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EFFICACY OF MECHANICAL CHEST VIBRATION ON OXYGENATION AND VENTILATION PARAMETERS IN MECHANICALLY VENTILATED ORGANOPHOSPHORUS POISONING PATIENTS: A RANDOMIZED CONTROLLED TRIAL

Vishnu Vardhan G.D[1], Akshaya N. Shetti[2], Vaijayanti K. Badhe[3], Moli Jai Jain[4], Anup Kharde[5] Sasipriya A.S[6]

[1]Professor & HOD, Department of Cardio-Respiratory Physiotherapy Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra; Ph. D. Scholar, Pravara Institute of Medical Sciences.
[2]Professor, Department of Anaesthesiology, Dr. Balasaheb Vikhe Patil Rural Medical College, Loni, Maharashtra
[3]Professor & HOD, Department of Anaesthesiology, Dr. Balasaheb Vikhe Patil Rural Medical College, Loni, Maharashtra
[4]Post Graduate student, Department of Cardio-Respiratory Physiotherapy Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra.
[5]Professor, Department of Community Medicine,Zydus Medical College & Hospital,Dahod,Gujarat.
[6]Assistant Professor, Department of Mathematics, Faculty of Engineering and Technology, Datta Meghe Institute of Higher Education and Research (DU) Sawangi (Meghe),Wardha.

Corresponding author:
Vishnu Vardhan G.D, Professor & HOD, Department of Cardio-Respiratory Physiotherapy Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra; Ph. D. Scholar, Pravara Institute of Medical Sciences.
E-mail: vishnudiwakarpt@gmail.com

Abstract:
Objective: Conventional Chest physiotherapy includes manual chest percussion, manual chest vibration, postural drainage and suctioning. The objective of this research is to determine the effectiveness of mechanical chest vibration on ventilation and oxygenation status parameters in mechanically ventilated organophosphorus poisoning patients.
Material and Methods: The present study was a parallel group, randomized, controlled trial registered in Clinical Trial Registry of India (CTRI/2018/07/015074). 62 Mechanically ventilated Organophosphorus poisoning patients in medical intensive care unit of both genders of age between 20-80 years were allocated in 2 groups. Experimental group received Mechanical chest vibration by a device called G5 Vibracare along with conventional chest physiotherapy followed by suctioning for a total duration of 30 minutes twice a day. Control group consists of conventional chest physiotherapy which included manual chest percussion, manual chest vibration, and suctioning. The outcome measures evaluated in both groups were Ventilator Parameters (Static Compliance, Dynamic Compliance, VD/VT, FiO_2), Oxygenation Parameters (PaO_2, $PaCO_2$, PaO_2/FiO_2), Quantity of secretions, and Duration of intubation were noted on day 1 and on the day of extubation.
Results: Post rehabilitation the pair mean difference results observed for static compliance (10.68 vs 8.00), dynamic compliance (12.60 vs 11.04) PaO_2 (-56.28 vs 11.04), VD/VT (-0.06 vs -0.05), FiO_2 (-26.68 vs-24.92), quantity of secretions (-3.680 vs -3.20) following the intervention. This shows pair mean difference was more pronounced in the Experimental group compared with the Control group.
Conclusion: The study concluded that the paired mean difference of Experimental Group (Mechanical chest vibration and Conventional Chest Physiotherapy) showed a improvement than the control group. Mechanical chest vibration had shown improvement in static compliance, dynamic compliance, quantity of secretions in experimental group than the control group.

Keywords: Mechanical chest vibration, Conventional Chest Physiotherapy, Compliance, Dead Space Ventilation, Quantity of Secretions

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INTRODUCTION:

Organophosphorus substances cause clinical manifestations by inhibiting the cholinesterase enzyme, which leads to a build-up of acetylcholine at different receptors and has three different effects: Muscarinic, Central and Nicotinic. Muscarinic effects lead to pulmonary oedema, sweating, and bradycardia due to acts on the bronchi, salivary, lacrimal, sweat, etc. [1] The motor and sympathetic nicotinic effects of nicotine cause fasciculation, muscle wasting, and tachycardia. Giddiness, anxiety, emotional lability, ataxia, confusion and apathy are the main consequences. [2]

Organophosphorus substances have numerous toxicological effects on the circulatory and respiratory systems, and as a result, overstimulation of muscarinic acetylcholine receptors in the parasympathetic nervous system results in respiratory illnesses such as central failure of breathing. The main findings were loss of central inspiratory drive owing to poisoning and quickly progressing bradypnea leading to apnoea due to respiratory effect loss.[3] Atropine is administered until secretions dry in order to provide immediate attention to the airway and adequate oxygenation. Respiratory distress is widespread and the main cause of death in critical cases, adequate ventilation is crucial for these patients. The correct management includes the use of continuous pulse oximetry, antidote administration, mechanical breathing, and hospitalisation to an intensive care unit.[4]

Additionally recommended is cardiac monitoring while atropine is being administered. Frequent suctioning of the airway along with Chest Physiotherapy is usually necessary until the patient is adequately atropinized. Due to secretions, a diminished level of consciousness, or weak respiratory muscles, endotracheal intubation is frequently required in cases of acute poisoning. [5]

Conventional Chest physiotherapy includes manual chest percussion, manual chest vibration, postural drainage and suctioning. Secretion retention is caused by mucociliary clearance being obstructed by viscous secretions, the presence of an endotracheal or tracheal tube, dehydration, hypoxia, immobility, and inadequate gas humidification.[6,7] The G5 Vibracare (Mechanical Chest Vibration) is a hand-held device that vibrates the chest wall. It helps to vibrate the airways and mobilize secretions. An additional benefit of the mechanical chest vibration device for the cardio respiratory physiotherapist is that it helps reduce back pain from prolonged bending for extended periods of time in the intensive care unit.[8]

High-frequency chest wall oscillations enter the airways as a result of mechanical vibration. The purpose of this research is to determine the effectiveness of mechanical chest vibration on ventilation and oxygenation status parameters in mechanically ventilated organophosphorus poisoning patients.

METHODS AND METHODOLOGY:

The present study received approval from the Institutional Ethical Committee of the Pravara Institute of Medical Sciences [DU], Loni, Maharashtra, India 413736 (PIMS/PhD/2018/63). The study was a parallel group, randomized, controlled trial registered in Clinical Trial Registry of India (CTRI/2018/07/015074). Mechanically ventilated Organophosphorus poisoning patients of both genders of age between 20-80 years were among the participants. The patient's family members gave their informed consent. Haemodynamically unstable patients, chest trauma, Rib fracture, Haemothorax were not included.

Study procedure:

By using permuted block randomization, patients were split into two groups: Control and Experimental. Conventional chest physiotherapy (manual chest percussion, manual chest vibration, and suctioning) was administered to the patient in the Control group while mechanical chest vibration (G5 Vibracare) and conventional chest physiotherapy were administered to the patient in the Experimental group. Permuted block randomization was done with Microsoft excel 2007 with a 1:1 allocation ratio using fixed block size of 4. The allocation sequence was generated with Microsoft excel 2007. The allocation sequence was concealed from the principal investigator by using sequentially numbered, opaque, sealed and stapled envelopes. The envelope was opened by a third person independent of the recruitment process for allocation assignment. Ventilator Parameters (Static Compliance, Dynamic Compliance, VD/VT, FiO_2), Oxygenation Parameters (PaO_2, $PaCO_2$, PaO_2/FiO_2), Quantity of secretions after each session, and Duration of intubation were noted on Day 1 and on the day of extubation. Outcome measures were noted down by the third assessor.

Experimental group received Mechanical chest vibration by a device called G5 Vibracare along with conventional chest physiotherapy followed by suctioning for a total duration of 30 minutes twice a day. Control group consists of conventional chest physiotherapy which included manual chest percussion, manual chest vibration, and suctioning. Conventional chest physiotherapy was given followed by suctioning for a total duration of 30 minutes twice a day.

Statistical analysis:
Data coding and entry was done in Microsoft Excel spread sheetsand descriptive and inferential statistical analysis was done by using SPSS version 21 (Statistical Package for Social Sciences) software. The raw data was compiled, classified, presented in a tabulated manner to bring out important details. Descriptive analysis was done by Frequency, proportion, mean, median, standard deviation and quartile. Bar diagram and Box plot used for presentation for qualitative and quantitative data respectively. Normality of data was assessedusing Shapiro Wilk Test & p value < 0.05 considered statistically significant Qualitative data analysis done by Chi-square test. Quantitative data analysis was done using test, Wilcoxon matched pairs test. Effect size was calculated using Cohen'd. Effect less than 0.2 and more than 0.5 and 0.8 were classified as small, medium and large effect.

RESULTS:

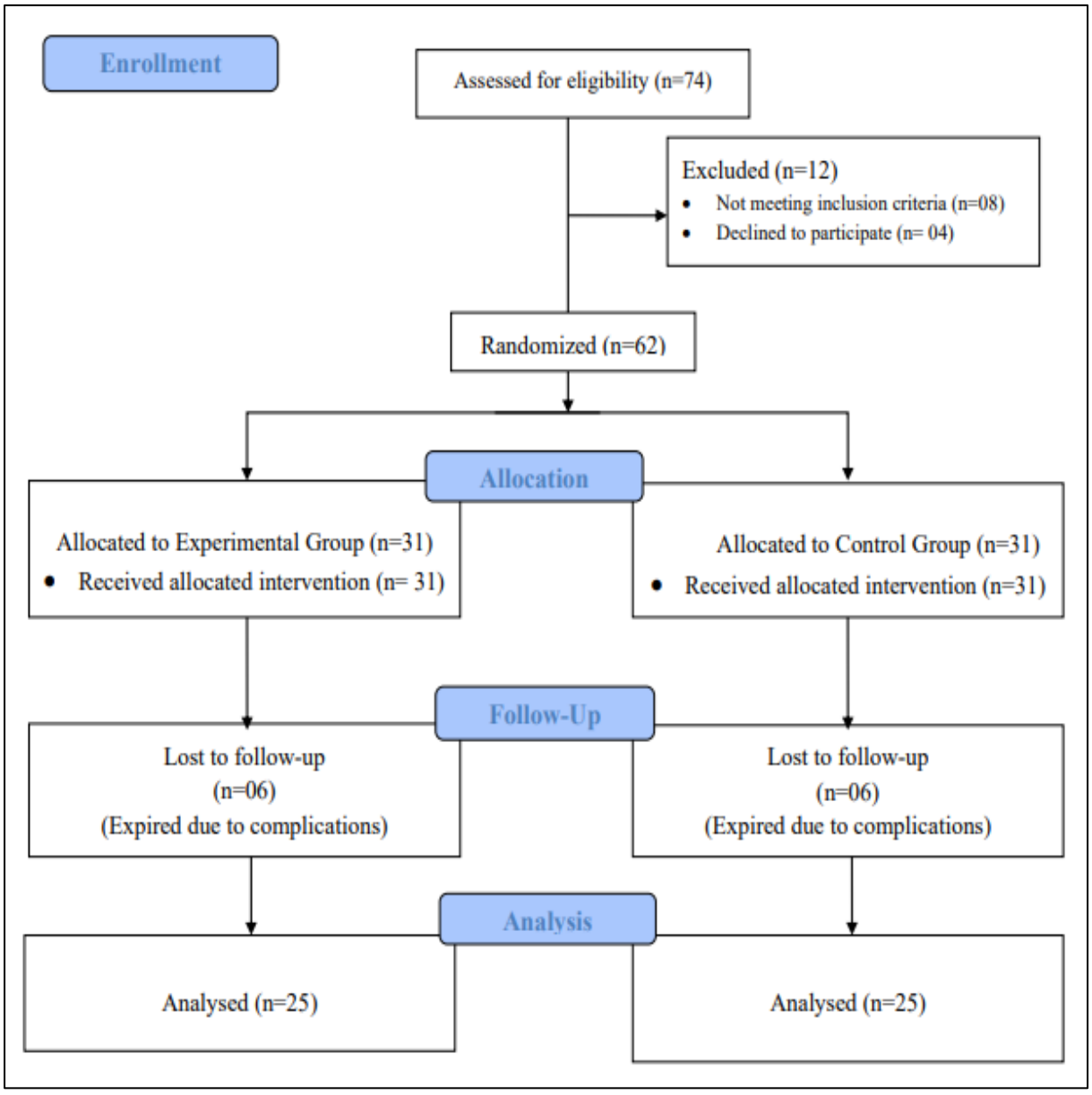

Figure 1: CONSORT flow chart of the study procedure

Table 1: Outcome measures

Variables	**Measurement scale**	**Measurement method**
1. Ventilator Parameters: a) Static Compliance (40 to 60 ml/cm H2O)	Ratio Scale	Ventilator Variables displayed on the Monitor on the Savina Ventilator.

b) Dynamic Compliance (30 to 40 ml/cm H2O) c) VD/VT (0.2-0.3) d) Fraction of inspired oxygen		
2. Oxygenation Parameters: a) PaO_2 (80-100 mm Hg) b) $PaCO_2$ (35-45 mm Hg) c) PaO_2/FiO_2 (200-300 mm Hg)	Ratio Scale	Arterial Blood Gas Analysis
3. Quantity of secretions	Ratio Scale	Mucous Extractor
4. ICU STAY: a) Duration of intubation b) Duration of stay in the Intensive Care Unit.	Ratio scale	Observational Method

Table 2: Statistical analysis of all the outcome measures Pre and Post-intervention in Experimental group.

Outcome measure	Experimental group					
	Day 1			Post		
	Mean ± S.D.	Median	Q1-Q2	Mean ± S.D.	Median	Q1-Q2
Static compliance	32.80 ± 07.12	31.00	28.00-38.00	43.48 ± 5.90	45.00	38.0-48.50
	Wilcoxon Signed Rank Test: P: 0.0001* Significant					
Dynamic compliance	22.08 ± 5.00	23.00	18.0-25.0	34.68 ± 5.42	35.00	31.50-38.50
	Wilcoxon Signed Rank Test: P: 0.0001* Significant					
PaO_2	161.88 ± 68.97	165.0	127.0-190.50	105.60±31.22	104.0	86.0-127.00
	Wilcoxon Signed Rank Test: P: 0.0002* Significant					
$PaCO_2$	42.60 ± 14.37	39.00	33.0-54.50	39.40 ± 6.50	39.00	36.0-43.50
	Wilcoxon Signed Rank Test: P: 50 Non-Significant					
VD/VT	0.50 ± 0.05	0.50	0.50-0.50	0.43±0.08	0.40	0.40-0.50
	Wilcoxon Signed Rank Test: P: 0.0001* Significant					
PaO_2/FiO_2	273.20 ±123.0	270.0	177.0-366.0	303.12 ±84.82	297.0	240.5-356.0
	Wilcoxon Signed Rank Test: P: 0.36 Non-Significant					
Quantity of Secretion	4.92 ± 0.75	5.0	4.50 – 5.0	1.24 ± 0.43	1.0	1.0 – 1.50
	Wilcoxon Signed Rank Test: P: 0.0001* Significant					
FiO_2	62.40 ± 15.07	60.0	50.0-80.0	35.72 ± 3.2	37.0	33.0-37.0
	Wilcoxon Signed Rank Test: P: 0.0001* Significant					

Table 3: Statistical analysis of all the outcome measures Pre and Post-intervention in Control group.

Outcome measures	Control group					
	Day 1			Post		
	Mean ± S.D.	Median	Q1-Q2	Mean ± S.D.	Median	Q1-Q2
Static compliance	34.24 ± 6.96	34.0	29.0-38.0	42.24 ± 7.08	41.0	36.0-48.50
	Wilcoxon Signed Rank Test: P: 0.0001* Significant					
Dynamic compliance	25.12 ± 5.34	26.00	19.0-29.50	36.16 ± 5.16	36.00	33.0-38.50
	Wilcoxon Signed Rank Test: P: 0.0001* Significant					
PaO_2	141.0 ± 57.9	149.0	93.0-186.0	123.68 ± 42.89	120	88.0-160.50
	Wilcoxon Signed Rank Test: P: .015 Non-Significant					
$PaCO_2$	38.6 ± 13.18	37.0	28.0-46.0	37.16 ± 6.28	37.0	33.0-41.50
	Wilcoxon Signed Rank Test: P: 0.74 Non-Significant					
VD/VT	0.48 ± 0.04	0.50	0.50 – 0.50	0.43 ± 0.05	0.40	0.40 -0.50
	Wilcoxon Signed Rank Test: P: 0.002* Significant					
PaO_2/FiO_2	246.6 ± 115.15	253.0	136.50-337.5	355.6 ± 113.3	375.0	256.5-444.5
	Wilcoxon Signed Rank Test: P: 0.001* Significant					
Quantity of Secretion	4.68 ±0.62	5.00	4.0-5.0	1.48 ±0.58	1.00	1.0-2.0
	Wilcoxon Signed Rank Test: P: 0.001* Significant					
FiO_2	60.40 ± 14.35	60.0	47.50 – 70.0	35.48 ± 2.53	37.0	33.0 – 37.0
	Wilcoxon Signed Rank Test: P: 0.001* Significant					

Table 4: Comparison of outcome measures in both the groups.

Sr. No.	Variable	Experimental Group			Control Group		
		Paired Mean Difference	Cohen's D	Effect Size	Paired Mean Difference	Cohen's D	Effect Size
1.	**Static Compliance Post and D1**	10.68	1.40	Large	8.00	0.80	Large
2.	**Dynamic Compliance Post & D1**	12.60	1.70	Large	11.04	1.48	Large
3.	**PaO_2 Post & D1**	-56.28	-0.74	Medium	Non-Significant		
4.	**PCO_2 Post & D1**	Non-Significant			Non-Significant		
5.	**VD/VT Pre & Post**	-0.06	-1.06	Large	-0.05	-0.78	Medium
6.	**PaO_2/FiO_2 Post & D1**	Non-Significant			109.00	0.67	Medium
7.	**Secretion Post & D1**	-3.680	-4.25	Large	-3.20	-4.83	Large
8.	**FiO_2 Pre & Post**	-26.68	-1.73	Large	-24.92	-1.71	Large

The results in the current study explain the mean static compliance on Day 1 was 32.80 ± 07.12 and mean static compliance on the day of exudation was 43.48 ± 5.90 in Experimental Group (Paired mean difference 10.68) and the mean Static Compliance on Day 1 was 34.24 ± 6.96 and mean static compliance on the day of exudation was 42.24 ± 7.08 in Control Group. (Paired mean difference 8.00)

The mean dynamic compliance on Day 1 was 22.08 ± 5.00 and mean dynamic compliance on the day of exudation was 34.68 ± 5.42 in Experimental Group (Paired mean difference 12.60) and the mean dynamic compliance on Day 1 was 25.12 ± 5.34 and mean dynamic compliance on the day of exudation was 36.16 ± 5.16 in Control Group. (Paired mean difference 11.04)

The mean partial pressure of oxygen (PaO2) on Day 1 was 161.88 ± 68.97 and mean partial pressure of oxygen PaO2 on the day of exudation was 105.60 ± 31.22 (Paired mean difference -56.28) in Experimental Group. The mean partial pressure of Oxygen PaO2 on Day 1 was 141.0 ± 57.95 and mean partial pressure of Oxygen PaO2 on the day of exudation was 123.68 ± 42.89 in Control Group. (Paired mean difference 11.04)

The mean Dead space to Tidal volume fraction (VD/VT) on Day 1 was 0.50 ± 0.05 and mean Dead space to Tidal volume fraction (VD/VT) on the day of exudation was 0.43 ± 0.08 in Experimental Group. (Paired mean difference -0.06) The mean Dead space to Tidal volume fraction (VD/VT) on Day 1 was 0.48 ± 0.04 and mean Dead space to Tidal volume fraction (VD/VT) on the day of exudation was 0.43 ± 0.05 in Control Group. (Paired mean difference -0.05)

The mean quantity of secretions on Day 1 was 4.92 ± 0.75 vs 4.68 ±0.62 and mean quantity of secretions on the day of exudation was 1.24 ± 0.43 vs 1.48 ±0.58 in Experimental Group compared to control group with Paired mean difference comparison was -3.680 vs -3.20.

DISCUSSION

The results in the current study show that as compared to the control group, patients receiving Mechanical Chest Vibration (G5 Vibracare) device produced a higher frequency than manual chest vibration shows a better improvement in experimental group than the control group.

Low compliance was reported in the majority of organophosphorus poisoning patients as a result of accumulation of secretions. Conditions that lower the patient's functional residual capacity are typically linked to low lung compliance readings. Low lung volumes, restrictive lung defects, and low minute ventilation are common in patients with non-compliant lungs. [9]

Jones A et al and Konrad et al reported patients may experience a decrease in pulmonary compliance as a result of mechanical ventilation, increased mucus production, and reduced mucociliary clearance mechanisms may all contribute to patients' decreased pulmonary compliance. [10,11] The results in the current study show that as compared to the control group, paired mean difference of static compliance (10.68 vs 8.00) and dynamic compliance (12.60 vs 11.04) is more in experimental group compared to control group. After chest physiotherapy, there is an increase in lung compliance because more functional alveolar units are recruited as a result of the small airways' secretions being mobilised and cleared. This implies that after chest physiotherapy, functional residual capacity (FRC) increased. [11]

In arterial blood gas analysis, on day 1 the patient had elevated levels of $PaCO_2$ due to atelectasis which is one of the major complications in Organo Phosphorus Poisoning patients. PaCo2 values were decreased due to retention of secretions due to atelectasis. Chest physiotherapy helps to clears the accumulation of secretions and improve lung mechanics.

A study on the effects of prolonged mechanical ventilation in elderly patients was done by Meinders et al. According to the study, the improvement in ABG can be attributed to a decrease in obstruction and resistance brought on by secretions , which raise airway pressure and reduce compliance.[12] Similarly, the Oxygenation Index (PaO_2/FiO_2) and $PaCO_2$ changes after 30 minutes of various modes of chest physiotherapy were examined in a study by Hussey J et al on 45 mechanically ventilated paediatric participants (percussion, vibration and bagging). PaO_2/FiO_2 significantly improved after percussion and suctioning(p=0.008), PaCO2 improved towards normal (p = 0.007) according to Hussey et al. (p=0.007). [13]

The VD/VT on Day 1 was 0.50 ± 0.05 vs 0.48 ± 0.04 and on the day of exudation was 0.43 ± 0.08 vs 0.43 ± 0.05 in Experimental Group compared to control group. The results in the current study show that as compared to the control group, paired mean difference of VD/VT is more in experimental group compared to control group.

A study was carried out by Yu-Jiao Zhang et al to assess the reliability of a prediction equation or the dead-space fraction obtained from ventilator volumetric capnography (volumetric CO_2) to predict the survival of mechanically ventilated patients with acute respiratory distress syndrome (ARDS). The study came to the conclusion that, on the fourth day of mechanical ventilation for patients with ARDS, VD/VT determined by a prediction equation developed by Frankenfield et al was more accurate to estimate patients' survival than VD/VT derived from ventilator volumetric CO_2. [14]

The mean PaO_2/FiO_2 on Day 1 was 273.20 ±123.0 and mean PaO_2/FiO_2 on the day of exudation was 303.12 ±84.82 vs 355.60 ± 113.33 in experimental Group as compared to control group. Similarly, the mean day of extubation in the experimental group was 3.920 ± 1.80 and the mean day of extubation in the control group was 4.04 ± 2.07. The results in the current study depicts patients in the experimental group were extubated earlier than the control group. Yu-Chih Chen et al conducted a study to see how mechanical vibration affected the expectoration of airway secretions and prevented lung collapse in patients receiving mechanical ventilation. They concluded that patient receiving mechanical chest vibration had lower Lung Collapse Index and larger dry sputum weight (DSW) (LCI). [15]

The results in the current study show that as compared to the control group, paired mean difference of quantity of secretion is reduced in experimental group compared to control group as Mechanical Chest Vibration (G5 Vibracare) device produced a higher frequency than manual chest vibration which shows a better improvement in experimental group than the control group.

Mechanical chest vibration has a higher frequency than manual chest vibration which aids in evacuation of secretions and enables early extubation of patients in Intensive Care Unit. Mechanical chest vibration is ergonomically helpful for cardiorespiratory physiotherapists as in conventional chest physiotherapy the cardiorespiratory physiotherapist needs to bend and give treatment which leads to back pain in cardiorespiratory physiotherapists due to improper posture. As the target population was Organophosphorus Poisoning Patients, multiple patients in intensive care unit population were not included. The study was a unicentric study, multicentric study to be in involved in future.

Conclusion:

The study concluded that the paired mean difference of Experimental Group (Mechanical chest vibration and Conventional Chest Physiotherapy) showed a improvement than the control group. Mechanical chest vibration had shown improvement in static compliance, dynamic compliance, quantity of secretions in experimental group than the control group.

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