Original Article

The Effects of Continuous Positive Airway Pressure Mask on Hemodynamic Parameters after Open Heart Surgery: A Randomized Controlled Trial

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Abstract

Background: Controversies exist regarding the effects of continuous positive airway pressure (CPAP) mask on hemodynamic parameters after open heart surgeries. **Objectives:** This study aimed to investigate the effects of CPAP mask on hemodynamic parameters after open heart surgery. **Methods:** This randomized controlled trial was conducted in 2015 on 72 patients who were to undergoing open heart surgery in Kashan, Iran. Patients were randomly assigned to an intervention (n = 36) and a control (n = 36) group. After postoperative extubation, a CPAP mask (with a pressure of 5 cmH_2O) used for patients in the intervention group (30 min every 8 h for five times). A checklist was used to document hemodynamic parameters 10 min before and after each phase of the intervention. Data analysis was performed using the repeated measures analysis of variance and the Chi-square, Fisher's exact, and the independent-sample t-tests. **Results:** Results showed that CPAP mask had no significant effects on systolic blood pressure (P = 0.12), heart rate (P = 0.34), and mean arterial pressure (P = 0.12). However, it significantly affected diastolic blood pressure (P < 0.001) and central venous pressure (P < 0.01). **Conclusion:** CPAP mask has no negative effects on hemodynamic parameters. Thus, it can be safely used for patients who undergo open heart surgeries.

Keywords: *Blood pressure, Cardiac surgery, Continuous positive airway pressure, Hemodynamic status, Intensive Care Unit*

Introduction

Coronary artery disease is one of the leading causes of death around the world.[1] The most common surgical treatment for coronary artery disease is coronary artery bypass graft (CABG) surgery.[2,3] In Iran, 25000 open heart surgeries are done every year,[2] 60% of which are CABG.[4] Open heart surgeries are very difficult and complex and necessitate cardiac standstill and extracorporeal circulation; therefore, they are accompanied by a wide range of potential complications[5] the most common and the most serious are respiratory complications.[6] Respiratory complications not only increase the length of stay in the hospital and Intensive Care Units but also increase health-care costs and postoperative mortality rate.[7]

After open heart surgeries, patients are transferred to Cardiac Surgery Intensive Care Unit (CSICU). CSICU nurses play an important role in the prevention and treatment of postoperative complications[8] through using modalities such as noninvasive positive pressure ventilation and continuous positive airway pressure (CPAP) mask. CPAP mask is an easy-to-use and well-tolerated modality and hence can be freely used in CSICUs, where nurses need to implement prompt interventions.[9]

CPAP mask can produce hemodynamic effects. Some studies showed that using a CPAP mask reduces both

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pulmonary workload and cardiac preload[7] without negatively affecting heart rate (HR),[10] right ventricular index, ejection fraction, end-systolic and end-diastolic volume indices, stroke volume, cardiac index, mean arterial pressure (MAP), and cardiac output.[11-14] Some other studies showed that CPAP mask reduces cardiac output among patients with chronic heart failure, atrial fibrillation,[15] and hypertension.[16] Great controversies exist about the effects of CPAP mask on hemodynamic parameters. Moreover, most previous studies into the effects of CPAP mask were conducted on patients with heart failure who usually have relatively stable conditions. Currently, there is no convincing evidence regarding the effects of CPAP mask on patients undergoing heart surgeries.

Objectives

This study was undertaken to investigate the effects of CPAP mask on hemodynamic parameters after open heart surgery.

Methods

This randomized controlled clinical trial was conducted in 2015 in Shahid Beheshti Hospital, Kashan, Iran. In this study, 72 patients who were undergoing open heart surgery were consecutively selected and randomly assigned to intervention (n = 36) and control (n = 36) group. Randomization was done through coin tossing for each patient. Based on the results of a previous study (d = 7; difference in mean HR and σ = 14),[17] the sample size calculation formula revealed that 32 patients were needed for each group. Yet, we recruited 36 patients to each group.

The inclusion criteria were an age of >18 years, an elective open heart surgery, cardiopulmonary bypass during the surgery, an ejection fraction of greater than 40%, at least, one chest tube in the pleural cavity, postoperative mechanical ventilation for <12 h, no need for medications such as epinephrine, dopamine, and dobutamine at the beginning of the study, and no definite diagnosis of chronic obstructive pulmonary disease or asthma. The exclusion criteria included an unstable respiratory condition in the 2nd postoperative day, the need for re-intubation and invasive oxygen therapy, hemodynamic instability, the need for bronchodilators or inotropic medications, intolerance to CPAP mask, lack of cooperation, and willingness to withdraw from the study.

A two-part instrument was used for data collection. The first part consisted of questions on patients' demographic and clinical characteristics including age, gender, height, weight, body mass index, smoking history, number of cigarettes smoked a day, ejection fraction, aortic clamping time, duration of cardiopulmonary bypass and surgery, type of the surgery, type of drainage system, amount of drainage during the first 48 h after the surgery, and the history of diabetes mellitus, hypertension, and hyperlipidemia. The second part was a checklist consisting of items on hemodynamic parameters including systolic blood pressure (SBP), diastolic blood pressure (DBP), MAP, central venous pressure (CVP), and HR. All these parameters were measured in mmHg, except for HR which was measured in beats per minute.

Patients in the intervention group were treated with CPAP mask. Thus, after postoperative extubation, a CPAP face mask with a pressure of 5 cmH_2O was used for each patient for 30 min/8 h for five times [Figure 1]. Patients in the control group did not receive CPAP therapy; however, all patients in both groups received nursing and therapeutic care measures routinely provided to all patients in the study setting, including chest physiotherapy, incentive spirometry, and oxygen therapy. In the intervention group, hemodynamic parameters were

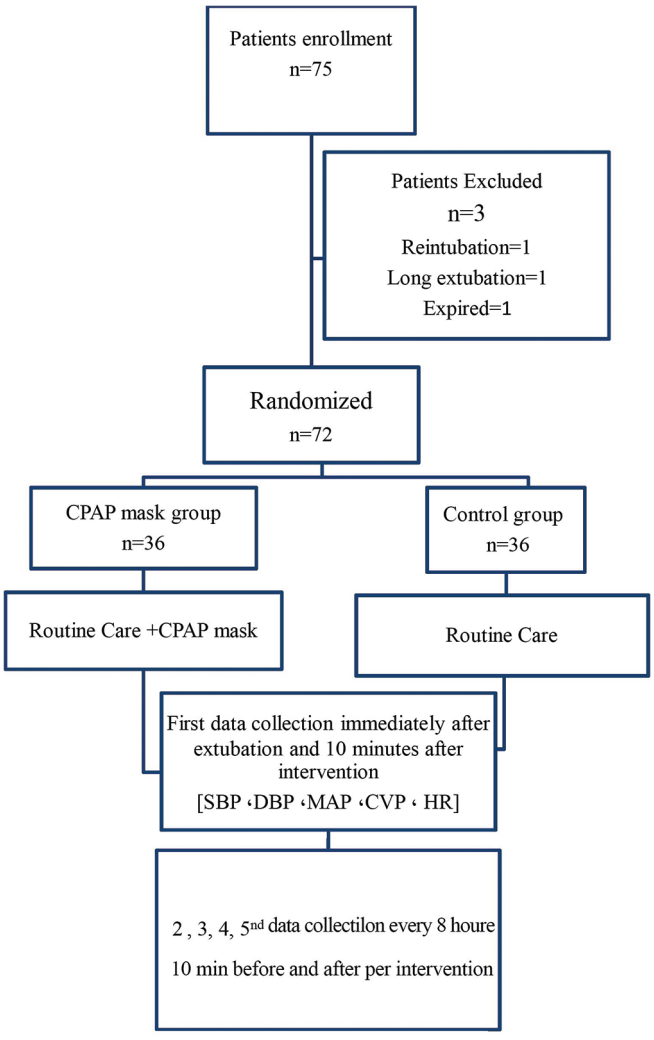

Figure 1: The study flow diagram

measured and documented 10 min before and after each phase of the intervention. The hemodynamic parameters of patients in the control group were also measured at similar time points.

Ethical considerations

This study was approved by the Research Ethics Committee of Kashan University of Medical Sciences, Kashan, Iran (with the code of IR.KAUMS.REC.1394.116) and was registered in the Iranian Registry of Clinical Trials (with the code of IRCT138902013146N2). Necessary permissions were obtained from the authorities of Shahid Beheshti Hospital, Kashan, Iran. In addition, all patients were supplied with information about the study objectives and were assured about the safety of the study intervention, the confidentiality of their personal information, and that the study would not incur them additional costs. All patients signed a written informed consent before entering the study. They were also informed that participation in and withdrawal from the study were voluntary.

Data analysis

Data analysis was performed using the SPSS software version 13.0 (SPSS Inc., Chicago, IL, USA). Normality testing was done using the Kolmogorov–Smirnov test, the results of which illustrated that all study variables had a normal distribution. The repeated measures analysis of variance was used to evaluate the effects of the intervention on SBP, DBP, HR, CVP, and MAP. The Chi-square, Fisher's exact, and the independent-sample *t*-tests were also used to compare the study groups regarding patients' gender, smoking history, history of diabetes mellitus, hypertension, and hyperlipidemia, type of surgery and drainage system, age, height, weight, body mass index, number of cigarettes smoked a day, ejection fraction, amount of drained fluids, aortic clamping time, and the duration of cardiopulmonary bypass and surgery.

Results

Most patients in both the control and the intervention group were female (69.40% and 66.67%, respectively). The means of patients' age in these groups were 61.38 ± 9.08 and 59.72 ± 12.25, respectively. There were no significant differences between the groups regarding demographics and clinical characteristics except for surgery time [$P < 0.05$; Table 1].

Table 1: Between-group comparisons regarding patients' demographic and clinical characteristics

Variable[a]	Intervention	Control	*P*
Age (year)	59.72 ± 12.25	61.38 ± 9.08	0.51[b]
Height (cm)	166.22 ± 9.18	164.13 ± 9.64	0.35[b]
Weight (kg)	73.61 ± 14.84	73.41 ± 12.39	0.93[b]
BMI	26.63 ± 4.67	27.86 ± 5.38	0.30[b]
Number of cigarettes smoked a day	5.25 ± 11.75	5.27 ± 8.44	0.99[b]
Ejection fraction (%)	55.55 ± 5.03	52.91 ± 6.58	0.06[b]
Aortic clamp time (min)	38.61 ± 15.35	34.86 ± 7.69	0.19[b]
Cardiopulmonary bypass time (min)	70.08 ± 19.63	64.66 ± 12.03	0.16[b]
Surgery time (h)	3.44 ± 0.48	3.16 ± 0.45	0.01[b]
Amount of drainage (ml/48 h)	234.72±214.49	197.22 ± 154.77	0.39[b]
Gender, *n* (%)			
Male	11 (30.60)	12 (33.33)	0.80[c]
Female	25 (69.40)	24 (66.67)	
Smoking history			
No	24 (66.67)	23 (63.89)	0.80[c]
Yes	12 (33.33)	13 (36.11)	
Type of surgery			
CABG	33 (91.66)	36 (100)	0.27[d]
Valve	1 (2.77)	0	
Both	2 (5.56)	0	
Type of drainage system			
Mediastinal and left plural	24 (66.67)	30 (83.33)	0.17[d]
Mediastinal and right plural	1 (2.77)	0	
Mediastinal and left and right plural	11 (30.56)	6 (16.67)	
History of diabetes mellitus, hypertension, or hyperlipidemia			
No	30 (83.33)	30 (83.33)	0.99[d]
Yes	6 (16.67)	6 (16.67)	

[a]Data are presented as mean±SD or *n* (%), [b]Independent-sample *t*-test, [c]Chi-square test, [d]Fisher's exact test. BMI: Body mass index, CABG: Coronary artery bypass graft, SD: Standard deviation

In repeated measures analysis, Mauchley's sphericity test showed that sphericity was not assumed for SBP ($\chi^2_{(44)} = 177.811$, $P < 0.001$), DBP ($\chi^2_{(44)} = 142.207$, $P < 0.001$), MAP ($\chi^2_{(44)} = 156.834$, $P < 0.001$), CVP ($\chi^2_{(44)} = 255.608$, $P < 0.001$), and HR ($\chi^2_{(44)} = 1370.994$, $P < 0.001$). Therefore, the degrees of freedom were corrected using Greenhouse-Geisser method. The results showed that CPAP mask had significant effects on DBP [Table 2] and CVP [Table 3], while it had no significant effects on SBP [Table 4], HR [Table 5], and MAP [Table 6].

Discussion

The present study showed that CPAP mask had no significant effects on SBP, MAP, and HR. Similarly, Altmay *et al*. reported the insignificant effects of CPAP on HR and MAP among male patients undergoing CABG.[18] Other studies also showed that CPAP mask did not significantly affect HR and arterial blood pressure among patients who had undergone

Table 2: Mean diastolic blood pressure (mmHg) before and after the intervention in both groups

Time	Mean±SD		Repeated measures ANOVA (*P*)
	CPAP	Control	
First			
Before	71.30 ± 8.81	69.97 ± 6.53	0.01
After	69.27 ± 9.29	70.80 ± 7.04	
Second			
Before	73.00 ± 9.78	69.11 ± 8.24	
After	67.16 ± 8.92	69.41 ± 8.86	
Third			
Before	69.69 ± 7.54	68.38 ± 8.72	
After	67.52 ± 7.56	69.80 ± 8.20	
Fourth			
Before	68.75 ± 7.49	68.08 ± 6.37	
After	64.83 ± 9.05	68.05 ± 7.06	
Fifth			
Before	66.58 ± 7.79	68.88 ± 8.72	
After	66.63 ± 11.72	70.05 ± 7.85	

SD: Standard deviation, CPAP: Continuous positive airway pressure, ANOVA: Analysis of variance

Table 3: Mean central venous pressure (mmHg) before and after the intervention in both groups

Time	Mean±SD		Repeated measures ANOVA (*P*)
	CPAP	Control	
First			
Before	13.63 ± 3.71	11.05 ± 2.93	0.01
After	12.36 ± 3.98	11.19 ± 2.85	
Second			
Before	14.13 ± 4.31	12.75 ± 3.20	
After	13.58 ± 4.05	13.50 ± 3.72	
Third			
Before	14.58 ± 3.54	14.13 ± 3.12	
After	14.19 ± 4.49	14.41 ± 3.23	
Fourth			
Before	14.83 ± 4.39	14.33 ± 3.11	
After	13.69 ± 4.19	14.52 ± 3.45	
Fifth			
Before	14.80 ± 3.94	14.94 ± 3.59	
After	14.13 ± 3.81	14.88 ± 3.55	

SD: Standard deviation, CPAP: Continuous positive airway pressure, ANOVA: Analysis of variance

Table 4: Mean systolic blood pressure (mmHg) before and after the intervention in both groups

Time	Mean±SD		Repeated measures ANOVA (*P*)
	CPAP	Control	
First			
Before	122.94 ± 14.62	121.66 ± 10.88	0.12
After	119.33 ± 14.35	120.38 ± 11.08	
Second			
Before	123.86 ± 14.76	116.66 ± 21.29	
After	116.97 ± 15.92	119.66 ± 12.73	
Third			
Before	122.72 ± 13.99	121.22 ± 12.39	
After	119.25 ± 12.23	122.91 ± 11.33	
Fourth			
Before	121.69 ± 15.16	121.94 ± 12.43	
After	119.02 ± 16.70	119.25 ± 12.04	
Fifth			
Before	120.30 ± 13.16	119.00 ± 13.26	
After	119.11 ± 15.56	121.75 ± 13.92	

SD: Standard deviation, CPAP: Continuous positive airway pressure, ANOVA: Analysis of variance

Table 5: Mean heart rate (beats/min) before and after the intervention in both groups

Time	Mean±SD		Repeated measures ANOVA (*P*)
	CPAP	Control	
First			
Before	94.33 ± 13.87	92.72 ± 11.29	0.34
After	91.75 ± 13.24	91.38 ± 12.10	
Second			
Before	88.41 ± 13.41	87.00 ± 9.78	
After	85.52 ± 12.23	86.13 ± 9.12	
Third			
Before	85.38 ± 9.76	103.17 ± 9.25	
After	83.63 ± 10.60	86.08 ± 9.66	
Fourth			
Before	82.72 ± 9.73	86.66 ± 12.83	
After	80.52 ± 10.77	86.33 ± 12.82	
Fifth			
Before	84.86 ± 13.97	86.66 ± 10.39	
After	82.44 ± 11.75	86.11 ±10.06	

SD: Standard deviation, CPAP: Continuous positive airway pressure, ANOVA: Analysis of variance

open heart surgery.[7,10,13,19] In contrast, some studies reported that CPAP mask significantly reduced cardiac output[15,19] and arterial blood pressure among patients with chronic heart failure.[16] It is noteworthy that patients with heart failure have low cardiac output and ejection fraction and thus, their hemodynamic status is very sensitive to small changes in intrathoracic pressure. CPAP mask increases intrathoracic pressure which in turn reduces venous return to the heart and thereby, reduces cardiac output.[17] However, all patients who participated in the present study had an ejection fraction of greater than 40%, and therefore, CPAP mask did not significantly affect their ejection fraction, CVP (an indicator of cardiac preload), HR, cardiac output, and stroke volume. Landoni *et al*. also showed that CPAP mask neither affected end-diastolic and end-systolic blood volumes nor stroke volume and ejection fraction after cardiac surgery.[11] These findings also confirm that CPAP mask has no effects on venous return and cardiac output in patients with normal ejection fraction who undergo open heart surgery.

Table 6: Mean arterial pressure (mmHg) before and after the intervention in both groups

Time	Mean±SD		Repeated measures ANOVA (*P*)
	CPAP	Control	
First			
Before	88.25 ± 9.33	86.61 ± 7.01	0.12
After	86.69 ± 9.08	87.05 ± 7.44	
Second			
Before	88.94 ± 9.72	86.08 ± 9.05	
After	82.91 ± 10.26	85.81 ± 9.16	
Third			
Before	87.02 ± 7.08	85.83 ± 8.86	
After	84.86 ± 8.09	87.11 ± 8.43	
Fourth			
Before	85.61 ± 10.45	85.71 ± 7.75	
After	82.36 ± 11.46	84.75 ± 7.91	
Fifth			
Before	84.88 ± 8.94	84.94 ± 9.39	
After	83.11 ± 10.88	87.30 ± 10.07	

SD: Standard deviation, CPAP: Continuous positive airway pressure, ANOVA: Analysis of variance

The results of the present study also revealed that the use of CPAP mask after open heart surgery not only causes no serious side effects but also improves cardiac function. Ducros and Plaisance also reported the same findings.[12] Such improved cardiac function may be due to the improved gas exchange between the blood and the atmospheric air in the lung[20] or due to reduced myocardial oxygen consumption following improved cardiac output.[14]

Conclusion

The results of this study showed that CPAP mask had no negative effects on SBP, HR, and MAP after open heart surgery. However, it significantly affected DBP and CVP. It is noteworthy that the effects of CPAP mask on DBP and CVP were only statistically significant. In other words, the effects have no clinical significance because these effects are short-term and disappear very soon. Consequently, CPAP mask can be safely used as a noninvasive method to prevent respiratory complications after open heart surgeries. Health policy makers can take the positive effects of CPAP mask on postoperative patient outcomes when weighing its costs against its benefits.

One limitation of this study was that CPAP was used with a low pressure of 5 cmH_2O. Future studies are recommended to replicate this study with a CPAP mask pressure of 10 cmH_2O. Moreover, this study was conducted on patients with normal ejection fraction, and hence, further studies are needed to investigate the safety and the effects of CPAP mask on patients with low ejection fraction.

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Conflicts of interest

There are no conflicts of interest.

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