Effect of Early Postoperative Noninvasive Ventilation on Arterial Blood Gas After Abdominal Surgery

Eurasian Clinical and Analytical Medicine Original Research

Early Postoperative Noninvasive Ventilation

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Abstract

Aim: In the present randomized controlled trial, we investigated the effects of early postoperative noninvasive ventilation on gas exchange and other parameters of arterial blood gas in patients scheduled for an upper abdominal surgery.

Material and Methods: Forty-four patients scheduled for upper abdominal surgery were allovasive ventilation for two hours postoperatively. pH, SaO2, PaCO2, and HCO3 values obtained preoperatively and postoperatively before and after the applications were compared.

Results: There was no statistically significant difference betwen the groups (p>0.05) in regard to demographic data (mean age, BMI, FEV1/FVC, anesthesia and surgery time, gender distribution). Noninvasive ventilation corrected the fall in pH values more effectively than the face mask oxygen application. SaO2 dropped significantly after the operation in both groups. Change percentage in SaO2, PaCO2, and HCO3 values after the applications were similar among groups.

Discussion:. There is no advantage of postoperative noninvasive ventilation in regard to early SaO2, PaCO2, or HCO3 values. Studies with more extended follow-up time and a larger number of subjects are needed for accurate data.

Keywords

Abdominal; Blood Gas Analysis; Noninvasive Ventilation; Surgical Procedures

DOI:10.4328/ECAM.93
Received : 23.05.2016
Accepted : 28.05.2016
Published Online : 01.09.2016
Printed Online : 01.09.2016
Eu Clin Anal Med 2016;4(3):82-6

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How to cite this article: Yeksan AN, Tunalı Y. Effect of Early Postoperative Noninvasive Ventilation on Arterial Blood Gas After Abdominal Surgery. Eu Clin Anal Med 2016;4(3): 82-6.

Introduction

Respiratory dysfunction is inevitable for both general anesthesia in which muscle paralysis and mechanical ventilation are ensured and regional anesthesia in which spontaneous breathing is preserved. That kind of dysfunction persists in the postoperative period and results in clinically important pulmonary complications in 1-2% of minor surgeries and in up to 20% of abdominal and thoracal surgeries [1]. Postoperative pulmonary complications (PPC) remain and are always a concern of clinicians because they are associated with prolonged hospital stay, increased morbidity/mortality, and increased healthcare costs. A multi-center prospective study including 2464 patients revealed that at least one pulmonary complication occured in 5% of patients in the postoperative period [2].

Impaired blood oxygenation occurs in most anesthetized patients. Atelectasis and hypoventilation due to residual drug effects are two of the most common causes of early postoperative hypoxemia [3]. Atelectasis occurs in 90% of anesthetized patients [4]. It is quite apparent that atelectatic lung is more prone to pulmonary complications. Hence, preventing atelectasis and recruiting collapsed alveoli are the main strategies in avoiding PPC. There are many maneuvers used for this purpose, including PEEP application, recruitment maneuver, sigh, double tidal volume, and avoiding 100% oxygen use to prevent absorbtion atelectasis [5,6,7]. Postoperative and perioperative noninvasive ventilation (NIV) is a more recently tried method for both the prophylactic and curative purposes of managing atelectasis, postoperative hypoxemia, and respiratory insufficiency [8-13].

There are risk factors that make patients more prone to PPC, including age, obesity, preexisting pulmonary disease, malnutrition, and muscle diseases. The type and time of surgery are also determinant in risk identification. Cardiac and thoracic surgery are the most risky procedures in this regard. Abdominal surgery does not prominently increase the rate of atelectesia formation, but it is more difficult and requires more time to recruit collapsed lung areas [14]. That is why lung infection and other pulmonary complications are more likely to occur in abdominal surgery [14,15].

Early postoperative hypoxemia and respiratory insufficiency is temporary and reversible in most cases. Residual drug effects, pain, and atelectasis are common causes of hypoxemia in this period [3,8]. In the present randomized controlled trial, we investigated the effect of the early postoperative prophylactic use of NIV on gas exchange and other parameters of arterial blood gas in patients scheduled for an upper abdominal surgery under general anesthesia.

Material and Methods

This prospective randomized controlled trial was performed in Cerrahpasa School of Medicine general surgery operating rooms during a two-month period after obtaining approval from the ethics committee and the informed consent of all participants. Patients scheduled for an upper abdominal surgery (liver surgery, Whipple procedure, gastrectomy, etc.) aged between 40-65 and who had a Tiffeneau-Pinelli index (ratio of forced expiratory volume in 1 second to forced vital capacity; FEV1/FVC) of 40-70% and a body mass index (BMI) of 30-40 kg.m-2 were included in the study. Patients with a history of cardiac arrest, postoperative agitation, encephalopathy, excessive respiratory secretion, or uncontrolled vomiting or who needed massive blood transfusion perioperatively were excluded from the study. Labile hemodynamics, hemoptysia, gastrointestinal bleeding, and any contraindication for epidural catheterization were the other excluding criteria of the present study.

On the day before the operation, blood samples for arterial blood gas (ABG) analysis were taken from all participants while resting and breathing room air. The preoperational pH, SaO2, PaCO2, and HCO3 measurements were all recorded. All patients were premedicated with intravenous 0.03 mg.kg-1 midazolam (Demizolam 5mg amp, Dem Drug Company, Istanbul, TURKEY) after ensuring a venous access with a 20 G IV cannula in the preparation room. Electrocardiography (ECG), noninvasive blood pressure, and peripheral oxygen saturation (SpO2) were employed for standard monitoring of hemodynamics of all patients in the operating room (Avance GE Healthcare, Madison, USA). A standard epidural catheter was inserted through a 18 G Tuohy tip epidural needle into the site of the 10-11th thoracic vertebral level with the patient in a sitting position for postoperative pain management with continous infusion of local anesthetic via a patient-controlled analgesia pump (CADD-LEGACY PCA, Model 6300, Smiths Medical, UK). Five centimeters of the cranially directed catheter was left in epidural space. The anesthesia induction was executed with intravenous 2 mg.kg-1 propofol (Propofol amp %1, Propofol Fresenius Kabi, Hamburg, Germany), 0.6mg.kg-1 rocuronium (Esmeron amp 10 mg.mL-1 Merck, Sharp & Dohme, Whitehouse Station, USA), and 1-2 μg.kg-1 fentanyl (Fentanyl amp 0.5 mg.10 mL-1, Abbott, Illinois, USA). Endotracheal tubes with an inner diameter of 7.5 and 8 mm respectively for females and males were used via the orotracheal route, and end-tidal carbon dioxide (EtCO2) was monitored for all patients after intubation. Maintenance of anesthesia was ensured with inhaled 1 MAC desflurane (Suprane volatile solution, Eczacıbası, Baxter, Puerto Rico, USA). Mechanical ventilation in volume-controlled mode was started with the parameters of FiO2: 40%, tidal volume: 6-8 mL.kg-1, respiratory frequency: 12/min, I/E 1/2, and PEEP: 6 cmH2O (Avance GE Healthcare, Madison, USA). The ventilation parameters were then adjusted according to EtCO2 levels targeting 35-38 mmHg partial carbon dioxide pressure in expired air.

Additional intravenous 50 μg fentanyl was given when the heart rate or mean blood pressure was increased by 20% compared to initial values, and 10 mg rocuronium was administered every 30 minutes. Local anesthetic (0.25% 10 ml bupivacaine; Marcaine 0.5% injectable solution, AstraZeneca, Lake Forest, USA) was given via the epidural route approximately 30 minutes before awakening. Fluid resuscitation was standardized as calculating maintenance fluid according to the 4/2/1 rule, based on body weight, and by administering additional intravenous fluid at a rate of 6-10 ml.kg-1.h-1 depending on incision size. Blood loss was replaced at a 1/1 rate with erythrocyte suspension and fresh frozen plasma. Total fluid balance was intervened so as not to exceed +1500 ml, and urine output was followed with a Foley catheter. Inhalational anesthetic was stopped after closure of the incision and decurarization was performed with intravenous 0.015 mg.kg-1 atropine and 0.03 mg.kg-1 neostigmine when first muscle effort was noticed after cessation of the gas. All patients were extubated after ensuring sufficient muscle strength and the ability to follow all commands. The patient-controlled analgesia method was used for managing postoperative pain. Bupivacaine solution (1 mg.ml-1) was prepared for epidural infusion at a rate of 4 ml.h-1 with bolus doses of 2 ml. The pump was set for 30 min lock-out intervals between the patient's demands.

The patients were randomly allocated into two groups (Group C as control group and Group N as study group) by closed envelope method in the recovery room. Each group consisted of 22 patients. The patients in Group C received 6 L.min-1 oxygen via an ordinary face mask and patients in Group N received NIV via an oronasal mask in BiPAP S/T mode (Respironics BiPap® Vision® Ventilatory Support System) with parameters of FiO2: 50%, EPAP: 5 cmH2O, and IPAP: 10 cmH2O for two hours. Blood samples were taken from all patients for ABG analysis before (at postoperative 10th minute) and after (at postoperative 2nd hour) these applications and SaO2, PaCO2, pH, HCO3 were all recorded again (Table 1).

In our study, preoperational values, postoperative values obtained before the application (postoperative 1), and postoperative values obtained after the application in the recovery room (postoperative 2) were compared for both groups.

Statistical Analyses

NCSS (Number Cruncher Statistical System, 2007) and PASS (Power Analysis and Sample Size, 2008 Statistical Software, Utah, USA) programs were used for statistical analysis of the obtained data in this study. Along with descriptive statistics (mean, standard deviation, median, frequency, and rate), intergroup comparison of quantitative data was also made using Student's t-test for the parameters normally distributed and Mann Whitney U test for the parameters not normally distributed. Repeated Measures and Bonferroni tests were employed for ingroup comparison of the parameters distributed normally and for post hoc analysis, respectively. Yates Continuity Correction and Fisher's exact tests were used for comparison of qualitative data. Results were evaluated at a 95% confidence and a p<0.05 significance level.

Results

This study was performed in Cerrahpasa School of Medicine monobloc theater between 01.02.2011-30.03.2011. Ninety-eight elective upper abdominal surgeries, including liver surgery, Whipple procedure, gastrectomy, cholesistectomy, and splenectomy were executed during this two-month period. 54 of the patients met our inclusion criteria. Eight patients refused to participate in the study and two later wanted to be excluded from the study because of oranasal face mask disturbance. Consequently, data from a total of 44 patients was collected in the present study.

There was no statistically significant difference among groups (p>0.05) considering demographic data (mean age, BMI, FEV1/FVC, anesthesia and surgery time, and gender distribution) (Table 2).

Mean pH values of Group C were significantly higher for preoperative and postoperative 1 (before the application) measurements (p<0.01), but there was no statistically significant difference (p=0.914) among groups when postoperative 2 mean pH values (after the application) were compared (Table 3). Both postoperative 1 and postoperative 2

Table 1. The recorded parameters and timing of follow-up.

	pH	SaO_2	$PaCO_2$	HCO_3
Preop*	+	+	+	+
Postop 1**	+	+	+	+
Postop 2***	+	+	+	+

*: Preoperational values,
**: Postoperative values obtained before the application,
***: Postoperative values obtained after the application.

Table 2. Comparison of demographic data among groups.

		Group C (n=22)	Grup N (n=22)	[a]p
		Mean±SD	Mean±SD	
Age (years)		55,95±15,98	55,41±12,38	0,900
BMI ($kg.m^{-2}$)		27,17±5,41	29,48±6,75	0,217
Anesthesia Time (min)		210,00±77,31	183,41±60,66	0,211
Surgery Time (min)		180,23±74,49	160,91±57,36	0,341
FEV_1/FVC (%)		88,45±10,68	91,18±9,20	0,369
		n (%)	n (%)	[b]p
Gender	Male	12 (%54,5)	11 (%50,0)	1,000
	Female	10 (%45,5)	11 (%50,0)	

[a]Student t Test [b]Yates Continiuty Correction Test [c]Mann Whitney U test

Table 3. In-group and inter-group comparison of pH values

pH	Group C (n=22)	Group N (n=22)	[a]p
	Mean±SD	Mean±SD	
Preop	7,44±0,04	7,41±0,04	0,002**
Postop 1	7,38±0,03	7,36±0,03	0,005**
Postop 2	7,39±0,05	7,39±0,04	0,914
[c]p	0,001**	0,001**	
[d]Preop-Postop 1	0,001**	0,001**	
[d]Preop-Postop 2	0,001**	0,755	
[d]Postop 1- Postop 2	0,500	0,001**	
Change (%)	**Median (Min-Max)**	**Median (Min-Max)**	**[b]p**
Preop-Postop 1	-0,80 (-1,61-0)	-0,61 (-1,48-0,41)	0,280
Preop-Postop 2	-0,60 (-1,74-1,09)	-0,27 (-0,81-0,95)	0,009**
Postop 1- Postop 2	-0,07 (-0,68-1,36)	-0,41 (-0,14-1,09)	0,014*

[a]Student t Test [b]Mann Whitney U Test [c]Repeated Measures Test
[d]Adjustment for multiple comparisons: Bonferroni test *p<0,05 **p<0,01

Table 4. In-group and inter-group comparison of SaO_2 values.

SaO2	Group C (n=22)	Group N (n=22)	[a]p
	Mean±SD	Mean ±SD	
Preop	97,63±1,59	97,13±1,82	0,329
Postop 1	94,72±3,00	93,92±5,89	0,573
Postop 2	98,55±0,97	97,49±2,32	0,054
[c]p	0,001**	0,010*	
[d]Preop-Postop 1	Tedavi öncesi (TÖ)	0,047*	
[d]Preop-Postop 2	Tedavi sonrası (TS)	1,000	
[d]Postop 1- Postop 2	0,001**	0,007**	
Change (%)	**Medyan (Min-Mak)**	**Medyan (Min-Mak)**	**[b]p**
Preop-Postop 1	-2,31 (-10,92-1,16)	-1,81 (-21,28-7,58)	0,549
Preop-Postop 2	0,72 (-1,50-4,75)	0,72 (-7,67-9,23)	0,460
Postop 1- Postop 2	3,44 (-0,30-11,24)	1,86 (0-23,08)	0,218

[a]Student t Test [b]Mann Whitney U Test [d]Adjustment for multiple comparisons: Bonferroni test *p<0,05 **p<0,01

Table 5. In-group and inter-group comparison of PaCO2 values.

$PaCO_2$	Group C (n=22)	Group N (n=22)	[a]p
	Mean ±SD	Mean ±SD	
Preop	34,13±3,69	35,95±3,37	0,096
Postop 1	39,00±3,99	39,68±7,93	0,649
Postop 2	38,21±4,44	39,80±15,51	0,647
[c]p	0,001**	0,261	
[d]Preop-Postop 1	0,001**	0,112	
[d]Preop-Postop 2	0,002**	0,784	
[d]Postop 1- Postop 2	1,000	1,000	
Change (%)	**Median (Min-Max)**	**Median (Min-Max)**	**[b]p**
Preop-Postop 1	14,95 (-9,40-47,16)	6,80 (-18,78-97,47)	0,098
Preop-Postop 2	11,05 (-17,63-49,32)	4,68 (-25,26-191,87)	0,069
Postop 1- Postop 2	-3,20 (-22,52-18,24)	-3,85 (-45,38-179,53)	0,342

[a]Student t Test [b]Mann Whitney U Test [c]Repeated Measures Test [d]Adjustment for multiple comparisons: Bonferroni test **p<0,01

Table 6. In-group and inter-group comparison of HCO3 values.

HCO_3	Group C (n=22)	Group N (n=22)	[a]p
	Mean±SD	Mean±SD	
Preop	24,62±2,50	23,77±1,65	0,193
Postop 1	23,14±2,02	21,88±1,87	0,037*
Postop 2	23,77±1,93	23,11±1,65	0,231
[c]p	0,027*	0,001**	
[d]Preop-Postop 1	0,022*	0,001**	
[d]Preop-Postop 2	0,190	0,165	
[d]Postop 1- Postop 2	0,167	0,001**	
Change (%)	**Median (Min-Max)**	**Median (Min-Max)**	**[b]p**
Preop-Postop 1	-5,81 (-23,55-15,02)	-7,75 (-19,11-3,86)	0,318
Preop-Postop 2	-3,19 (-21,88-10,30)	-2,53 (-12,06-12,11)	0,917
Postop 1- Postop 2	2,64 (-8,13-18,98)	5,15 (-0,74-13,64)	0,082

[a]Student t Test [b]Mann Whitney U Test [c]Repeated Measures Test [d]Adjustment for multiple comparisons: Bonferroni test *p<0,05 **p<0,01

mean pH values were significantly lower than mean preoperative pH value in Group C. Mean postoperative 1 pH value (before application) was also significantly lower than mean preoperative value in Group N (p=0.01); unlike Group C, mean postoperative 2 (after application) pH value was similar to preoperative value (p=0.755) in Group N (Table 3). This result showed that noninvasive ventilation corrected the fall in pH values more effectively than the face mask oxygen application.

The mean preoperative SaO2 values were similar among groups (p=0.557). Althoughthere was a similar fall in SaO2 values in both groups (p=0.255) when preoperative and postoperative 1 (before application) measurements were compared, this fall was corrected by a similar percentage (p=0.405) with both applications when the postoperative 1 (before application) - postoperative 2 (after application) SaO2 change percentage value was calculated (Table 4).

The mean preoperative PaCO2 values were similar for eachgroup (p=0.096). Although there was a similar rise in PaCO2 values in both groups (p=0.098) when preoperative and postoperative 1 (before application) measurements were compared, this rise was corrected by a similar percentage (p=0.342) with both applications when the postoperative 1 (before application) - postoperative 2 (after application) PaCO2 change percentage value was calculated (Table 5).

The mean preoperative HCO3 values were similar for each group (p=0.193). Although there was a similar fall in HCO3 values in both groups (p=0.318) when preoperative and postoperative 1 (before application) measurements were compared, this fall was corrected by a similar percentage (p=0.082) with both applications when the postoperative 1 (before application) - postoperative 2 (after application) HCO3 change percentage value was compared (Table 6).

Discussion

Hypoxemia is common in the early postoperative period. Hence, prophylactic oxygen supplementation in this period is a frequent application. Many studies have investigated whether oxygen is actually needed in the recovery room or not. Russel et al. observed 100 patients operated on under general or regional anesthesia. Early desaturation (SpO2<92) was found in 15% of the patients upon arrival in the recovery room. This early desaturation was found to have positive correlation with age, weight, anesthesia time, perioperative fluid balance over +1500 ml, female gender, and general anesthesia [16]. In another study, oxygen administration was cessated after 30 minutes in the recovery room [3]. At least one hypoxemic episode occured in 41% of 173 patients; intermediate or severe hypoxemia occurred in 64% of these episodes, more than expected [3]. On the contrary, DiBenetto et al. reported that 63% of 500 patients under room air in a recovery room did not need supplemental oxygen because their SpO2 levels did not drop below 94%. Authors defended the opinion of not supplying prophylactic oxygen based on this study [17]. Mean age, BMI, anesthesia time, and gender distribution were similar among groups in the present study. All patients for whom fluid balance was restricted to be under +1500 were operated on under general anesthesia (Table 2). SaO2 levels at the 10th minute (represented by the postoperative 1 value), obtained before oxygen or NIV application, dropped significantly when compared to preoperative measurements in both groups (Table 4). This supports the idea of prophylactic oxygen administration in the early postoperative period.

Pain is among the main causes of early postoperative hypoxemia [3,8]. Postoperative pain control was provided with epidural bupivacaine infusion with a PCA pump to prevent severe pain that could invalidate the results of this study. There is a positive correlation among BMI and atelectesia formation under anesthesia [18,19]. Chronic obstructive lung disease is another risk factor for postoperative hypoxemia [19]. Hence, the participants of this study were chosen among patients having FEV1/FVC of 40-70% and BMI of 30-40 kg.m2. However, mean BMI and FEV1/FVC values were similar in each group so the results were not expected to be affected by these particular risk factors. Additionally, hypoxemia occurs in 30-50% of patients undergoing upper abdominal surgery [8]. In view of these factors, it can be claimed that the subjects of this study were under high risk for postoperative hypoxemia occurrence.

A published meta-analysis of all related papers that were published between 1966-1992 revealed decreased PPC rates when different maneuvers, such as incentive spirometry, intermittent valsalva maneuvers, and deep inspiration exercise, were evaluated [19]. More recently, NIV, also an airway pressure increasing method, has been tried for prophylactic purposes after various surgery types. In these trials, better oxygenation, decreased PPC, and earlier pulmonary function regain were the results in the groups receiving NIV [10-13]. Prophylactic use of NIV also resulted in correction of impaired oxygenation in our study group. However, impairment in oxygenation on the postoperative 1 measurements (before application) was remedied in a similar percentage in the control group (Table 4). So, in our study, there was no advantage of early postoperative NIV application regarding oxygenation than in most other studies. However, the methodologies of prophylactic NIV studies following abdominal surgery are different from the present study's methodologies. Most used CPAP instead of BiPAP and none of the control group patients received oxygen via face mask as in the present study [20-24]. In prophylactic BiPAP after abdominal surgery studies, the follow-up time was longer than ours. Also, oxygenation parameters have been shown to be better in more recent study groups [25,26].

None of the above-mentioned studies emphasized ABG parameters other than oxygenation and ventilation. In contrast, we compared pH and HCO3 values statistically and revealed that the deterioration in pH value on postoperative measurements before application was corrected more effectively in the NIV group than in the control group. However, this has no clinical significance because the fall in pH values did not exceed the acidosis threshold.

Postoperative pain is one of the most determinant factors for respiratory function in the early postoperative period, especially after major abdominal surgery. All study participants used patient-controlled analgesia pumps for local anesthetic administration via the epidural route to manage their postoperative pain. The pain situation of patients was not evaluated postoperatively to reveal if there was a difference among the groups in this regard. The study results would be more significant if preoperative and postoperative spirometric evaluations were

also carried out, together with arterial blood gas analysis, and if the follow-up time was long enough to fully reveal effects of NIV. All these points are limitations to the present study.

In conclusion, there was no advantage of early postoperative NIV after upper abdominal surgery in regard to pH, SaO2, PaCO2, or HCO3 values when compared to face mask oxygen application. However, our follow-up time was two hours postoperatively; there is a need for studies with extended follow-up time and a larger number of subjects for more accurate data.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

Funding: None

Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

References

1. Kroenke K, Lawrence VA, Theroux JF, Tuley MR, Hilsenbeck S.Postoperative complications after thoracic and major abdominal surgery in patients with and without obstructive lung disease. Chest 1993;104(5):1445-51.
2. Canet J, Gallart L, Gomar C, Paluzie G, Vallès J, Castillo J, Sabaté S, Mazo V, Briones Z, Sanchis J. Prediction of postoperative pulmonary complications in a population-based surgical cohort. Anesthesiology 2010;113(6):1338-50.
3. Daley M.D, Norman P.H, Colmenares M.E, Sandler A.N. Hypoxaemia in adults in the post-anaesthesia care unit. Canadian Journal of Anaesthesia 1991;38(6):740-6.
4. Gunnarsson L, Tokics L, Gustavsson H, Hedenstierna G.Influence of age on atelectasis formation and gas exchange impairment during general anaesthesia. Br J Anaesth 1991;66(4):423-32.
5. Hedenstierna G, Edmark L.The effects of anesthesia and muscle paralysis on the respiratory system. Intensive Care Med 2005;31(10):1327-35.
6. Rothen HU, Sporre B, Engberg G, Wegenius G, Hedenstierna G.Re-expansion of atelectasis during general anaesthesia: a computed tomography study. Br J Anaesth 1993;71(6):788-95.
7. Rusca M, Proietti S, Schnyder P, Frascarolo P, Hedenstierna G, Spahn D.R, Magnusson L. Prevention of Atelectasis Formation During Induction of General Anesthesia. Anesth Analg 2003;97:1835–9.
8. Jaber S, Chanques G, Jung B. Postoperative noninvasive ventilation. Anesthesiology 2010;112(2):453-61.
9. Carron M, Zarantonello F, Tellaroli P, Ori C. Perioperative noninvasive ventilation in obese patients: a qualitative review and meta-analysis. Anaesthesiol 2006;23(2):154-9.
10. Aguilo R, Togores B, Pons S, Mateu R, Barbé F, Agusti A. Noninvasive ventilatory support after lung resectional surgery. Chest 1997;112:117–21.
11. Perrin C, Jullien V, Vénissac N, Berthier F, Padovani B, Guillot F, Coussement A, Mouroux J: Prophylactic use of noninvasive ventilation in patients undergoing lung resectional surgery. Respir Med 2007;101:1572–8.
12. Jousela I, Räsänen J, Verkkala K, Lamminen A, Mäkeläinen A, Nikki P. Continuous positive airway pressure by mask in patients after coronary surgery. Acta Anaesthesiol Scand 1994;38(4):311-6.
13. 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.
14. Van Kaam AH, Lachmann RA, Herting E, De Jaegere A, van Iwaarden F, Noorduyn LA, at al. Reducing atelectasis attenuates bacterial growth and translocation in experimental pneumonia. Am J Respir Crit Care Med 2004;169(9):1046-53.
15. Miller R.D, editor. Miller' s Anesthesia Volume 2. 7th ed. Philadelphia: Elsevier; 2010.
16. Russell G.B, Graybeal J.M. Hypoxemic Episodes of Patients in a Postanesthesia Care Unit. Chest 1993;104:899-903.
17. DiBenedetto RJ, Graves SA, Gravenstein N, Konicek C. Pulse oximetry monitoring can change routine oxygen supplementation practices in the postanesthesia care unit. Anesth Analg 1994;78(2):365-8.
18. How to inform a morbidly obese patient on the specific risk to develop postoperative pulmonary complications using evidence-based methodology. Eur J Anaesthesiol 2006;23(2):154-9.
19. Thomas JA, McIntosh JM. Are incentive spirometry, intermittent positive pressure breathing, and deep breathing exercises effective in the prevention of postoperative pulmonary complications after upper abdominal surgery? A systematic overview and meta-analysis. Phys Ther 1994;74(1):3-10.
20. Stock M, Downs J, Gauer P, Alster J, Imrey P: Prevention of postoperative pulmonary complications with CPAP, incentive spirometry, and conservative therapy. Chest 1985;87:151–7.
21. Bohner H, Kindgen-Milles D, Grust A,Buhl R, Lillotte WC, et al. Prophylactic nasal continuous positive airway pressure after major vascular surgery: results of a prospective randomized trial. Langenbecks Arch Surg 2002;387(1):21-6.
22. Anderes C, Anderes U, Gasser D, Dittmann M, Turner J, Brennwald J, el al. Postoperative spontaneous breathing with CPAP to normalize late postoperative oxygenation. Intensive Care Med 1979;5(1):15-21.
23. Carlsson C, Sonden B, Thylen U.Can postoperative continuous positive airway pressure (CPAP) prevent pulmonary complications after abdominal surgery? Intensive Care Med 1981;7(5):225-9.
24. Denehy L, Carroll S, Ntoumenopoulos G, Jenkins S. A randomized controlled trial comparing periodic mask CPAP with physiotherapy after abdominal surgery. Physiother Res Int 2001;6(4):236-50.
25. Joris J, Sottiaux T, Chiche J, Desaive C, Lamy M: Effect of bi-level positive airway pressure (BiPAP) on the postoperative pulmonary restrictive syndrome in obese patients undergoing gastroplasty. Chest 1997;111:665–70.
26. Ebeo CT, Benotti PN, Byrd RP Jr, Elmaghraby Z, Lui J. The effect of bi-level positive airway pressure on postoperative pulmonary function following gastric surgery for obesity. Respir Med 2002;96(9):672-6.