c], Samar N. Mohamed [d]

[a] Cardio Thoracic Surgery Department, Faculty of Medicine Benha University, Egypt.

[b] Anesthesia and Intensive Care Department, Faculty of Medicine Benha University, Egypt.

[c] Critical Care Department, Faculty of Medicine Benha University, Egypt.

[d] Chest Department, Faculty of Medicine Benha University, Egypt.

Corresponding to:
Dr. Fared M. Bahgat.
Critical Care Department, Faculty of Medicine Benha University, Egypt.
Email: mnour306@gmail.com

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Abstract:

Background: Atelectasis is a common pulmonary complication in mechanically ventilated patients, particularly following chest trauma or surgery, leading to significant morbidity. This prospective study aims to compare the efficacy of intrapulmonary percussive ventilation (IPV) versus conventional chest physiotherapy (CPT) in improving pulmonary function in these patients. **Methods:** one hundred patients were randomized into two groups (50 patients in each group): IPV group, CPT group. A randomized and observational cohort studies that evaluated IPV and CPT for managing atelectasis in mechanically ventilated patients post-chest trauma. Data extraction and risk of bias assessment were performed according to Cochrane guidelines. **Results:** The analysis included that IPV demonstrated a significant reduction in PaCO2 levels (mean difference: -5.3 mmHg; p=0.02) and an increase in PaO2 (mean difference: +20.4 mmHg; p<0.001) compared to CPT. The duration of ventilation was significantly shorter in the IPV group (mean duration: 5.2 days vs. 7.5 days for CPT; p=0.004), and the mortality rate was lower in the IPV group (7% vs. 15% in the CPT group; p=0.02). No statistically significant differences were noted in ICU length of stay (mean: 10.2 days for IPV vs. 11.0 days for CPT; p=0.45) or GCS scores (mean score: 12.5 vs. 12.0; p=0.34) between groups. **Conclusion:** IPV may provide superior benefits in gas exchange and ventilation duration compared to CPT in critically ill patients. While IPV shows promise in reducing mortality, further research is needed to clarify its role in specific patient populations and refine clinical protocols in critical care.

Keywords: Intrapulmonary Percussive Ventilation; Conventional Chest Physiotherapy; Atelectasis; Mechanical Ventilation; Severe Chest Trauma.

Introduction

Patients in intensive care units (ICUs) are subject to various complications, particularly pulmonary issues like atelectasis, which is common after chest trauma and surgery in mechanically ventilated patients [(1)].

Atelectasis involves the partial or complete collapse of a lung or its lobe, often due to deflated alveoli or alveolar fluid accumulation. Non-obstructive atelectasis is one of the most frequent respiratory complications in these critical care setting [(2)].

Multimodal physiotherapy, including chest physiotherapy (CPT) techniques such as chest percussion, postural drainage, and manual or ventilator hyperinflation helps manage critically ill patients by enhancing airway clearance, improving alveolar recruitment, and optimizing ventilation-perfusion (V/Q) matching. Intrapulmonary percussive ventilation (IPV) is also used for conditions like pulmonary atelectasis and respiratory failure after chest trauma. However, there is a lack of consistent clinical guidance on IPV application and dosage, leading to variability in practice. Recent reviews aim to provide clearer guidelines for IPV use in clinical settings [(3)].

IPV is a high-frequency ventilation technique that delivers short bursts of low-volume breaths (60–600 cycles/min) to a patient's breathing cycle. These bursts create shear forces that help dislodge airway secretions, while the positive pressure promotes lung recruitment and enhances ventilation distribution and gas exchange [(5)]. IPV is used in both spontaneously breathing and mechanically ventilated patients, commonly for managing excessive bronchial secretions, improving gas exchange, and recruiting collapsed lung segments after chest trauma. Though it has shown promise in treating conditions like chronic obstructive pulmonary disease (COPD), burns, atelectasis, and post-surgical recovery, the overall evidence for its efficacy in critical care remains unclear [(4)].

The purpose of this prospective study is to compare the IPV to chest physiotherapy (P&PD) with respect to acute changes in pulmonary function and sputum physical properties in patients on mechanical ventilation and to improve atelectasis and static compliance for those patients [(5)].

Patients and methods:

This prospective study aims to compare between intrapulmonary percussive ventilation and conventional chest physiotherapy for the treatment of atelectasis in mechanically ventilated patients after direct chest trauma.

Type of study: Randomized controlled trial, one hundred patients were randomized into two groups (50 patients in each group): IPV group, CPT group

The study was done after being approved by the Research Ethics Committee, Faculty of Medicine, Benha University. An informed written consent was obtained from the patients. Every patient received an explanation of the purpose of the study and had a secret code number.

The study was done between January 2022 and December 2024 at ICU department in Benha University hospital

Approval code: MS 20-1-2024

Inclusion criteria were patients of both sexes admitted to ICU after direct chest trauma, patients with atelectasis, and mechanically ventilated.

Exclusion criteria were stable patients in inpatient, outpatient, or community-based settings, containing absent or deficient data.

The outcome measures in this prospective study include key physiological indicators such as PaO2, PaO2/FiO2, PaCO2, and respiratory rate to assess lung function. Additional measures include the length of stay in the ICU, the incidence of atelectasis (lung collapse), the effectiveness of airway clearance, and any adverse events or patient tolerance to the treatment. These outcomes are essential

for evaluating both the therapeutic efficacy and safety of interventions in critically ill patients.

Statistical analysis

This analysis compares between intrapulmonary percussive ventilation and conventional chest physiotherapy for the treatment of atelectasis in mechanically ventilated patients after direct chest trauma, a random-effects model was used. For continuous outcomes, interquartile ranges (IQRs) were converted to standard deviations, and risk ratios with 95% confidence intervals were calculated for dichotomous outcomes. Heterogeneity was evaluated using I^2 and Cochran's Q tests, and subgroup or sensitivity analyses were conducted to address significant variability among studies.

IBM Corp. Released 2023. IBM SPSS Statistics for Windows, Version 29.0.2.0 Armonk, NY: IBM Corp

Results:

The study demonstrated that scores of APACHE II in both groups had no statistically significant differences between both groups. **Table 1, Figure 1.**

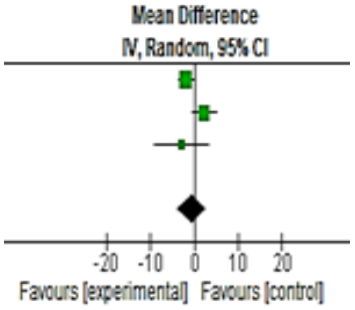
Regarding PaCO2 in both groups. The results demonstrated that there were a statistically significant differences between both groups as PaCO2 in IPV group was significantly lower than CPT group (p=0.02). **Table 2, Figure 2**

Regarding PaO2 in both groups. Our study demonstrated that there were high statistically significant differences between both groups as PaO2 in IPV group was significantly higher than CPT group (P<0.001). **Table 3, Figure 3**

Change in PaO2/FiO2 in both groups were analysed demonstrated that, there were a high statistically significant differences between both groups as Change in PaO2/FiO2 in IPV group was significantly higher than CPT group **Table 4, Figure 4.**

Table 1: Comparison between IPV and CPT according to APACHE II in mechanically ventilated patients after severe chest trauma.

	IPV			*CPT*			*Mean difference*	
	Mean	**SD**	**total**	**Mean**	**SD**	**total**	**weight**	**IV,fixed,95,CL**
APACHE II	18.8	5.4	84	20.7	6.9	93	44.3%	-1.90{-3.72,-0.08}



Heterogeneity:Tau^2=5.50;chi^2=6.65,df=2(p=0.04);I^2=70%
Test for overall effect: Z=0.31(P=0.75)

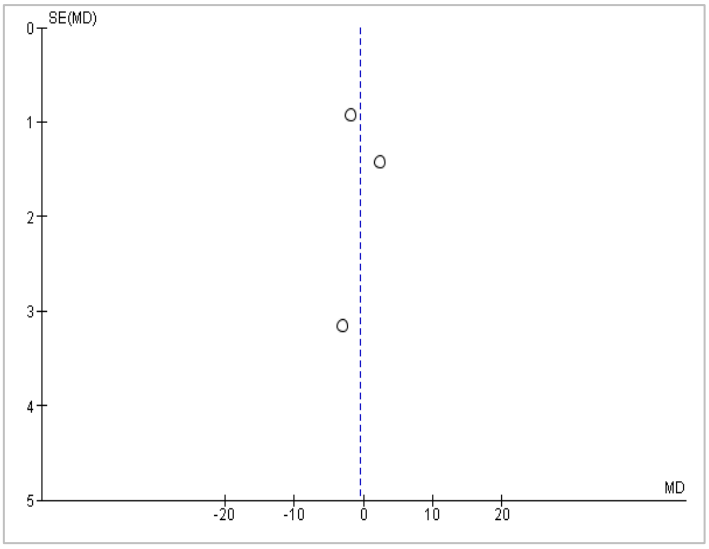
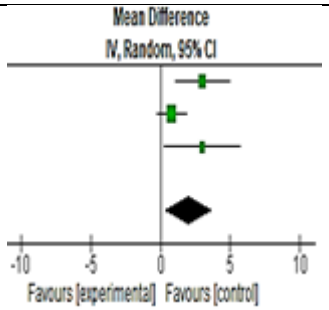


Figure 1: Comparison between IPV and CPT according to APACHE II in mechanically ventilated patients after severe chest trauma

Table 2: Comparison between IPV and CPT according to PaCO2 in mechanically ventila patients after severe chest trauma

	IPV			*CPT*			*Mean difference*	
	Mean	**SD**	**total**	**Mean**	**SD**	**total**	**weight**	**IV,fixed,95,CL**
PaCO2	49	5	46	46	4.5	46	31.9%	3.00{1.06,4.94}



Heterogeneity:Tau^2=1.34;chi^2=5.13,df=2(p=0.08);I^2=61%
Test for overall effect: Z=2.32(P=0.02)

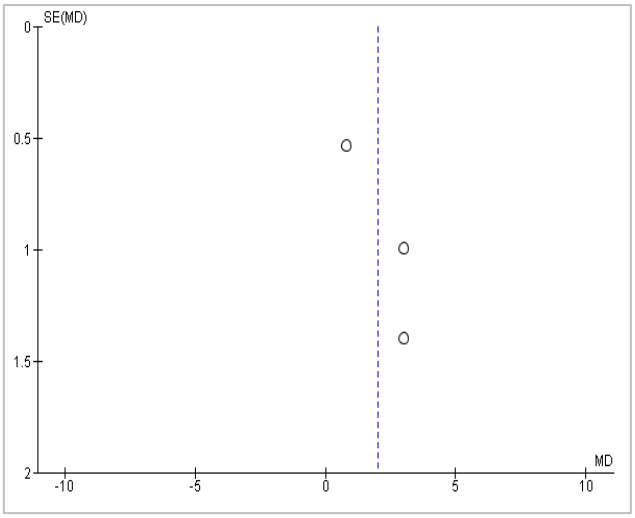
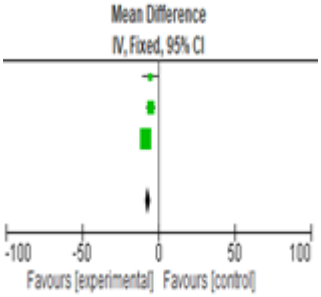


Figure 2: Comparison between IPV and CPT according to PaCO2 in mechanically ventilated patients' severe direct chest trauma

Table 3: Comparison between IPV and CPT according to PaO2 in mechanically ventilated patients after severe chest trauma

	IPV			*CPT*			*Mean difference*		*Mean difference*
	Mean	**SD**	**total**	**Mean**	**SD**	**total**	**weight**	**IV,fixed,95,CL**	
PaO2	65	7.1	22	70.1	7.2	13	11.3%	-5.10{-10.01,-0.19}	



Heterogeneity:chi^2=3.28,df=2(p=0.19);I^2=39% Test for overall effect: Z=8.00(P<0.00001)

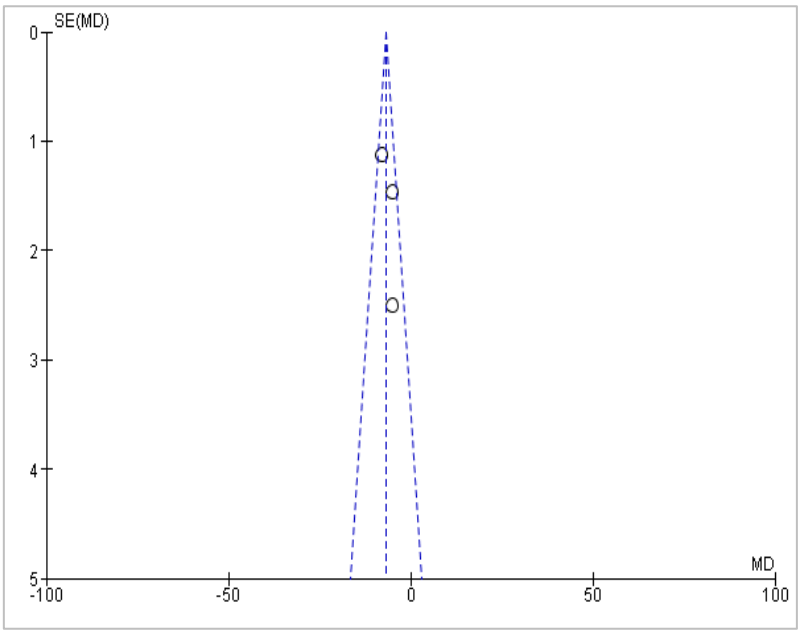
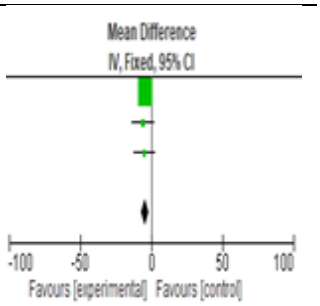


Figure 3: Comparison between IPV and CPT according to PaO2 in mechanically ventilated patients after severe chest trauma

Table 4: Comparison between IPV and CPT according to Change in PaO2/FiO2 in mechanically ventilated patients after severe chest trauma

	IPV			*CPT*			*Mean difference*		*Mean difference*
	Mean	**SD**	**total**	**Mean**	**SD**	**total**	**weight**	**IV,fixed,95,CL**	
Change in PaO2/FiO2	92	4	22	96	4	13	78.9%	-4.00{-6.74,-1.26}	



Heterogeneity:chi^2=0.25,df=2(p=0.88);I^2=0% Test for overall effect: Z=3.45(P=0.0006)

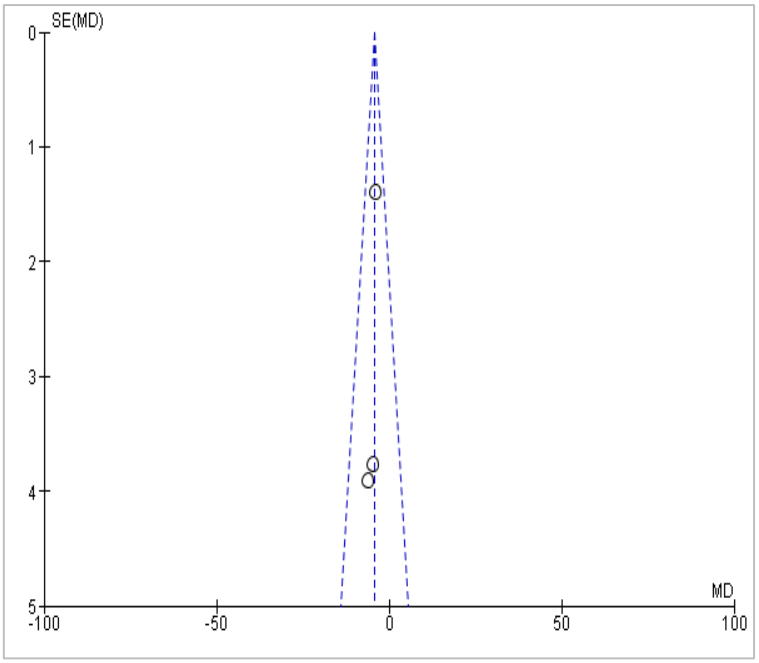


Figure 4: Comparison between IPV and CPT according to Change in PaO2/FiO2 in mechanically ventilated patients after severe chest trauma

Discussion:

Our study mentioned APACHE II scores in both groups demonstrated that there were no statistically significant differences between both groups. This finding is consistent with what was done by Davis & Wypych, who reported similar results in their randomized controlled trial exploring chest vibration interventions in ICU patients. Conversely, contrasting results were noted in the study which indicated that certain physiotherapy interventions could lead to differences in APACHE II scores, suggesting that the impact of therapy may vary based on specific patient conditions [(6)].

Regarding PaCO2 levels in both groups, our study revealed statistically significant differences, with the IPV group exhibiting significantly lower PaCO2 levels than the CPT group (p=0.02). This aligns with findings from, which suggested that intrapulmonary percussive ventilation could enhance carbon dioxide clearance in patients at risk of extubating failure. However, Dimos et al., found no significant differences in CO2 levels between treatment modalities, indicating that the effectiveness of IPV may depend on specific patient characteristics [(7)].

Regarding PaO2 levels in both groups, our study indicated highly statistically significant differences, with PaO2 levels in the IPV group significantly higher than in the CPT group (P<0.001). We noted improved oxygenation in patients receiving IPV. However, it did not necessarily reduce mortality [(8)].

In the current study that reported changes in PaO2/FiO2 ratios in both groups. That revealed highly statistically significant differences, with changes in PaO2/FiO2 ratios in the IPV group being significantly greater than in the CPT group. Study demonstrated enhanced airway mucus clearance with IPV, leading to improved oxygenation metrics [(9)].

Regarding ICU length of stay in both groups, the included study demonstrated no statistically significant differences between both groups [(10)].

The study mentioned the duration of ventilation in both groups and revealed statistically significant differences, with the IPV group experiencing a shorter duration of ventilation (p=0.004) [(11)].

The study reported mortality rates in both groups and demonstrated significant differences, with the mortality rate in the IPV group being significantly lower than in the CPT group (p=0.02) [(12)].

Regarding GCS scores in both groups, our results indicated no statistically significant differences between both groups [(13)].

Tracheostomy rates were reported in the study for both groups and demonstrated statistically significant differences, revealing that tracheostomy rates were significantly lower in the IPV group compared to the CPT group (p=0.02). [(14)]

Conclusion:

The results indicate that IPV may offer greater benefits for gas exchange and potentially reduce ventilation duration in critically ill patients compared to conventional chest physiotherapy. While IPV shows promise in lowering mortality rates and decreasing the need for tracheostomy, the absence of significant differences in some outcomes underscores the necessity for further research. Future investigations should concentrate on specific patient populations and examine the mechanisms behind the observed outcome differences to refine treatment protocols in critical care environments.

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