

## Effect of Cough Assist Device on Hemodynamic Status and Oxygen Saturation for Ventilated Children

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### ABSTRACT

**Background:** Coughing is an important protective mechanism for cleaning airways from fluids and foreign substances. Life-threatening situations may emerge when coughing loses its efficiency due to muscular weakness or impaired mucociliary function. **Objective:** This study aimed to investigate how a cough assist device affects hemodynamic monitoring and oxygen (O<sub>2</sub>) saturation in children using mechanical ventilation (MV).

**Patients and methods:** Fifty children who had pneumonia and receiving MV, from both gender with age ranged from 4 to 9 years old, were included in this research study. The children were divided into two equal groups using a random way: The intervention group received both a cough assist device and conventional chest physiotherapy, while the control group received only conventional chest physiotherapy.

**Results:** Compared to the control group, the intervention group had a substantial reduction ( $p < 0.05$ ) in respiratory rate (RR) and a significant rise ( $p < 0.01$ ) in O<sub>2</sub>, VTe, and Cdyn following treatment.

**Conclusion:** Children on MV had improved respiratory parameters, oxygen saturation, and chest condition when a cough assist device was used combined with conventional chest physical therapy.

**Keywords:** Cough assist, Oxygen saturation, Hemodynamic status, Mechanical ventilation, Pneumonia.

### INTRODUCTION

An estimated 120 million cases of pneumonia and 1.3 million fatalities are reported worldwide annually. Children less than two account for about 80% of pediatric pneumonia-related mortality in poor nations. Although the prognosis for pneumonia has improved and the condition is associated with fewer deaths in affluent nations, over 2.5 million people are affected by pneumonia each year, making it a serious burden. Between one-third and one-half of these instances result in hospitalizations <sup>[1]</sup>.

MV is widely utilized in critical care to treat patients, including adults, children, and newborns. Irrespective of the underlying disease, this supportive therapy has several repercussions, including ventilator-associated lung damage and pneumonia, which may lengthen its duration <sup>[2]</sup>. For almost half a century, babies and children have been formally receiving critical care. Among the most popular and significant ICU operations is invasive MV, which sustains the lives of around 30% of patients in a pediatric intensive care unit (PICU) <sup>[3]</sup>.

Although the possible detrimental consequences of an excess of oxygen at the tissue level are not often addressed, the implications of a reduction in oxygen (O<sub>2</sub>) supply in critically sick patients are well-known and feared <sup>[4]</sup>. It is common protocol for all staff members working in emergency rooms and pediatric assessment units to keep an eye on a child's vital signs, including their temperature, pulse, blood pressure, and breathing rate. RR is a very essential indication for both the initial and ongoing assessment of unwell children. It is a technique for assessing a child's clinical state and a predictor of notable worsening <sup>[5]</sup>.

The task of developing expert consensus commands or evidence-based guidelines on hemodynamic

monitoring that are specifically meant for use in children was given to the members of the Cardiopulmonary Dynamics Part at October 2016 annual meeting of the European Society of Pediatric and Neonatal Intensive Care (ESPNIC) <sup>[6]</sup>. Pulmonary secretions are often removed with manual or mechanical chest physical therapy procedures such as vibration and percussion. It is thought that when chest wall manipulations are made, pulmonary secretions are liquefied. This allows mechanical energy to enter the airways, where they can be evacuated by positioning, suctioning, or coughing <sup>[7]</sup>.

By transferring secretions from the periphery to the proximal airways via gravity, therapeutic positioning seeks to promote mucociliary clearance (postural drainage), raise lung volumes, decrease breathing effort, limit heart strain, and maximize ventilation-perfusion ratios <sup>[8]</sup>.

A method of clearing the airways called mechanical insufflation-exsufflation works by first forcing secretions out of the way with a rapid, strong exsufflation with negative pressure, ready for suctioning, and then taking a deep breath with positive pressure. Intermittent usage is a major consideration in the design of many of the commercially marketed devices. Determining the maximal inspiratory and expiratory pressures, in addition to the inhalation, pause, and exhalation durations, is the first step towards achieving an efficient expiratory flow <sup>[9]</sup>. It has been recommended for use to facilitate weaning or reduce the risk of reintubation in patients on MV who show symptoms of mucus buildup and weak cough (peak cough flow <160 liters per minute) <sup>[10]</sup>. The current study's objective was to investigate how a cough assist device affects hemodynamic monitoring and oxygen saturation in children using a mechanical ventilation.

**PATIENTS AND METHODS**

Fifty pediatric patients on MV who had pneumonia were divided into two groups of equal numbers at random for this study. The research was designed as a prospective, randomized, parallel trial.

**Inclusion criteria:** Children between the ages of 4 and 9 years who were diagnosed with pneumonia, intubated on MV, and vitally stable throughout the trial.

**Exclusion criteria:** Clinically unstable, recent upper gastrointestinal operation, diaphragmatic hernia, pneumothorax (if a chest tube is present) and elevated intracranial pressures.

**Intervention:** Start chest physical therapy sessions either prior to or following a 2-hour feeding and nebulizer session.

- **Control group:** Included twenty five children who received only conventional chest physiotherapy including postural drainage, percussion, vibration, thoracic squeezing, in addition to bed mobility exercises.

- **Study group:** Included twenty five children who received conventional chest physiotherapy program with the cough assist device.

The cough assist device was first powered by the Power Potton cough aid device protocol, which comprised three to five cycles of insufflation and exsufflation pressure ranging from +15 cmH<sub>2</sub>O to the -15 cmH<sub>2</sub>O and a maximal pressure of + 40 cmH<sub>2</sub>O to the - 40 cmH<sub>2</sub>O. There was a one-second break between each of the two to three-second inhalation and exhalation cycles. During each session, the pressure was modified for each child based on the volume of secretions, tolerance, and chest auscultation. At the conclusion of the session, we attached the device's tube to the patient's tube, hit start, and ended. There were designated rest periods for extracting secretions from the mouth, nose, or mechanical breathing device tube. There were four to six complete sets, each lasting thirty minutes. We used this device for a single daily session.

**Outcome measures:** Oxygen saturation (SaO<sub>2</sub>), respiratory rate (RR), expired tidal volume (VTe), and dynamic compliance (Cdyn) were recorded from the monitor and mechanical ventilator that were connected to the child before and after the session, from the day of admission to intensive care to the day of weaning from the MV device.

**Ethical approval:** The study was approved by the Ethical Committee of Cairo University's Faculty of Physical Therapy (No.: P.T.REC/012/003526). Following a thorough explanation of the benefits and potential issues, children's guardians signed a consent forms. The confidentiality of the data was assured. The Helsinki Declaration was adhered to at every stage of the investigation.

**Statistical analysis**

Every statistical analysis was carried out using Windows SPSS Version 25.0. The study employed unpaired t-tests to compare subject characteristics between groups, the mean ± SD were employed, and X<sup>2</sup>-test to compare the distribution of sexes. The data were tested for normal distribution using the Shapiro-Wilk test. To evaluate the homogeneity between groups, Levene's test for homogeneity of variances was used. To assess the effects within and between groups on SaO<sub>2</sub>, RR, HR, systolic and diastolic blood pressure, VTe, and Cdyn, a two-way mixed MANOVA was used. Multiple comparisons were performed after applying Bonferroni adjustments. All statistical tests were conducted with a significance threshold of p ≤ 0.05.

**RESULTS**

Table (1) showed the subject characteristics of control and study groups. There was no significant difference between groups in age, weight and the distribution of sexes (p > 0.05).

**Table (1):** Comparison of subject characteristics between control and study groups

	<b>Control group</b>	<b>Study group</b>	<b>P-value</b>
	<b>Mean ± SD</b>	<b>Mean ± SD</b>	
<b>Age (years)</b>	5.32 ± 1.52	5.56 ± 1.58	0.58
<b>Weight (kg)</b>	16.20 ± 4.19	15.96 ± 4.66	0.84
<b>Sex, n (%)</b>			
Girls	13 (52%)	13 (52%)	1
Boys	12 (48%)	12 (48%)	

Mean ± SD, Standard deviation; p value, Level of significance.

**Effect of treatment on SaO<sub>2</sub>, RR, VTe and Cdyn:**

Two-way mixed MANOVA showed that there was a significant interaction between treatment and time (F = 30.34, p = 0.001). There was a significant main effect of time (F = 80.38, p = 0.001). There was a significant main effect of treatment (F = 6.92, p = 0.003).

**Within group comparison:**

There was a significant increase in SaO<sub>2</sub>, VTe and Cdyn of control and study groups after treatment in comparison with before (p < 0.001). The percent of changes of SaO<sub>2</sub>, VTe and Cdyn of control group were 3.01%, 11.96% and 43.40% respectively and that of study group were 15%, 35.50% and 134.69% respectively. There was a significant decrease in RR, HR, systolic and diastolic blood pressures of study group post-treatment compared to pretreatment (p < 0.01), while there was no significant change in control group (p > 0.05) (Tables 2 & 3).

**Between group comparison:**

There was no significant difference between groups before treatment (p > 0.05). There was a significant increase in SaO<sub>2</sub>, VTe and Cdyn (p < 0.01) and a significant decrease in RR, HR and systolic and diastolic blood pressures of study group compared to that of control group after treatment (p < 0.05) (Tables 2 & 3).

**Table (2):** Mean SaO<sub>2</sub>, RR, HR, and systolic and diastolic blood pressures pre- and post-treatment in control and study groups

	Pre treatment	Post treatment	MD	% of change	P value
	Mean ±SD	Mean ±SD			
<b>SaO<sub>2</sub> (%)</b>					
Control group	84.92 ± 3.99	87.48 ± 2.68	-2.56	3.01	0.001
Study group	83.76 ± 3.94	96.32 ± 2.43	12.56	15	0.001
MD	1.16 <i>p = 0.31</i>	-8.84 <i>p = 0.001</i>			
<b>RR (breath/mi)</b>					
Control group	24.20 ± 5.49	24.72 ± 4.42	0.52	2.15	0.55
Study group	25.04 ± 5.47	21.12 ± 3.97	3.92	15.65	0.001
MD	-0.84 <i>p = 0.59</i>	3.6 <i>p = 0.004</i>			

Mean ±SD, Standard deviation; MD, Mean difference; *p* value, Probability value.

**Table (3):** Mean VTe, Cdyn pre and post treatment of control and study groups

	Pre treatment	Post treatment	MD	% of change	P value
	Mean ±SD	Mean ±SD			
<b>VTe (ml)</b>					
Control group	75.81 ± 16.96	84.88 ± 16.42	-9.07	11.96	0.001
Study group	74.42 ± 19.79	100.84 ± 21.02	-26.42	35.50	0.001
MD	1.39 <i>p = 0.79</i>	-15.96 <i>p = 0.004</i>			
<b>Cdyn (ml/cmH<sub>2</sub>O/kg)</b>					
Control group	0.53 ± 0.17	0.76 ± 0.18	-0.23	43.40	0.001
Study group	0.49 ± 0.18	1.15 ± 0.24	-0.66	134.69	0.001
MD	0.04 <i>p = 0.47</i>	-0.39 <i>p = 0.001</i>			

Mean ±SD, Standard deviation; MD, Mean difference; *p* value, Probability value.

## DISCUSSION

The current study was established to determine how a cough assist device affected the vital signs of children admitted to the PICU as well as the respiratory parameters of a MV system. The study group's RR was much lower than the control group's, according to the results. The cough assist device study group's VTe, dynamic compliance, and oxygen saturation were significantly increased. Our findings were consistent with those of **Arjoni et al.** [11] who examined the impact of cough-assist on the arterial blood's oxygenation and hemodynamic status in patients admitted to ICUs. They discovered that the intervention group, which received both traditional chest physical therapy and cough assist device, had higher arterial oxygen saturation than the control group, which received traditional chest physical therapy alone.

Furthermore, a significant difference in RR was observed in this trial between an intervention group (who received both a cough assist device and standard

chest physiotherapy) and the control group. According to studies by **Luthfianto and Irdawati** [12] on the effect of chest physical therapy on oxygen saturation and RR in pediatric pneumonia, the child with pneumonia in the study group was able to resolve dyspnea and clear the airway using these techniques, in contrast to the control group. Both oxygen saturation and RR improved throughout this treatment and progressively returned to normal.

For adults with pneumonia who were receiving invasive ventilation, another trial by **van der Lee et al.** [13] showed the advantages of respiratory physiotherapy intervention. Comparing the trial group with the cough assist device to the control group, the former observed improvements in tidal volumes, lung compliance, and sputum clearance.

The present study validated the findings of **Knudsen et al.** [14] who reported that patients undergoing MV improved their oxygen saturation levels quickly and required less oxygen therapy. Subjects in the mechanical insufflation/exsufflation

(MIE) group also required fewer tracheal and pharyngeal suction than those in the control group.

Our findings are in conflict with those of **Siriwat et al.** [15] who compared the effects of mechanical insufflation-exsufflation with conventional chest physical therapy in children with cerebral palsy and found no significant difference in the two groups' physical measurement data for oxygen saturation, RR, and HR. Nevertheless, after four days, there was no statistically significant change between the groups' SpO<sub>2</sub> levels, heart rates, and breathing patterns according to daily recorded data.

## CONCLUSION

Applying a cough assist device to children with pneumonia on MV resulted in greater improvements in O<sub>2</sub> saturation, VTe, Cdyn, and RR than conventional chest physiotherapy techniques alone.

## RECOMMENDATIONS

- Future research on PICUs is required. It is imperative to conduct additional research to investigate the impact of cough assist devices on children who are not ventilated.
- The effectiveness of cough assist devices in cystic fibrosis patients.
- More research is needed to determine how cough assist devices affect children who had heart surgery.

**Conflict of interest:** None.

**Fund:** None.

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