

Comparison of Effect of Noninvasive Pressure Techniques on Postoperative Pulmonary Functions in Patients Undergoing Major Abdominal Surgery

Noninvazif Basınç Tekniklerinin Major Abdominal Cerrahi Olgularında Postoperatif Solunum Fonksiyonlarına Etkilerinin Karşılaştırılması

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Abstract

Objective: The objective of the study was to examine the superiority of postoperative noninvasive pressure techniques over each other in terms of pulmonary function tests (PFTs), arterial blood gas tests, and lung complication development in patients undergoing major abdominal surgery.

Material and Methods: In total, 45 patients aged between 20 and 80 years, with ASA (American Society of Anesthesiologists) I-III, and undergoing major abdominal surgery were equally and prospectively randomized into three groups in terms of the use of postoperative control (Group A), continuous positive airway pressure (Group B), and noninvasive pressure support ventilation (Group C). Preoperatively and at postoperative hour 0, hour 6, and hour 24, hemodynamic and arterial blood gas test data were recorded. Additionally, PFTs and chest radiography were performed using pre- and postoperative techniques.

Results: A statistically significant difference was found between the systolic and diastolic blood pressures at postoperative hour 6 among the groups in our study. However, when arterial CO₂ pressures at postoperative hour 6 in the groups were compared, they were determined to be higher in Group A than in Groups B and C. In groups of patients with and without the development of atelectasis, significant differences were found in terms of age, operation time, and duration of intensive care stay and hospital stay.

Conclusion: Postoperative noninvasive pressure techniques yielded better results in preventing the development of atelectasis than control techniques. However, we believe that assessment with arterial blood gas tests and PFTs is also important for preventing and predicting the development of atelectasis as well as considering a patient's age, smoking history, operation time, and duration of intensive care stay.

Keywords: Atelectasis, postoperative pulmonary complications, ventilation

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Öz

Amaç: Postoperatif noninvazif basınç tekniklerinin, majör abdominal cerrahi geçiren hastalarda akciğer fonksiyon testleri, arteriyel kan gazı ve akciğer komplikasyonları gelişimi yönünden üstünlüğünü araştırmayı amaçladık.

Gereç ve Yöntemler: Yirmi ile 80 yaş arası 45 hasta, ASA I-III ve majör abdominal cerrahisi yapılan hastalar ameliyat sonrası kontrol (Grup A), Continuous Positive Airway Pressure (Grup B) ve Noninvasive Pressure Support Ventilation (Grup C) gruplarına prospektif, randomize olarak üç gruba ayrıldı. Preoperatif (T0) ve postoperatif 0.saat (T1), 6.saat (T2) ve 24.saat (T3)'te, hemodinamik ve arteriyel kan gazları verileri kaydedildi. Ayrıca, preoperatif ve postoperatif teknikler pulmoner fonksiyon testleri (SFT) ve göğüs radyografisi çekildi.

Bulgular: Çalışmamızda gruplar arasında 6. saatte sistolik ve diyastolik kan basınçları arasında istatistiksel olarak anlamlı farklılık bulundu. Bununla birlikte, postoperatif 3 saatteki ve 6. saatteki arteriyel CO₂ basınçları karşılaştırıldığında, Grup A'da diğer 2 gruba göre daha yüksek olduğu tespit edildi. Atektazi gelişimi olan ve olmayan gruplarda yaş, operasyon süresi, yoğun bakım kalış süreleri ve hastanede kalış açısından anlamlı fark bulundu.

Sonuç: Kullandığımız postoperatif noninvazif basınç teknikleri, kontrol grubuna göre atelektazinin gelişmesinin önlenmesinde daha iyi sonuçlar verdi. Bununla birlikte, atelektazi gelişimini önlemede ve öngörmeye, arteriyel kan gazı ve SFT ile yapılan değerlendirmenin yanı sıra, hastaların yaşı, sigara öyküsü, ameliyat süresi, yoğun bakım kalış süresinin de dikkate alınmasında önemli olduğunu düşünüyoruz.

Anahtar Kelimeler: Atektazi, postoperatif pulmoner komplikasyonlar, ventilasyon

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Introduction

Pulmonary complications resulting from surgical interventions are important causes of mortality and morbidity (1-5). The incidence of postoperative pulmonary complication development varies from 6% to 80% (3-8). The most important respiratory complications include atelectasis pneumonia, acute bronchitis, bronchospasm, pulmonary thromboembolism, pleural fluid, pneumothorax, prolonged postoperative hospitalization, prolonged mechanical ventilation, and acute respiratory distress syndrome (2-6). Various pulmonary physiotherapy practices are used to avoid the development of pulmonary complications and to treat these complications (2-7). There are few well-planned studies in this regard, and study data are conflicting (4-11). In the present study, we aimed to examine superiority of the postoperative noninvasive pressure techniques noninvasive pressure support ventilation (NIPSV) and continuous positive airway pressure (CPAP) over each other in terms of pulmonary function tests (PFTs), arterial blood gas tests, and lung complication development in patients undergoing major abdominal surgery.

Material and Methods

Subjects

In this study, 45 patients aged between 20 and 80 years, with ASA I-III, and undergoing major abdominal surgery (stomach, liver, pancreas, colon, and small intestine surgery) were assessed. The trial was approved by an independent ethics committee (Türkiye Yüksek İhtisas Training and Research Hospital) and was conducted in accordance with the principles of the Declaration of Helsinki. All patients with their parents or legally acceptable representatives provided written informed consent. After obtaining written informed consent, the patients were prospectively equally randomized into three groups in terms of the use of control, CPAP, and NIPSV using the envelope method (Figure 1).

Patients who had a psychiatric disorder or maxillofacial anatomic defect hindering the operation, required emergency surgery, had a body

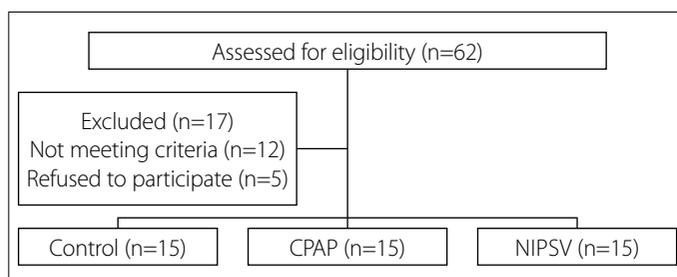


Figure 1. Participant flowsheet.

CPAP: continuous positive airway pressure; NIPSV: noninvasive pressure support ventilation

mass index higher than 30 kg/m², had preoperative and postoperative hemodynamic instability, had myocardial infarction or had undergone cardiac surgery within the last 6 months, and had a cardiac and pulmonary disease were excluded from the study. Moreover, patients who experienced postoperative hemodynamic disturbances, chest pain, and changes in consciousness; cannot tolerate the operation; or develop surgical area complications (bleeding, anastomotic leakage, and ileus) were excluded from the study.

Assessment

Preoperative arterial blood gas measurement, direct posteroanterior chest radiography, and PFTs were performed. After peripheral vascular access in the operation room, noninvasive blood pressure, electrocardiograph, and peripheral O₂ saturation (SpO₂) were monitored and the values were recorded. Anesthesia was induced using 3-5 mg/kg thiopental (Pental, İ.E Ulagay, İstanbul, Türkiye), 0.6 mg/kg rocuronium (Esmeron, Organon, Netherlands), and 0.5 µg/kg fentanyl (Fentanyl, Johnson & Johnson, Belgium); female patients were intubated using 7-7.5, and male patients were intubated using 8-8.5 mm inner diameter sizes of endotracheal intubation tube. Before the operation, patients underwent arteria radialis cannulation for invasive arterial blood pressure and blood gas monitoring. During the operation, the patients were put on a mechanical ventilator and maintained on volume controlled ventilation with a tidal volume of 8-10 mL/kg and respiration frequency of <10-14/min (end-tidal CO₂, 25-35 mmHg; pCO₂, 35-45 mmHg; peak inspiratory pulmonary pressure, <30 cm H₂O) using 50% O₂ and 50% air and minimum alveolar concentration (MAC) 1.3 sevoflurane (Sevorane, Baxter, Australia) as the inhalation agent. Upon the completion of surgery, 0.02-0.04 mg/kg neostigmine (Neostigmine, Adeka, Samsun, Türkiye) and 0.01-0.02 mg/kg atropine (Atropin sülfat, Galen, İstanbul, Türkiye) were administered to reverse the neuromuscular block. When a patient's spontaneous ventilation tidal volume was >5 mL/kg⁻¹ the respiratory rate was less than 30/min, SpO₂ was more than 90%, end-tidal CO₂ was below 60 mmHg, and rapid shallow breathing index (respiratory frequency/tidal volume) was <105, the patient was extubated. For postoperative analgesia, patient-controlled analgesia was initiated using intravenous meperidine HCl (Aldolan, Liba, İstanbul, Türkiye) during surgical fascia closure and the visual analog scale was set at <4. When patients were transferred to the recovery room, no ventilation was performed (Group A) for 4 h starting from hour 2 after randomization, while CPAP 7.5 cm H₂O was given (Group B) and NIPSV (Group C) providing ventilation with a tidal volume of 8-10 mL/kg, breathing rate below 25, and SpO₂ above 90%. Preoperatively and at postoperative hour 0, hour 6, and hour 24, hemodynamic and arterial blood gas test data were recorded. In addition, PFTs were repeated preoperatively and at postoperative hour 6 and hour 24, and results were compared with chest radiographs preoperatively and at postoperative hour 24. While chest radiographs were evaluated in the Radiology Department, atelectasis

and other pathological symptoms were recorded. Operation duration, smoking status, postoperative lung complications, recovery, and duration of intensive care and hospital stay were recorded.

Statistical Analysis

Results were recorded on a computer, and the Statistical Package for Social Science (SPSS) software for Windows 17 (SPSS Inc.; Chicago, IL, USA) was used. Results are presented as mean±standard deviation. The chi-square test was used in cross tables. The age, operation time, duration of intensive care and hospital stay, PFT parameters, arterial blood gas

parameters, hemodynamic symptoms, and average pulse oximetry findings in the groups were recorded; ANOVA was performed for parametric data, and the Kruskal-Wallis test was performed for non-parametric data. A p-value of <0.05 was considered statistically significant. When post hoc power analysis was performed using the values obtained at the end of our study, the power of the study was found to be 0.8 in case there are 15 patients in each group and an alpha value of 0.05 was considered.

Results

In total, 45 patients, 16 females (35%) and 29 males (65%), with a mean age of 48.2±12.4 years were included in the study. The patients were randomized into three groups. There was no difference among the groups in terms of distribution by gender. Among the groups, no statistically significant difference could be found in terms of durations of hospital stay, intensive care stay, and operation (Table 1). Among the groups, no statistically significant difference was found in terms of the development of atelectasis and the effect of gender and smoking on the development of atelectasis. A statistically significant difference was found between Groups A and B between systolic and diastolic blood pressures at postoperative hour 6 (Table 2).

Among the three groups, there was no difference in terms of average heart rate, forced vital capacity, forced expiratory value in 1 s (FEV₁), peak expiratory flow (PEF), and forced expiratory flow (FEF) 25-75% from PFTs; pH in blood gas tests; arterial O₂ pressure; and SpO₂ values at all time points. However, when the arterial CO₂ pressure at postoperative hour

Table 1. Demographic characteristics

	Group A	Group B	Group C	p
Gender (F/M)	7/8	4/11	5/10	
Age (years) (mean±SD)	47.4±13.3	49±11.3	49.5±12.9	0.89
Operation time (h) (mean±SD)	3.5±0.8	3.8±0.8	3.6±0.9	0.514
Intensive care stay (h) (mean±SD)	10.1±7.7	8.8±2.9	8.27±2.2	0.9
Hospital stay (days) (mean±SD)	5.6±1.9	5.7±1.9	5.4±1.2	0.87

Group A: control group; Group B: CPAP group; Group C: NIPSV group
F: female; M: male; SD: standard deviation; CPAP: continuous positive airway pressure; NIPSV: noninvasive pressure support ventilation

Table 2. Distribution of systolic and diastolic blood pressures among the groups

Variables ^a		Group A	Group B	Group C	p
Blood pressure	T0	126.63±14.471	133.53±19.390	128.60±16.088	0.507
Systolic (mmHg)	T1	143.07±11.423	148±16.410	141.40±16.418	0.46
	T2	128.00±14.036	143.07±13.812	136.93±11.003	0.011
	T3	124.27±14.754	130.60±17.033	129.33±9.529	0.474
Blood pressure (mmHg)	T0	74.27±10.450	78.33±9.940	76.67±7.403	0.495
Diastolic (mmHg)	T1	82.8±8.777	86.8±6.805	83.73±6.933	0.327
	T2	75.67±9.969	85.00±6.655	80.73±4.436	0.007
	T3	74.33±8.829	76.27±8.713	77.44±5.598	0.558

Group A; control group; Group B: CPAP group; Group C: NIPSV group

^aValues: mean±SD

T0: preoperatively; T1: postoperative hour 0; T2: postoperative hour 6; T3: postoperative hour 24

CPAP: continuous positive airway pressure; NIPSV: noninvasive pressure support ventilation

Table 3. Distribution of blood gas values among the groups

Variables ^a		Group A	Group B	Group C	p
PaCO ₂	T0	30.93±2.520	32.75±2.622	31.8±2.731	0.18
	T1	34.6±2.261	35.53±1.727	35.13±1.302	0.37
	T2	32.93±2.434	30.07±1.624	30.4±1.298	0.012
	T3	32.93±2.434	32.67±1.676	32.47±1.598	0.805

Group A: control group; Group B: CPAP group; Group C: NIPSV group

^aValues: mean±SD

T0: preoperatively; T1: postoperative hour 0; T2: postoperative hour 6; T3: postoperative hour 24

CPAP: continuous positive airway pressure; NIPSV: noninvasive pressure support ventilation

Table 4. Factors affecting the development of atelectasis

Variables ^a	Atelectasis		p
	Yes (n=9)	No (n=36)	
Age (years)	61.5±5.9	45.4±11.4	0.00
Operation time (h)	4.2±0.71	3.5±0.88	0.026
Intensive care stay (h)	13.8±8.4	7.8±2.5	0.00
Hospital stay (days)	7.5±1.5	5±1.3	0.00

^aValues: mean±SD**Table 5.** Relationship of atelectasis with other parameters

Variables ^a	Atelectasis	Total	Mean	SD	p	
Saturation	T0	No	36	97.42	1.663	0.001
		Yes	9	94.44	2.297	
	T1	No	36	94.67	2.318	0.001
		Yes	9	91.89	2.088	
	T2	No	36	97.17	1.859	0.003
		Yes	9	94.89	1.764	
T3	No	36	96.22	1.588	0.001	
	Yes	9	93.44	1.424		
PaO ₂	T0	No	36	93.75	6.026	0.001
		Yes	9	86.33	5.315	
	T1	No	36	87.42	4.854	0.001
		Yes	9	81.67	4.243	
	T2	No	36	93.25	6.500	0.02
		Yes	9	87.56	4.640	
T3	No	36	89.25	4.358	0.01	
	Yes	9	85.00	4.500		
PaCO ₂	T0	No	36	31.39	2.555	0.03
		Yes	9	33.56	2.555	
	T1	No	36	35.00	1.639	0.520
		Yes	9	35.44	2.455	
	T2	No	36	30.75	2.034	0.31
		Yes	9	31.33	1.658	
T3	No	36	32.33	1.757	0.01	
	Yes	9	34.11	1.900		
pH	T0	No	36	7.4252	0.02400	0.11
		Yes	9	7.4100	0.02828	
	T1	No	36	7.3981	0.02040	0.05
		Yes	9	7.3833	0.01658	
	T2	No	36	7.4239	0.02032	0.02
		Yes	9	7.4067	0.01000	
T3	No	36	7.4142	0.01697	0.02	
	Yes	9	7.3979	0.02204		

T0: preoperatively; T1: postoperative hour 0; T2: postoperative hour 6; T3: postoperative hour 24
SD: standard deviation

6 in the three groups was compared, it was determined to be higher in Group A than in the other two groups; this difference was statistically significant (Table 3).

Among 45 patients, atelectasis was observed in 9 patients; considering distribution by groups, there were 4 patients in Group A, 2 in Group B, and 3 in Group C. No statistically significant difference was determined in terms of the development of atelectasis among patients in the groups ($p=0.659$). No statistically significant difference was determined in terms of the development of atelectasis related to smoking among patients in the groups ($p=0.659$). In groups of patients with and without the development of atelectasis, statistically significant differences were found in terms of age, operation time, and duration of intensive care stay and hospital stay (Table 4).

When all patients were evaluated in terms of the development of atelectasis, the percentage values of FEV₁ at postoperative hour 24 in patients without the development of atelectasis (75.8 ± 8.3) was found to be higher than in the group of patients with the development of atelectasis (66.8 ± 6.8); this difference was statistically significant ($p<0.001$). The preoperative values and postoperative PEF values at hours 6 and 24 (89.5 ± 7.2 , 65 ± 7.4 , and 74 ± 6.7 , respectively) and the preoperative and postoperative FEF 25-75% values at hours 6 and 24 (89.9 ± 6.4 , 65.3 ± 6.4 , and 74.3 ± 6.9 , respectively) of the patients without the development of atelectasis were found to be higher than the preoperative and postoperative PEF and FEF 25-75% values at hours 6 and 24 in the group of patients with the development of atelectasis (82.7 ± 5.7 , 57.4 ± 3.3 , and 65.4 ± 7.5 , respectively vs. 79.6 ± 5.2 , 57.8 ± 3.2 , and 64.8 ± 6 , respectively); this difference was statistically significant ($p<0.001$). The PaO₂ values in blood gas test results and pH values on performing pulse oximetry preoperatively and at postoperative hours 0, 6, and 24 in patients without the development of atelectasis were found to be higher than those in patients with the development of atelectasis; this difference was statistically significant (Table 5).

Discussion

Pulmonary complications following major abdominal surgery are important causes of mortality and morbidity. During anesthesia induction, pulmonary complications still pose a problem, despite advances in surgical practices and postoperative care (3, 4). The incidence of postoperative pulmonary complication development seen varies widely and depends on the type of surgery and risk factors (2-7). Various pulmonary physiotherapy practices are frequently used to treat these complications and prevent their development. The superiority of different techniques over each other remains controversial in the literature (2-9). In these studies, it was determined that pre- and postoperative pulmonary physiotherapy practices are effective in patients with a high risk of developing complications (4-8). In the present study, no difference was found in terms of the development of atelectasis, although CPAP and NIPSV yielded better results in some postoperative pulmonary functions than the control technique.

In our study, while the averages of arterial O₂ saturation at postoperative hour 6 were significantly low in the Group A than the B and C Groups, the averages of arterial CO₂ pressure at postoperative hour 6 were observed to be significantly higher. At postoperative days 1 and 2, it was observed that the PaO₂ value was better in the PEEP and CPAP groups than in the control group in a study (12). In another study, the superiorities of noninvasive mechanical ventilation techniques were compared

in stable chronic obstructive pulmonary disease (COPD) patients, and while CPAP was administered at different pressures in a group, CPAP and NIPSV were administered at low pressures to patients in the other group. In conclusion, PaO₂ and PCO₂ values were found to be better in each group than the baseline values (13). In the literature, there are several publications indicating that noninvasive pressure techniques further improve arterial blood gases and decrease PCO₂ and increase PaO₂ values (8-12). Our study also supports these statements, and the blood gas values of the patients in the CPAP and NIPSV groups were better than those of the patients in the control group.

Of the 45 patients in total, 9 developed atelectasis, and no statistically significant difference was found in terms of the frequency of the development of atelectasis by group. The results differ from those in similar studies present in the literature. In a study by Carlsson et al. (14) CPAP was given to 13 of 24 patients and only O₂ was given to 11 patients for 4 h on the postoperative first day, and atelectasis was detected in 10 of 13 patients in the CPAP group and 10 of 11 patients in O₂ group. We believe that the frequency of the development of atelectasis is higher than that in our study because the patient population in this study (15) has a higher average age, which is an important risk factor in terms of postoperative pulmonary complication development. In a study by Stock et al. (15) atelectasis was found in 5 of 23 patients in the CPAP group and in 8 of 20 patients in the control group, and the frequency of the development of atelectasis following CPAP was similar to that in our patients.

In previously conducted studies, although a large number of patients who smoked had normal PFT results or demonstrated minimal changes, most smokers had mucus hypersecretion or deterioration in mucociliary clearance. It is known that patients who smoke have difficulties in clearing secretions that accumulate on the airways during the postoperative period, causing the frequency of atelectasis and bronchopneumonia to increase (16, 17). In a study conducted by Stolz et al. (18) the development of postlobectomy atelectasis was retrospectively investigated in 412 patients undergoing pulmonary lobectomy; a statistically significant difference could not be found, although smoking and the frequency of the development of atelectasis were higher than non-smokers. In our study, smoking frequency was higher in patients developing atelectasis, even though there was no significant difference when the postoperative development of atelectasis was analyzed between smokers and non-smokers. Hence, we believe that quitting smoking before undergoing an operation will prevent the development of this complication.

We observed that the operation times are longer in patients developing atelectasis than in those not developing atelectasis. In a study that investigated postoperative pulmonary complication development with regard to operation times in patients with COPD undergoing surgery, Kroenke et al. (19) found that the postoperative pulmonary complication rate increases in patients with an operation time longer than 3.5 h. In a study, the postoperative pneumonia frequency was found to be 5 times higher in patients undergoing surgeries exceeding 4 h than in those undergoing surgeries less than 2 h (20). In the literature, the relationship between patients having an operation time exceeding 3-4 h and postoperative pulmonary complication development was significant (19-22). We believe that performing postoperative respiratory physiotherapy in patients with longer operation times would cause few pulmonary complications.

In our study, significant differences were found in the postoperative development of atelectasis in terms of FEV₁, PEF, and FEF 25-75% values. In a prospective study on patients undergoing upper abdominal surgery, Kocabas et al. (23) showed that the incidence of respiratory complications was higher in patients with low preoperative PFTs. The relationship between PFTs and pulmonary complication development is not clear in the literature; however, it is known that FEV₁ values lower than 70% are risk factors for pulmonary complication development (9, 24). We revealed that spirometry values are good indicators of the development of postoperative pulmonary complications; this finding supports those present in most studies in the literature.

In our study, significant differences were found in terms of arterial O₂ saturation and arterial O₂ pressure, arterial CO₂ pressure, and arterial blood pH values with the development of atelectasis. In a study conducted by Fuso et al. (25) the authors revealed a more frequent pulmonary complication patients in which low preoperative PaO₂ values and emphasized that it is important in the prediction of pulmonary complication development. We believe that the assessment of arterial blood gas results is an important indicator of the development of atelectasis.

We believe that a few limitation of this study are worthy of discussion. Patients were monitored from the postoperative period to the time of discharge. Accordingly, we obtained information on early postoperative complications. If the patients were followed up for a longer period, the development of long-term complications could have been reported. Another limitation is that the power of our study is limited due to the size of the sample.

Conclusion

We showed that postoperative noninvasive pressure techniques yielded better results in terms of blood gas values and in terms of preventing the development of atelectasis than the control technique. However, we believe that assessment with arterial blood gas and PFTs is also important in preventing and predicting the development of atelectasis that a patient's age, smoking history, operation time, and duration of intensive care stay. Further studies with a larger number of subjects and longer follow-up periods are needed.

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