

Impact of Continuous Positive Airway Pressure (CPAP) Masks on Arterial Blood Gas Parameters and Pulmonary Side Effects after Open-heart Surgery: A Randomized Clinical Trial

Fatemeh Nadi¹ , Ismail Azizi Fini^{2*} , Fatemeh Sadat Izadi AvANJI² 

¹ Faculty of Nursing and Midwifery, Kashan University of Medical Sciences, Kashan, Iran

² Trauma Nursing Research Center, Kashan University of Medical science, Kashan, Iran

* **Corresponding author:** Ismail Azizi Fini, Trauma Nursing Research Center, Kashan University of Medical science, Kashan, Iran. Tel: 09122475747, 03155103136; Email: azizifinies@yahoo.com

Article Info	ABSTRACT
<p>Article type: Original article</p>	<p>Background and Aim: Pulmonary side effects are one of the most prevalent and critical sequels following open-heart surgery. A preventive measure for pulmonary side effects after open-heart surgery is to apply continuous positive airway pressure (CPAP) masks. However, studies regarding the usage of these masks have demonstrated contradictory results. Therefore, the present investigation aimed to evaluate the influence of CPAP masks on reducing pulmonary side effects following open-heart surgery.</p>
<p>Article History: Received: 02 December 2019 Revised: 01 January 2020 Accepted: 04 January 2020</p>	<p>Materials and Methods: This clinical trial was performed on 72 subjects selected through the continuous sampling method out of the patients with open-heart surgery and assigned to two groups of 36 in 2015 in Kashan, Iran. The participants in the test group went under CPAP with 5 cmH₂O pressure immediately post-extubation for five times of 30 min with the intervals of 8 h (a total of 150 min during 40 h). On the other hand, the subjects of the control group only received the routine care of the department. Pulmonary sequels, including pleural effusion, pneumothorax, and atelectasis, in addition to some other variables, namely PO₂, PCO₂, oxygen saturation (O₂ Sat), and respiratory rate (RR) were assessed. All the data were analyzed by the Chi-square test and independent t-test.</p>
<p>Keywords: Cardiac surgical procedures Continuous positive airway pressure Lung Thoracic surgery</p>	<p>Results: Our findings demonstrated that CPAP application can significantly diminish the occurrence of atelectasis and pleural effusion after open-heart surgery (P<0.05). Moreover, the results revealed that CPAP mask usage leads to a significant reduction in RR and arterial PCO₂, while elevates PO₂ and O₂ Sat significantly (P<0.05).</p> <p>Conclusion: Results of the current study showed that the non-invasive application of CPAP mask immediately post-extubation in patients who undergo open-heart surgery can effectively improve pulmonary function and decrease the incidence of pulmonary side effects, such as atelectasis.</p>

➤ How to cite this paper

Nadi F, Azizi Fini I, Izadi AvANJI FS. Impact of Continuous Positive Airway Pressure (CPAP) Masks on Arterial Blood Gas Parameters and Pulmonary Side Effects after Open-heart Surgery: A Randomized Clinical Trial. J Vessel Circ. Winter 2020; 1(1): 1-7. DOI: [10.21859/JVesselCirc.1.1.1](https://doi.org/10.21859/JVesselCirc.1.1.1)

Introduction

Open-heart surgery is one of the most common treatments for cardiovascular diseases that might be accompanied by various side effects, such as pulmonary sequels (1). Open-heart surgeries include coronary bypass, valves repair or replacement, congenital heart diseases, and

cardiac transplant (2). According to the annual reports, 30-40 thousand open-heart surgeries are performed yearly in Iran (1). Although open-heart surgery is a reliable technique for enhancing myocardial perfusion, the operation might cause a wide range of disorders in different body organs,



especially the lungs due to blood exit from the body and the cessation of the function of heart and lungs (2).

Nowadays, despite the improvements in the methods of cardiopulmonary bypass (CPB) and post-op cares, still pulmonary function defect after surgery has remained as one of the remarkable post-surgery side effects (3). Regarding the incidence of these sequels, it was stated in the literature that blood confronts a large surface of artificial materials at the first step of CPB leading to the synthesis and secretion of numerous toxic chemicals and vasoactive agents.

Next, the activation of neutrophils and their presence in pulmonary blood circulation results in deep endothelial, epithelial, and interstitial pulmonary damage. This injury may be accompanied by increased endothelial permeability, diminished pulmonary capacity, and disturbed gas exchange (4).

All these events after surgery can cause atelectasis, pneumonia, pleural effusion, and reduced pulmonary capacity leading to decreased oxygen delivery to the tissues (5). Some studies reported the incidence of post-operation atelectasis and pleural effusion as 15-98% (6) and 63% (7), respectively. Considering the extent and importance of changes in pulmonary function after open-heart surgery, these patients require suitable interventions.

There is no consensus in the existing literature concerning the best intervention for the rehabilitation and improvement of respiratory system function in patients under open-heart surgery (8). However, there are some techniques for the prevention and treatment of these side effects (9), among which respiratory physiotherapy (10), post-op positioning, and pain management could be noted (11, 12).

One of the recommended methods for decreasing the incidence of pulmonary sequels is to apply continuous positive airway pressure (CPAP) masks (13, 14). These masks non-invasively enhance the respiratory condition of the patients with spontaneous respiration during inspiration and expiration by inducing a continuous positive pressure in airways at inspiration and expiration (15). The CPAPs can be used easily for respiratory support, cost low, are well-tolerated, and prevent repetitive intubation (16).

Studies regarding the application of CPAP have revealed controversial results. Zarbock et al. reported that the long-term utilization of non-invasive CPAP following heart surgery improves arterial blood oxygenation and reduces pulmonary side effects, such as pneumonia, repeated

intubation, and return to the Intensive Care Unit (ICU) (2)

The results of another study showed that CPAP masks can be useful for treating or preventing atelectasis in patients after open-heart surgery (17). Furthermore, another study revealed that arterial blood gases remarkably get enhanced in patients receiving CPAP mask after open-heart surgery (18). On the other hand, Altmay et al. found no influence regarding invasive CPAP application during CPB on post-op pulmonary function (19).

Considering the mentioned contradictions, different methodologies in using this technique, and the importance of preventing pulmonary sequels after heart surgery, we aimed to evaluate the impact of CPAP mask on arterial blood gases and the reduction of pulmonary side effects after heart surgery. The results of the present study might be useful in promoting care services after heart surgery, which leads to the sooner discharge of the patient from the ICU. Moreover, some sequels, including a long stay in hospital and high costs for the patients and health organizations might decline.

Materials and Methods

This double-blind randomized clinical trial (blind for both patient and statistician) was carried out on the study population of all patients referring to the heart surgery ICU of Shahid Beheshti Teaching Hospital of Kashan in 2015. A total of 72 patients who were candidates for open-heart surgery were selected through the continuous sampling method and were assigned to the two groups of test (n=36) and control (n=36) by random placement using a coin. The sample size was calculated utilizing the following formula based on the results of the previous studies (the mean of heart rate difference; $d=7$ and $\sigma=14$) (20):

$$n = \frac{(z_{1-\alpha/2} + z_{1-\beta})^2 \delta^2}{d^2} = \frac{(1.96 + 0.84)^2 14^2}{7^2} = 32$$

The inclusion criteria entailed 1) being over 18 years old, 2) having elective surgery under CPB pump, 3) having an ejection fraction of over 40%, 4) having at least one evacuation drain in the pleural region, 5) receiving mechanical ventilation post-operation for less than 12 h, 6) not requiring inotropic agents at the beginning of the study (e.g., epinephrine, dopamine, dobutamine), and 7) not having any history of chronic obstructive pulmonary disease or asthma. The exclusion criteria were 1) need for repeated intubation during the

study, 2) hemodynamic instability, 3) need for bronchodilator or inotropic medications, and 4) not tolerating CPAP mask.

Data Collection Tools

The data collection instrument entailed three parts, the first of which addressed age, gender, smoking history, surgery type, drainage type, background disease, BMI, ejection fraction, aortic cross-clamping time (XCT), CPB time, left-side drainage, and right-side drainage. The second part was about arterial blood gases, including PO₂, PCO₂, oxygen saturation (O₂ Sat), and respiratory rate (RR) that were recorded 10 min pre- and post-intervention from the arterial blood gas (ABG) description of the patients checked by GEM premier3000 system.

In addition, the third part evaluated the pulmonary side effects, namely atelectasis, pneumothorax, and pleural effusion, which were diagnosed 24 h after the removal of drains using a chest X-ray by a radiologist. The face and content types of the validity of the instrument were assessed and confirmed by ten members of the scientific committee of Kashan University of Medical Sciences. In order to examine the reliability, the checklist was completed for five patients by two separate assessors and the agreement coefficient was obtained as 0.92.

Intervention Procedure

At the beginning of the study (before surgery), a mask for mouth and nose with a suitable size was applied to all patients. The subjects were requested to breathe with the mask for 1 min to understand the study conditions and decide for participation in the investigation. The selected mouth and nose mask for each patient was kept at the ICU until transfer from the operation room.

In the test group, the mask connected to the CPAP system with the pressure of 5 cmH₂O was located and fixed on the mouth and nose of the participants so that air could not exit the edges of a mask when entered the pathways with pressure. The masks were used for the patients five times after open-heart surgery immediately after

extubation and then every 8 h for 30 min (2). The subjects of both intervention and control groups received the routine care of the unit.

Ethical Considerations

The researchers selected the samples based on the inclusion criteria after receiving approval from the Ethics Committee of Kashan University of Medical Sciences and the authorities of the hospital and ICU. First, individuals who were a candidate for heart surgery were selected and the aims of the study were explained to all the participants.

Following receiving written informed consent, the subjects were told that continuing or leaving the study will not affect the treatment procedure and will not have any expenses. Moreover, the participants were assured regarding the confidentiality of the data and the researchers explained that they could leave the study anytime they desired. The present study was approved by the University with the code of IRCT138902013146N2 and the ethical code of IR.KAUMS.REC.1394.116.

Statistical Analysis

All the data were analyzed by descriptive statistics, independent t-test, and Chi-square test using the SPSS software version 13. Moreover, the Kolmogorov-Smirnov test was utilized to evaluate the normality of the data showing that all the data had a normal distribution.

Results

A total of 72 patients under open-heart surgery participated in this study. Our findings showed that the mean age of people was 61.38±9.08 years in the control group and 59.72±12.25 years in the test group without a significant difference between the two groups (P=0.51).

Furthermore, ejection fraction, left-side drainage, aorta clamp right-side drainage, and XCT were not significantly different between the two groups (P>0.05) (Table 1). According to the results of this study, 33.3% and 30.6% of the subjects in the control and test groups were male, respectively. Therefore, the two groups did not have a significant difference regarding gender (P=0.05) (Table 2).

Table 1. Demographic and clinical variables in the two groups of control and intervention

Variable	Group		P-value
	Intervention Mean±SD	Control Mean±SD	
Age (years)	59.72±12.25	61.38±9.08	0.51
BMI	26.63±4.67	27.73±5.36	0.35
Ejection fraction (%)	55.55±5.03	52.91±6.58	0.06
Left-side drainage (cc)	199.3±188.36	168.05±127.98	0.41
Right-side drainage (cc)	35.41±84.17	29.16±87.52	0.75
Aorta clamping (min)	38.61±15.35	34.86±7.69	0.19
Pump time (min)	70.08±19.63	64.66±12.03	0.16

* Independent t-test

Table 2. Frequency of demographic variables in the two groups

Variable		Group		P-value
		Intervention	Control	
Gender	Male	11(30.6)	12 (33.3)	0.5*
	Female	25 (69.4)	24 (66.7)	
Smoking history	No	24 (66.7)	23 (63.9)	0.5**
	Yes	12 (33.3)	13(36.1)	
Type of surgery	CABG	33 (91.7)	36 (100)	0.2**
	Valve	1(2.8)	0	
	Both	2 (5.6)	0	
Type of drain	Mediastinal and left plural	24 (66.7)	30 (83.3)	0.2**
	Mediastinal and right plural	1 (2.8)	0	
	All three	11 (30.6)	6 (16.7)	
Gender	No	30 (83.3)	30 (83.3)	0.2**
	Yes	6 (16.7)	6 (16.7)	

n (%)

*Independent t-test

**Chi-square test

Table 3. Incidence frequency of pulmonary side effects in the intervention and control groups

Variable		Group		P-value
		Intervention n (%)	Control n (%)	
Atelectasis	Yes	8 (22.2)	17 (47.2)	0.04*
	No	28 (77.8)	19 (52.8)	
Pleural effusion	Yes	2 (8.3)	11 (30.6)	0.01*
	No	34 (91.7)	25 (69.4)	
Pneumothorax	Yes	1 (2.8)	4 (11.1)	0.35*
	No	35 (97.2)	32 (88.9)	

* Fisher's exact test

Table 4. Mean and standard deviation of PO₂, PCO₂, O₂ Sat, and RR in the intervention and control groups before and 10 min after each time of intervention

Intervention time	Group	First		*P-value	Second		P-value	Third		P-value	Fourth		P-value	Fifth		P-value
		Intervention	Control		Intervention	Control		Intervention	Control		Intervention	Control		Intervention	Control	
RR	Before	17.8±3.61	16.4±2.26	0.05	18.3±3.98	17.7±2.09	0.43	18.5±4.57	17.6±2.45	0.3	18.7±4.8	19.1±2.51	0.71	18.6±4.56	19.6±2.59	0.28
	After	13.8±3.3	15.8±2.54	0	14.4±3.01	16.7±2.98	0	15.3±3.96	17.0±3.11	0.04	15.2±3.93	19.3±2.42	0	16.9±4.12	19.6±2.56	0.002
PO ₂	Before	89.6±17.21	94.8±25.82	0.31	88.9±23.27	97.0±35.25	0.25	80±21.79	76.5±15.81	0.44	74.2±18.79	78.5±24.45	0.4	72.9±15.57	72.1±16.06	0.83
	After	141.7±47.35	114.6±37.31	0.009	117.6±36.96	94.9±31.54	0.006	103.8±29.47	78.1±17.93	0	102.3±21.07	74.5±18.6	0	94.7±26.32	75.1±18.06	0
PCO ₂	Before	38±3.87	36.9±3.78	0.22	40.1±4.15	38.7±3.79	0.13	37.9±3.01	37.8±3.64	0.88	39.9±5.58	37.9±3.74	0.08	36.5±5.43	37.9±5	0.25
	After	36±3.49	39.1±4.28	0.001	41.0±7.15	37.7±3.97	0.01	37.3±5.56	40.6±5.58	0.01	36.1±5	40.9±5.22	0	35.6±5.34	38.4±5.59	0.03
O ₂ Sat	Before	95±2.98	95.4±2.86	0.49	96.1±2.56	96.6±2.24	0.4	95.1±2.95	94.8±3.3	0.68	94.3±2.67	95.1±2.74	0.22	94.3±2.81	94.3±2.49	0.96
	After	97.7±2.11	95.5±3.52	0.003	97.6±2.11	96.4±2.29	0.02	96.2±2.5	94.3±3.02	0.006	96.3±2.64	94.6±2.2	0.004	95.9±2.72	94.8±2.26	0.07

*Independent t-test

The results of Fisher's exact test revealed that the two groups were significantly different in terms of atelectasis (P=0.04) and pleural effusion (P=0.01) and the incidence of these problems was lower in the intervention group, compared to the control group (Table 3). Moreover, the results of the independent t-test showed that there was a significant difference between the two groups regarding the means of PO₂, PCO₂, O₂ Sat, and RR after each time of intervention (P<0.05). It was found that arterial O₂ Sat and PO₂ augmented after each time of intervention, while arterial PCO₂ and RR diminished after each intervention time (Table 4).

Discussion

The present study aimed to evaluate the impact of CPAP mask on the incidence of pulmonary side effects in patients after heart surgery. Our results

revealed that using a CPAP mask led to a decreased incidence of atelectasis after open-heart surgery. Some studies reported the incidence of atelectasis as 6-42% (21) and it was found as 47.2% and 22.2% in the control and test groups of this study, respectively.

Al. Mutairi et al. (2013) carried out a clinical trial aimed to investigate the influence of the early application of CPAP mask on the treatment or prevention from atelectasis following coronary artery bypass grafting. They demonstrated that the CPAP group had better results in terms of treating and preventing atelectasis, compared to the motivational spirometry group (17).

The results of other studies showed that CPAP mask can be effective in preventing atelectasis after surgery (21-23). It could be claimed that heart surgery results in reduced lung volumes, alveolar

collapse, and the collapse of some parts of the lungs as atelectasis and diminished oxygenation. Consequently, the generation of continuous positive pressure in the airways and alveoli as the base of the function mechanism of CPAP masks (1) causes the alveoli to widen due to the positive pressure and the atelectasis is resolved.

Moreover, the literature indicates that improved oxygenation using CPAP mask results from the resolution of atelectasis in patients following heart surgery (23, 2). Pasquina et al. (2004) completed an investigation on 155 patients in the heart surgery ICU to compare non-invasive pressure support ventilation (NIPSV) and CPAP in terms of atelectasis treatment.

The mentioned authors concluded that CPAP was less influential than NIPSV in treating atelectasis (22). In terms of the CPAP mask, both the latter and present studies had similar findings. However, the impact of the CPAP mask in the mentioned investigation was less remarkable, in comparison with NIPSV.

Our findings revealed a significant difference in the incidence of pleural effusion between the test and control groups and the incidence rate was lower among the patients of the control group. Results of the study completed by Oliveira et al. demonstrated that CPAP mask usage led to the diminished pleural effusion in tuberculosis patients (24). Furthermore, Marti et al. reported that CPAP imposed a positive effect in individuals with heart failure due to pleural effusion (16).

Application of CPAP mask elevates the intrathoracic pressure (25) resulting in decreased liquid leakage in thoracic space. The results of Gust et al. showed that CPAP mask utilization prevents the elevation in extravascular liquid in the lungs (26). In addition, it could be stated that the improvement of heart function is among the physiological impacts of CPAP (27).

On the other hand, in subjects who undergo heart surgery, the receiving and pumping actions of heart as the main function of this organ are not retrieved during the first days after the operation, which leads to elevated liquid leakage to the interstitial space. Therefore, a CPAP mask can enhance heart function (27) and reduce heart workload (28) by decreasing transmural pressure.

Results of the current study indicated that pneumothorax incidence is not significantly different between the two groups. Nonetheless, it is noteworthy that a lower number of patients were clinically affected by pneumothorax in the intervention group. There is no clinical trial concerning the influence of the CPAP mask on pneumothorax incidence or treatment. However, the results of some studies in non-surgical patients

(29) and children (30) demonstrate that continuous usage of CPAP mask can cause pneumothorax. Variety in the findings might be attributed to the study groups and study duration. The literature notes that pneumothorax due to CPAP is rare (29).

Our findings revealed that PO_2 and O_2 Sat raised in the test group post-intervention, compared to the control group. In other words, oxygenation was improved in these individuals and PCO_2 along with RR diminished in the test group, in comparison with the control group. The results of some other studies indicated that the oxygenation condition improved following CPAP mask usage, while an investigation on patients with rib fracture reported that oxygenation did not have a significant difference between the CPAP and IPPV groups (31).

A reason for this controversy might be the lack of adaptation to the CPAP mask among the patients under study. The latter point has also been mentioned in the literature (32). Enhancement in the oxygenation condition of the patients in the present study could be explained by the continuous positive pressure induced by CPAP during inspiration and expiration, which keeps airways and alveoli open leading to augmented inspiratory reserve volume and residual volume (RV).

Increased RV causes more air to remain in the lung resulting in higher rates of gas exchange. Moreover, the removal of V/Q mismatch due to the widening of alveoli and better gas emission from blood in the participants of the test group can be considered as another reason for boosted oxygenation and decreased PCO_2 .

In the current investigation, the CPAP mask was utilized with the purpose of preventing pulmonary sequels. According to the findings, no serious and dangerous side effect was observed and similar studies have also noted this point (22, 23). We cannot conclude from the present investigation whether CPAP mask had a treating or preventive role. Consequently, further studies regarding atelectasis treatment after heart surgery are required, which has also been mentioned in similar investigations (22).

The mask used in this study could not be tolerated by some patients because of the complete covering of the mouth and nose. As a result, some subjects could not cooperate and much time was spent on sampling by the researchers, which can be considered as a limitation for this study.

Conclusion

Results of the current study demonstrated that CPAP mask application can effectively and safely diminish atelectasis and pleural effusion along with

enhancing oxygenation and ventilation in patients following open-heart surgery.

Acknowledgments

Authors of the present investigation would like to extend their gratitude to the participants in this study. In addition, they would appreciate the nurses and physicians of the heart surgery ICU of Beheshti Hospital, Kashan.

Conflict of interest

There was no conflict of interest among the authors of the present study.

Funding

This study was a part of a thesis with the code of 94116, which was completed by the financial support of Kashan University of Medical Sciences in 2015.

References

- Afazel M, Nadi F, Pour-Abbasi M, Azizi-Fini I, Rajabi M. The effects of continuous positive airway pressure mask on hemodynamic parameters after open heart surgery: a randomized controlled trial. *Nurs Midwifery Stud* 2017; 6(3):109-14. [Link](#)
- Zarbock A, Mueller E, Netzer S, Gabriel A, Feindt P, Kindgen-Milles D. Prophylactic nasal continuous positive airway pressure following cardiac surgery protects from postoperative pulmonary complications: a prospective, randomized, controlled trial in 500 patients. *Chest* 2009;135(5):1252-9. [PMID: 19017864](#)
- Davoudi M, Farhanchi A, Moradi A, Bakhshaei MH, Safarpour G. The effect of low tidal volume ventilation during cardiopulmonary bypass on postoperative pulmonary function. *J Tehran Heart Cent* 2010;5(3):128-31. [PMID: 23074580](#)
- Chaney MA, Nikolov MP, Blakeman BP, Bakhos M. Protective ventilation attenuates postoperative pulmonary dysfunction in patients undergoing cardiopulmonary bypass. *J Cardiothorac Vasc Anesth* 2000;14(5):514-8. [PMID: 11052430](#)
- Alavi M, Pakroob B, Mirmesdagh Y, Bakhshandeh H, Babaei T, Hosseini S, et al. The effects of positive airway pressure ventilation during cardiopulmonary bypass on pulmonary function following open heart surgery. *Res Cardiovasc Med* 2013;2(2):79-84. [PMID: 25478498](#)
- Nakazato K, Takeda S, Tanaka K, Sakamoto A. Aggressive treatment with noninvasive ventilation for mild acute hypoxemic respiratory failure after cardiovascular surgery. *J Cardiothorac Surg* 2012;7:41. [PMID: 22554005](#)
- Light RW, Rogers JT, Moyers JP, Lee YG, Rodriguez RM, Alford Jr WC, et al. Prevalence and clinical course of pleural effusions at 30 days after coronary artery and cardiac surgery. *Am J Respir Crit Care Med* 2002;166(12 Pt 1):1567-71. [PMID: 12406850](#)
- Pantoni CB, Di Thommazo L, Mendes RG, Catai AM, Luzzi S, Amaral Neto O, et al. Effect of different levels of positive airway pressure on breathing pattern and heart rate variability after coronary artery bypass grafting surgery. *Braz J Med Biol Res* 2011;44(1):38-45. [PMID: 21085891](#)
- Figueirêdo L, Araújo S, Abdala RC, Abdala A, Guedes CA. CPAP at 10 cm H₂O during cardiopulmonary bypass does not improve postoperative gas exchange. *Rev Bras Cir Cardiovasc* 2008;23(2):209-15. [PMID: 18820784](#)
- Moreno AM, Castro R, Sorares P, Sant'Anna M, Cravo S, Nóbrega A. Longitudinal evaluation the pulmonary function of the pre and postoperative periods in the coronary artery bypass graft surgery of patients treated with a physiotherapy protocol. *J Cardiothorac Surg* 2011;6:62. [PMID: 21524298](#)
- Freitas ER, Soares BG, Cardoso JR, Atallah AN. Incentive spirometry for preventing pulmonary complications after coronary artery bypass graft. *Cochrane Database Syst Rev* 2012;9:CD004466. [PMID: 22972072](#)
- Wynne R, Botti M. Postoperative pulmonary dysfunction in adults after cardiac surgery with cardiopulmonary bypass: clinical significance and implications for practice. *Am J Crit Care* 2004;13(5):384-93. [PMID: 15470854](#)
- Denehy L, Berney S. The use of positive pressure devices by physiotherapists. *Eur Respir J* 2001;17(4):821-9. [PMID: 11401079](#)
- Lin C, Yu H, Fan H, Li Z. The efficacy of noninvasive ventilation in managing postextubation respiratory failure: a meta-analysis. *Heart Lung* 2014;43(2):99-104. [PMID: 24594246](#)
- Brown LK, Javaheri S. Positive airway pressure device technology past and present: what's in the "Black Box"? *Sleep Med Clin* 2017;12(4):501-15. [PMID: 29108606](#)
- Martí C, García L, Ornaque I, Digon E, Fuhrán N, Bartolomé C, et al. Effectiveness of continuous positive airway pressure (CPAP) face mask Boussignac-Vygon as a treatment of acute respiratory failure. *Infection* 2005;1:158. [Link](#)
- Al-Mutairi FH, Fallows SJ, Abukhudair WA, Islam BB, Morris MM. Difference between continuous positive airway pressure via mask therapy and incentive spirometry to treat or prevent post-surgical atelectasis. *Saudi Med J* 2012;33(11):1190-5. [PMID: 23147875](#)
- El-Kader SM. Blood gases response to different breathing modalities in phase I of cardiac rehabilitation program after coronary artery bypass graft. *Eur J Gen Med* 2011;8(2):85-91. [Link](#)
- Altmay E, Karaca P, Yurtseven N, Özkul V, Aksoy T, Özler A, et al. Continuous positive airway pressure does not improve lung function after cardiac surgery. *Can J Anaesth* 2006;53(9):919-25. [PMID: 16960270](#)
- Akar Bayram N, Ciftci B, Durmaz T, Keles T, Yeter E, Akcay M, et al. Effects of continuous positive airway pressure therapy on left ventricular function assessed by tissue Doppler imaging in patients with obstructive sleep apnoea syndrome. *Eur J Echocardiogr* 2009;10(3):376-82. [PMID: 18845553](#)
- Souza Possa S, Braga Amador C, Meira Costa A, Takahama Sakamoto E, Seiko Kondo C, Maida Vasconcellos AL, et al. Implementation of a guideline for physical therapy in the postoperative period of upper abdominal surgery reduces the incidence of atelectasis and length of hospital stay. *Rev Port Pneumol* 2014;20(2):69-77. [PMID: 24290563](#)
- Pasquina P, Merlani P, Granier JM, Ricou B. Continuous positive airway pressure versus noninvasive pressure support ventilation to treat atelectasis after cardiac surgery. *Anesth Analg* 2004;99(4):1001-8. [PMID: 15385340](#)
- Ferreira GP, Baussano I, Squadrone V, Richiardi L, Marchiaro G, Del Sorbo L, et al. Continuous positive airway pressure for treatment of respiratory complications after abdominal surgery: a systematic review and meta-analysis. *Ann Surg* 2008;247(4):617-26. [PMID: 18362624](#)
- Oliveira JF, Mello FC, Rodrigues RS, Boechat AL, Conde MB, Menezes SL. Effect of continuous positive airway pressure on fluid absorption among patients with pleural effusion due to tuberculosis. *Rev Bras Fisioter* 2010;14(2):127-32. [PMID: 20464170](#)
- Naughton MT, Rahman MA, Hara K, Floras JS, Bradley TD. Effect of continuous positive airway pressure on intrathoracic and left ventricular transmural pressures in patients with congestive heart failure. *Circulation* 1995;91(6):1725-31. [PMID: 7882480](#)
- Gust R, Gottschalk A, Schmidt H, Böttiger BW, Böhner H, Martin E. Effects of continuous (CPAP) and bi-level positive airway pressure (BiPAP) on extravascular lung water after

- extubation of the trachea in patients following coronary artery bypass grafting. *Intensive Care Med* 1996; 22(12):1345-50. PMID: [8986484](#)
27. Pengo MF, Bonafini S, Fava C, Steier J. Cardiorespiratory interaction with continuous positive airway pressure. *J Thorac Dis* 2018;10(Suppl 1):S57-70. PMID: [29445529](#)
28. Kaye DM, Mansfield D, Naughton MT. Continuous positive airway pressure decreases myocardial oxygen consumption in heart failure. *Clin Sci* 2004;106(6):599-603. PMID: [14756635](#)
29. Vianello A, Arcaro G, Gallan F, Ori C, Bevilacqua M. Pneumothorax associated with long-term non-invasive positive pressure ventilation in Duchenne muscular dystrophy. *Neuromuscul Disord* 2004;14(6):353-5. PMID: [15145335](#)
30. Lee BR, Shin SH, Kim MJ, Kim E, Choi YJ, Park JD, et al. Clinical characteristics of pediatric pneumothorax during a noninvasive positive pressure ventilation. *Allergy Asthma Respir Dis* 2019;7(1):51-6. [Link](#)
31. Gunduz M, Unlugenc H, Ozalevli M, Inanoglu K, Akman H. A comparative study of continuous positive airway pressure (CPAP) and intermittent positive pressure ventilation (IPPV) in patients with flail chest. *Emerg Med J* 2005;22(5):325-9. PMID: [15843697](#)
32. Pinto VL, Sharma S. Continuous positive airway pressure (CPAP). New York: StatPearls Publishing; 2019. PMID: [29489216](#)