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The effect of smoking on arterial blood gases, respiratory mechanics and hemodynamic parameters in patients undergoing laparoscopic cholecystectomy

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ABSTRACT

Aims: Smoking is the most important risk factor for postoperative pulmonary complications. This study aims to analyze the effects of smoking on the respiratory functions during laparoscopic cholecystectomy operations and how these effects may reflect on hemodynamic parameters.

Methods: Forty patients undergoing laparoscopic cholecystectomy were included in the study. Patients were divided into two groups: smokers (Group I) and non-smokers (Group II). Respiratory function tests (RFTs), arterial blood gas (ABG) analysis, and posteroanterior (PA) chest X-ray were evaluated preoperatively and postoperatively. Intraoperative hemodynamic parameters and arterial blood gas values of the patients were recorded.

Results: Throughout the observation time, there was significant difference in mean partial carbon dioxide (PCO_2) levels in ABG analysis. PCO_2 levels were significantly higher in the smoking group (Group I). There was also significant difference in mean carboxyhemoglobin (HBCO) levels, which were higher in Group I. Within the groups, significant changes in HBCO levels between at least two follow-up times were observed only in Group II. In Group I, there was significant difference in all RFTs measurements between preoperative and postoperative periods. In Group II, except for forced expiratory volume at 1 second to forced vital capacity ratio (FEV_1/FVC), significant differences were found in all RFTs measurements between preoperative and postoperative periods.

Conclusion: In this study examining the effects of smoking on hemodynamic parameters, arterial gas analyses, and respiratory function tests during and after laparoscopic cholecystectomy surgeries, although PCO_2 was higher in the smoking group during the follow-up period, it was lower than the non-smoking group at the 1st postoperative hour. However, smokers had lower PO_2 levels in the postoperative period and higher HBCO values. Respiratory function tests were more suppressed in smokers, these changes were not clinically significant, and there were no lung or respiratory complications observed in the patients. Smoking does not appear to have an impact on hemodynamic parameters during laparoscopic cholecystectomy surgeries.

Keywords: Laparoscopic cholecystectomy, pulmonary function tests, arterial blood gases, smoking

INTRODUCTION

Smoking is the most important risk factor for postoperative pulmonary complications.[1] Pulmonary irritants and ciliated toxins present in cigarette smoke cause an increase in the quantity and stickiness of mucus secretion, depression of the upward-moving function of the ciliated epithelium's secretion and narrowing of the small airways. Main postoperative complications that may develop due to smoking include increased secretions, lung ventilation disorders, atelectasis, hypoxemia, and lung infections.

The toxins in cigarette smoke inhibit the immune mechanism, and carbon monoxide obstructs oxygen transport and utilization. As a result of these effects, a decrease in functional residual capacity, compliance, airflow rate, diffusion capacity, and surfactant levels, along with a deterioration in the ventilation/perfusion ratio, lead to the development of chronic obstructive pulmonary disease.[2,3]

Postoperative pulmonary complications are more frequently observed in smokers compared to non-smokers. Pulmonary complications can also occur in smokers without lung and heart disease. Complications are more common in older and heavy smokers. The frequency of postoperative complications is 15% in smokers, while it is 6% in non-smokers. Increased levels of carboxyhemoglobin (HBCO) in smokers without significant disease affect tissue oxygenation. Those who quit smoking for eight weeks have fewer surgery-related pulmonary complications.[4,5]

Nicotine stimulates the cardiovascular system, leading to increased blood pressure, heart rate (HR), myocardial contractility, irritability, and oxygen consumption, and causing peripheral vasoconstriction. These changes contribute to the development of postoperative complications.

The most significant drawbacks of laparoscopy are the cardiopulmonary effects of pneumoperitoneum, the insufflation of systemic carbon dioxide (CO_2) gas into the extraperitoneal area, venous gas embolism, damage to intraabdominal organs, and the difficulties brought by positioning.[6]

Hypercapnia, which may develop with CO_2 insufflation during laparoscopy, leads to hemodynamic changes through its direct cardiovascular effects and indirect effects due to sympathoadrenal activation. Tachycardia, arrhythmia, an increase in cardiac output, and a decrease in systemic vascular resistance occur. An increase in myocardial Oxygen (O_2) consumption can lead to myocardial infarction.[7]

In laparoscopic cholecystectomy surgeries with CO_2 insufflation, the adverse effects of smoking on arterial blood gas (ABG) analyses and pulmonary functions may become more pronounced.

The aim was to investigate the negative effects of smoking on ABG values and pulmonary functions. These effects are more pronounced during laparoscopic cholecystectomy procedures involving CO_2 insufflation.[8] We examined these effects and their reflection on hemodynamic parameters.

METHODS

This study, was designed as a prospective and observational study, produced from a thesis done in 2010 with the institutional approval of the Dışkapı Yıldırım Beyazıt Training and Research Hospital All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

After obtaining approval of the and written informed consent from patients, 40 patients aged 20-70 years old who were scheduled to undergo elective laparoscopic cholecystectomy under general anesthesia and were classified in the American Society of Anesthesiologists (ASA) I-IV physiologic class, were included in the study. Patients were divided into two groups: smokers and non-smokers.

Patients with obstructive sleep apnea, morbid obesity, contraindications for radial artery cannulation, inability to comply with the pulmonary function test (PFTs), or a history of thoracic surgery were excluded from the study.

The patients who smoked were designated as Group I, and the patients who did not smoke were designated as Group II. The body mass index (BMI), comorbidities, medications (bronchodilator therapy, antihypertensive therapy, steroids, antiarrhythmics), and the duration and amount of smoking for patients in all patients were recorded.

Preoperative laboratory examinations included PFTs: Forced expiratory volume in 1 second (FEV_1),Forced vital capacity (FVC), FEV_1/FVC ratio, Peak expiratory flow (PEF), FEF 25-75 (Forced expiratory flow), ABG analyses: pH (Acid-base balance), PCO_2 (Arterial partial pressure of carbon dioxide), PO_2 (Arterial partial pressure of oxygen), BE (Base deficit), SpO_2 (Arterial oxygen saturation), HCO_3 (Serum bicarbonate) HBCO, and posteroanterior (PA) chest X-ray. If new respiratory system symptoms, a smoking history (> 20 pack-years) or was conducted. Additional treatments were recorded.

Patient received intravenous premedication with 0.03 mg/kg midazolam 30 minutes before being taken to the operating room.

Upon entering the operating room, standard monitoring including electrocardiography (ECG), peripheral oxygen saturation (SpO_2), noninvasive arterial blood pressure (NIAB), (Drager Infinity Delta; 16 Electronics Avenue, Danvers, MA 01923 USA), and a peripheral intravenous line was established. Radial artery cannulation (22 G) was performed under local anesthesia following the Allen test. Anesthesia induction was achieved with 2 mg/kg intravenous propofol, 2 mg/kg fentanyl, and 0.6 mg/kg rocuronium. Anesthesia was maintained with a mixture of oxygen and air, and desflurane, and a nasal temperature probe was applied.

Ventilation was maintained in volume control mode with a tidal volume of 6-8 ml/kg, a respiratory rate of 12 breaths/min, and a positive end-expiratory pressure (PEEP) of 3 cmH_2O, aiming for an end-tidal carbon dioxide ($ETCO_2$) of 30-35 mmHg. If hypercapnia ($ETCO_2$ ≥35 mmHg) occurred, ventilation parameters were adjusted to increase the respiratory rate and maximum airway pressure not exceeding 30 cmH_2O, and these changes were recorded. Intraabdominal pressure was set to 14 mmHg.

Systolic arterial pressure (SAP), diastolic arterial pressure (DAP), mean arterial pressure (MAP), SpO_2, and HR were recorded before induction and at 5-minute intervals during surgery along with $EtCO_2$ values.

ABG analyses were performed before induction, after intubation, 15 minutes after CO_2 insufflation, 10 minutes after desufflation, 1 hour after the end of the operation, and 24 hours after the operation, recording the values of pH, PCO_2, PO_2, BE, SpO_2, HCO_3, and HBCO.

At the end of surgery, volatile agent was turned off, and patients were extubated after directing 0.04 mg/kg neostigmine and 0.02 mg/kg atropine according to clinical extubating criteria. The time from turning off the volatile agent to extubating was recorded as the extubating time. The duration of the surgery, insufflation time, and desufflation times were recorded. PFTs and PA chest X-rays were repeated 24 hours postoperatively.

Postoperative pain control was managed with 1-2 mg/kg intravenous tramadol and 15 mg/kg intravenous paracetamol administered 30 minutes before the end of surgery. Pain levels were assessed using the visual analog scale (VAS; 0-10 points) at 1, 6, 12, and 24 hours postoperatively. If the VAS score was 4 or higher, additional analgesic requirements were met with 50 mg intravenous Dex ketoprofen.

Arrhythmias, desaturation ($SpO_2 \leq 90$), hypercapnia ($EtCO_2 > 35$), hypoxemia ($PO_2 \leq 75$), hypotension (values 20% below baseline measurements), hypertension (values 20% above baseline measurements), and postoperative pulmonary complications (atelectasis, pneumothorax, pneumomediastinum, infiltration, air accumulation due to insufflation, diaphragmatic eventration) were recorded as complications.

Statistical Analysis

Since group assignment was based on whether patients had a history of smoking, the patient selection was not randomized.

Data analysis was performed using SPSS (Statistical Package for Social Science) version 11.5 for Windows. The normality of distribution of continuous variables was assessed using the Shapiro-Wilk test. Descriptive statistics were presented as mean±standard deviation for continuous variables or as median (minimum-maximum), and nominal variables were presented as counts and percentages (%).

Statistical significance of differences in means between groups was assessed using Student's t-test, and significance of differences in medians was investigated using the Mann-Whitney U test. Nominal variables were examined using Pearson's chi-square test or Fisher's exact test.

Repeated measures analysis of variance (ANOVA) was used to evaluate repeated hemodynamic measurements and respiratory function test measurements. In case of significant differences within groups, Bonferroni-corrected multiple comparison tests were used for hemodynamic measurements, and Bonferroni-corrected dependent t-tests were used for respiratory function tests to determine the time points responsible for the differences.

Changes over time in VAS measurements within groups were examined using the Friedman test. If the Friedman test statistic indicated significance, Bonferroni-corrected Wilcoxon signed-rank tests were used to identify the time points responsible for the differences.

Results were considered statistically significant at $p<0.05$. Bonferroni correction was applied to control Type I error in all possible multiple comparisons.

RESULTS

The study was completed with 40 patients. No significant differences were found between the groups in terms of age, BMI, ASA classification, comorbidity frequency, and insufflation-desufflation duration ($p>0.05$) (Table). However, there were differences between the groups in terms of gender distribution, smoking pack-years, and operation duration ($p<0.05$). In the smoking group, 65% (13 patients) were women, while all patients in the non-smoking group were women. The duration and amount of smoking varied among patients. The average smoking amount in Group I was 10 pack-years.

Hemodynamic parameters SAP, DAP, MAP, and HR, SpO_2, and $EtCO_2$ values were similar between the groups.

In intragroup statistics, there was an increase in $EtCO_2$ after insufflation and desufflation, with a decrease in $EtCO_2$ at 40 minutes in the smoking group and at 35 minutes in the non-smoking group (Figure 1).

Table. Demographic characteristics of cases by groups

Variables	Group I	Group II	p value
Age	44±12	43±15	0.864
Gender M/F	7/13	0/20	0.008
Body Mass Index	27.8±4.5	28.9±4.5	0.425
ASA 1/2/3	8/12/0	11/8/1	0.264
Comorbidities	12 (%60.0)	9 (%45.0)	0.342
Smoking packs /year	10(5-35)	-	-
Operation time (minute) [median (min-maks)]	50 (32-85)	63 (27-110)	0.017
Insufflation-desufflation time [median (Min- Maks)] (second)	41.5 (26-77)	56 (21-101)	0.068

ASA: American Society of Anesthesiologists, M: Male, F: Female, Values: median ± standard deviation, Value: median (minimum value- maximum value

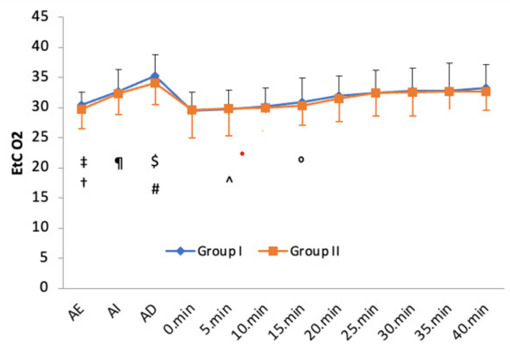

Figure 1. Comparison of $ETCO_2$ between groups
Values: Mean + Standard Deviation (SD) AE: After Intubation, AI: After Insufflation, AD: After Desufflation, $EtCO_2$: End-tidal carbon dioxide

† The difference between the relevant observation time and AE in Group I is statistically significant (p<0.025).
‡ The difference between the relevant observation time and AE in Group II is statistically significant (p<0.025).
¶ The difference between the relevant observation time and AI in Group I is statistically significant (p<0.025).
# The difference between the relevant observation time and AD in Group I is statistically significant (p<0.025).
$ The difference between the relevant observation time and AD in Group II is statistically significant (p<0.025).
^ The difference between the relevant observation time and the 5th minute in Group II is statistically significant (p<0.025).
º The difference between the relevant observation time and the 15th minute in Group I is statistically significant (p<0.025).

No significant difference was found in the mean PO_2 levels throughout the entire observation period (p=0.749). Within groups, there was a significant change in PO_2 levels between at least two observation times (p<0.025 according to Bonferroni correction). In smoking patients, the PO_2 level at the postoperative 24th hour was significantly lower compared to preoperative values (Figure 2).

No significant difference was found in the mean pH levels throughout the entire observation period (p=0.084). The amount of change in pH over time did not show a significant difference between the groups.

Mild acidosis was observed in both groups after desufflation (Figure 3). Throughout the entire observation period, there was a significant difference in mean PCO_2 levels, with the smoking group having significantly higher PCO_2 levels. Within the groups, significant changes in PCO_2 levels between at least two observation times were found only in Group II ($p < 0.025$ according to Bonferroni correction).

In the non-smoking group, the PCO_2 value at postoperative 24 hours was significantly higher compared to the value at 1 hour postoperatively (Figure 4).

Throughout the entire observation period, there was a significant difference in mean HBCO levels, with the smoking group having significantly higher HBCO levels (p<0.001). In

Group I, HBCO levels were significantly higher ($p<0.001$) (Figure 5).

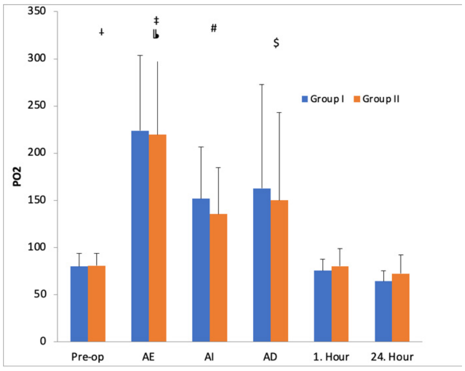

Figure 2. Changes in PO_2 over time in the groups

Values: Mean + Standard Deviation (SD) Pre-op: Preoperative, AE: After Intubation, AI: After Insufflation, AD: After Desufflation, PO_2: Arterial partial pressure of oxygen

† In Group I, the difference between the relevant observation time and the pre-op is statistically significant ($p<0.025$)
‡ In Group II, the difference between the relevant observation time and the AE is statistically significant ($p<0.025$)
¶ In both Group I and Group II, the difference between the relevant observation time and AE is statistically significant ($p<0.025$).
# In both Group I and Group II, the difference between the relevant observation time and AI is statistically significant ($p<0.025$).
$ In both Group I and Group II, the difference between the relevant observation time and AD is statistically significant ($p<0.025$).

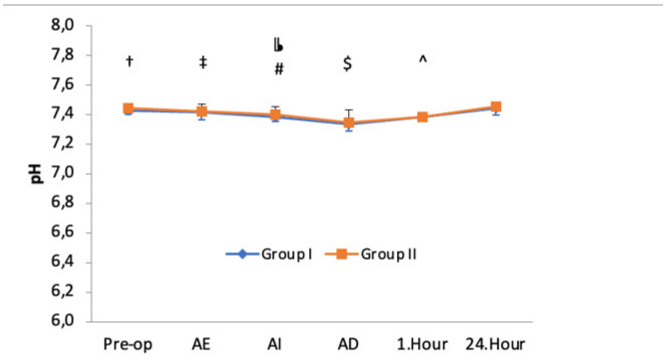

Figure 3. pH changes of the groups over time

Values: Mean + Standard Deviation (SD) Pre-op: Preoperative, AE: After Intubation, AI: After Insufflation, AD: After Desufflation, pH: Acid-base balance

† In both Group I and Group II, the difference between the relevant observation time and the pre-op is statistically significant ($p<0.025$)
‡ In both Group I and Group II, the difference between the relevant observation time and the AE is statistically significant ($p<0.025$)
¶ The difference between the relevant observation time and AI in Group I is statistically significant ($p<0.025$).
# The difference between the relevant observation time and AI in both Group I and Group II is statistically significant ($p<0.025$).
$ The difference between the relevant observation time and AD in both Group I and Group II is statistically significant ($p<0.025$).
^ The difference between the relevant observation time and 1st hour in both Group I and Group II is statistically significant ($p<0.025$

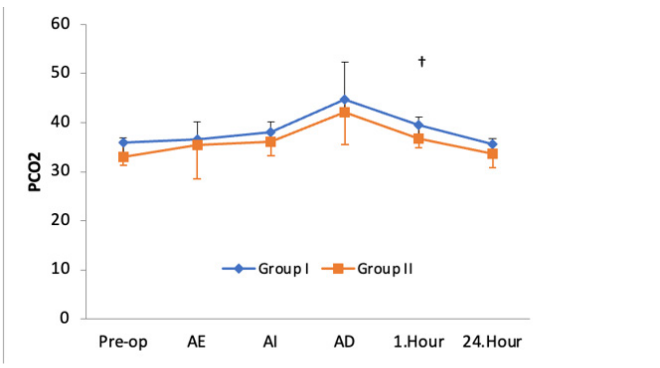

Figure 4. PCO_2 changes of the groups over time

Values: Mean + Standard Deviation (SD), Pre-op: Preoperative, AE: After Intubation, AI: After Insufflation, AD: After Desufflation, PCO2: Arterial partial pressure of carbon dioxide
† The difference between the relevant observation time and the 1st hour in Group II is statistically significant ($p<0.025$).

In Group I, all PFTs values, and in Group II, all PFT values except for FEV_1/FVC, were significantly suppressed in the postoperative period (Figure 6)

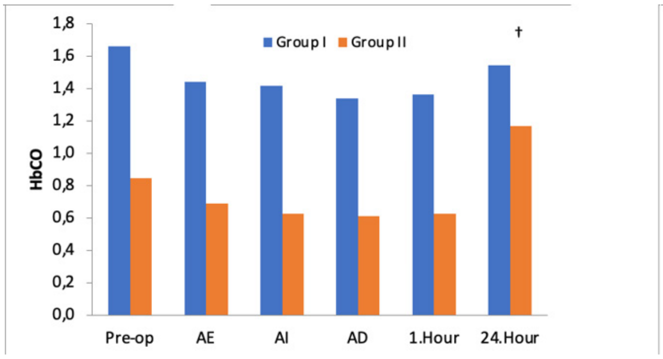

Figure 5. Changes in HBCO levels over time in groups

Values: Mean + Standard Deviation (SD), Pre-op: Preoperative, AE: After Intubation, AI: After Insufflation, AD: After Desufflation, HbCO: Carboxyhemoglobin

† The difference between the relevant observation time and the 24th hour in Group II is statistically significant ($p<0.025$).

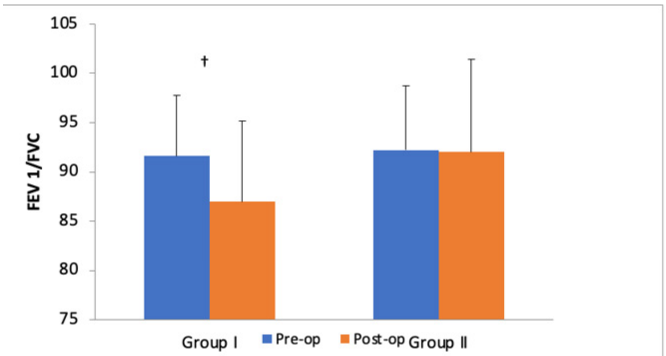

Figure 6. FEV_1/FVC changes of the groups over time

Values: Mean + Standard Deviation (SD), Pre-op: Preoperative, FEV_1: Forced expiratory volume in 1 second, FVC: Forced vital capacity, FEV_1/FVC: Ratio
† In Group I, the difference between pre-op and post-op is statistically significant ($p=0.024$)

DISCUSSION

In this study, we investigated the effects of laparoscopic surgery and smoking, both of which are known to have undesirable effects on respiratory functions, particularly when these two risk factors are present together. According to the results of the study, there are no clinical outcomes related to respiratory functions associated with smoking in patients undergoing laparoscopic cholecystectomy, although there are some differences in laboratory values related to respiratory functions.

Kim et al.[9] compared the effects of pneumoperitoneum on hemodynamic parameters in hypertensive and normotensive patients undergoing laparoscopic cholecystectomy. They found that HR and cardiac output significantly decreased in hypertensive patients, while the changes in mean blood pressure were similar in both groups. In our study, all patients were normotensive during the preoperative period, and there were no hemodynamic differences or complications between the groups.

In our study, when comparing $EtCO_2$ levels between groups, values were within normal limits in both groups postintubation, post-CO_2 insufflation, and throughout intraoperative monitoring. In smoking patients, there was a statistically significant increase in $EtCO_2$ after desufflation, but the values remained within the normocapnic limits (mean 35.3 mmHg).

During the same period, PCO_2 values increased above normal levels. We believe this increase is due to a transient increase in CO_2 reaching systemic circulation from collapsed peritoneal capillaries. Following desufflation, CO_2 increase corresponded to mild acidosis in both groups (Group I mean pH 7.337; Group II mean pH 7.347). In our study, PO_2 levels decreased after CO_2 insufflation in both groups but were not hypoxemic, consistent with typical blood gas changes seen in laparoscopic surgery. However, in smokers, PO_2 levels were significantly lower at 24 hours postoperatively compared to preoperative levels (mean 79.9 mmHg preop. and mean 64.2 mmHg at 24 hours postop.). This decrease did not clinically affect patients or require treatment. This finding could be attributed to chronic changes in the lungs due to smoking. Arabacı et al.[10] analyzed ABG results of smokers and non-smokers undergoing coronary artery surgery and found that smokers, both men and women, had lower PO_2 (66.1 vs. 69.1) and higher PCO_2 (38.6 vs. 32.0) in the postoperative period. According to our results, there was a significant difference between postoperative 1 hour and 24 hours in the non-smoking group, although PCO_2 was higher in the smoking group during the follow-up period, it was lower than the non-smoking group at the 1st postoperative hour. In these patients, PCO_2 compensation was achieved through increases in HCO_3 and BE.

Hirvonen et al.[11] conducted a study on laparoscopic hysterectomy operations, where they adjusted the minute volume (MV) by either keeping the frequency fixed at 12 and changing the tidal volume, or keeping the tidal volume fixed at 8 ml/kg and changing the frequency to maintain $EtCO_2$ between 33-36 mmHg. The researchers observed mild metabolic acidosis during laparoscopy. In this study, the required MV to maintain normocapnia increased by 25% during CO_2 insufflation. The researchers recommended increasing the tidal volume while keeping the respiratory rate low to prevent intraoperative hypercapnia. In our study, mechanical ventilation was maintained with frequency, tidal volume, and pressure or volume-controlled respiration to keep $EtCO_2$ below 35 mmHg, and the expected changes related to ventilation were eliminated.

The mean HBCO level was found to be significantly higher in the smoking group. In the non-smoking group, HBCO levels were found to be significantly lower post-extubating, post-insufflation, post- desufflation, and at postoperative 1 hour compared to postoperative 24 hours. These findings are consistent with the information that HBCO levels are higher in smokers and explain the condition of patients with lower PO_2 levels.

During the operation, the degree of pneumoperitoneum and the height of intra-abdominal pressure have a significantly more critical role on respiratory function and blood gas values than position. In laparoscopic cholecystectomy operations, when intraabdominal pressure exceeds 15 mmHg due to CO_2 pneumoperitoneum, the diaphragm moves upward, leading to respiratory changes.[12] In our study, we ensured that intraabdominal pressure did not exceed 15 mmHg.

Numerous studies in the literature examining respiratory function tests after open and laparoscopic cholecystectomy have shown a suppression of respiratory functions.[13,14] Similarly, smoking has also been shown to result in decreased spirometry measurements.[15]

Mohsen et al.[16] found that patients undergoing various laparoscopic procedures in the lower abdomen exhibited significant reductions in FVC, FEV_1, and PEF values on the first day after laparoscopy compared to pre-laparoscopy values. In this study, we identified suppression in respiratory mechanics consistent with the literature.

The incidence of atelectasis after laparoscopic cholecystectomy surgeries is significantly lower compared to open cholecystectomy surgeries.[17,18] In our study, we did not observe any complications regarding lung complications or changes in PA chest X-ray.

Limitations

Our study has limitations. The male-to-female ratio for gallbladder stone prevalence is 3:1.[19] When examining the patient characteristics, all the patients in the non-smoking group and 65% of the patients in the smoking group were women. This may have introduced a bias regarding the non-smoking patient group and gender inequality. Another methodological issue is the variability in smoking habits among patients in the smoking group (minimum 5, maximum 35 pack-years). This led to the evaluation of patients who smoked a small amount and for a short period in the same category as those who smoked a large amount and for a long period.

CONCLUSION

In this study, we examined the effects of smoking on hemodynamic parameters, blood gases, and PFTs during and after laparoscopic cholecystectomy surgeries. We found that in the postoperative period, patients who smoked had higher levels of PCO_2 and HBCO compared to non-smoking patients. Additionally, smokers had lower PO_2 levels postoperatively and experienced more suppression in PFTs. The FEV_1/FVC ratio in non-smokers did not change postoperatively. These changes were not clinically significant, and no lung or respiratory complications were observed. Smoking did not have an impact on hemodynamic parameters during laparoscopic cholecystectomy surgeries.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study, was designed as a prospective and observational study, produced from a thesis done in 2010 with the institutional approval of the Dışkapı Yıldırım Beyazıt Training and Research Hospital.

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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