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Efficacy of Bubble Positive Expiratory Pressure Device in Post Thoracic Surgery Patients

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Abstract

Background: Pulmonary complications are common after cardiac surgery such as reduction of oxygen saturation, pneumonia, pulmonary embolism and pleural effusions. Pulmonary complications after cardiac surgery result in prolonged hospitalization and increase in healthcare cost, patients have limited homeostatic reserve associated with chronic heart failure, pulmonary illness and multiple comorbidities.

Aim of Study: To investigate the effect of bubble positive expiratory pressure device on arterial blood gases and chest expansion measurement in post thoracic surgery patients.

Patients and Methods: Fifty-two (52) male and female patients after thoracic surgery their age 50-75 years; randomly allocated into equal two groups. Group A (control group) received conventional treatment including diaphragmatic breathing exercises and pursed lip breathing exercises, Group B (study group) received conventional treatment and bubble positive expiratory pressure device. The treatment was applied two times per day for one week. Arterial blood gases measured by arterial blood gases device and chest expansion measured by tape measurement preand post-treatment.

Results: The study group (B) showed statistical significance reduction in partial pressure of carbon dioxide in arterial blood ($PaCO_2$) and improvement in partial pressure of oxygen in arterial blood (PaO_2) and arterial oxygen saturation (SAT) than control group (A). There was no significance difference in acid-base balance of the blood (PH), concentration of bicarbonate in arterial blood (HCO_3) and chest expansion measurement between study group (B) and control group (A).

Conclusion: Bubble positive expiratory pressure device and conventional treatment improve PaO_2 and SAT and reduces $PaCO_2$ in patients after thoracic surgeries than conventional treatment alone.

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Key Words: *Thoracic surgery – Diaphragmatic breathing exercises – Pursed lip breathing exercises – Bubble positive expiratory pressure device – Arterial blood gases – Chest expansion measurement.*

Introduction

THORACIC surgery is a field of medicine that deals with the diagnosis and surgical treatment of conditions caused by illness or injury in the esophagus, trachea, lungs, pleura, diaphragm, heart, pericardium, thymus gland and mediastinal structures *[1]*. Approximately 530,000 thoracic surgeries are performed yearly in the U.S. Coronary artery bypass grafting is the most commonly cardiac surgery procedure in the world, representing approximately about 200,000 cases in US *[2]*.

Pulmonary complications after cardiac surgery include atelectasis, pleural effusions, pneumonia, pulmonary edema, cardiogenic pulmonary edema, acute respiratory distress syndrome, pulmonary embolism, phrenic nerve injury, pneumothorax, sternal wound infection and mediastinitis *[3]*.

Pulmonary complications after open-heart surgery in early postoperative days were 15.08% with an overall mortality 18.5%. Patients who undergo CABG develop pulmonary complications (7.82%) while the valvular replacement is of 2.23% and 5.05% is of congenital heart diseases out of 18.5% of mortality rate *[4]*. Improper breathing can affect oxygen and carbon dioxide exchange and cause panic attacks, fatigue, anxiety and physical and emotional disturbances *[5]*. Breathing exercises are a form of exercise that can be used for health related reasons due to enhance the respiratory system through improving ventilation, strength respiratory muscles, improve breathing efficiency and reduce stress. Deep breathing helps to relieve shortness of breath by preventing air from getting trapped in the lungs and helps inhalation of more fresh air into base of lungs [6]. Breathing against an expiratory resistance known as positive expiratory pressure (PEP) is indicating for increasing lung volume, Functional Residual Capacity (FRC) and Tidal Volume (VT), reducing hyperinflation, improving airway clearance, helping to hold open your airways and allowing more air to flow in and out. The air can then get behind the phlegm helping to move it more easily upwards through the open airways. You should then be able to cough or huff (as instructed by your Physiotherapist) and clear the phlegm from your lungs [7].

Blood gas analysis is a diagnostic tool to evaluate the partial pressures of gas in blood and acid base content. ABG (arterial blood gases) test measures arterial partial pressure of oxygen (PaO_2), the arterial partial pressure of carbon dioxide ($PaCO_2$), bicarbonate level (HCO_3) in the blood and the blood's PH. Also measure concentrations of lactate, hemoglobin, electrolytes as Na, K, Ca and Mg. In addition, the arterial oxygen saturation can be determined [8]. Frequent measurements of chest expansion are reliable method for severity assessment and treatment response of many pulmonary, neurological and musculoskeletal diseases such as: chronic obstructive pulmonary diseases, ankylosing spondylitis and spinal cord injuries [9].

Patients and Methods

Patients:

This study was conducted on fifty-two (52) male and female patients having pulmonary complications after thoracic surgery with age ranged from 50-75 years, were screened to be enrolled into randomized control trial. They had been recruited from Cairo University Hospital (cardiothoracic ICU), to participate in this study through a period of 8 months (from December 2022 to July 2023). All patients received complete explanation about procedures of the program of treatment and measurement devices. This study was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/004367).

Inclusion criteria:

All participants had the following criteria: Fifty-two male and female patients after thoracic surgery (coronary artery bypass graft, valve repair or replacement and aortic aneurysm) referred by physician, medically stable patients (normal range of heart rate, blood pressure and oxygen saturation on room air), both genders (10), age 50-75 years old [10,11], BMI 25-29.9kg/m^2 [12,13].

Exclusion criteria:

Participants excluded if they had one of the following criteria [14]: Smokers' patients, patients with rib fracture, patients developing cancer, patients have dementia.

Patients were randomly allocated into equal two groups through selecting slips of paper from a container, each paper had number 1-26 was group A and 27-52 was group B. Control group (A) received conventional treatment including diaphragmatic breathing exercises and pursed lip breathing exercises, study group (B) received conventional treatment and bubble positive expiratory pressure device. The treatment was applied two times per day for one week.

Procedures:

The purpose of this clinical trial was accurately described to each patient and all patients signed the consent form.

a- Assessment devices and measurements:

- *Arterial blood gases (ABG's):*

Is a blood test which is giving an indication of ventilation, gas exchange and acid-base status. It is a blood sample from any artery and enter arterial blood gases device [15]. ABG measurements are PH for blood acids and bases, partial pressure of oxygen (PaO_2) for pressure of oxygen in the blood, partial pressure of carbon dioxide ($PaCO_2$) carbon dioxide amount in the blood, bicarbonate (HCO_3) is calculated using the measured values of pH and $PaCO_2$ to determine the amount of the basic compound made from carbon dioxide (CO_2), oxygen saturation (SAT) how much hemoglobin is carrying oxygen [16]. The arterial blood gases values are PH measurement of acidity or alkalinity, based on the hydrogen (H+) ions present (The normal range is 7.35 to 7.45, If: PH >7.45 alkalosis, PH <7.35 acidosis). PaO_2 measure the partial pressure of oxygen that is dissolved in arterial blood (The normal range is 85 to 100mm Hg). $PaCO_2$ measure the amount of carbon dioxide dissolved in arterial blood (The normal range is 35 to 45mm Hg, If: $PaCO_2$ >45 acidosis, $PaCO_2$ <35 alkalosis). HCO_3 measure the calculated value of the amount of bicarbonate in the blood stream (The normal range is 22 to 26 mEq/liter, If: HCO_3 >26 alkalosis, HCO_3 <22 acidosis). SAT measure the arterial oxygen saturation (The normal range is 95% to 100%) [17].

- *Tape measurement:*

Chest expansion was measured circumferentially with a centimeter tape measure. Readings were carried out in one plane at 4th intercostal space, the difference between deep expiration and deep inspiration has been measured for two times and the best reading was taken, the patient in sitting position as in Fig. (1). Normally, a (2-5) cm of chest expansion can be observed [18].

Fig. (1): Chest expansion measurement.

b- Treatment procedures:

1- Diaphragmatic breathing exercises:

Position the patient in a high-fowler's position, sitting on side of bed, or with head of bed elevated. Then patient was instructed to take slow, deep breaths, push abdomen out upon inspiration and place hands on client's chest wall to help him direct air to the lower and peripheral areas of the lungs. The patient was instructed to inhale deeply through the mouth or nose to exhale through the mouth in three short huffs or coughs and expectorate any sputum into tissues. Coughing sequence was repeated two or three times. Deep breathing was repeated again as before. Ask the patient to inhale slowly and deeply, pushing abdomen out then exhale through pursed lips and to contract abdomen. Breathing exercises consistently for one minute at a time and rest for two minutes. The patient instructed to increase periods of exercise to ten minutes, four times each day (Fig. 2) **[19].**

2- Pursed lip breathing exercises:

Position the patient in sitting with back straight or lie down. Shoulders were relaxed as much as possible. The patient was instructed to inhale through your nose for two seconds, feel the air move into your abdomen and try to fill your abdomen with air instead of just your lungs then purse his lips like blowing on hot food and then breathe out slowly, take twice as long to exhale as you took to breathe in. This sequence was repeated. Over time, the patient could increase the inhale and exhale counts from 2 seconds to 4 seconds, and so on (Fig. 3) **[20].**

3- Bubble positive expiratory pressure:

The patient was instructed to breathe in through their nose if possible, breathe out through tube and repeat this 6-10 times. Each breath should be slightly bigger than their normal breath size, and both the "in and out breaths" should be done slowly. The bubbles raised to the top of the bottle and poured out into the tray. After the 6-10 blows remove the tube was removed and took a rest for a few seconds. Then the patient did 1-2 huffs (a fast breath out with an open mouth, as if they were steaming up a mirror), or 1 huff and 1 cough. If the patient had moved any secretions into their mouth, he should spit these out then rested again for a few seconds. Steps repeated until their chest sounds clear when they huff (Fig. 4) **[21].**

Statistical analysis:

Data were screened, for normality assumption test and homogeneity of variance. Normality test of data using Shapiro-Wilk, that reflect the data was normally distributed (p>0.05) after removal outliers that detected by box and whiskers plots. Additionally, Levene's test for testing the homogeneity of variance revealed that there was no significant difference (p>0.05). All these findings allowed to conducted parametric and non-parametric analysis. The data is normally distributed and parametric analysis is done.

Fig. (2): Diaphragmatic breathing exercises.

Fig. (3): Pursed lip breathing exercises.

Fig. (4): Bubble Positive expiratory pressure exercise.

Results

In the current study, a total of 52 patients post thoracic surgery from both gender (29 males and 23 females) were participated and distributed randomly into two equal groups (26 patients/group). The results of patients' clinical general demographic data (Table 1) showed that no significant differences ($p>0.05$) in mean values of patients age ($p=0.079$), weight ($p=0.314$), height ($p=0.843$), BMI ($p=0.094$), and gender ($p=0.780$) between group A and group B.

Statistical multiple pairwise comparison tests for arterial blood gases and chest expansion in post thoracic surgery patients within each group showed that no significant differences ($p>0.05$) between pre- and post-treatment for pH (Table 2; Fig. 5), HCO_3 (Table 2; Fig. 8), and chest expansion (Table 2; Figure 10) within Group A ($p=0.999$, $p=0.984$, $p=0.727$, respectively) and Group B ($p=0.995$, $p=0.583$, and $p=0.684$, respectively). However, there were significantly ($p<0.05$) increased in PaO_2 ($p=0.0001$; Table 2 and Fig. 6) and SAT ($p=0.002$; Table 2 and Fig. 9) at post-treatment compared to pre-treatment within group B, but insignificantly ($p>0.05$) increased at post-treatment for PaO_2 ($p=0.152$) and SAT ($p=0.097$) within group A. Moreover, there was significantly ($p<0.05$) decreased in $PaCO_2$ ($p=0.001$; Table 2 and Fig. 7) at post-treatment compared to pre-treatment within group B, but insignificantly ($p>0.05$) decreased at post-treatment for $PaCO_2$ ($p=0.079$) within group A. Moreover, the patients who received group B improved more PaO_2 (3.95%), SAT (2.62%), and $PaCO_3$ (6.35%) than those received group A (1.57, 1.44, and 3.12%, respectively).

Statistical multiple pairwise comparison tests for arterial blood gases and chest expansion in post thoracic surgery patients between both groups (Table 2) indicated that no significant difference ($p>0.05$) in pH, HCO3, and chest expansion at pre-treatment ($p=0.996$, $p=0.752$, and $p=0.088$, respectively) and post-treatment ($p=0.994$, $p=0.800$, and $p=0.099$, respectively) between Group A and Group B. Moreover, no significant differences ($p>0.05$) between Group A and Group B at pretreatment for PaO_2 ($P=0.936$), $PaCO_2$ ($p=0.061$), and SAT ($p=0.074$), but there were significant differences ($p<0.05$) at post-treatment for PaO2 ($p=0.036$), $PaCO_2$ ($p=0.0001$), and SAT ($p=0.001$) between both groups. So, this significant increase in mean values of PaO_2 and SAT and decrease in $PaCO_2$ at post-treatment is favorable of group B (92.15 ±2.66, 95.31±2.07, and 40.85±2.83, respectively) than group A (44.08 ±2.92, 92.58±3.28, and 44.08±2.92, respectively).

Table (1): Patients clinical general characteristics in both groups.

Items	Groups (Mean ± SD)		p-value
	Group A (n=26)	Group B (n=26)	
Age (year)	59.35±3.96	56.96±5.49	0.079
Weight (kg)	85.05±7.52	84.65±7.79	0.314
Height (cm)	170.96±7.53	173.46±10.00	0.843
BMI (kg/m^2)	29.02±0.68	28.15±1.05	0.094
Gender (Males: Females)	14 (53.80%): 12 (46.20%)	15 (57.70%): 11 (42.30%)	0.780

- Quantitative data (age, weight, height, and BMI) are reported as mean ± standard deviation and compared by t-independent test.
- Qualitative data (gender) are reported a frequency (percentage) and compared by Chi-square test.

p-value: Probability value p-value >0.05: Non-significant.

Table (2): Within and between groups comparison for outcome variables.

Variables	Items	Groups (Mean ± SD)		Change	*p*-value
		Group A (n=26)	Group B (n=26)		
pH	Pre-treatment	7.36±0.02	7.37±0.03	0.01	0.996
	Post-treatment	7.37±0.01	7.39±0.02	0.02	0.994
	Change (MD)	0.01	0.02		
	Improvement %	0.14%	0.27%		
	p-value	0.999	0.995		
PaO2	Pre-treatment	88.73±3.68	88.65±3.89	0.08	0.936
	Post-treatment	90.12±3.45	92.15±2.66	2.03	0.036*
	Change (MD)	1.39	3.50		
	Improvement %	1.57%	3.95%		
	p-value	0.152	0.0001*		
PaCO2	Pre-treatment	45.50±2.76	43.62±3.03	1.88	0.061
	Post-treatment	44.08±2.92	40.85±2.83	3.23	0.0001*
	Change (MD)	1.42	2.77		
	Improvement %	3.12%	6.35%		
	p-value	0.079	0.001*		
HCO3	Pre-treatment	24.07±1.67	23.90±2.63	0.17	0.752
	Post-treatment	24.06±1.71	24.20±1.88	0.14	0.800
	Change (MD)	0.01	0.30		
	Improvement %	0.04%	1.26%		
	p-value	0.984	0.583		
SAT	Pre-treatment	91.27±3.34	92.88±2.32	1.61	0.074
	Post-treatment	92.58±3.28	95.31±2.07	2.73	0.001*
	Change (MD)	1.31	2.43		
	Improvement %	1.44%	2.62%		
	p-value	0.097	0.002*		
Chest expansion measurement	Pre-treatment	104.92±4.28	102.65±5.25	2.26	0.088
	Post-treatment	105.38±4.09	103.19±5.24	2.19	0.099
	Change (MD)	0.46	0.54		
	Improvement %	0.44%	0.53%		
	p-value	0.727	0.684		

- Group A (control group) received diaphragmatic breathing exercises and pursed lip breathing exercises for one week 2 sessions per day.
- Group B (experimental group) received diaphragmatic breathing exercises, pursed lip breathing exercises and bubble PEP device for one week 2 sessions per day.
- Data are reported as mean ± standard deviation (SD) and compared statistically by 2x2 M ANOVA test.

MD: Mean difference. *p*-value: Probability value. *Significant (p<0.05).

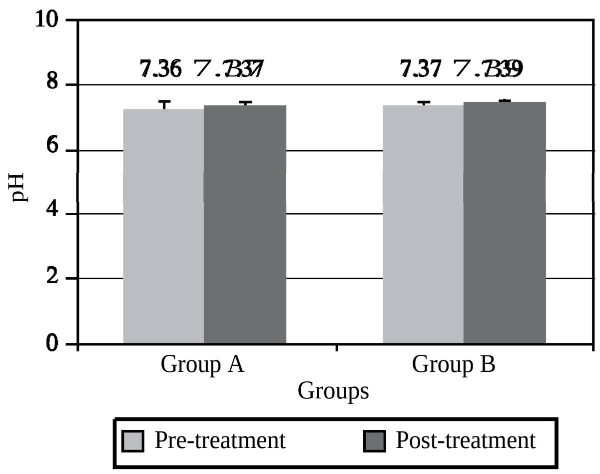

Fig. (5): Pre- and post-treatment pH within each group.

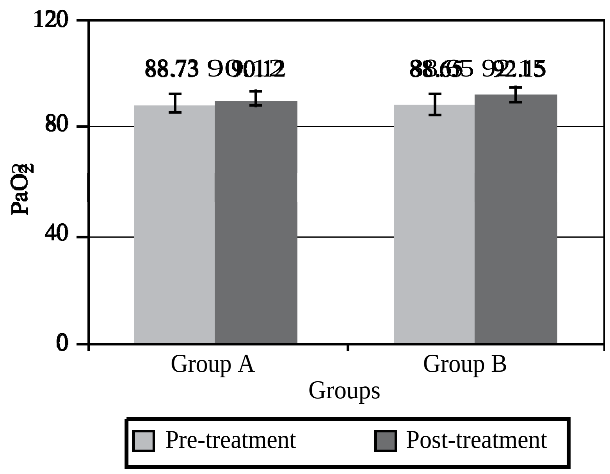

Fig. (6): Pre- and post-treatment PaO_2 within each group.

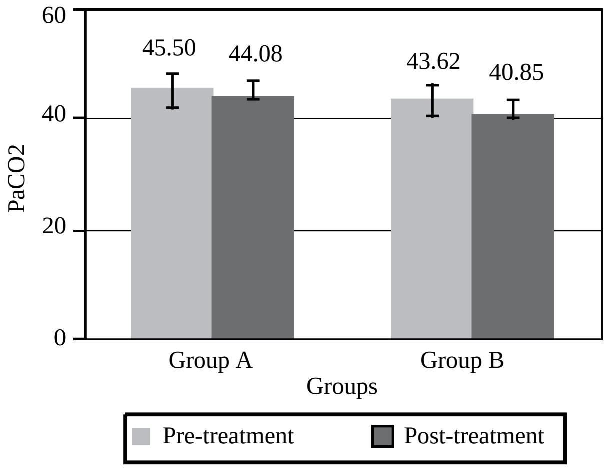

Fig. (7): Pre- and post-treatment $PaCO_2$ within each group.

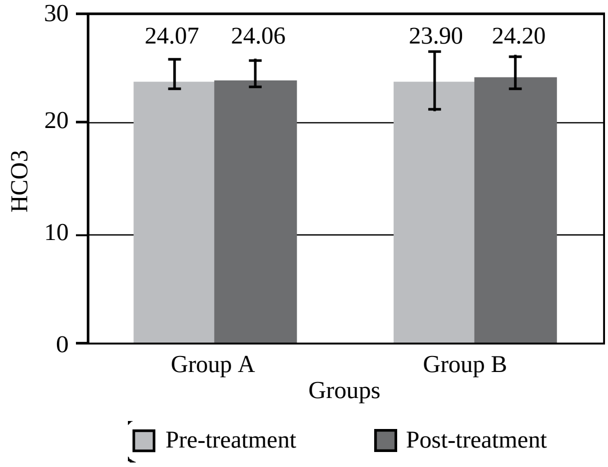

Fig. (8): Pre- and post-treatment HCO_3 within each group.

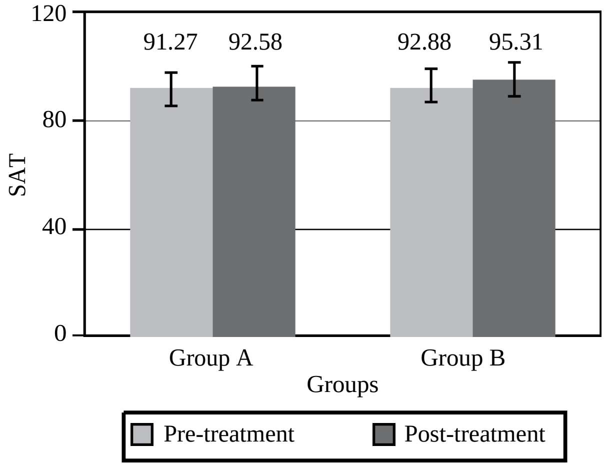

Fig. (9): Pre- and post-treatment SAT within each group.

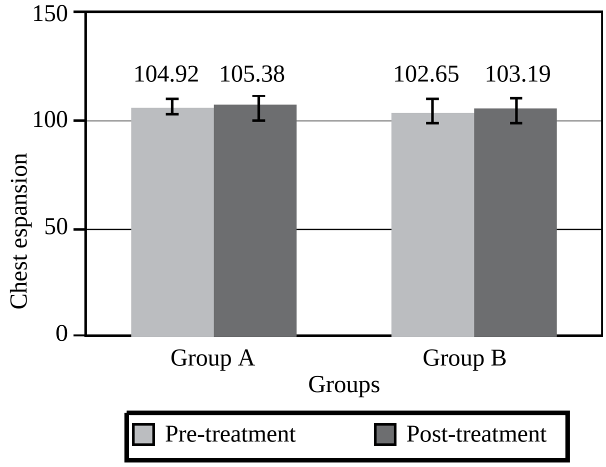

Fig. (10): Pre- and post-treatment chest expansion within each group.

Discussion

This study was conducted to investigate the effect of bubble positive expiratory pressure on arterial blood gases and chest expansion in male and female patients after thoracic surgeries.

Comparing study populations general characteristics indicated no significance difference in mean age, gender, weight, height and BMI (p>0.05). That there was no significant difference of PaO_2, $PaCO_2$ and SAT between group A and group B at pre-treatment. However, there was significant difference of PaO_2, $PaCO_2$ and SAT between group A and group B at post-treatment. So, this significant increase in PaO_2 and SAT at post-treatment is favorable of group B than group A and significant decrease in $PaCO_2$ at post-treatment is favorable of group B than group A. That there was no significant difference of PH, HCO_3 and chest expansion measurement between group A and group B at pre-treatment and there was no significant difference of PH, HCO_3 and chest expansion measurement between group A and group B at post-treatment.

The results of the current study agree with the study done by Mahadik et al., [22] reported that a bubble positive expiratory pressure device with conventional treatment as active range of motion, deep breathing exercises and incentive spirometer had effect on oxygen saturation after open heart surgery more than conventional treatment alone.

Urell et al., [23] reported that significant improvement in PaO_2 and oxygen saturation in patients who had performed higher rate of deep breathing with PEP device, cost-effective blow bottle positive expiratory pressure device in early post-operative phase of cardiac surgery to improve oxygenation showed significant improvement in oxygen saturation due to recruitment of alveoli.

Zaman et al., [24] reported that an immediate effects of deep breathing exercises with blow bottle PEP verses conventional treatment as incentive spirometry with expiratory positive airway pressure on preventing pulmonary complications following CABG. So, deep breathing exercise with a PEP device is more effective in improving oxygen saturation in case of CABG patients.

The results of the current study agree with study done by Ali et al., [25], reported that significant increase in PaO_2 and oxygen saturation and significant decrease in $PaCO_2$ in group who received PEP therapy and routine physical therapy more than group received routine physical therapy alone after cardiac surgeries.

The results of the current study agree with Iverson et al.,[26] comparative study of intermittent positive-pressure breathing, blow bottles and incentive spirometer prevention of atelectasis after cardiac surgery patients in 3 groups. Group 1 was received intermittent positive pressure breathing, group 2 was given blow bottles, group 3 of patients inhaled through the incentive spirometer. On the third postoperative day there was a significant improvement in PaO_2 in the group using blow bottles and a lesser improvement in the groups using intermittent positivepressure breathing or the incentive spirometer.

In contrast, a study conducted by Westerdahl et al., [27] on the immediate effects of deep breathing exercises on atelectasis and oxygenation after cardiac surgery in 3 study groups on the second postoperative day. Group 1 received deep breathing exercises, group 2 inspired deeply but exhaled through a PEP blow bottle device, group 3 deep breathing was performed through a positive expiratory pressure/ respiratory muscle training set. Results were deep breathing without any mechanical device was as effective as deep breathing with a mechanical PEP device.

A study conducted by Larsen et al., [28] on patients after coronary artery bypass graft found no difference between the group treated with routine chest physiotherapy plus PEP and the group treated with routine chest physiotherapy alone.

Conclusion:

The present clinical trial has concluded that treating patients after thoracic surgeries with bubble positive expiratory pressure device in addition diaphragmatic and pursed lip breathing exercises were more effective than diaphragmatic and pursed lip breathing exercises alone. Bubble positive expiratory pressure device has gained better benefits than diaphragmatic and pursed lip breathing exercises only in improving PaO_2 and oxygen saturation and reducing $PaCO_2$.

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تأثير جهاز الفقاعات ذو الضغط الزفيرى الإيجابى
فى المرضى بعد جراحة الصدر

الخلفيـة العلميـة: المضاعفات الرئوية شائعة بعد عمليات القلب مثل انخفاض تشبع الدم بالأكسجين والالتهاب الرئوى والانسداد الرئوى والانصباب الجنبى. المضاعفات الرئوية شائعة بعد عمليات القلب تؤدى إلى العلاج فى المستشفى لفترة طويلة وزيادة تكلفة الرعاية الصحية والمرضى يكون لديهم احتياطى توازنى محدود مع قصور القلب المزمن وأمراض الرئة والأمراض المصاحبة المتعددة.

الهدف من البحث : دراسة تأثير جهاز الفقاعات ذو الضغط الزفيرى الإيجابى على طريق جهاز غازات الدم الشريانى وقياس توسع الصدر فى المرضى بعد جراحة الصدر.

المرضى و وسائل البحث : تم اختيار ٥٢ مريض ومريضة بعد عمليات جراحة الصدر تتراوح أعمارهم ما بين ٥٠ – ٧٥ عاما ثم تم تقسيمهم عشوائياً لمجموعتين. مجموعة أ (مجموعة التحكم) تلقوا برنامج العلاج الطبيعى التقليدى وتشتمل تمارين التنفس البطنى وتمارين التنفس بالشفاه. مجموعة ب (مجموعة الدراسة) تلقوا العلاج التقليدى سالف الذكر بالاضافة الى تمارين جهاز الفقاعات ذو الضغط الزفيرى الإيجابى. ومن ثم خضعوا لجلسات علاجية بمعدل مرتين يومياً لمدة اسبوع وتم قياس غازات الدم الشريانى بواسطة جهاز غازات الدم وقياس توسع الصدر بواسطة شريط القياس قبل وبعد الدراسة.

النتائج: تبين بعد الدراسة أن انخفاض الضغط الجزئى لثانى اكسيد الكربون فى الدم الشريانى مجموعة (ب) أكثر من مجموعة (أ). وتحسن الضغط الجزئى للأكسجين و تشبع الدم بالأكسجين فى مجموعة (ب) أكثر من تحسنهم فى مجموعة (أ). ولم يحدث تغير فى المجموعة (أ) و المجموعة (ب) فى توازن الأحماض والقواعد فى الدم و وتركيز البيكربونات فى الدم الشريانى وقياس توسع الصدر.

الاستنتاج: استخدام جهاز الفقاعات ذو الضغط الزفيرى الإيجابى مع العلاج التقليدى أدى الى تحسن الضغط الجزئى للأكسجين وتشبع الدم بالأكسجين وانخفاض الضغط الجزئى لثانى اكسيد الكربون فى الدم الشريانى فى المرضى بعد عمليات جراحة الصدر اكثر من استخدام العلاج التقليدى بمفرده.