Blood Gases Response to Different Breathing Modalities After Coronary Artery Bypass Grafting.

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ABSTRACT

Background and purpose: *Impairment of gas exchange is one of the most significant post operative complications of coronary artery bypass graft (CABG) as recovery from major surgery is primarily endangered by post operative pulmonary complications. The purpose of this study was to determine which therapeutic method from incentive spirometry (IS), non-invasive intermittent positive pressure breathing (IPPB) and continuous positive airway pressure breathing (CPAP)in addition to postoperative pulmonary physiotherapy obtain the best improvement in blood gases after CABG.* ***Subjects and methods:*** *Thirty six patients of both sexes who underwent CABG divided into three groups. Group (1) received breathing training with IS in addition the chest physiotherapy program for patients after CABG and Group (2) received breathing training with CPAP in addition to the chest physiotherapy program for patients after CABG., where Group(3) received breathing training with IPPB in addition to the chest physiotherapy program for patients after CABG. Measurements of blood gases were done before the study in the first post operative day and repeated at the end of the study in the tenth postoperative day.* ***Results:*** *There was a significant difference between group (1) & (2) and group (1) & (3). Where there was no significant difference between group (2) & (3).* ***Conclusion:*** *It is recommended to use the incentive spirometry in addition to the usual physical therapy program in clinical management of patients after CABG.*

INTRODUCTION

Coronary artery bypass graft (CABG) surgery improves survival for patients with severe coronary artery disease. Patients with less severe disease often elect to undergo coronary revascularization to reduce their angina and to improve their quality of life[2].

Recovery from major surgery is primarily endangered by postoperative pulmonary complications e.g. atelectasis, pneumonia or pulmonary dysfunction which remain the major causes of postoperative morbidity and mortality[24].

The basic mechanism of postoperative pulmonary complications is lack of lung inflation that occurs because of change in breathing to shallow, prolonged recumbent positioning and temporary diaphragmatic dysfunction. Mucociliary clearance also is impaired postoperatively, which along with the decreased cough effectiveness and increases risks associated with retained pulmonary secretion[11].

Continuous positive airway pressure is a common therapy to support pulmonary function in early postoperative period. The effects of CPAP application on lung volumes include increased vital capacity, reduced respiratory rate, reduced minute ventilation and increase functional residual capacity (FRC). Increase in FRC leads to improved arterial saturation, lung compliance and a decrease in work of breathing[24].

Incentive spirometry is simply a visual and/or audiovisual device that encourages slow, deep inspiration i.e. visual input of balls rising in chambers, colored lights, sounds or dials reflect the degree of inspiratory effort. It provides low level resistive training while minimizing the potential of fatigue to the diaphragm which is useful for patients who are resistant or unable to co-operate fully with maximal inspiratory efforts. And, it remains a widely used technique for the prophylaxis and treatment of respiratory complications in post surgical patients and can be used independently by patients[6,11].

Non-invasive intermittent positive pressure breathing (IPPB) is a simple, portable, non invasive form of ventilatory support and suitable for use in home, general word and incentive care unit. It increases ventilation, improves the arterial blood gases and decreases the work of the respiratory muscles[5,16].

Breathing exercises have been used to increase lung volume, improve gas exchange and ventilation distribution. Diaphragmatic, segmental and costal respiratory exercise may alleviate surgically induced alterations such as diminished diaphragmatic mobility and restrictive pulmonary changes through increase diaphragmatic mobility and decrease basal atelectasis[3,13].

The aim of this study was to detect which therapeutic method from incentive spirometry (IS), non-invasive intermittent positive pressure breathing (IPPB) and continuous positive airway pressure breathing (CPAP) in addition to postoperative pulmonary physiotherapy obtain the best improvement in blood gases after CABG.

SUBJECTS, MATERIAL AND METHODS

Subjects

Thirty six consecutive patients of both sexes underwent elective coronary artery bypass graft surgery who gave informed written consent form, their age ranged from 42-51years.All the participants were chosen randomly from the physical therapy department in the National Heart Institute. After obtaining consent, patients were randomly allocated by means of a random numbers table to one of three equal groups.

Equipments and measurements

1-Acid –Base Analyzer: ABL 3075R24 NB by radiometer A/S COPENHAGEN a computerized device used to calculate partial pressure of oxygen in arterial blood sample (PaO_2), as well as pH, PaCO2. Normal values of arterial blood gases are PH (7.35-7.45), PaO_2 (80-100mmHg) and $PaCO_2$ (35-45mmHg)[18].

2-Incentive spirometry (Voldyne Volumetric manufactured by Sherwood Medical Company, U.S.A.): It is a respiratory therapy device that provides visual feedback in term of volumetric success as a patient performs a deep breath. Incentive spirometer consider as a guideline for progression of treatment.

3-Non-invasive intermittent positive pressure breathing and continuous positive airway pressure (RTX modes 10 Downage, respicare dragger, London)it is a pressure cycle ventilator that triggered by a patients inhalation to deliver ambient air or oxygen to the patient until a preset pressure (15-20cmH_2O)is reached through face mask.

PROCEDURES

Patients were divided into three equal groups

Group (1): Patients in this group received the usual chest physiotherapy program for patients after CABG which was started on the morning of the first post operative day, a physiotherapist supervised and assisted the treatment twice a day in the first two post operative days and once a day from the third to the tenth days. During any session, the patients performed three to five deep breaths interspersed with periods of quiet breathing followed by two or three coughs or huffs (with wound support by a pillow or his/her hands). This maneuver was carried out at least 10 times over a 15 minutes period. Additional techniques such as positioning and chest wall percussion used if breathing and coughing exercises alone were not effective in clearing excessive or retained pulmonary secretions. Patients were instructed to perform breathing and coughing exercise independently every hour. Patients in this group received the same previous exercises during the first four days after the surgery, then all patients in this group were given breathing exercise training with incentive spirometry in addition to the usual physical therapy program for patients after CABG up to the tenth post operative day. Application of breathing training with incentive spirometer was applied for five minutes, five times a day.

Group (2): Patients in this group received the same previous exercises during the first four days after the surgery, and then all patients in this group were given breathing exercise training with continuous positive pressure breathing through face mask, from long sitting position with supported back. The application time was 15 minutes, and the pressure of CPAP was l0 cmH_2O every day in addition to the usual physical therapy program for patients after CABG up to the tenth post operative day.

Group (3): Patients in this group received the same previous exercises during the first four days after the surgery, then all patients in this group were given Non-invasive intermittent positive pressure breathing (IPPB) in addition to the usual physical therapy program for patients after CABG up to the tenth post operative day .The time of application of IPPB was 15 minutes/day ,the percentage of inspiratory phase was equal 20% and the peak inspiratory airway pressure equal15 cmH_2O to provide a sufficient widening of thoracic cage diameter.

Measurements of blood gases included partial arterial pressure of oxygen (PaO_2), partial arterial pressure of carbon dioxide ($PaCO_2$) and pH were taken at the first postoperative day before the study and repeated at the tenth postoperative day at the end of the study.

Statistical analysis

The mean values of PaO_2, $PaCO_2$ and pH were measured and calculated before the study in the first postoperative day and at the end of the study in the tenth postoperative day for the three groups, then the analysis of variance was used for comparison between groups ($p<0.05$).

RESULTS

Comparative study between the pretreatment values of the three groups

As shown in table (1), the analysis of variance of arterial blood gases for pH of the three groups pretreatment had a statistical no significant difference “F” value was 0.2783, $P < 0.05$ ($F_{0.05} = 3.23$).

Table (1): Shows analysis of variance of arterial blood gases for pH before treatment and significance difference of "F" ratio.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	1.0719E-03	2	5.3595E-4	0.2783	Non Sig.
Within Groups	6.35501E-03	33	1.9257606		
Total	6.4622E-03	35			

Level of significance P < 0.05

As shown in table (2), the analysis of variance of arterial blood gases for PaO_2 of the three groups pretreatment had a statistical no significant difference "F" value was 0.5219, P < 0.05 ($F_{0.05} = 3.23$).

Table (2): Shows analysis of variance of arterial blood gases for PaO_2 before treatment and significance difference of "F" ratio

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	5.055563	2	2.5277	0.5219	Non Sig.
Within Groups	159.833337	33	4.8434		
Total	164.8889	35			

Level of significance P < 0.05.

As shown in table (3), the analysis of variance of arterial blood gases for $PaCO_2$ of the three groups pretreatment had a statistical no significant difference "F" value was 0.352, P < 0.05 ($F_{0.05} = 3.07$).

Table (3): Shows analysis of variance of arterial blood gases for $PaCO_2$ before treatment and significance difference of "F" ratio

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	5.0556	2	2.5277	0.352	Non Sig.
Within Groups	237.1667	33	7.1868		
Total	242.2222	35			

Level of significance P < 0.05

Comparative study between the post treatment values of the three groups

As shown in table (4), the analysis of variance of the value of arterial blood gases for pH in the three groups post treatment had a statistical no significant improvement, "F" value was 19.77, P < 0.05 ($F_{0.05} = 3.23$).

Table (4): Shows analysis of variance of arterial blood gases for pH in the tenth postoperative day (post treatment) in the three groups.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	1.8317E-03	2	9.1583E-03	19.77	Sig.
Within Groups	1.5283E-03	33	4.6315E-04		
Total	3.36E-03	35			

Level of significance P < 0.05

As shown in table (5) and fig. (1), the least significant difference of pH in the tenth postoperative day between incentive spirometry (IS) group and non invasive intermittent positive pressure breathing (IPPB) group and between incentive spirometry (IS) group and continuous positive airway pressure breathing (CPAP) group was statistically significant improvement, but between non invasive intermittent positive pressure breathing (IPPB) and continuous positive airway pressure breathing (CPAP) group was not statistically significant improvement.

Table (5): Shows least significance difference of pH in the tenth postoperative day (post treatment) in the three groups.

Stat. Values / Program	Standard Error	L.S.D. " Calculated" Value	Significance
IS-IPPB	0.013	0.051	Sig.
IS-CPAP	0.012	0.044	Sig.
IPPB-CPAP	0.011	0.007	Non Sig.

IS-IPPB: Incentive spirometer versus intermittent positive pressure breathing
IS-CPAP : Incentive spirometer versus continuous positive airway pressure
IPPB-CPAP: Intermittent positive pressure breathing versus continuous positive airway pressure
L.S.D. "calculated" value: Least significant difference
L.S.D. "tabulated" value equal 0.009.
Sig.: Significant
Non Sig.: Non- significant

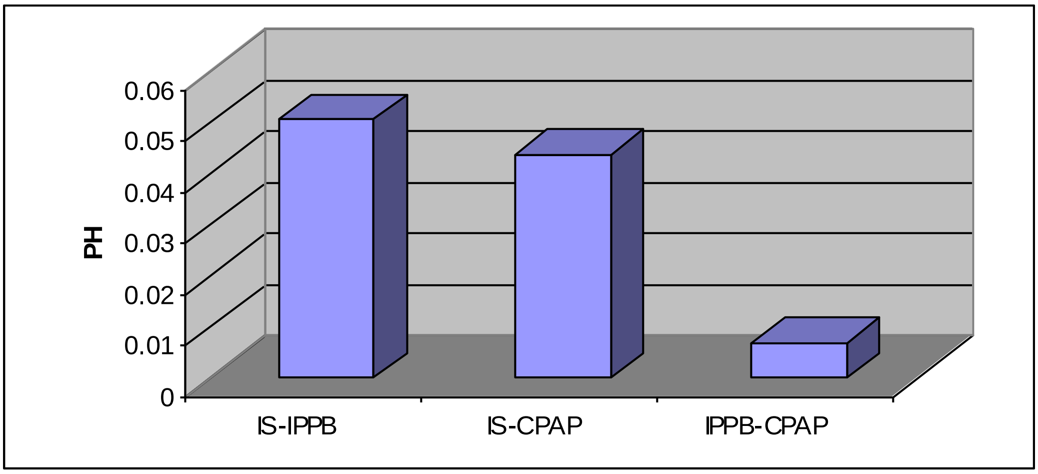

Fig. (1): Shows mean difference of pH in the tenth postoperative day between the three groups.

As shown in table (6), the analysis of variance of the value of arterial blood gases for PaO_2 in the three groups post treatment had a statistical a significant improvement, "F" value was 27.05, $P < 0.05$ ($F_{0.05} = 3.23$).

Table (6): Shows analysis of variance of arterial blood gases for PaO_2 in the tenth postoperative day (post treatment) in the three groups.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	887.722	2	443.861	27.05	Sig.
Within Groups	541.5	33	16.409		
Total	1419.222	35			

Level of significance P < 0.05

As shown in table (7) and fig. (2), the least significant difference of PaO_2 in the tenth postoperative day between incentive spirometry (IS) group and non invasive intermittent positive pressure breathing (IPPB) group and between incentive spirometry (IS) group and continuous positive airway pressure breathing (CPAP) group was statistically significant improvement, but between non invasive intermittent positive pressure breathing (IPPB) and continuous positive airway pressure breathing (CPAP) group was not statistically significant improvement.

Table (7): Shows least significance difference of PaO_2 in the tenth postoperative day (post treatment) in the three groups.

Stat. Values / Program	Standard Error	L.S.D. " Calculated" Value	Significance
IS-IPPB	2.089	11.834	Sig.
IS-CPAP	1.986	8.084	Sig.
IPPB-CPAP	1.398	3.75	Non Sig.

IS-IPPB: Incentive spirometer versus intermittent positive pressure breathing
IS-CPAP: Incentive spirometer versus continuous positive airway pressure
IPPB-CPAP: Intermittent positive pressure breathing versus continuous positive airway pressure
L.S.D. "calculated" value: Least significant difference
L.S.D. "tabulated" value equal 1.671.
Sig.: Significant
Non Sig.: Non significant

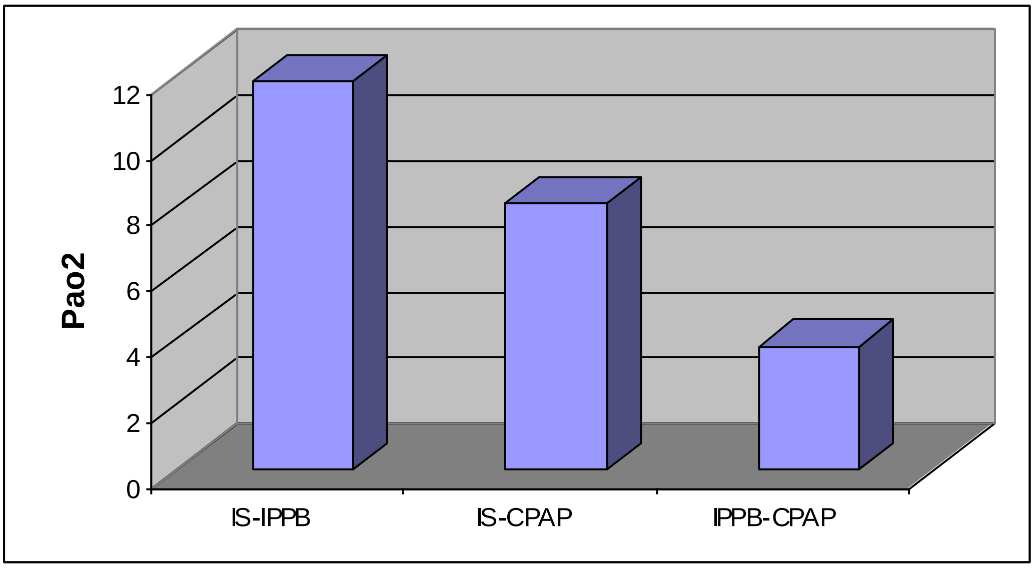

Fig. (2): Shows mean difference of PaO_2 in the tenth postoperative day between the three groups.

As shown in table (8), the analysis of variance of the value of arterial blood gases for $PaCO_2$ in the three groups post treatment had a statistical a significant improvement, "F" value was 28.058, $P < 0.05$ ($F_{0.05} = 3.23$).

Table (8): Shows analysis of variance of arterial blood gases for $PaCO_2$ in the tenth postoperative day (post treatment) in the three groups.

Source of variation	Sum of squares	Degree of freedom	mean of squares	F-ratio	Significance
Between Groups	239.0556	2	119.528	28.058	Sig.
Within Groups	140.583	33	4.26		
Total	379.639	35			

Level of significance P < 0.05

As shown in table (9) and fig. (3), the least significant difference of $PaCO_2$ in the tenth postoperative day between incentive spirometry (IS) group and non invasive intermittent positive pressure breathing (IPPB) group and between incentive spirometry (IS) group and continuous positive airway pressure breathing (CPAP) group was statistically significant improvement, but between non invasive intermittent positive pressure breathing (IPPB)and continuous positive airway pressure breathing (CPAP) group was not statistically significant improvement.

Table (9): Shows least significance difference of $PaCO_2$ in the tenth postoperative day (post treatment) in the three groups.

Stat. Values / Program	Standard Error	L.S.D. " Calculated" Value	Significance
IS-IPPB	1.276	6.09	Sig.
IS-CPAP	1.182	5.58	Sig.
IPPB-CPAP	1.090	1.5	Non Sig.

IS-IPPB: Incentive spirometer versus intermittent positive pressure breathing
IS-CPAP: Incentive spirometer versus continuous positive airway pressure
IPPB-CPAP: Intermittent positive pressure breathing versus continuous positive airway pressure
L.S.D. "calculated" value: Least significant difference
L.S.D. "tabulated" value equal 2.02.
Sig.: Significant
Non Sig.: Non significant

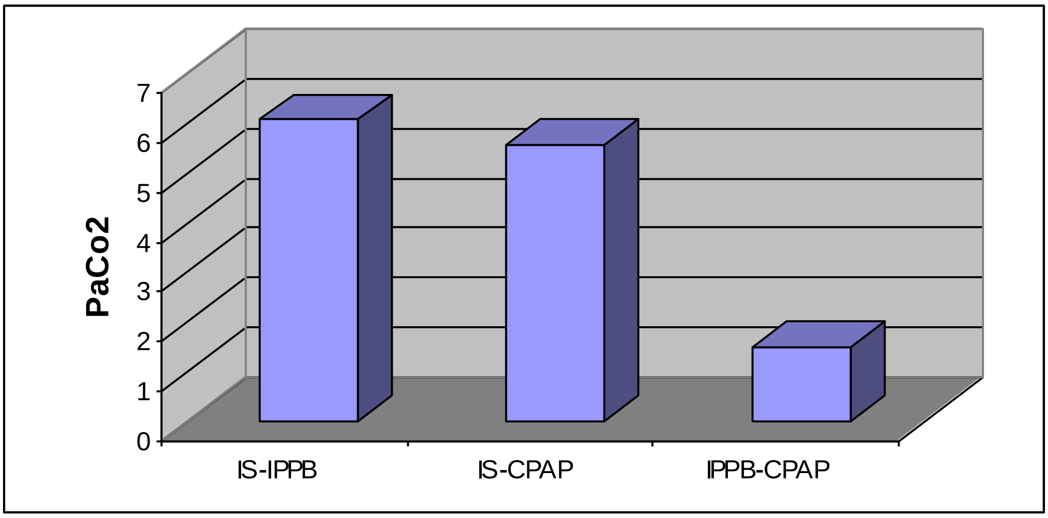

Fig. (3): Shows mean difference of $PaCO_2$in the tenth postoperative day between the three groups.

DISCUSSION

Chest physiotherapy facilitates physical, psychological and emotional recovery for patients following coronary revascularization and evidence suggests that it improves short and long term prognosis and allow blood gases to be returned to the preoperative levels. This study was performed to determine the difference between the effect of incentive spirometry, continuous positive airway pressure and Non-invasive intermittent positive pressure breathing on blood gases after coronary artery bypass surgery.

The results obtained in the present study indicated that, there was a significant difference in blood gases (PaO_2, $PaCO_2$ and pH) after the use of incentive spirometry (IS), non-invasive intermittent positive breathing (IPPB) and continuous positive airway pressure (CPAP). On comparing the results of non invasive IPPB & that of CPAP group, the statistical analysis showed non significant difference between both of them. This means that both techniques have nearly similar effects upon blood gases after cardiac surgery.

From our point of view, the improvement of blood gases after non-invasive intermittent positive breathing (IPPB) and continuous positive airway pressure (CPAP) of treatment can be explained as a result of improvement of oxygenation, ventilation-perfusion ratio, coughing functional residual capacity and lung compliance. While in the incentive spirometry group the improvement was more significant and may be due to biofeedback, motivation and encouraging to breathe to total lung capacity as much as the patient can, which prevent atelectasis and reduce post operative hypoxemia.

Incentive spirometry was proposed on the theoretical basis of encouraging patient's breath to total lung capacity and sustain that maximum inflation which opens the collapsed alveoli, to prevent atelectasis. Also postoperative hypoxemia may be reduced with this technique[11].

Incentive spirometry combined with physical therapy was more effective than post operative physical therapy alone in prevention of atelectasis in patients with chronic airflow limitation following coronary artery bypass surgery[6,7].

Continuous positive air way pressure can restore functional residual capacity, reduce the work of breathing and unload respiratory muscles and it may also augment cardiac function by reducing preload and left ventricular transmural pressure in patients with severe congestive heart failure. CPAP may increase total oxygen body stores by increasing lung volumes including FRC[10,15,22].

Continuous positive air way pressure has been suggested to have multifactorial including dilating and splinting the upper airway, changing chest wall stability, pulmonary mechanics, lung volumes and respiratory muscles dynamics. Also, CPAP enhances end expiratory lung volume which prevents alveolar collapse and thus assists the next inspiration[8,18].

Application of continuous positive air way pressure for patients with obstructive sleep apnea is effective in increasing arterial oxygen saturation and has been reported to change cardiac autonomic activity and hemodynamics include less sympathetic activity at rest and improved cardiovascular response to stress[9,17,20].

Non –invasive IPPB as a form of ventilatory support play a role in improving pulmonary function after open heart surgery .It increased ventilation, improved the arterial blood gases, and decreased the work of breathing. It can aid in removal of retained secretions, reduces the incidence of postoperative atelectasis and pneumonia as well as re-expanding collapsed alveoli[5,14,19,21].

Non-invasive IPPB provides mechanical ventilation assistance. This positive pressure ventilation is opposite to normal physiological ventilation in that normal ventilation occurs when negative pressure created by contraction of the diaphragm causes air to enter the lungs .Inspiration occurs by pulling air into the lungs, whereas ventilators push air into the lungs .This is important as the thoracic cavity becomes an area of higher pressure which may creates adverse cardiovascular homodynamic events[5].

Patients receives ventilation assistance by non-invasive IPPB appear to relay on the machine to perform the deep breathing and hence, is reluctant to actively use the respiratory muscles, presumably because of greater incisional pain associated with active muscular contraction as opposed to passive muscular movements[16].

On the other hand, non-invasive IPPB was not essential for prevention of atelectasis in the post operative patients and may be inferior to other methods as incentive spirometry. During application of non invasive IPPB, the patient appeared to relay on the machine to perform the deep breathing and hence, was reluctant to actively use the respiratory muscles, presumably because of greater incisional pain associated with active muscular contraction as opposed to passive muscular movement[23]. This may explain the lower improvement in blood gases measures in IPPB group and in CPPB group than in IS group at this study.

Because of passive nature of inspiration and absences of normal diaphragmatic activity extra volume is distributed to areas already well ventilated. So, non-invasive IPPB can actually promote atelectasis by diminishing basal ventilation and is less effective than spontaneous deep breaths. The administration of non-invasive IPPB with post operative patients is not uniformly beneficial, particularly if adequate post operative physiotherapy is applied. Although there may be special indications for non-invasive IPPB therapy, its use should be selective since it is unlikely to benefit post-operative patients without pre-existing pulmonary disease[1].

After a controlled trial of using non-invasive IPPB, incentive spirometry and deep breathing exercises aiming to prevent pulmonary complications after upper abdominal surgery, hospital stay was significantly shorter in patients received incentive spirometry than the other groups[4].

As a contradict to the results of this study, Comparison among the different regimens of treatment such as breathing and coughing exercises, incentive spirometry, non-invasive IPPB and periodic application of continues positive airway pressure (CPAP) after coronary artery surgery. No treatment regimen was found to be superior to any other in the prevention of postoperative pulmonary complications[12], but this difference can be explained due to period of treatment, type of patients, when treatment program started or variation in rehabilitation program.

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الملخص العربى

استجابة غازات الدم لاستخدام طرق تنفسية مختلفة بعد جراحات ترقيع الشريان التاجي

تهدف هذه الدراسة إلى معرفة تأثير طرق تنفسية مختلفة فى تحسين غازات الدم بعد جراحات ترقيع الشريان التاجي . أجرى البحث على سته وثلاثين مريضاً تراوحت اعمارهم بين 42- 51 سنة قد أجرى لهم جراحة القلب المفتوح مقسمين إلى ثلاث مجموعات متساوية. **المجموعة الأولى** أجرى لهم تمارين جهاز الحافز التنفسى بالإضافة إلى العلاج الطبيعى المعتاد في المرحلة الأولى من برنامج تأهيل القلب بعد جراحة القلب المفتوح و**المجموعة الثانية** أجرى لهم تمارين جهاز ضغط التنفس الموجب المستمر بالإضافة إلى العلاج الطبيعى المعتاد في المرحلة الأولى من برنامج تأهيل القلب بعد جراحة القلب المفتوح و **المجموعة الثالثة** أجرى لهم تمارين جهاز ضغط التنفس المتقطع الموجب الغير تداخلى بالإضافة إلى العلاج الطبيعى المعتاد في المرحلة الأولى من برنامج تأهيل القلب بعد جراحة القلب المفتوح . أظهرت النتائج وجود فروق ذات دلالة إحصائية فى قياس غازات الدم بين مرضى المجموعه الاولى والثانيه و الاولى والثالثه فى حين لم يوجد فروق ذات دلالة إحصائية بين مرضى المجموعه الثانيه والثالثه .لذلك توصى الدراسه بإستخدام جهاز الحافز التنفسى ضمن برنامج العلاج الطبيعى في تأهيل القلب بعد جراحة القلب المفتوح .

الكلمات الدالة: جهاز الحافز التنفسى- جهاز ضغط التنفس المتقطع الموجب الغير تداخلى- جهاز ضغط التنفس الموجب المستمر – غازات الدم - جراحة القلب المفتوح .