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Manual Hyperinflation, A Novel Technique in Physiotherapy of Pediatric Post Cardiac Surgery Patients

Eman Abdel-Wahab Abdel-Mageed Mohamed*[1], Naglaa Ahmed Zaky Aly[1], Mohammed Abdel-Gayed Ibrahim[2], Tamer Mohamed El-Saeed[1]

[1]Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Egypt

[2]Department of Cardiothoracic Surgery, Faculty of Medicine, Ain Shams University, Egypt

***Corresponding author**: Eman Abdel-Wahab Abdel-Mageed Mohamed, **Mobile**: (+20) 01141716119, **E-Mail**: amdabdelmageed@gmail.com

ABSTRACT

Background: Physiotherapy plays an important role in Pediatric Intensive Care Unit (PICU) after cardiac surgery, and addition of manual hyperinflation (MHI) to physiotherapy program may help early weaning from mechanical ventilation and decrease length of stay in PICU.

Objective: To measure the effect of MHI on ventilation period and ICU stay days in pediatric post cardiac surgery patients.

Patients and methods: Thirty patients from both sexes were selected from PICU at Academic Institute for Heart Surgery, Ain Shams University. Their ages ranged from 6 to 36 months.

Results: There was a significant decrease in $PaCO_2$ post treatment compared with that pre-treatment in the study and control groups ($p<0.001$). There was a significant increase in PaO_2 post treatment compared with that pre-treatment in the study and control groups ($p<0.001$). Comparison between groups post treatment revealed a significant increase in PaO_2 and a significant decrease in $PaCO_2$ of the study group compared with that of the control group ($p<0.01$). There was a significant decrease in ventilation days and ICU stay days of the study group.

Conclusion: Based on this study, it could be concluded that manual hyperinflation improves arterial oxygenation and reduces length of stay in PICU.

Keywords: Arterial Blood Gases, Cardiac Surgery, Manual Hyperinflation, Pediatric Intensive Care Unit.

INTRODUCTION

Patients with congenital heart disease are at risk of difficulty in movement, cognition, language, breathing, and feeding after heart surgery. Rehabilitation treatment can even reduce complications and length of stay (LOS) during PICU and hospitalization. The purpose is to reduce morbidity and mortality through acute postoperative time in children after surgery, and describe rehabilitation program. However, there is little information about the type of acute postoperative treatment that children require [(1)].

For a variety of reasons, mechanically ventilated patients are at risk of secretion retention. Tracheal intubation will disturb the mucociliary escalator and make the patient vulnerable to infection, thereby increasing the volume and viscosity of the mucus. The relative immobility of mechanically ventilated patients in bed can cause atelectasis, changes in coughing production, and stagnant secretions [(2)]. Respiratory physical therapy intervention is routinely used in the treatment of ventilated children in the pediatric intensive care unit to prevent mucus retention and pulmonary complications, enhance oxygenation, and re-expand the collapsed lobes [(3)].

Physical therapists have been using manual hyperinflation for many years to mobilize excess lung secretions, re-inflate the area of atelectasis, and improve oxygenation [(4)]. Physical therapists working in the intensive care unit often use manual hyperinflation techniques in combination with other interventions to expand the lungs and release secretions, and in most centers this technique is also commonly used for critically ill infants and children [(5)].

Research in the field of pediatric post cardiac surgery in ICU is deficient. New horizons for physiotherapy are opening and new evidence based guidelines should be created for treatment plans to follow, which will transform physiotherapy from an art to a science.

Decreasing the number of ICU stay days has a social dimension by decreasing the burden of long term sequelae thereby improving the whole health care system throughout. So this study was conducted to evaluate and decrease morbidity and mortality in pediatrics after cardiac surgery.

The aim of this study was to investigate effect of manual hyperinflation on arterial blood gases in children after cardiac surgery.

PATIENTS AND METHODS

Thirty patients from both sexes were selected from PICU at Academic Institute for Heart Surgery, Ain Shams University. Their ages ranged from 6 to 36 months.

Children were divided randomly into 2 groups of equal number**, Group A**: (Control group, fifteen subjects) received traditional chest physiotherapy only (postural drainage, positioning, passive movement, manual intervention (percussion and vibration) and suction) twice/day for 15 minutes each session till discharge

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from ICU and **Group B**: (Study group, fifteen subjects) received the same traditional chest physiotherapy as group A in addition to manual hyperinflation. Treatment was conducted twice/day for six sets of six MHI breaths till discharge.

Ethical approval:

This study was approved by the Research Ethics Committee of Physical Therapy College, Cairo University. Every patient signed an informed written consent for acceptance of the operation. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Inclusion criteria: Age ranged from 6 months to 3 years old. They were mechanically ventilated for more than 2 days, hemodynamically stable according to normal vital signs for this stage.

Exclusion criteria: Children who were excluded from this study had Pacemaker Implantation, Atrial Fibrillation, Positive End Expiratory Pressure (PEEP)>10 cm H_2O to avoid barotraumas, Pneumothorax and Infant Respiratory Distress Syndrome (IRDS).

Procedures:

For evaluation: Arterial blood gases: An arterial blood gas (ABG) samples were drawn from the central arterial line and analyzed using arterial blood gases analyzer, (***PHOX PLUS C 402103020, USA).*** The machine was used to measure pH, partial pressure of oxygen and carbon dioxide and bicarbonate concentration.

For treatment: Traditional chest physiotherapy program was applied for 15 minutes twice/day including percussion, vibration, postural drainage, passive movement for both groups and manual hyperinflation besides traditional program for study group.

Manual hyperinflation technique:

Bag valve resuscitation circuit locked at pressure = 35 cm H_20 was used. Therapist hands were washed prior to application; disposable plastic clean gloves were worn. The child was appropriately positioned in half supine relaxed position with head support to maximize ventilation and to drain secretions.

To set up the MHI circuit, a heat moist exchange (HME) filter was attached to the bag so as to ensure a positive end expiratory pressure (PEEP) valve sat at the patient's baseline PEEP setting. The oxygen tube was attached to the oxygen outlet and flowed at 15 liters/minute and reservoir bag was confirmed not split, filled with gas. The circuit had a safety valve that prevented peak inspiratory pressure from exceeding 35 cm H_2O so manometer was not required.

Ventilator alarm was muted to prevent anxiety of the child and surrounding children, and was disconnected from junction of the Bennet's connector and the patient was connected to the circuit. For tracheostomised patient, ventilator was disconnected and the Laerdal circuit was attached to the tracheostomy.

Hand ventilating the patient was started at the same rate and volume as baseline. Once satisfied that the patient was ventilating, the ventilator was placed in standby mode.

MHI was delivered with hands larger than baseline tidal volume, an inspiratory hold and a quick release to re-inflate areas of atelectasis and remove secretions but did not exceed PEEP to avoid barotrauma. Six sets of six MHI breaths was applied. MHI breaths had a slow inspiration for three seconds duration, a three second end inspiratory pause (hold) then an uninterrupted expiration as a quick release. For all patients, heart rate (HR) and SPO_2 were monitored during session to avoid adverse events.

After completion of treatment, the patient was reconnected to the ventilator to check that the correct mode was delivered, the child's tidal volume and respiratory rate on the ventilator and if respiratory pattern, signs of distress (tachypnea, cyanosis, tachycardia) was observed, and position of endotracheal tube or tracheostomy. The monitor normally indicated that the cardiovascular system was stable and the oxygen saturation was within normal limits for the child. Patient was repositioned the same as before we started the session.

Statistical analysis:

Qualitative data were presented as frequency and percentage. Quantitative data were presented as mean+standard deviation (SD) if parametric or as median and interquartile range (IQR) if nonparametric. Chi squared test was conducted for comparison of sex distribution between both groups. Normal distribution of data was checked using the Shapiro-Wilk test for all variables. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. Unpaired t test was conducted for comparison of age, pH, PaO_2, $PaCO_2$ and HCO_3 between groups. Paired t-test was conducted for comparison between pre and post treatment in each group. Days of ventilation and ICU length of stay was compared between groups by Mann–Whitney U test. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for the social sciences (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

RESULTS

Subject characteristics:

Figures (1 and 2) shows the subject characteristics of the control and study groups. There was no significant difference between groups in age or sex.

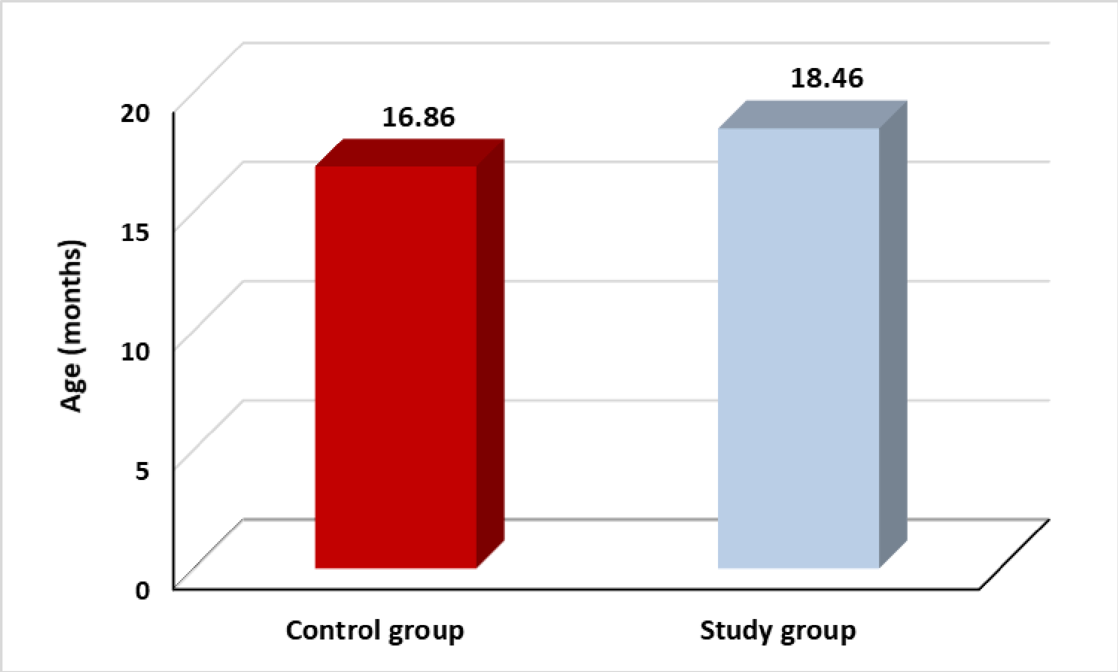

Fig. (1): Mean age of control and study groups.

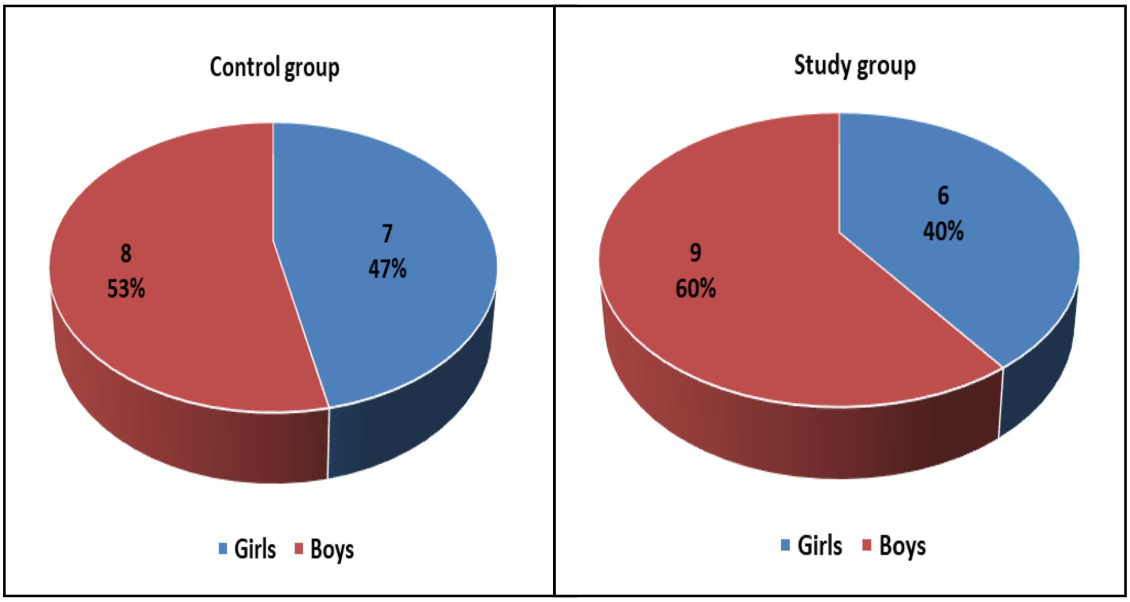

Fig. (2): Sex distribution of the control and study groups.

Effect of treatment on arterial blood gases, days of ventilation need, and days of ICU stay:

Within group comparison:

There was a significant increase in PaO_2 and a significant decrease in $PaCO_2$ and HCO_3 post treatment compared with that pre-treatment in the control and study groups. There were no significant changes in pH in the control and study group (table 1).

Between groups comparison:

There was no significant difference between groups pre-treatment. Comparison between groups post treatment revealed a significant increase in PaO_2 and a significant decrease in $PaCO_2$ of the study group compared with that of the control group, while there was no significant difference in pH and HCO_3 between groups (table 1).

Table (1): Mean pH, PaO_2, $PaCO_2$, HCO_3 pre and post treatment of the control and study group

	Control group (N = 15)	Study group (N = 15)			
	Mean ± SD	Mean ± SD	MD	t- value	p value
pH					
Pre treatment	7.37 ± 0.05	7.36 ± 0.04	0.01	0.51	0.61
Post treatment	7.38 ± 0.0	7.39 ± 0.05	-0.01	-0.12	0.9
MD	-0.0	-0.03			
% of change	0.14	0.41			
t- value	-1.77	-1.71			
	p = 0.09	***p = 0.1***			
PaO_2 (mmHg)					
Pre treatment	94 ± 10.11	97.4± 11.61	-3.4	-1.85	0.73
Post treatment	104.8 ± 8.95	124.06 ± 9.21	-19.26	-5.8	0.001
MD	-10.8	-26.66			
% of change	11.49	27.37			
t- value	***-6.51***	-11.6			
	p <0.001	***p <0.001***			
$PaCO_2$ (mmHg)					
Pre treatment	41.86 ± 1.45	42.2 ± 2.48	-0.34	-0.46	0.65
Post treatment	39.8 ± 1.42	37.73 ± 1.86	2.07	3.42	0.002
MD	2.06	4.47			
% of change	4.92	10.59			
t- value	8.32	12.29			
	p <0.001	***p <0.001***			
HCO_3 (mEq/L)					
Pre treatment	27.78± 3.2	28.98 ± 3.07	-1.2	-1.05	0.30
Post treatment	24.87 ± 2.28	23.84 ± 2.21	1.03	1.26	0.22
MD	2.91	5.14			
% of change	10.48	17.74			
t- value	4.19	8.66			
	p <0.001	***p <0.001***			

SD, standard deviation; MD, mean difference

There was a significant decrease in ventilation days and ICU length of stay days in control group compared with the study group (Table 2).

Table (2): Mean ventilation days and ICU days of stay for the control and study group

	Study group *(N = 15)*	Control group *(N = 15)*		
	Median (IQR)	Median (IQR)	U- value	p-value
Ventilation days	7 (14,3)	3 (5,2)	59.5	0.02
ICU days	8 (13,5)	6 (7,5)	60.5	0.02

DISCUSSION

The aim of this study is to evaluate effect of manual hyperinflation and selected physical therapy program on period of mechanical ventilator and PICU length of stay using arterial blood gases cores as a method of re-evaluation.

To cope with the principle of "stopping preventable deaths of children under age of five years", health system consultant developed certain accountability measures to address barriers and improve access to pediatric early rehabilitation **[6]**. A major barrier to early mobilization is the notion that children who require cardiorespiratory support with invasive devices cannot be mobilized safely [7,8].

It is recommended that ICU respiratory care procedures should be changed, including reducing prolonged sedation, improving early physical activity, improving sleep and protecting the respiratory tract. The respiratory ICU care process model decreased the ICU stay time by three days (thirteen-ten days), and reduces the incidence of tracheostomy and mechanical ventilator weaning failure **[9]**.

The mobilization and removal of respiratory secretions during physical therapy played an important role in enhancing bronchial hygiene and gas exchange, optimizing respiratory mechanics in critically ill children and was reflected in arterial blood gases (pH, PaO_2, $PaCO_2$, HCO_3) **[10]**. Manual hyperinflation is a technique used by physiotherapists in patients who require an intensive care unit because it augments passive lung inflation, thereby enhancing the elastic resilience of the lungs, thereby increasing peak expiratory flow [11]**.** The main purpose of using manual hyperinflation is to effectively and efficiently improve the airway clearance in intubated patients. Blockage of airway secretions can lead to airway obstruction, leading to reabsorption of gases distal to the obstruction, and to collapse of lung lobes in mechanically ventilated patients. MHI has been shown to clear airway secretions by application of expiratory flow higher than inspiratory flow [12]**.**

A recent randomized controlled study done concluded improvement of PaO_2, static compliance and decreased period of mechanical ventilation, in patients after myocardial revascularization[13]. One more randomized controlled study stated that MHI improved oxygenation after surgery [14].

Hypoxemia was reported in up to 60% of patients with hypoxic periods within the first two days after tracheal extubation. Indeed, higher levels of fraction of inspired oxygen (FiO2) during mechanical ventilation, because of general anesthesia during surgery, are associated with atelectasis formation and MHI cause short-term hyperinflation of lung in form of slow deep breaths which maximize collateral ventilation and the quick release, which improves expiratory phase. The whole process helped in mobilize secretions up to bronchial tree, enhanced lung tissue perfusion and allowed healthier pattern of ventilation [15].

This study revealed that, there was a significant increase in PaO_2 and significant decrease in $PaCO_2$ post-treatment compared with pre-treatment in the study and control groups, and there was no significant difference in pH, HCO_3 between both groups pre-treatment.

The purpose of programmed physiotherapy in the critical area is to apply advanced, cost effective therapeutic modality to reduce patient's dependency on the ventilator, to improve residual function, to prevent the need for new hospitalizations and to improve the patient's quality of life. Physiotherapy treatment when started early helps prevent weaning delay, limited mobility and total dependence on the ventilator [16]. The programmed chest physical therapy removes secretions, prevents waste build-up, improves mobilization of airway secretions, and helps to ventilate the lungs of newborns with respiratory problems. This enhances the efficiency and delivery of oxygenation, which means improved recordings of arterial blood gases [17].

CONCLUSION

Our study showed that, selected physiotherapy program in addition to manual hyperinflation had a significant ((improvement)) on the arterial blood gases and showed shorter period of mechanical ventilation and length of stay in PICU than physiotherapy program applied only.

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Conflict of Interest: Nil.

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