

Arterial Blood Gases Response to Incentive Spirometry Versus Continuous Positive Airway Pressure breathing After Coronary Artery Bypass Graft Surgery

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Abstract

Background: Postoperative respiratory complications such as hypoxemia and atelectasis remain important causes of mortality after CABG.

Objective: The aim of this study was to compare the changes in arterial blood gases after the use of incentive spirometry (IS) with continuous positive airway pressure (CPAP) during intensive care unit period, after coronary artery bypass graft (CABG) also to provide an idea about which of them is more effective method following coronary artery bypass surgery in intensive care unit.

Methods: 30 volunteer patients' (22 males and 8 females) who had coronary artery bypass surgery participated in this study and they were randomly selected from surgical department at intensive care unit (ICU) in National Heart Institute, Egypt, their ages ranged from 45 to 55 years. Participants were randomly assigned between two equal groups. Group 1 received incentive spirometry breathing training in addition to routine chest physiotherapy following CABG, while Group 2 received CPAP in addition to routine chest physiotherapy program following CABG.

Results: The results obtained in this study indicated that, there was statistical significant increase PaO₂ and decrease in PaCO₂ after two hours of using incentive spirometry, which indicated long term effect of incentive spirometry. While there was no statistical significant improvement in arterial blood gases after two hours of using CPAP which indicated short term effect of CPAP (p<0.05).

Conclusion: Incentive spirometry is superior to continuous positive airway pressure breathing to long term improve arterial blood gases following coronary artery bypass graft surgery.

Keywords: Coronary artery bypass graft surgery; Incentive spirometry; Continuous positive airway pressure breathing

Introduction

Ischemic heart disease continues to be one of the most common chronic illnesses in most of the developed world [1,2]. The surgical treatment for coronary artery disease has become increasingly sophisticated in the past two decades with an expected mortality extremely low [3]. Coronary artery bypass graft (CABG) has a main benefit for relief of symptoms and increase survival rate for patients with coronary artery disease [4].

The annual number of CABG surgeries is declining in the United States [5]. While the burden of comorbidities is increasing, the rates of mortality and most in-hospital complications are improving [6]. The increasing rate of postoperative bleeding necessitates the need to develop strategies to improve the risk of bleeding in this patient population [7]. However, postoperative hypoxemia can be resulted from ventilation-perfusion mismatching due to inadequate transport and delivery of oxygen to the tissues or heart lung machine which cause blood loss and destruction of the blood elements [8,9].

Inspiratory muscle training is primarily used as pre-operative preparation in high-pulmonary-risk patients to reduce the incidence of post-operative pulmonary complications [10-12]. However, incentive spirometry (IS) is the most widely prescribed procedure for postoperative patients that emphasize inflation to increase lung volume and maintain patency of small airways by active recruitment of respiratory muscles [13]. In addition, patients who are at post-operative pulmonary complications risk can benefit from being taught the use of IS during preoperative teaching to promote better inflation of the

lung postoperatively as IS can be used independently by the patient to ensure that each inspiration is physiologically optimal [14]. While, continuous positive airway pressure (CPAP) can provide an alternative and preferable form of treatment after CABG to avoid endotracheal intubations and its associated complications [15]. Moreover, many investigators showed that CPAP improves oxygenation, reduces work of breathing and improves cardiac output after CABG [16]. This study was designed to compare the impact of incentive spirometry and CPAP on arterial blood gases after CABG.

Subjects

30 volunteer patients (22 males and 8 females) who had coronary artery bypass surgery participated in this study and they were randomly selected from surgical department at intensive care unit (ICU) in National Heart Institute. Their ages ranged from 45 to 55 years. The initial medical and laboratory data of each participant was obtained to ensure that none had previous other complications that might restrict their activity and interfere with the results of the data. Patients

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had intra-operative myocardial infraction, marked hypotension, or pacemaker and patients who were ventilated more than 24 hours were excluded.

Participants were randomly enrolled into two study groups: Group 1: Fifteen patients received incentive spirometry (IS). However, Group 2: Fifteen patients received continuous positive airway pressure (CPAP).

Instrumentations

- **Acid-Base Analyzer:** A computerized device (ABL 3075R24 NB by Radiometer A/S COPENHAGEN) used to calculate partial pressure of oxygen in arterial blood sample (PaO₂) as well as pH, PaCO₂. Normal values of arterial blood gases are PH (7.35-7.45), PaO₂ (80-100 mmHg) and PaCO₂ (35-45 mmHg) [17]. Blood samples were being drawn from (arm, leg, thigh) cannula before starting treatment, after 30 min and after two hours from completion of treatment. The values of PaO₂, PaCO₂ and pH were measured for both groups.
- **Intensive care unit monitor:** A computerized monitor (Howlett Packard model 66, M 1176A, U.S.A) used for measuring oxygen saturation through pulse oximeter.
- **Incentive spirometry:** Incentive spirometer (DHD, Cliniflo, Medimark) used for respiratory muscles training postoperatively.
- **Continuous positive airway pressure:** Advanced continuous positive airway pressure (RTX model 10, Downage, NW 44/AA, London) used to improve respiration in postoperative patients.

Procedure

Pre-operative meeting

Patients were educated the postoperative program (the use of incentive spirometry and application of continuous positive air way pressure), two days preoperatively. The aims of the preoperative meeting were to make patients acquainted with the therapeutic procedure to gain high level of cooperation and to be informed about the risk of pulmonary complications from open heart surgery in addition to the importance of chest physical therapy as a preventive treatment tool. Demonstration and practice sessions were done to teach patients the postoperative regimen.

All patients received preoperative instructions about the post-operative physical therapy program depending upon their group protocol in the form of:

Group 1: Preoperative instructions about the proper use of incentive spirometry and its practical application. They taught to make quiet expiration firstly, after that; they encouraged inhaling slowly and as deeply as possible through mouth piece of incentive spirometry. During inspiration each patient was asked to maintain the eye on the rising ball in the incentive spirometry.

Group 2: Preoperative instructions about the postoperative use of continuous positive airway pressure. Patient received CPAP through face mask, from half lying position.

Treatment procedure

Postoperative physical therapy program started when the patient was extubated from mechanical ventilation, hemodynamically stable in the first day postoperatively and continued until discharge from the intensive care unit (ICU). Participants of both group received the

physical therapy program including chest physical therapy modalities, early mobilization at least three times per week.

Group 1: The patients in this group received incentive spirometry while they were in long sitting position and instructed to use the incentive spirometry as they had been learned in the preoperative meeting. They were instructed to perform expiration outside the mouth piece then inspired through it as deeply as possible making ball of the incentive spirometry fixed on desired location. They were being instructed to perform five to ten slow maximal inspirations through the mouth piece of incentive spirometry. This maneuver continued for 15 minutes with one minute of rest between each 2 sets of the exercise.

Group 2: The patients in this group received continuous positive airway pressure while they were in half lying position. The continuous positive pressure breathing was connected to oxygen adaptor that provides oxygen supply for operating the continuous positive airway pressure breathing. The unit was switched on then the parameters were selected where the peak pressure was 10 cm H₂O to provide a sufficient widening of thoracic cage diameter, the pressure was constant during inspiration and expiration, the duration of application was 15 minutes through a face mask and finally, alarm was being activated for disconnection from CPAP apparatus.

Statistical analysis

The mean values of PaO₂, PaCO₂ and pH recorded before treatment (Pre), after 30 minutes (Post 1), and after 2 hours (Post 2) of either CPAP or IS therapy were compared using paired „t” test. Independent „t” test was used for the comparison between the two groups (P<0.05).

Results

The two groups were considered homogeneous regarding the baseline descriptive characteristics (Table 1).

As observed in Table 2, the PaO₂ reported mean values of 76.3 ± 7.6, 79.2 ± 8.4, and 82.4 ± 8.7 mmHg, before therapy (Pre), after 30 minutes (post 1), and after 2 hours (Post 2) of Group 1 respectively, PaO₂ showed an increase in its mean values throughout time of measurements. Although there were no statistical significant (P>0.05) increase of PaO₂ after 30 minutes (Post 1), while there were statistical significant (P<0.05) increase of PaO₂ after 2 hours (Post 2), when compared with pretreatment value (Pre). There were a statistical significant (P<0.05) increase of PaO₂ after 2 hours (Post 2), when compared with its mean value after 30 minutes (Post 1), which indicated continuous increase of PaO₂ and long term effect of IS therapy. However, the PaCO₂ had mean values of (36.74 ± 5.74, 35.26 ± 6.75, and 32.91 ± 4.55 mmHg), before therapy (Pre), after 30 minutes (Post 1), and, after 2 hours (post 2), respectively. The PaCO₂ showed reduction in its mean value throughout time of measurements. Although there were no statistical significant (P>0.05) decrease of PaCO₂ after 30 minutes (Post 1), while

Variable	Mean + SD		Significance
	Group 1	Group 2	
Age (year)	56.2 ± 3.16	53.5 ± 4.27	P>0.05
Weight (Kg)	98.27 ± 7.93	98.73 ± 7.42	P>0.05
Height (Cm)	170.87 ± 3.85	171 ± 4.21	P>0.05
BMI (Kgm/m ²)	33.84±2.82	33.92 ± 3.54	P>0.05
HR (b/min)	109.22 ± 12.26	111.14 ± 12.03	P>0.05
RR (T/min)	29.37 ± 1.81	30.15 ± 1.78	P>0.05
SBP (mmHg)	124.24 ± 9.5	123.32 ± 7.09	P>0.05
DBP (mmHg)	75.28 ± 8.61	74.73 ± 6.32	P>0.05

Table 1: Comparison of baseline characteristics between Group 1 and Group 2.

there were statistical significant ($P < 0.05$) decrease of PaCO_2 after 2 hours (Post 2), when compared with pretreatment value (Pre). There were a statistical significant ($P < 0.05$) reduction of PaCO_2 after 2 hours (Post 2), when compared with its mean value after 30 minutes (Post 1), which indicated continuous reduction of PaCO_2 and long term effect IS therapy. Moreover, the pH had mean values of (7.41 ± 0.03 , 7.42 ± 0.05 , and 7.39 ± 0.11) for pre (before therapy), after 30 minutes (Post 1), and after 2 hours (Post 2), respectively. There were no statistical significant ($P > 0.05$) changes in mean values of pH throughout time of measurements (Table 2).

As observed in Table 3 the PaO_2 reported mean values of (72.1 ± 7.63 , 81.23 ± 8.5 , and 75.1 ± 5.47 mmHg), before therapy (Pre), after 30 minutes (post 1), and after 2 hours (Post 2) respectively. There were statistical significant ($P < 0.05$) increase of PaO_2 after 30 minutes (Post 1) when compared with pretreatment value (Pre). While there were no significant statistical ($P > 0.05$) increase of PaO_2 after 2 hours (Post 2), when compared with its mean value pretreatment (pre) or after 30 minutes (Post 1), which indicted short-term effect of CPAP therapy. However, the PaCO_2 had mean values of (36.86 ± 2.99 , 33.5 ± 3.1 , and 36.29 ± 3.45 mmHg), before therapy (Pre), after 30 minutes

(Post 1), and, after 2 hours (post 2), respectively, There were statistical significant ($P > 0.05$) decrease of PaCO_2 after 30 minutes (Post 1), while there were no statistical significant ($P < 0.05$) decrease of PaCO_2 after 2 hours (Post 2), when compared with pretreatment value (Pre). There were a significant statistical ($P < 0.05$) reduction of PaCO_2 after 30 minutes (Post 1), when compared with its mean value after 2 hours (Post 2), which indicated short term reduction of PaCO_2 after CPAP therapy. Moreover, the pH had mean values of (7.4 ± 0.04 , 7.38 ± 0.1 , and 7.36 ± 0.1) for pre (before therapy), after 30 minutes (Post 1), and after 2 hours (Post 2) respectively. There were no statistical significant ($P > 0.05$) changes in mean values of pH throughout time of measurements (Table 3).

As revealed from Table 4 the mean values of PaO_2 for CPAP before treatment was (72.1 ± 7.63 mmHg) and it was (76.3 ± 7.6 mmHg) for IS group, and revealed no significant ($P > 0.05$) differences between both groups. While the mean value of PaO_2 after 30 minutes (Post 1) was (81.23 ± 8.5 mmHg) for CPAP group, and it was (79.2 ± 8.4 mmHg) for IS group, and revealed no statistical significant differences ($P > 0.05$). At 2 hours post treatment (Post 2), the PaO_2 had mean value of (75.1 ± 5.47 mmHg) for CPAP and (82.4 ± 8.7 mmHg) for IS, those results

Variable	Statistics	Time of Measurements					
		Pre	Post 1	Pre	Post 2	Post 1	Post 2
PaO_2	Mean \pm SD	76.3 \pm 7.6	79.2 \pm 8.4	76.3 \pm 7.6	82.4 \pm 8.7	79.2 \pm 8.4	82.4 \pm 8.7
	T-value	1.66		6.18		6.66	
	Significance	$P > 0.05$		$P < 0.05$		$P < 0.05$	
PaCO_2	Mean \pm SD	36.74 \pm 5.74	35.26 \pm 6.75	36.74 \pm 5.74	32.91 \pm 4.55	35.26 \pm 6.75	32.91 \pm 4.55
	T-value	1.09		4.56		2.85	
	Significance	$P > 0.05$		$P < 0.05$		$P < 0.05$	
PH	Mean \pm SD	7.41 \pm 0.03	7.42 \pm 0.05	7.41 \pm 0.03	7.39 \pm 0.11	7.42 \pm 0.05	7.39 \pm 0.11
	T-value	0.29		0.97		0.92	
	Significance	$P > 0.05$		$P > 0.05$		$P > 0.05$	

Table 2: Mean value and significance of PaO_2 , PCO_2 and PH before therapy (Pre), after 30 minutes (post 1), and after 2 hours (post 2) of Group 1.

Variable	Statistics	Time of Measurements					
		Pre	Post 1	Pre	Post 2	Post 1	Post 2
PaO_2	Mean \pm SD	72.1 \pm 7.63	81.23 \pm 8.5	72.1 \pm 7.63	75.1 \pm 5.47	81.23 \pm 8.5	75.1 \pm 5.47
	T-value	6.47		2.81		1.32	
	Significance	$P < 0.05$		$P > 0.05$		$P > 0.05$	
PaCO_2	Mean \pm SD	36.86 \pm 2.99	33.5 \pm 3.1	36.86 \pm 2.99	36.29 \pm 3.45	33.5 \pm 3.1	36.29 \pm 3.45
	T-value	0.66		3.23		2.2	
	Significance	$P < 0.05$		$P > 0.05$		$P < 0.05$	
PH	Mean \pm SD	7.4 \pm 0.04	7.38 \pm 0.1	7.4 \pm 0.04	7.36 \pm 0.1	7.38 \pm 0.1	7.36 \pm 0.1
	T-value	0.29		0.97		0.92	
	Significance	$P > 0.05$		$P > 0.05$		$P > 0.05$	

Table 3: Mean value and significance of PaO_2 , PCO_2 and PH before therapy (Pre), after 30 minutes (post 1), and after 2 hours (post 2) of Group 2.

Variable	Statistics	Time of Measurements					
		Pre		Post 1		Post 2	
		CPAP	IS	CPAP	IS	CPAP	IS
PaO_2	Mean \pm SD	72.1 \pm 7.63	76.3 \pm 7.6	81.23 \pm 8.5	79.2 \pm 8.4	75.1 \pm 5.47	82.4 \pm 8.7
	T-value	0.37		0.021		1.98	
	Significance	$P > 0.05$		$P > 0.05$		$P < 0.05$	
PaCO_2	Mean \pm SD	36.86 \pm 2.99	36.74 \pm 5.74	33.5 \pm 3.1	35.26 \pm 6.75	36.29 \pm 3.45	32.91 \pm 4.55
	T-value	0.06		0.53		0.21	
	Significance	$P > 0.05$		$P > 0.05$		$P < 0.05$	
PH	Mean \pm SD	7.4 \pm 0.04	7.41 \pm 0.03	7.38 \pm 0.1	7.42 \pm 0.05	7.36 \pm 0.1	7.39 \pm 0.11
	T-value	0.99		1.143		0.76	
	Significance	$P > 0.05$		$P > 0.05$		$P > 0.05$	

Table 4: Mean value and significance of PaO_2 , PCO_2 and PH in Group 1 and Group 2 before therapy (Pre), after 30 minutes (post 1), and after 2 hours (Post 2).

revealed significant increase in PaO₂ (Post 2) for IS group. However, the mean value of PaCO₂ for CPAP before treatment (Pre) was (36.86 ± 2.99 mmHg) and it was (36.74 ± 5.74 mmHg) for IS group, and revealed no significant (P>0.05) differences between both groups. While the mean value of PaCO₂ after 30 minutes (Post 1) was (33.5 ± 3.1 mmHg) for CPAP group, and it was (35.26 ± 6.75 mmHg) for IS group, this revealed no statistical significant decrease between both groups. After 2 hours post treatment (Post 2), the PaCO₂ had mean value of (36.29 ± 3.45 mmHg) for CPAP and (32.91 ± 4.55 mmHg) for IS group. Those results revealed significant reduction in (P>0.05) PaCO₂ at that time (Post 2) for IS group. Moreover, the mean values of pH for CPAP before treatment (Pre) was (7.4 ± 0.04) and it was (7.41 ± 0.03) for IS group, and revealed no significant (P>0.05) differences between both groups. While the mean value of pH after 30 minutes (Post 1) was (7.38 ± 0.1) for CPAP group, and it was (7.42 ± 0.05) for IS group, and revealed no statistical significant differences (P>0.05). At 2 hours post treatment (Post 2), the pH had mean value of (7.36 ± 0.1), for CPAP and (7.39 ± 0.11) for IS group. These results revealed no significant reduction in (P>0.05) pH at that time (Post 2) for CPAP and IS group (Table 4).

Discussion

Coronary artery bypass grafting is performed to reduce angina, improve left ventricular function and increases survival for patient with coronary artery disease [18]. However, postoperative respiratory complications such as hypoxemia and atelectasis remain important causes of mortality after CABG. The aim of this study was to compare the changes in arterial blood gases after the use of incentive spirometry with continuous positive airway pressure during intensive care unit period, after CABG also to provide an idea about which of them is more effective method following coronary artery bypass surgery in intensive care unit. The parameters measured in this study were the arterial blood gases (PaO₂, PaCO₂ and pH). A comparison was made between the effect of IS and CPAP on these measures.

Regarding baseline parameters, the results obtained in the present study indicated that, there was no significant difference in baseline values of arterial blood gases (pH, PaO₂, PaCO₂) and patient demographic data before using IS or CPAP. However, the obtained results in this study indicated that, there was no statistical significant change in arterial blood gases after half an hour of using incentive spirometry, while there were statistical significant increases in PaO₂ and decrease in PaCO₂ after half an hour of using CPAP which indicated short term effect of CPAP.

Lumb and Nunn reported that IS improved blood oxygenation via recruitment of ventilation in non-ventilated alveoli that means IS becomes beneficial for postoperative respiratory training as it causes increase in retractive forces to open the collapsed alveoli [19]. However, the effect of incentive spirometry compared to routine chest physical therapy revealed that IS was more effective in reduction of postoperative pulmonary complications [20]. In addition, Dull and colleague found that IS was superior to routine pulmonary physical therapy, intermittent positive pressure breath and deep breathing exercise following CABG, so that IS has become common therapy during postoperative period [21]. In the other hand, Matte and colleagues compared the effects of CPAP, IS and bi-level positive airway pressure (BPAP) in addition to standard chest physiotherapy after CABG, results revealed that PaO₂, vital capacity significantly better with BPAP and CPAP than IS in the second postoperative day [22]. Moreover, Ricksten and colleagues proved that CPAP was superior

than IS in improving blood oxygenation and limit the incidence of postoperative pulmonary complications [23]. The improvement in gas exchange with the use of CPAP occurs because it provides sufficient oxygenation and CO₂ elimination by unloading the inspiratory muscle, maintain alveolar ventilation and, thereby, stabilizing arterial pH. In addition, CPAP allows patients to take deeper breaths with less effort so it increases the volume of gas delivered to the lung and improves gas exchange which reverse clinical abnormality resulting from hypoxemia and hypercapnia [24,25].

The explanation of no statistical significant increase in arterial blood gases after half an hour of using incentive spirometry may be due to increase oxygen consumption during deep breathing with the IS. While during CPAP increase oxygen consumption doesn't occur due to its passive nature [26]. While, continuous positive airway pressure has a limited effect after open heart surgery, as CPAP causes improvement in value of functional residual capacity that led to transient improvements of oxygenation in patient group during CPAP application following cardiac surgery [27]. However, adding postoperative noninvasive ventilation to usual care following coronary artery bypass grafting at extubation reduced the recovery time and reduce risk of pulmonary complications [28]. Moreover, the explanation of improvement in arterial blood gases after half an hour of using CPAP is that mechanical trauma of the lungs during CABG might play a role in development of postoperative intra pulmonary shunting which lead to hypoxemia. The effect of using CPAP is due to a transient reduction in shunting and improvement of oxygenation [29,30].

Conclusion

Continuous positive airway pressure provide no additional benefit when patient routinely performing incentive spirometry after coronary artery bypass grafting unless it is essential to immediately improve postoperative arterial oxygenation, in the other hand incentive spirometry has long term effect in reduction of postoperative complication due to biofeedback effect that encourage patient to breath actively to total lung capacity which leads to improve blood oxygenation.

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