Difference between continuous positive airway pressure via mask therapy and incentive spirometry to treat or prevent post-surgical atelectasis

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ABSTRACT

الأهداف: تقييم تأثير استخدام جهاز المساعدة على التنفس (CPAP) بواسطة كمامة لعلاج الانخماص الرئوي بعد إجراء العمليات الجراحية للقلب المفتوح.

الطريقة: لقد هدفت هذه الدراسة الاستفتائية الدراسة إلى مشاركة 32 مشارك لكي تصبح نتائج الدراسة إيجابية. وقد شملت 108 مريض من مستشفى الملك فهد للقوات المسلحة، جدة، المملكة العربية السعودية وذلك خلال الفترة من مارس 2010م إلى مارس 2011م. وكان هؤلاء المرضى من الذين أجروا عمليات جراحية للقلب المفتوح وانطبقت عليهم متطلبات الدراسة. لقد تم تقسيم المشاركين عشوائياً إلى ثلاث مجموعات وهي كالتالي: مجموعة قياس النفس المحفز (IS)، ومجموعة جهاز المساعدة على التنفس (CPAP) كل ساعتين، ومجموعة جهاز المساعدة على التنفس كل أربع ساعات. واُستخدم قياس السعة الشهيقية (ICs) باللترات لمقارنة تقدم الثلاثة طرق، وفي نفس الوقت تم قياس معدل التنفس، ومعدل نبضات القلب، ونسبة الأوكسجين بالدم لكل المجموعات. كما وعُرفت حالة الفشل للطرق العلاجية المستخدمة في الدراسة عندما يحتاج المريض للتنفس الصناعي، أو جهاز المساعدة على التنفس المتقدم، أو العلاج الطبيعي للصدر.

النتائج: لقد شارك 36 مشارك في كل مجموعة (98 ذكر و10 إناث بين الأعمار 9.3±62 عاماً). وأشارت نتائج الدراسة بأن السعة الشهيقية قد زادت بشكل كبير في مجموعة جهاز المساعدة على التنفس لكل ساعتين بالمقارنة مع مجموعة قياس النفس المحفز (مجموعة الشاهد)، أو مجموعة جهاز المساعدة على التنفس لكل أربع ساعات. كما ونقصت نسبة الأوكسجين بالدم بشكل كبير في مجموعة قياس النفس المحفز، ومجموعة جهاز المساعدة على التنفس لكل أربع ساعات بالمقارنة مع مجموعة جهاز المساعدة على التنفس لكل ساعتين. ولكن لم يلاحظ فرق كبير في معدل التنفس، ومعدل نبضات القلب بين المجموعات الثلاثة.

خاتمة: أظهرت الدراسة بأن استخدام جهاز المساعدة على التنفس مبكراً بواسطة كمامة لمدة نصف ساعة كل ساعتين يعطي نتائج أفضل في إعادة فتح حجيرات الهواء في الرئتين بعد إجراء العمليات الجراحية للقلب المفتوح.

Objectives: To assess the effect of early use of continuous positive airway pressure (CPAP) therapy to treat or prevent acute atelectasis in post-operative cardiac patients particularly smokers and elderly patients.

Methods: A pilot study suggested enrolling at least 32 participants in each group to be significant. One hundred and eight patients from King Fahd Armed Forces Hospital, Jeddah, Kingdom of Saudi Arabia who met the inclusion criteria participated in this study conducted between March 2010 and March 2011. The participants were divided randomly into 3 groups, incentive spirometry (IS) therapy, and CPAP therapy every 2 (CPAP2hrs), or 4 hours (CPAP4hrs). Inspiratory capacity (IC) was used to compare the 3 therapy regimes. Simultaneously, respiratory rate (RR), heart rate (HR) and oxygen saturation (SpO_2) were measured for all groups. Failure was defined as requiring intubation, bi-level positive airway pressure, or added chest physiotherapy.

Results: Thirty-six patients participated in each group (98 male and 10 female, with a mean age of 62±9.3 years). The IC increased significantly in the CPAP2hrs group when compared with the control group or the CPAP4hrs group. The SpO_2 decreased significantly in the control group and the CPAP4hrs groups when compared with the CPAP2hrs group. Also, there were no significant differences in RR and HR between all groups.

Conclusion: Early use of CPAP via mask therapy for half an hour every 2 hours had better outcomes to re-open collapsed alveoli after cardiac surgery.

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Atelectasis is a medical complication that may affect part of one lung or both lungs as a result of the lungs not fully inflating. It is regularly described as a collapse of the lung tissue but is not identical with a collapsed lung, which is a more specific condition that features atelectasis.[1] Atelectasis may be either an acute or chronic condition.[2] The most common cause of acute atelectasis is post-surgical atelectasis, characterized by restricted breathing after thoracic or abdominal surgery. Smokers and elderly people are at an increased risk of atelectasis, and it is those groups of patients targeted in this study.[3] There is a large number of coronary artery bypass graft (CABG) performed in the worldwide and there is a high occurrence of post-operative pulmonary complications in cardiac surgery (range 20-95%).[4] The high incidence of PPCs can result in high mortality and increased length of hospital stay, which leads to an increase in the cost of the surgery. Several studies[5,6] have been conducted in the last decade to recognize those patients with high risk of PPCs and the best methods to treat or prevent these complications.

The goal of atelectasis treatment is to remove lung secretions and re-expand the affected lung tissue. Post-surgical atelectasis can be treated by chest physiotherapy (CPT), focusing on deep breathing and encouraging coughing.[7] Incentive spirometry (IS) (the regular method to treat atelectasis) is often used as part of the breathing exercises, and is also used to prevent atelectasis after surgery.[8] Once the IS therapy is used frequently on a regular basis; airway patency can be maintained and alveolar atelectasis can be prevented or reversed.[9] However, the effectiveness of IS therapy has been questioned by several publications,[10-12] and other publications that argue the use of IS therapy for major post- operative patients.[4,9,13]

Continuous positive airway pressure (CPAP) therapy is part of a main group of therapies called non-invasive ventilation (NIV) or non-invasive positive pressure ventilation (NPPV).[14] The clinical use of NPPV began with the introduction of intermittent positive pressure breathing (IPPB) in 1947,[16] which was widely used to deliver aerosolized medications for 10-15 minutes several times a day. When Sullivan and colleagues introduced the CPAP via mask in 1981,[15] it became the initial choice for the management of obstructive sleep apnea, and was later used successfully with acute respiratory failure. During the last decade, the CPAP delivery system has been significantly developed in the technology and patient interfaces.[16]

In the past, several studies[2,9,17-19] used CPAP therapy to treat PPCs and found no significant difference from other therapies. However, the type of CPAP delivery system used was not a standalone system and without any new features, such as auto-leak compensation, the period of CPAP therapy was shorter (10 to 15 minutes), and the frequency of the therapy was fewer (2-4 times a day). The above characteristics will influence the effectiveness of CPAP therapy. All methods of therapy such as IS, coughing and breathing exercises, or CPAP have a valuable role to play in the prevention or the treatment of post-operative pulmonary complications. However, the type of therapy that should be used is not completely clear yet.

Therefore, this study aims to assess the effect of the early use of CPAP via mask therapy to treat or prevent acute atelectasis in post-operative cardiac patients particularly smokers and elderly patients

Methods. This prospective randomized study recruited participants from patients scheduled for cardiac surgery in King Fahd Armed Forces Hospital in Jeddah, Saudi Arabia from March 2010 to March 2011. A pilot study was carried out to examine the significance of the sample size, and it was suggested to enroll at least 32 participants in each group to be significant. The patients who agreed to participate in the study came to the hospital to read the participant's sheet before the cardiac surgery and sign the consent form. The present study follows the guidelines for medical research involving human subjects according to the principles of the Helsinki Declaration. All procedures in this study followed King Fahd Armed Forces Hospital patient safety guidelines, which are based on American guidelines. The King Fahd Armed Forces Hospital Research and Ethics Committee approved this study.

One hundred and twenty participants agreed to enroll in the study; however, 5 of them refused to participate after the cardiac surgery, and 7 were excluded as they developed one or more of the exclusion criteria after the surgery. One hundred and eight post cardiac surgery patients who met the inclusion criteria (smoker, hemodynamically stable, healthy lungs, and above 50 years old) participated in this study. Patients who had massive atelectasis (more than 50% of alveolar collapse), predicted mortality rate more than 30% (depending on pre-surgery patient's assessment), undergone repeat cardiac surgery, severe pulmonary edema, severe bleeding (more than 100 ml per hour), history of chronic lung diseases, unstable

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angina, and contraindication for CPAP or IS therapy were excluded. The participants were divided randomly into 3 groups; the control group used IS (Respiflo 5000 incentive spirometer, Tyco Healthcare Group LP, Mansfield, Massachusetts, USA) 15 times per hour. The first trial group used CPAP via mask (4-6 cmH_2O) (the type of CPAP delivery system used in this study is ResMed VPAP III, ResMed, Milton, Australia) for half hour every 2 hours, while the second trial group used CPAP via mask (4-6 cmH_2O) for half hour every 2 hours. Each group used the therapy for 3 days after extubation during the wake-up hours in the cardiac unit (usually from 6 am to 8 pm). Inspiratory capacity (IC) (a maximum volume of air inhaled after a normal expiration) measured in liters was used to compare the 3 therapy regimes. The IC was measured by an incentive spirometer (Respiflo 5000 incentive spirometer, Tyco Healthcare Group LP, Mansfield, Massachusetts, USA) and to confirm the accuracy and reliability of IC measurements, the participants were asked to repeat the test 3 times and the largest volume was taken. The IC was measured after the cardiac operation as baseline-test, after 12 hours from the start of each therapy, after 24 hours, 48 hours, and post therapy. Simultaneously, respiratory rate (RR), heart rate (HR) and saturation of peripheral oxygen (SpO_2%) (saturation of arterial oxygen is a ratio expressed as a percentage of the volume of oxygen carried to the maximum volume that can be carried by the hemoglobin and measured by a pulse oximeter device) were measured for all groups. Also, chest x-ray was performed to confirm the improvement or the prevention of post-surgical atelectasis (categorized as zero=normal, 1=mild, 2=moderate, or 3=severe atelectasis) and sputum induction (a procedure to obtain deeply coughed-out sputum) was taken to clarify chest infection or pneumonia (categorized as zero=no growth, 1=mild, 2=moderate, or 3=heavy growth). Failure was defined as a need for advanced therapy such as mechanical ventilation and bi-level positive airway pressure (BiPAP) or added CPT therapy. In addition, secondary end points consisted of length of stay in hospital and 30 days mortality.

The Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) version 18.0 was used for the analyses of data, and one-way mixed model ANOVA and Tukey post-hoc tests were used to examine the differences between the baseline and post therapy. The Shapiro-Wilk test was used to explore the data outcomes, and the results suggested the use of the parametric data test (*p*-value). Also, the mean, standard deviation (SD), and 95% confidence intervals (95% CI) were calculated for all variables measurements.

Results. Thirty-six patients participated in each group (98 male and 10 female with a mean age of 62±9.3 years). Twenty-six (72%) participants from the CPAP2hrs group succeeded to re-open the collapsed alveoli, 20 (55%) participants from CPAP4hrs group succeeded to re-open the collapsed alveoli, and 19 (53%) participants from the IS control group succeeded to re-open collapsed alveoli. The IC was increased significantly in the CPAP2hrs group (baseline mean for IS control group: 1.34L and CPAP2hrs group: 1.42L, post-therapy mean was 1.59L in the IS control group

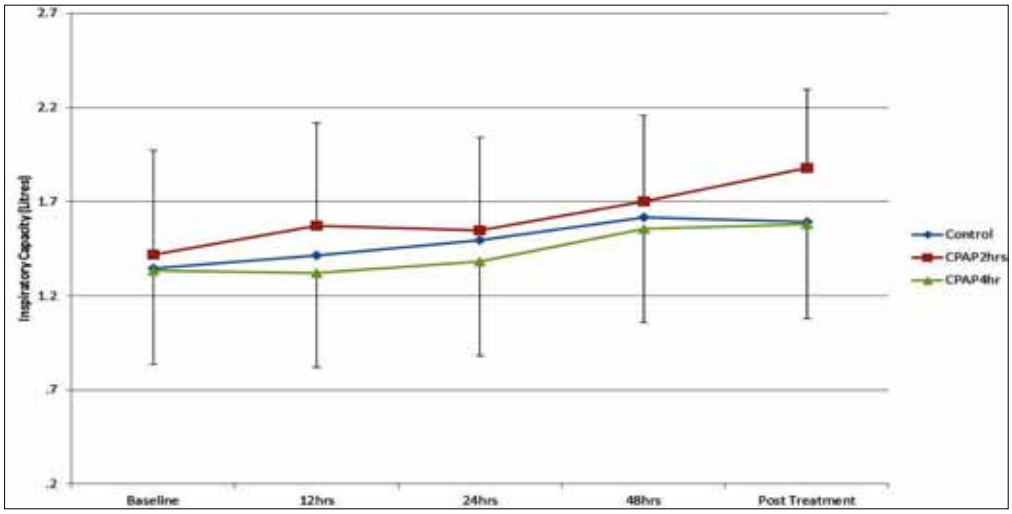

Figure 1 - Inspiratory capacity (IC) difference between continuous positive airway pressure (CPAP) every 2 hours therapy, every 4 hours, and control (incentive spiromtery [IS] therapy) group.

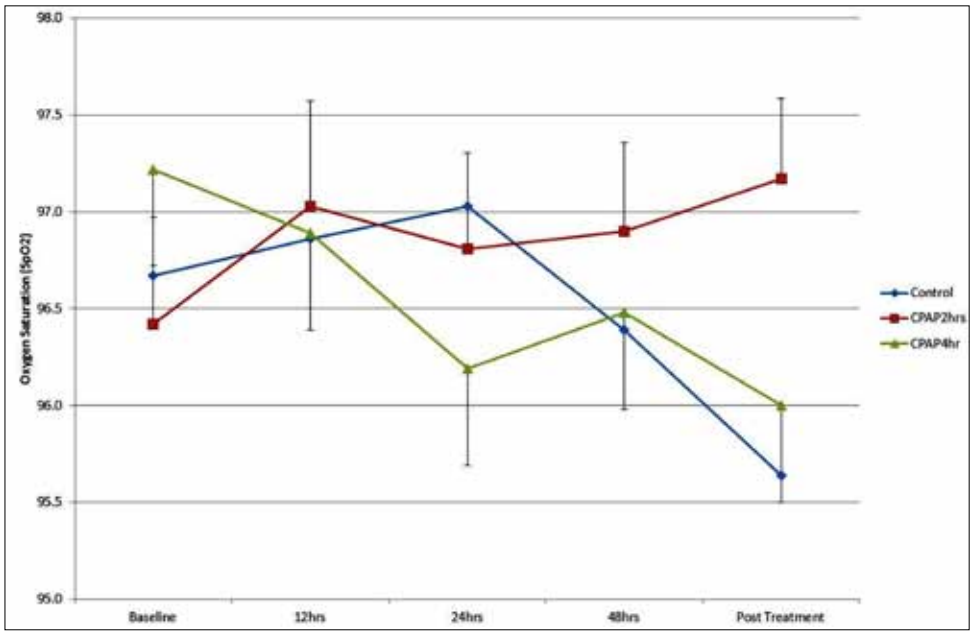

Figure 2 - Saturation of peripheral oxygen (SpO_2) difference between continuous positive airway pressure (CPAP) every 2 hours therapy, every 4 hours and control (incentive spiromtery [IS] therapy) groups.

and 1.88L in the CPAP2hrs group, p=0.037, 95% CI) (**Figure 1**). Also, when comparing the CPAP2hrs group with the CPAP4hrs group, there was a significant increase in IC in the CPAP2hrs group (baseline mean for CPAP2hrs: 1.42L, and CPAP4hrs: 1.33L, post therapy mean for CPAP2hrs: 1.88L, and CPAP4hrs: 1.58L, p=0.027, 95% CI). However, there was no significant difference in IC between the IS control group and the CPAP4hrs group (baseline mean for IS control group 1.34L and CPAP4hrs 1.33L, post-therapy mean for IS group: 1.59L, and for CPAP4hrs group 1.58L, p=0.99, 95% CI). The SpO_2 was decreased significantly more in the IS group as compared with the CPAP2hrs group (baseline mean 96.67% for IS group and 96.42% for CPAP2hrs group; post-therapy 95.6% for IS group, and 97.17% for CPAP2hrs group, p=0.001, 95% CI) (**Figure 2**). Also, the SpO_2 was decreased significantly more in the CPAP4hrs group as compared with the CPAP2hrs group (baseline mean 97.2% for CPAP4hrs, 96.42% CPAP2hrs; post-therapy 96% for CPAP4hrs and 97.2% CPAP2hrs, p=0.004, 95% CI). However, there was no significant difference in SpO_2 between IS control group and CPAP4hrs group (p=0.569). In addition, there were no significant differences in RR and HR between all groups of therapies.

The chest x-ray results confirmed an improvement in IC in the CPAP2hrs group; most of the successful participants had a zero category result (normal lungs) post therapy, while a baseline measurement resulted in one to 2 categories (mild to moderate atelectasis). Also, most of the sputum sample baseline measurements for all successful participants had very light to mild category result, and cleared or very light growth post therapies in all groups. However, some of unsuccessful participants had mild to moderate growth in sputum induction (4 participants from CPAP2hrs, 6 participants from CPAP4hrs, and 5 participants from the IS control group). In addition, most of participants who had heavy growth category in sputum induction at baseline measurements were not successful in all groups of therapies.

The average hospital stay for the IS control group was 9.5 days, CPAP2hrs group was 8.7 days, while the CPAP4hrs group was 9 days. There was a decrease in the hospital stay in the CPAP2hr group by almost one day as compared with the IS control group. Also, one participant from the CPAP2hrs group died within 30 days after the cardiac surgery, 2 died from the CPAP4hrs group, while nobody died from the IS control group. However, the reasons for death were related to the development of other medical conditions such as renal or cardiac complications not related to post-pulmonary complications. There were no significant differences in the mortality rate among all the groups of therapies.

Discussion. The main finding of this prospective randomized study is that the early use of CPAP 2 hours therapy for post-cardiac surgery patients resulted in

statistically significant improvement in treating post-surgical atelectasis, and lead to improved outcomes and a shorter hospital stay.

The findings of this study failed to confirm the effectiveness of IS therapy to reduce PPCs after cardiac surgery. The previous studies had similar results;[20] for example, a systematic review by Overend[9] found no strong evidence to support the use of IS therapy for decreasing PPCs. Also, Freitas et al[2] conducted a randomized controlled trial to assess the effects of IS therapy for preventing PPCs (such as atelectasis and pneumonia). They found that there was no significant difference between the IS therapy and other therapies such as intermittent positive pressure breathing (IPPB). However, the IPPB therapy is an old method of therapy and this study uses the new standalone system to deliver CPAP therapy. In addition, Rezaiguia and Jayr's[21] results show an equivalence in efficacy between the 3 therapies (IS, CPT, and IPPB) while treating post-operative complications. They suggest post-operative therapy should be continued for 3-5 days to prevent pulmonary complications, which agreed with the used of the therapy for 3 consecutive days in this study.

The effectiveness of CPAP therapy is influence by 5 main components: the type of CPAP delivery system, the period of CPAP therapy, the frequency of CPAP therapy, the interface (the type of mask used in CPAP), and the person who applies the therapy to the patient. Despite, the importance of auto- leak compensation in the new type of CPAP delivery system, the period of CPAP therapy and the frequency used in this study is what makes the significant difference, as there is no significant difference between CPAP therapies for half an hour every four hours and IS therapy in this study. The 2 hour frequency used in this study made a significant difference, as we found no significant difference between CPAP 4hrs therapy and IS therapy in this study. This agreed with previous study findings that used IPPB therapy to deliver CPAP therapy, and found no significant difference between IPPB therapy and IS therapy.[2,9,19] However, this disagrees with a shorter time period and frequency of CPAP therapy used in the above studies.

The decrease in length of hospital stay by approximately one day in the CPAP2hrs group in this study will reduce the cost of cardiac surgery. The daily cost of a coronary cardiac unit (CCU) bed in the hospital, where this study was conducted, is approximately 1500 US dollars, and despite the extra daily cost of other medical services this 1500 US dollars reduction in cardiac surgery will be a substantial saving in the annual cardiac surgery budget. For example, in the CPAP2hrs group involving 36 participants in this study; the total cost reduction in this group is estimated at 54000 US dollars. Also, the shorter hospital stay will lead to a shorter waiting list for cardiac surgery patients. Previous studies confirm that the high incidence of post coronary artery bypass graft (CABG) pulmonary complications can result in high mortality and increased hospital stay, which leads to an increase in the cost of the surgery.[4-6]

Limitation. Due to the fact that all the participants in this study were smokers, which caused them to produce excessive secretions after the cardiac surgery, and despite the CPAP therapy in this study being applied by well-trained respiratory therapists who do their best to encourage the participants to expectorate the mucus by deep breathing and coughing, still some participants had thick mucus requiring CPT to remove the secretions. However, added CPT will lead to a failure in this study, which makes the removal of very thick secretions a limitation of this study. Also, even with the use of very soft gel masks to deliver the CPAP therapy in this study, and added DuoDERM gel to prevent allergy-prone skin from redness, some participants who have sensitive skin will have redness in the contact area of the nose after mask removal, especially female participants, making it uncomfortable for them to use it again. One of the goals of post-operative atelectasis treatment is to remove the airway secretions from the lungs, and the use of CPT is one of the limitations in the present study. Adding CPT may easily remove the lung secretions and improve the lung expansion therapy. Future prospective studies to assess the benefit of combined CPAP therapy with CPT may lead to better outcomes.

In conclusion, the early use of CPAP via mask therapy for half an hour every 2 hours had better outcomes to re-open collapsed alveoli after cardiac surgery, especially in smokers and elderly patients in this study. However, the present study investigated a sub-group of patients (elderly smoker patients with healthy lungs) and that not exclude the benefits of IS therapy use with other groups of patients.

References

1. White CG, editor. Basic clinical lab competencies for respiratory care. 4th ed. USA (NY): Delmar Cengage Learning; 2002. p. 230.
2. Freitas ER, Soares BG, Cardoso JR, Atallah AN. Incentive spirometry for preventing pulmonary complications after coronary artery bypass graft. ***Cochrane Database Syst Rev*** 2007; 3: CD004466.
3. Moritz F, Brousse B, Gellée B, Chajara A, L'Her E, Hellot MF, et al. Continuous positive airway pressure versus bilevel noninvasive ventilation in acute cardiogenic pulmonary edema: a randomized multicenter trial. ***Ann Emerg Med*** 2007; 50: 666-675.

4. Brooks D, Crowe J, Kelsey CJ, Lacy JB, Parsons J, Solway S. A clinical practice guideline on peri-operative cardiorespiratory physical therapy. ***Physiotherapy Canada*** 2001; 53: 9-25.
5. Lawrence VA, Cornell JE, Smetana GW; American College of Physicians. Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery: systematic review for the American College of Physicians. ***Ann Intern Med*** 2006; 144: 596-608.
6. Canet J, Mazo V. Postoperative pulmonary complications. ***Minerva Anestesiol*** 2010; 76: 138-143.
7. Placidi G, Cornacchia M, Polese G, Zanolla L, Assael BM, Braggion C. Chest physiotherapy with positive airway pressure: a pilot study of short-term effects on sputum clearance in patients with cystic fibrosis and severe airway obstruction. ***Respir Care*** 2006; 51: 1145-1153.
8. Agostini P, Singh S. Incentive spirometry following thoracic surgery: what should we be doing? ***Physiotherapy*** 2009; 95: 76-82.
9. Overend TJ, Anderson CM, Lucy SD, Bhatia C, Jonsson BI, Timmermans C. The effect of incentive spirometry on postoperative pulmonary complications: a systematic review. ***Chest*** 2001; 120: 971-978.
10. Renault JA, Costa-Val R, Rosseti MB, Houri Neto M. Comparison between deep breathing exercises and incentive spirometry after CABG surgery. ***Rev Bras Cir Cardiovasc*** 2009; 24: 165-172.
11. Brasher PA, McClelland KH, Denehy L, Story I. Does removal of deep breathing exercises from a physiotherapy program including pre-operative education and early mobilisation after cardiac surgery alter patient outcomes? ***Aust J Physiother*** 2003; 49: 165-173.
12. Guimarães MM, El Dib R, Smith AF, Matos D. Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. ***Cochrane Database Syst Rev*** 2009; 3: CD006058.
13. Pasquina P, Tramèr MR, Walder B. Prophylactic respiratory physiotherapy after cardiac surgery: systematic review. ***BMJ*** 2003; 327: 1379.
14. Thys F, Roeseler J, Reynaert M, Liistro G, Rodenstein DO. Noninvasive ventilation for acute respiratory failure: a prospective randomised placebo-controlled trial. ***Eur Respir J*** 2002; 20: 545-555.
15. Bakker J, Campbell A, Neill A. Randomized controlled trial comparing flexible and continuous positive airway pressure delivery: effects on compliance, objective and subjective sleepiness and vigilance. ***Sleep*** 2010; 33: 523-529.
16. Mehta S, Hill NS. Noninvasive ventilation. ***Am J Respir Crit Care Med*** 2001; 163: 540-577.
17. Renault JA, Costa-Val R, Rossetti MB. Respiratory physiotherapy in the pulmonary dysfunction after cardiac surgery. ***Rev Bras Cir Cardiovasc*** 2008; 23: 562-569.
18. Pasquina P, Tramèr MR, Granier JM, Walder B. Respiratory physiotherapy to prevent pulmonary complications after abdominal surgery: a systematic review. ***Chest*** 2006; 130: 1887-1899.
19. Denehy L, Carroll S, Ntoumenopoulos G, Jenkins S. AA randomized controlled trial comparing periodic mask CPAP with physiotherapy after abdominal surgery. ***Physiother Res Int*** 2001; 6: 236-250.
20. Restrepo RD, Wettstein R, Wittnebel L, Tracy M. Incentive spirometry: 2011. ***Respir Care*** 2011; 56: 1600-1604.
21. Rezaiguia S, Jayr C. [Prevention of respiratory complications after abdominal surgery]. ***Ann Fr Anesth Reanim*** 1996; 15: 623-646. French

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Habib SS, Abba AA, Al-Zoghaibi MA, Subhan MM. Reference range values of fractional exhaled nitric oxide in healthy Arab adult males. ***Saudi Med J*** 2009; 30: 1395-1400.

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Al-Saadi MM, Meo SA, Al-Drees AM, Mohamed S, Shaikh SA, Al-Rubeaan K. Lung functions in poorly controlled type 1 Saudi diabetic children and adolescents. ***Saudi Med J*** 2006; 27: 1240-1243.