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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 approval of the Ethics Committee of 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

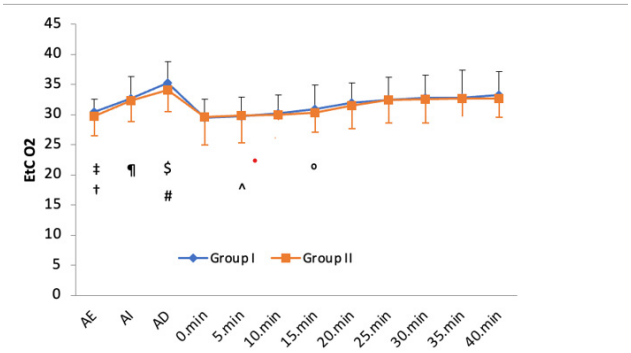

Figure 1: Comparison of $ETCO_2$ between groups
Values: Mean + Standard Deviation (SD) AE: After Intubation, AI: After Insufflation, AD: After Desufflation, $EtCO_2$: End-tidal carbon dioxide

† 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).

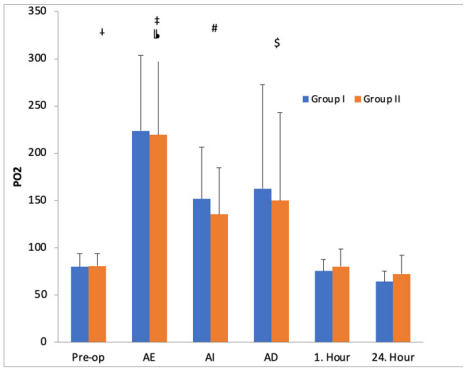

Figure 2. Changes in PO_2 over time in the groups

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).

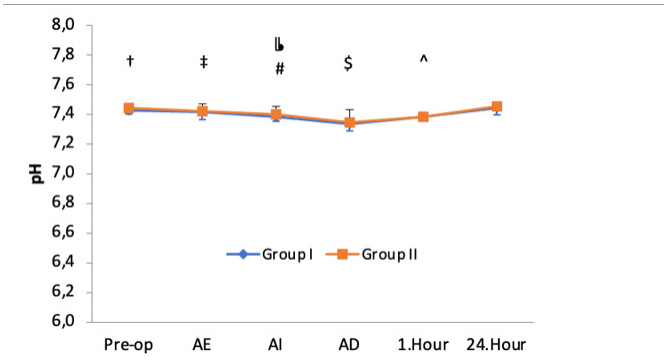

Figure 3. pH changes of the groups over time

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

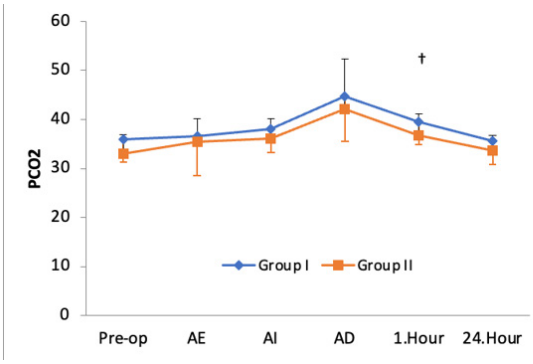

Figure 4. PCO_2 changes of the groups over time

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)

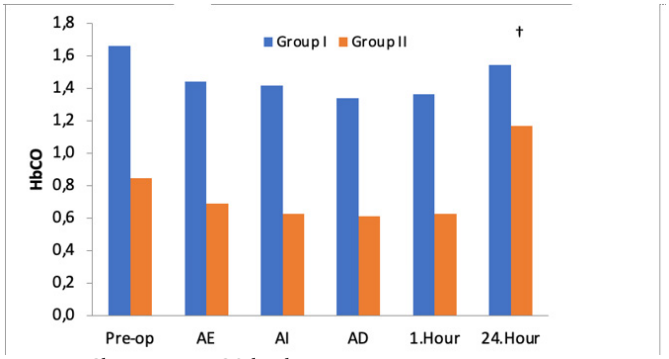

Figure 5. Changes in HBCO levels over time in groups

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).

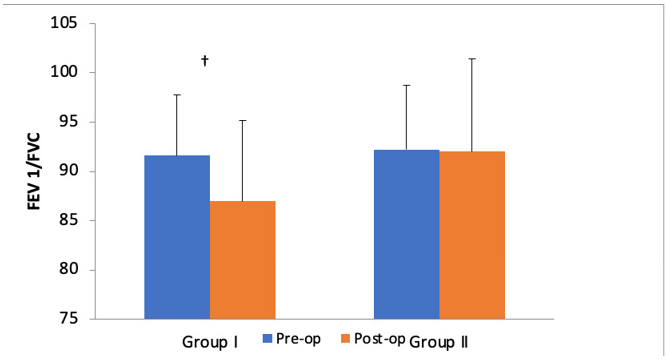

Figure 6. FEV_1/FVC changes of the groups over time

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 approval of the Ethics Committee of 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

Oya Çimen: project administration, conceptualization and writing – review & editing

Dilek Yazıcıoğlu: investigation and data curation, conceptualization, validation and writing – review & editing

Ömer Taylan Akkaya: resources, data curation and writing

Derya Özkan: supervision, validation and writing

Hüseyin Alp Alptekin: formal analysis and data curation

İbrahim Haluk Gümüş: supervision, conceptualization

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Mechanical power and postoperative pulmonary complications in patients undergoing major abdominal surgery

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ABSTRACT

Aims: Postoperative pulmonary complications (PPCs) are a major cause of perioperative morbidity and mortality in patients undergoing major abdominal surgery. Although various factors contribute to PPCs, intraoperative mechanical ventilation strategies play a critical role. Mechanical power, a parameter encompassing factors like tidal volume and respiratory rate, has emerged as a potential risk factor for ventilator-associated lung injury (VILI). This study aims to investigate the relationship between intraoperative mechanical power and PPCs.

Methods: This prospective, observational study included 207 patients aged 18 years and older undergoing elective major abdominal surgery between April and December 2022. Mechanical power was calculated using a simplified formula based on ventilator parameters recorded at 15-minute intervals. PPCs were evaluated within 24 hours postoperatively, following the European Perioperative Clinical Outcome (EPCO) guidelines. Primary outcome was the relationship between intraoperative mechanical power and PPCs, with secondary outcomes assessing the incidence of specific PPCs.

Results: PPCs occurred in 22.2% (n=46) of the patients. The mean mechanical power was 8.99 J/min in patients with PPCs and 8.56 J/min in those without, with no statistically significant difference. Atelectasis was the most common PPC. Factors such as chronic obstructive pulmonary disease (COPD), prolonged surgery, and higher ASA scores were associated with increased PPC risk.

Conclusion: Although no significant association between mechanical power and PPCs was found in this study, the findings underscore the importance of considering mechanical power in intraoperative ventilation strategies to reduce the risk of ventilator-associated lung injury. Further large-scale, prospective studies involving diverse patient populations are essential to clarify the role of mechanical power in minimizing PPCs and improving perioperative outcomes. Careful selection and management of ventilation strategies, with a focus on optimizing mechanical power, remain crucial in reducing PPC incidence and enhancing patient care.

Keywords: Lung injury, ventilators-mechanical, perioperative care, ventilator-induced lung injury

INTRODUCTION

Postoperative pulmonary complications (PPCs) are a significant cause of perioperative morbidity and mortality.[1] It is estimated that more than 200 million major surgeries are performed worldwide annually.[2] Various studies have shown that pulmonary complications are more common than cardiac complications and significantly increase hospital costs.[3] Studies indicate an incidence rate of up to 23%.[4] Respiratory tract infection, respiratory failure, pleural effusion, atelectasis, pneumothorax, bronchospasm, and aspiration pneumonitis are among the components of PPCs defined by the European Perioperative Clinical Outcome (EPCO) (Table 1).[5] The causes of these complications are multifactorial. The type of surgical procedure, the anesthesia method used, and preoperative risk factors specific to patients play a role. In addition to their multifactorial etiology, PPCs are associated with numerous preoperative, intraoperative, and postoperative risk factors. Miskovic and Lumb[4,6] categorized these factors as patient-related, procedure-related, and laboratory testing-related, and then examined non-modifiable and modifiable risk factors such as age, smoking, comorbidities, chronic lung disease, and type of surgery. Among the modifiable risk factors are intraoperative mechanical ventilator strategies. Intraoperative

ventilation strategies are important for preserving patients' lungs and reducing ventilation-related complications during surgery. Ventilator-associated lung injury (VILI) resulting from the use of mechanical ventilation is a significant concern with potential morbidity and mortality. Volutrauma, barotrauma, atelectotrauma, and biotrauma are the four classic mechanisms of VILI. The necessity of using lung-protective ventilation strategies to prevent VILI is widely accepted. Factors contributing to VILI are diverse and interact with each other, including tidal volume, peak pressure, plateau pressure, positive end expiratory pressure (PEEP), flow rate, and respiratory rate. Mechanical power, which encompasses all these factors, has emerged as a parameter considered in mechanical ventilator therapy in intensive care units (ICU) in recent years.

Table 1. Definitions of postoperative pulmonary complications

Respiratory infection	Patient has received antibiotics for a suspected respiratory infection and met one or more of the following criteria: new or changed sputum, new or changed lung opacities, fever, white blood cell count>12x10^9/L
Respiratory failure	Postoperative PaO_2<8kPa (60 mmHg) on room air, a PaO_2:FiO_2 ratio< 40kPa (300 mmHg) or arterial oxyhemoglobin saturation measured with pulse oximetry <90% and requiring oxygen therapy
Pleural effusion	Chest radiograph demonstrating blunting of the costophrenic angle, loss of sharp silhouette of the ipsilateral hemidiaphragm in upright position. Evidence of displacement of adjacent anatomical structures or (in supine position) a hazy opacity in one hemithorax with preserved vascular shadows
Atelectasis	Lung opacification with a shift of the mediastinum, hilum or hemidiaphragm toward the affected area, and compensatory over-inflation in the adjacent non-atelectatic lung
Pneumothorax	Air in the pleural space with no vascular bed surrounding in the visceral pleura
Bronchospasm	Newly detected expiratory wheezing treated with bronchodilators
Aspiration pneumonitis	Acute lung injury after the inhalation of regurgitated gastric contents

PaO_2: partial pressure of arterial oxygen, FiO_2: Fraction of inspired oxygen

The parameter initially proposed by Gattinoni et al.[7] represents the energy delivered to the respiratory system during mechanical ventilation. Due to the complexity of the initial formula, there have been difficulties in its application, leading to the development of simplified formulas. The formula developed by Giosa et al.[8] stands out for its effectiveness in volume-controlled ventilation and ease of use. Experimental and clinical studies have shown that the threshold value for the relationship between mechanical power and mortality ranges from 11.3 J/min to 17 J/min.[9–11] While there is research on mechanical power in ICUs, there is a lack of an adequate number of studies in patients undergoing mechanical ventilation in operating rooms. The aim of this study was to examine the correlation between intraoperative mechanical power exerted on the lungs and the occurrence of PPCs in patients undergoing major abdominal surgery. As a secondary objective, we aimed to identify specific factors, such as patient-related characteristics that may influence the relationship between mechanical power and PPCs. Additionally, we sought to evaluate the potential impact of mechanical power on different types of pulmonary complications, with the goal of optimizing ventilator settings to reduce the incidence of these complications.

METHODS

After obtaining written informed consent and approval from the ethics committee, patients aged 18 years and older undergoing elective major abdominal surgery with intraoperative volume-controlled ventilation were included in the study. The study was conducted prospectively and observationally between April 2022 and December 2022. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Routine preoperative anesthesia assessment was performed, and all patients were evaluated for age, gender, height, weight, and The American Society of Anesthesiologists (ASA) classification. Risk factors related to PPCs were queried. Mechanical ventilation parameters were recorded at 15-minute intervals until the 60th minute. Mechanical power was calculated using a simplified formula based on parameters obtained from the mechanical ventilator (minute ventilation x (Peak pressure+PEEP+Inspiratory flow rate / 6) / 20). The presence of pulmonary complications was evaluated at postoperative 24 hours. Pulmonary complications were assessed based on the definition framework prepared by EPCO (Table 1).[5] The primary outcome of this study is to evaluate the relationship between intraoperative mechanical power applied to the lungs and PPCs in patients undergoing major abdominal surgery. Secondary outcomes include assessing the incidence of specific PPCs such as atelectasis, bronchospasm, pleural effusion, and pneumonia.

Existing literature lacks studies assessing PPCs in humans through the lens of 'Mechanical Power'. Therefore, an effect size (d) of 0.50, indicative of a moderate effect, was utilized for the Student t-test. With a Type 1 error rate set at 0.05 and a power of 0.90, a total sample size of 172 individuals was calculated using a two-tailed hypothesis. Sample size calculation was performed using G-Power 3.1 software. To account for potential data loss, it was planned to recruit at least 10% more participants than the calculated sample size.

The analysis process was conducted using the Statistical Package for Social Science (SPSS) 24.0 program. Normality of distribution was assessed using the Kolmogorov-Smirnov test, histograms, and Skewness-Kurtosis coefficients. Categorical measurements were presented as numbers and percentages. For continuous measurements, mean and standard deviation were presented for those showing normal distribution, while median and minimum-maximum values were presented for those not showing normal distribution. Binary analyses for normally distributed data were evaluated using the student t-test, while binary analyses for non-normally distributed data were evaluated using the Mann Whitney U test. Pearson's chi-square test was applied to assess the relationship between categorical variables. A Type I error level of 0.05 was considered.

RESULTS

216 patients who underwent major abdominal surgery were included in the study. Statistical analysis and evaluation were performed for a total of 207 patients (Figure 1). PPCs were observed in 22.2% (n=46) of the included patients at 24 hours, while it was not observed in 77.8% (n=161) of the patients (Figure 2). When examining the demographic data of the patients, it was observed that there were more female individuals, with an average age of 59 years, and body mass index ranging from 20 to 35 kg/m^2. It was observed that atelectasis was the most common component in patients with

PPCs (Table 2). When the relationship between demographic and clinical characteristics of the patients and PPCs was examined, it was found that PPCs was more frequently observed in patients with a diagnosis of chronic obstructive pulmonary disease (COPD), those planned for postoperative ICU admission in preoperative evaluation, those with a surgical duration of more than two hours, and those with a higher ASA score (Table 3, Table 4, Table 5). The mean mechanical power value was calculated as 8.99 J/min for patients with PPCs and 8.56 J/min for those without PPCs. The relationship between PPCs components and mechanical power is shown in Table 6.

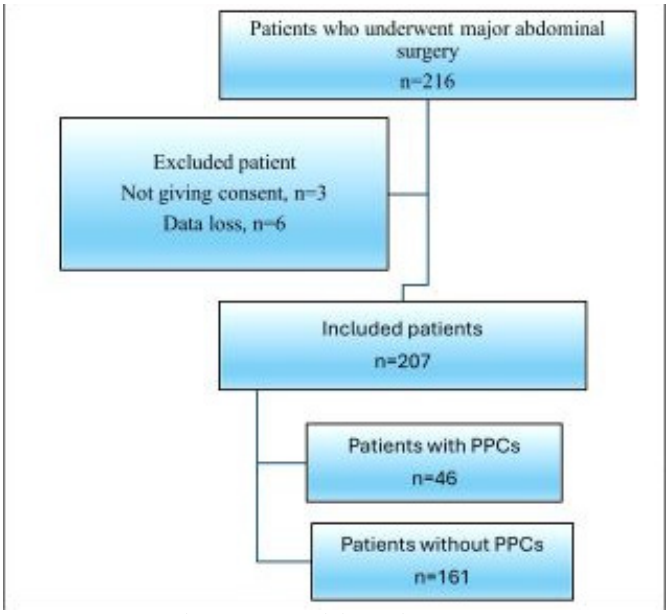

Figure 1. Patients undergoing major abdominal surgery

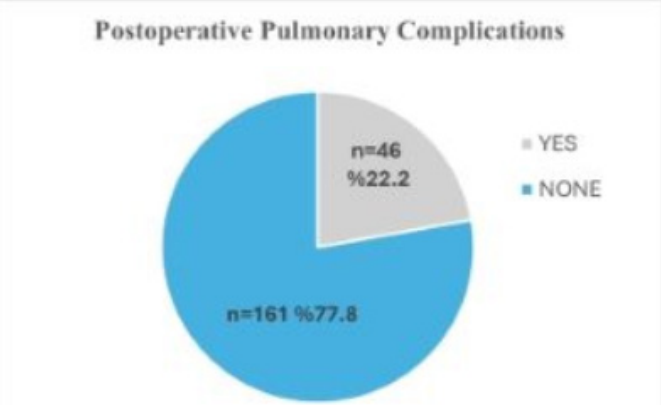

Figure 2. Postoperative pulmonary complications

Table 2. Distribution of postoperative pulmonary complications components

PPCs components	n (%)
Respiratory failure	25 (12.1)
Bronchospasm	5 (2.4)
Pulmonary infection	4 (1.9)
Pneumonia	18 (8.7)
Atelectasis	35 (16.9)
Pneumothorax	0 (0)
Aspiration pneumonia	0 (0)
Pleural effusion	20 (9.7)
Pulmonary edema	0 (0)

PPCs; postoperative pulmonary complications

Table 3. Patient-related factors and postoperative pulmonary complications

Clinical features		(%)	Postoperative pulmonary complications, (%)		
		Sum n=207	Yes n=46	None n=161	p
Gender	F	128 (61.8)	26 (20.3)	102 (79.7)	0.400
	M	79 (38.2)	20 (25.3)	59 (74.7)	
Smoking	Yes	58 (28.0)	13 (22.4)	45 (77.6)	1.000
	None	149 (72.0)	33 (22.1)	116 (77.9)	
COPD	Yes	16 (7.7)	8 (50.0)	8 (50.0)	0.010
	None	191 (92.3)	38 (19.9)	153 (80.1)	
BMI (kg/m^2)	0-30 (kg/m^2)	165 (79.8)	35 (21.2)	130 (78.8)	0.628
	>30 (kg/m^2)	42 (20.2)	11 (26.2)	31 (73.8)	

COPD; Chronic obstructive pulmonary disease, BMI; body mass index

DISCUSSION

In this study, the relationship between intraoperative mechanical power applied to the lungs and PPCs was investigated in patients undergoing major abdominal surgery. Pulmonary complications were observed in 22.2% of the patients at 24 hours. The mean mechanical power value was 8.99 J/min in patients with pulmonary complications, while it was 8.56 J/min in patients without pulmonary complications. There was no statistically significant difference. Additionally, a statistically significant difference was observed in ASA scores, COPD, surgical duration, and the parameter of planning postoperative ICU admission in preoperative evaluation, which were found to be associated with an increased risk of PPCs.

PPCs incidence rates vary due to factors such as different definitions in the literature, sample size, and surgical characteristics, ranging from 5.8% to 39%.[1,12,13] The formation of PPCs is associated with numerous risk factors. Literature suggests that both male and female genders have higher rates of PPCs occurrence in studies conducted on gender-related factors.[14,15] Another risk factor is inadequate postoperative analgesia. We believe that adequate analgesia was achieved in our study; therefore, no relationship was found between analgesia practices and PPCs. Ineffective postoperative analgesia can lead to complications, prolonged hospital stays, increased intensive care needs, decreased patient satisfaction, and chronic pain development.[16]

While there are studies indicating an association between smoking and PPCs, we did not reach a significant conclusion.[17,18] COPD has been identified as a risk factor for PPCs in 13 out of 15 studies in a review conducted by Smetana et al.[17] In another study, abnormal findings in lung examination (such as decreased breath sounds, prolonged expiration, crackles, wheezing, or rhonchi) were reported as the strongest determinants of postoperative pulmonary complication rates.[19] Decreased lung volumes after surgery are the main cause of PPCs. Obesity can lead to restrictive pulmonary physiology and further decrease lung volumes and postoperative deep breathing ability. However, studies evaluating postoperative PPCs have not found morbid obesity to be an increased risk factor.[17,20]

The ASA score aims to classify patients' health status based on their physical condition and comorbidities, and a high ASA score has been associated with an increased risk of PPCs.[21] This suggests that patients with higher ASA scores generally have more serious comorbidities, which may result in weaker

Table 4. Perioperative factors and postoperative pulmonary complications, (%).

Clinical features		(%)	Postoperative pulmonary complications, (%)		
		Sum n=207	Yes n=46	None n=161	p
PPI use	Yes	22 (10.6)	7 (31.8)	15 (68.2)	0.279
	None	185 (89.4)	39 (21.1)	146 (78.9)	
Steroid use	Yes	2 (1.0)	1 (50.0)	1 (50.0)	0.396
	None	205 (99.0)	45 (22.0)	160 (78.0)	
Preoperative antibiotic use	Yes	167 (80.7)	40 (24.0)	127 (76.0)	0.312
	None	40 (19.3)	6 (15.0)	34 (85.0)	
Postoperative analgesia	Epidural pca	3 (1,4)	0	3 (100)	0.639
	Iv pca	2 (1.0)	0	2 (100)	
	Oral	15 (7.2)	2 (13.3)	13 (86.7)	
	Parenteral	113 (54.6)	26 (23.0)	87 (77.0)	
	Regional block	10 (4.8)	1 (11.1)	8 (88.9)	
	Multimodal	64 (30.9)	17 (26.2)	48 (73.8)	
ASA score	1	18 (3.9)	0	8	0.005
	2	106 (51.2)	17 (16.0)	89 (84.0)	
	3	89 (43.0)	26 (29.2)	63 (70.8)	
	4	4 (1.9)	3 (75.0)	1 (25.0)	

PPI; proton pump inhibitor, pca; patient-controlled analgesia, ASA; American Society of Anaesthesiologists

Table 5. surgery related factors and postoperative pulmonary complications

Clinical features	(%)	(%)	Postoperative pulmonary complications, (%)		p
		Sum n=207	Yes n=46	None n=161	
Bowel resection	Yes	83 (40.1)	21 (25.3)	62 (74.7)	0.483
	None	124 (59.9)	25 (20.2)	99 (79.8)	
Nasogastric tube	Yes	137 (66.2)	33 (24.1)	104 (75.9)	0.468
	None	70 (33.8)	13 (18.6)	57 (81.4)	
Planning postoperative intensive care unit admission in preoperative evaluation	Yes	152 (73.4)	43 (28.3)	109 (71.7)	**0.001**
	None	55 (26.6)	3 (5.5)	52 (94.5)	
Surgical time	0-120 dk	69 (33.3)	6 (8.7)	63 (91.3)	**0.002**
	>120 dk	138 (66.7)	40 (29.0)	98 (71.0)	
Surgical method	Laparoscopic	45 (33.3)	7 (15.5)	38 (84.4)	0.391
	Open	148 (76.7)	34 (22.9)	114 (77.0)	
Incision site	Upper abdominal	48 (23.1)	13 (27.1)	35 (72.9)	0.468
	Lower abdominal	159 (76.8)	33 (20.8)	126 (79.2)	

Table 6. Relationship between mechanical power and postoperative pulmonary complications components

		Mechanical power average value (j/min)	Mean rank (SD)	p
PPCs	Yes	8.99	(2.53)	0.290
	None	8.56	(2.42)	
Respiratory failure	Yes	9.3	114.1	0.368
	None	8.6	102.6	
Bronchospasm	Yes	10.1	144.4	0.127
	None	8.6	103.0	
Pulmonary infection	Yes	9.4	128.0	0.418
	None	8.6	103.5	
Pneumonia	Yes	9.1	111.3	0.584
	None	8.6	103.3	
Atelectasis	Yes	9.1	113.3	0.311
	None	8.6	102.1	
Pleural effusion	Yes	0.0	97.3	0.599
	None	8.6	104.7	
Pneumothorax	Yes	0.0		
	None	8.6	104.7	
Pulmonary edema	Yes	0.0		
	None	8.6	104.7	
Aspiration pneumonia	Yes	0.0		
	None	8.6	104.7	

PPCs; postoperative pulmonary complications

respiratory functions. In our study, similar to the literature, PPCs was observed in 16% of patients with ASA II score, 29.2% of patients with ASA III score, and 75% of patients with ASA IV score ($p<0.005$). While higher ASA scores may increase the risk of pulmonary complications, other factors should also be considered. Therefore, it is important to make an individual assessment considering factors such as the patient's overall health status, anesthesia risk, and surgical planning.

Surgical field is one of the most important factors in predicting PPCs risk; the incidence of complications is inversely proportional to the distance of the surgical incision from the diaphragm.[22] For 11 studies conducted on patients undergoing esophagectomy, the postoperative pulmonary complication rate was 18.9%; for 16 studies on patients undergoing abdominal aortic aneurysm repair, the postoperative pulmonary complication rate was 25.5%; for six studies involving head and neck surgery patients, the postoperative pulmonary complication rate was 10.3%; for five studies examining hip surgery, the PPCs rate was 5.1%; and for two studies involving gynecological or urological procedures, the postoperative pulmonary complication rate was 1.8%.[17] In the same review conducted by Smetana et al.,[17] the postoperative pulmonary complication rates for upper abdominal and lower abdominal surgery were 19.7% and 7.7%, respectively. In our study, we included 207 patients who underwent major abdominal surgery, with 48 of them undergoing upper abdominal surgery. PPC was observed in 27.1% of patients undergoing upper abdominal surgery and in 20.8% of patients undergoing lower abdominal surgery.

The concept of mechanical power encompasses the main factors contributing to VILI, including elements such as tidal volume and driving pressure. Recent studies suggest that respiratory rate, a significant component of high mechanical power in patients under general anesthesia, is associated with PPCs.[23] It has been shown that a doubling of respiratory rate leads to a 1.4-fold increase in mechanical power.[24] Studies have demonstrated the relationship between mechanical power and mortality in patients with and without ARDS.[25,26] The threshold value at which the harmful effects of mechanical power occur is not yet fully established. In patients with ARDS, it has been shown that energy levels exceeding 17 J/min increase mortality.[25] Another study found an increase in 28-day mortality at mechanical power levels exceeding 22 J/min.[27] In a large multicenter retrospective cohort study involving approximately 230,000 intraoperative patients, the mean mechanical power value was 7.67 J/min for patients with PPCs and 6.62 J/min for those without PPCs, indicating that higher mechanical power values during ventilation are associated with a higher likelihood of PPCs.[28] In a retrospective study involving 3,000 ICU patients conducted by Şentürk et al.,[11] the median mechanical power value was found to be 11.3 J/min, with mortality rates of 35.4% for mechanical power <11.3 J/min and 49.1% for mechanical power >11.3 J/min ($p<0.001$). In our study, the mean mechanical power value was 8.99 J/min for patients with PPCs and 8.56 J/min for those without PPCs.

Limitations

One of the strengths of our study is its prospective design and data collection during the surgical procedure. However, there are several limitations to consider. The absence of a randomized controlled design is a primary limiting factor. Other limitations include the heterogeneity of the patient population, the single-center setting, the lack of assessment of preoperative respiratory function, and the restriction to a specific surgical procedure group or age range could have enhanced the study's validity by minimizing confounding variables and ensuring a more homogeneous patient population.

CONCLUSION

This study explored the relationship between intraoperative mechanical power applied to the lungs and PPCs in patients undergoing major abdominal surgery. Although no statistically significant association was found between mechanical power values and PPCs, the findings highlight the importance of optimizing intraoperative ventilation strategies to mitigate VILI. The use and management of mechanical power in the operating room may play a key role in reducing the risk of VILI, but more definitive evidence is required. Future prospective studies involving more diverse and extensive patient populations are needed to better understand the role of mechanical power in preventing PPCs. These studies may provide valuable insights that can guide adjustments in ventilator parameters to minimize lung injury, reduce morbidity and mortality, and optimize the use of healthcare resources. Incorporating mobile applications or mechanical ventilator software to calculate mechanical power may further enhance the precision and effectiveness of these strategies.

ETHICAL DECLARATIONS

Ethics Committee Approval

After obtaining written informed consent and approval from the ethics committee, patients aged 18 years and older undergoing elective major abdominal surgery with intraoperative volume-controlled ventilation were included in the study. The study was conducted prospectively and observationally between April 2022 and December 2022.

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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The progression of biochemical parameters and disease severity scores in patients with septic shock: a study of sequential measurements

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ABSTRACT

Aims: Sepsis and septic shock are critical conditions that contribute significantly to morbidity and mortality in intensive care units worldwide. Early diagnosis and treatment are crucial for improving survival, yet traditional diagnostic methods lack sensitivity. Biomarkers like C-reactive protein and procalcitonin, along with disease severity scores such as APACHE II, SOFA, and MODS, are increasingly used to assess patient status and predict outcomes. This study aims to explore the relationship between inflammatory biomarkers and disease severity scores in critically ill patients with septic shock.

Methods: This prospective study included 20 patients with septic shock admitted to the intensive care unit between July and September 2009. C-reactive protein, procalcitonin, cortisol, brain natriuretic peptide, lactate, and other physiological parameters were monitored over a three-day period. Disease severity was assessed using APACHE II, SOFA, and MODS scores, with mortality outcomes recorded. Data was analyzed using Spearman's correlation analysis.

Results: The study found no significant correlation between APACHE II scores at admission and 28-day mortality. However, both SOFA and MODS scores showed significant correlations with 28-day mortality when measured on the second and third days of intensive care unit admission. C-reactive protein and procalcitonin levels were elevated in all patients, yet no direct correlation with 28-day mortality was identified. Sequential monitoring of SOFA and MODS scores was more predictive of patient outcomes than single-day measurements.

Conclusion: Sequential assessments of disease severity scores provide valuable insights into the progression of septic shock. While C-reactive protein and procalcitonin are useful in monitoring infection, they alone may not be sufficient to predict mortality. In contrast, dynamic measurements of SOFA and MODS scores are better indicators of patient prognosis, particularly when combined with biomarker data. Continuous monitoring of disease severity scores, particularly SOFA and MODS, alongside biomarkers such as C-reactive protein and procalcitonin, enhances the prediction of mortality in septic shock patients. These tools, when used together, offer a comprehensive approach to managing critically ill patients in the intensive care unit, allowing for timely and effective interventions.

Keywords: Apache, biomarkers, organ dysfunction scores, sepsis, septic shock

INTRODUCTION

Sepsis defined as a systemic response to an infection is a major cause of morbidity and mortality, especially in the elderly, immunosuppressed, and critically ill patients.[1,2] Sepsis and septic shock represent significant healthcare challenges, impacting millions of individuals globally each year.[3] Early diagnosis and treatment of sepsis are the most important determinant factors of survival and outcome.[4] Microbiological results typically require a minimum of 2–3 days to be finalized

and are often not highly sensitive, particularly when cultures are obtained while patients are on antimicrobial treatment. As a result, around 40–50% of sepsis cases are classified as culture-negative.[5,6] Biomarkers have been investigated for their role in predicting sepsis, diagnosing the condition, evaluating the response to sepsis treatment, and guiding antibiotic therapy based on biomarker levels.[7] Currently, traditional clinical findings and laboratory tests such as white blood cell count, sedimentation rate, and C-reactive protein often lack sufficient sensitivity and specificity and may be inadequate for diagnosis. The greatest challenge remains the heterogeneity of the disease, complicating diagnosis and classification. Although numerous biomarkers have been investigated as potential indicators for sepsis, none have yet achieved the precision necessary to be universally accepted as definitive 'markers.'

Acute phase reactants such as C-reactive protein (CRP) are more useful in diagnosis and have prognostic significance in sequential measures.[7,8] Although procalcitonin (PCT) is elevated in nonseptic conditions such as cardiopulmonary bypass or pancreatitis, it is useful in diagnosis and follow-up.[9,10] There is no universally accepted cutoff value for procalcitonin in the diagnosis of sepsis; studies in the literature have either not specified a cutoff point or have used values ranging from 0.5 to 2 µg/L.[11]

Scoring systems are used for several purposes in intensive care units (ICUs); to facilitate the identification of patient groups requiring intensive care treatment, to facilitate the identification of patient groups to be included in clinical trials, to compare ICUs in terms of performance, to assess the performance of the same ICU in different time periods, and to arrange and follow the treatment of any patient.[12] Two main scoring systems are described for ICUs; the first scoring systems are based on physiological changes; these in groups are focused on single point and used in predicting mortality. Acute Physiology and Chronic Health Evaluation (APACHE) score is also a scoring system helping to predict mortality based on physiological changes.[13] The second group is a scoring system based on organ dysfunctions; these in groups are also referred to as follow-up scores and define morbidity. This group includes Multiple Organ Dysfunction Score (MODS) and Sequential Organ Failure Assessment (SOFA)[14,15] (Table 1).

Table 1. Comparison of mortality and morbidity estimation scoring systems

	Mortality (APACHE II)	Morbidity (MODS, SOFA)
Purpose	Predict mortality	Defines morbidity (organ failure)
Ease of use	Often complex calculations	Usually, simple
Timing	On acceptance or within the first 24 hours	Can be measured again and again (daily)
Disease process	Does not provide information for any organ function	Provides information about a desired organ function

APACHE: Acute Physiology and Chronic Health Evaluation, MODS: The Multiple Organ Dysfunction Score, SOFA: Sequential Organ Failure Assessment score

In our study, we aimed to investigate the association between inflammatory parameters and disease severity scores in patients with septic shock. Through this analysis, we aim to contribute to better risk stratification and potentially guide more effective treatment strategies in critically ill patients.

METHODS

This study was designed as a prospective observational study. Between July and September 2009, twenty patients with septic shock who were admitted to the ICU were included in this study. The study protocol was approved by the institutional ethics committee (Date:29.06.2009 Decision No:154-4922), and informed consent was obtained from all patients or, in the case of unconscious or sedated patients, from their legal representatives. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Patients who declined to participate or were under 18 years of age were excluded.

Upon admission, demographic characteristics and medical data, including age, gender, body weight, reasons for ICU admission, major diagnoses, and previous health status, were recorded. Radiological and microbiological examinations were performed under the supervision of the ICU coordinator, when necessary, to identify the potential infection site both at admission and during the ICU stay.

Blood samples were collected from each patient for three consecutive days, and disease severity scores were calculated. The diagnoses of systemic inflammatory response syndrome, local infection, sepsis, and septic shock were based on the society of critical care medicine consensus conference criteria.[16] Venous blood samples were obtained for biochemical analyses, including serum CRP, procalcitonin levels, and complete blood count, within approximately two hours of septic shock diagnosis.

Leukocyte counts, hemodynamic parameters, thrombocyte counts, cortisol levels, brain natriuretic peptide levels, lactate levels, high-density lipoprotein (HDL) levels, albumin levels, CRP levels, procalcitonin levels, central venous pressure (CVP) measurements, mixed venous oxygen saturation (SvO_2) measurements, and PaO_2/FiO_2 ratios were monitored over a three-day period. The APACHE II score was used to predict the severity and mortality of critical illness, while SOFA and MODS scores were calculated to document the severity of sepsis and organ dysfunction both at admission and on a daily basis.

All patients included in the study were monitored throughout their hospitalization to gather clinical outcome data, even after discharge from the ICU. Data recorded included the length of stay in both the hospital and ICU, hospital and ICU mortality, and 28-day mortality rates.

Statistical Analysis

The data obtained from the study were presented as median, minimum-maximum values, and mean±standard deviation (mean±SD). Statistical significance was set at $p<0.05$. Descriptive statistics and comparisons between groups for nonparametric data were performed using the Kruskal-Wallis and Mann-Whitney U tests. Spearman's Rho correlation analysis was employed for correlation assessments. All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) software (SPSS 16.0 for Windows, 2007, SPSS Inc., USA).

RESULTS

The demographic and medical data including the age, gender, their clinics before ICU admission, the presence of trauma, APACHE II, SOFA and MODS scores of the patients at the admission, are shown in Table 2.

Of the patients, 15 had a history of surgery, 13 had undergone emergency surgery, while two had undergone elective surgery. Five patients were admitted to ICU because of medical reasons.

Eight patients who suffered from trauma were followed up in ICU.

Table 2. Demographic and medical characteristics of patients

Age (years), SD		51.40±18.44
Sex, n (%)	Female	7 (35)
	Male	13 (65)
Accepted from, n (%)	Transferred from ward	2 (10)
	ICU	12 (60)
	Operating room	6 (30)
History of trauma, n (%)	Yes	8 (40)
	No	12 (60)
APACHE II score (mean), SD		20.95±7.22
MODS score (mean), SD		5.80±3.22
SOFA score (mean), SD		6.0±3.1

APACHE II: Acute Physiology and Chronic Health Evaluation, MODS: The Multiple Organ Dysfunction Score, SOFA: Sequential Organ Failure Assessment score, ICU: intensive care unit. Plus–minus values are means ±SD, n: number of patients.

The parameters including ICU and hospital stays, ICU - hospital and 28-day mortality are shown in Table 3. Of the total 20 patients, eight were dead in the ICU, the treatment of nine patients were continued in another service or another ICU, and three were discharged to their home.

Table 3. Clinical outcome of patients

Length of stay in ICU (days)	29.85±25.02
Length of stay in hospital (days)	47.70±26.78
ICU mortality (%)	40
Hospital mortality (%)	50
28 days mortality (%)	35

ICU: intensive care unit, plus–minus values are means ±SD

The relationships between scoring systems, some biomarkers values used to describe disease severity on the first day and follow up 24 and 48 hours and 28-day mortality were investigated. Analyses were used by Spearman's correlation analysis.

The progression of the patients' follow-up parameters, including leukocyte counts, hemodynamic parameters, thrombocyte counts, cortisol levels, brain natriuretic peptide levels, lactate levels, HDL levels, albumin levels, CRP levels, procalcitonin levels, CVP measurements, SvO_2 measurements, and PaO_2/FiO_2 ratios over a three-day period, are shown in Table 4.

Table 4. The progression of the patients' follow-up parameters

	On the day of septic shock diagnosis	24th hour	48th hour	p
Leukocyte, /mm³	13750	12950	10700	0.064
Thrombocyte, / mm³	176000	133500	137000	0.101
Cortisol, mcg/dL	28.5	31	20.5	0.421
BNP, pg/mL	1230	1033	932	0.672
Lactate, mmol/L	1.75	1.65	1.60	0.335
HDL, mg/dL	5	6	6	0.494
Albumin, g/dL	2.1	2.3	2.35	0.250
CRP, mg/dL	135	138	121	0.449
Procalcitonin, mcg/L	5.35	8.35	8.20	0.513
CVP, cmH_2O	8.5	10	7.5	0.082
SvO_2 sat, %	67.5	72.5	74.5	0.005
Horowitz Index	228	213	225	0.350

Values are the mean results BNP: brain natriuretic peptide, CRP: C-reactive protein CVP: central venous pressure, SvO_2 sat central venous oxygen saturation

No significant correlation was found between the MODS and SOFA values and 28-day mortality on the first day of septic shock diagnosis (p=0,084 p=0,059) but there was a significant positive correlation (moderate-high) between the MODS and SOFA scores and the 28-day mortality on the second and third days of septic shock (p2=0.030 p2=0.019 p3=0.007 p3=0.004). Comparisons of patients' disease severity scores according to the 28-day mortality status are shown in Figure 1 and Figure 2.

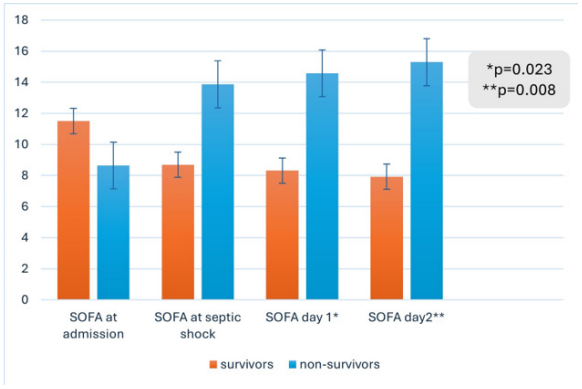

Figure 1. Comparison of SOFA to 28-day mortality
SOFA: sequential organ failure assessment

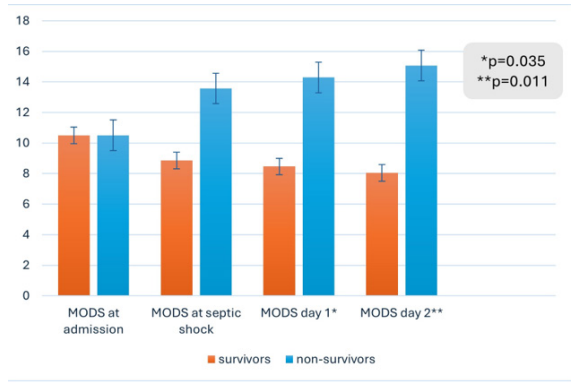

Figure 2. Comparison of MODS to 28-day mortality
MODS: multiple organ dysfunction score

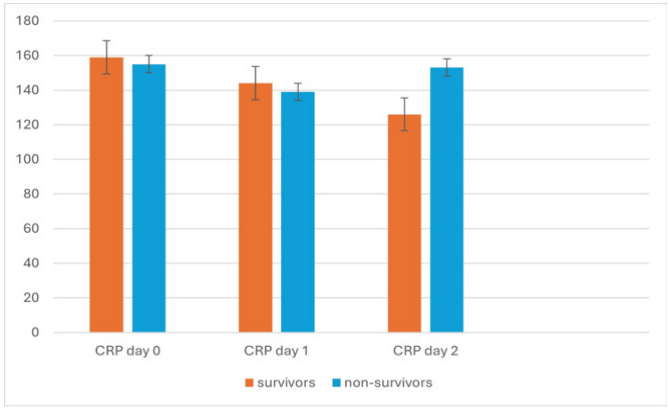

Figure 3. CRP and mortality
CRP: C-reactive protein, day 0; septic shock diagnosed, p values are > 0.05

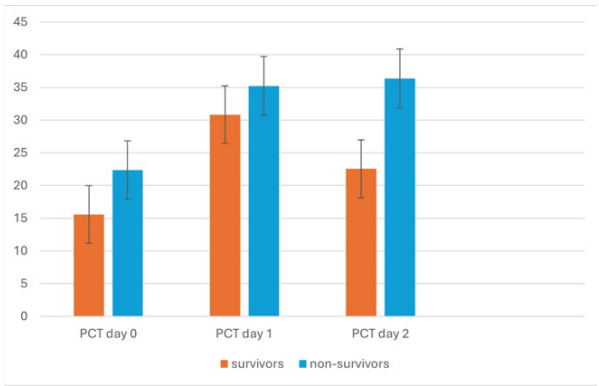

Figure 4. Procalcitonin and mortality
PCT: procalcitonin, day 0; septic shock diagnosed, p values are > 0.05

No correlation was observed between CRP and procalcitonin levels measured over three days and 28-day mortality. CRP and procalcitonin used in the diagnosis and follow-up of the infection were not associated with the 28-day mortality. In addition, there was no significant difference between

ICU-hospital mortality and serum lactate, HDL, CRP, and procalcitonin levels when compared to the survivors and deaths.

DISCUSSION

In this study, we evaluated the relationship between biochemical parameters and disease severity scores in patients diagnosed with septic shock. Our findings revealed that sequential measurements of inflammatory biomarkers were associated with worsening clinical status, as reflected by the APACHE II, SOFA, and MODS scores. This data emphasizes the utility of continuous biomarker monitoring for assessing disease progression and guiding therapeutic interventions in septic shock.

The primary objective of our study was to evaluate the prognosis of sepsis by analyzing 28-day mortality, intensive care mortality, and hospital mortality among patients with septic shock. The secondary objective was to investigate the relationship between inflammatory biomarkers, such as CRP and procalcitonin, and disease severity scores (APACHE II, SOFA, and MODS). We believe that understanding these parameters is crucial for improving patient outcomes. Sequential measurements of SOFA and MODS are particularly useful for predicting mortality, reflecting the dynamic nature of organ dysfunction in critically ill patients. By integrating these sequential scores with other biomarkers, we aim to enhance the accuracy of mortality predictions and guide more tailored treatment approaches.

In comparison to other models, it has been demonstrated that the SAPS III and LODS models offer superior discrimination for 28-day mortality compared to SIRS, SOFA, and SAPS II models.[17] In particular, the SAPS III model exhibited the best discrimination capacity for predicting 28-day mortality. While our study focused on the APACHE II and SOFA scores, future research could benefit from exploring the SAPS III model's capacity for improving mortality predictions in septic shock patients.

Previous research has demonstrated that CRP levels correlate well with the severity of sepsis and other inflammatory diseases.[18] A single measured CRP value has been shown in meta-analysis lack sufficient sensitivity for the diagnosis of sepsis.[19,20] A study conducted in Belgium highlighted a relationship between elevated CRP levels (>10 mg/dL) and increased incidence of organ failure and mortality in ICU patients.[21] However, other studies have suggested that CRP alone is insufficient to predict sepsis outcomes, and the relationship between sepsis severity and elevated CRP levels remains unclear.[22] While several studies have shown a correlation between serum PCT levels and the severity of sepsis and organ dysfunction, not all have supported this finding.[23,24] Recent evidence suggests that presepsin, as a biomarker, not only serves as a diagnostic tool for systemic bacterial infections but also offers significant prognostic value, making it useful in guiding clinical decisions in sepsis management.[25]

There is no gold standard for diagnosing sepsis in critically ill patients. Microbiological cultures, which are often insensitive and nonspecific, take time to produce results. Therefore, biomarkers like procalcitonin, which are stable, easy to measure, and provide rapid results, may be more useful. Although procalcitonin performance is not ideal for critically ill patients, it is considered superior to CRP.[26]

The varying results in published literature suggest that while CRP monitoring can be helpful for infection prediction and assessing antibiotic response in ICUs, it may not be sufficient for sepsis diagnosis or prognosis.[24] In our study, the median CRP level was 135 mg/L (±82.7), and the median procalcitonin level was 5.35 ng/mL (±26.3) in patients with septic shock. These values were significantly higher than the upper limits (CRP: 0-3 mg/L, procalcitonin: 0-2.0 ng/mL).

Scoring systems have become crucial in predicting mortality risk and intensive care outcomes. Several scoring systems have been developed for use in intensive care. The MODS and SOFA scoring systems can be rapidly calculated at the bedside using routinely gathered patient data, offering clinicians crucial insights into patient morbidity, disease progression, and response to treatments. They also provide an overview of organ function. Although both systems have been validated for daily use, the timing of data collection and the methods used to calculate scores differ.

The APACHE II score, widely used in ICUs to stratify acutely ill patients based on their severity of disease, provides a measure of mortality risk through a combination of physiologic data, age, and pre-existing health status. However, the APACHE II score has limitations in mortality prediction, as it may overestimate mortality risk due to dynamic physiological variables influenced by ongoing treatments, and the difficulty in selecting a single principal diagnostic category for patients with multiple comorbidities.[27]

The scoring systems employed in our study include APACHE II, MODS, and SOFA. Severity scores were calculated on the day of ICU admission and on two consecutive days after diagnosis. The median APACHE II score was 19.50 (±7.22) at admission. No statistically significant difference was observed between APACHE II scores at admission and ICU-hospital mortality or 28-day mortality.

No significant relationship was found between SOFA and MODS scores (organ failure scores) at the time of admission and mortality. However, the scores measured on the first and second days after septic shock significantly differed between survivors and non-survivors at 28 days.

Although our knowledge about the pathophysiology of sepsis has increased in recent years, sepsis is still an important cause of mortality and morbidity in critically ill patients in ICUs and is a major burden on the healthcare system.[28] Sepsis-related mortality is closely related to early diagnosis and early treatment of sepsis. Nowadays, the ideal markers to be used in early and accurate diagnosis are not yet available, so the search for the ideal markers has been continuing.

In this study, some markers used in sepsis, the diagnosis of septic shock, and follow up period were investigated. In addition, disease scores used to measure disease severity were calculated. It was seen that the levels of CRP and procalcitonin were significantly higher than the upper limit determined by the laboratory. These elevations continued during the follow-up period. Disease scores were also found to be higher, which was similar to the biochemical markers. When compared the survivals to the deaths in the following days, SOFA and MODS were found to be significantly associated with 28-day mortality.

Limitations

This study has several limitations. Firstly, the small sample size reduces the statistical power and limits the generalizability

of the results to a wider population. Additionally, the study was conducted in a single ICU at Ankara University, which may limit the applicability of the findings to other centers with different patient populations or treatment protocols. The follow-up period was relatively short, focusing on the monitoring of parameters over just three days. This may not fully capture the long-term trends or changes in biomarkers that could influence the progression of sepsis and septic shock. Furthermore, the absence of a control group, consisting of either non-septic patients or those with milder infections, makes it challenging to determine if the observed findings are specific to septic shock or applicable to other conditions. There is also the issue of measurement variability, as parameters such as hemodynamic data and biomarkers like CRP and procalcitonin can be influenced by ongoing treatments such as fluid resuscitation and antimicrobial therapy, introducing potential bias. Lastly, the retrospective nature of some data collection may result in incomplete or inconsistent information compared to a prospective study design.

Recent studies have shown that dynamic nomograms, incorporating variables such as SBP, cerebrovascular disease, and oxygenation index, may offer improved accuracy and discrimination in predicting 28-day mortality in septic shock patients compared to traditional scoring systems like SOFA and APACHE II.[29]

This study offers several notable strengths. First, it provides a comprehensive analysis of various biomarkers, including CRP, procalcitonin, cortisol, brain natriuretic peptide, and lactate, alongside physiological and hemodynamic parameters. This holistic approach enhances the understanding of the inflammatory response and organ function in patients with septic shock. Another significant strength is the sequential monitoring of these biomarkers and clinical parameters over a three-day period, which offers valuable insights into disease progression in critically ill patients.

Moreover, the study utilizes well-validated scoring systems such as APACHE II, SOFA, and MODS to assess disease severity and mortality risk. The use of these established scoring systems strengthens the methodology and allows for comparison with other research in critical care. The focus on prognostic indicators is also a highlight, as it underscores the role of disease severity scores and biomarkers in predicting ICU, hospital, and 28-day mortality, providing clinically relevant insights for prognosis in septic shock patients.

Additionally, the study demonstrates the potential utility of sequential SOFA and MODS scores in mortality prediction, making these tools practical for daily use in clinical practice to monitor septic patients and guide treatment decisions. Finally, the real-world ICU environment in which the study was conducted reflects actual clinical conditions and challenges, ensuring the findings are highly applicable to everyday critical care settings.

CONCLUSION

Consecutive measurements of disease severity scores, such as APACHE II, SOFA, and MODS, may provide valuable insights not only into the progression and severity of the disease but also in guiding treatment decisions and predicting patient outcomes in critically ill patients in ICUs. Regular monitoring of these scores, alongside key biomarkers like CRP and procalcitonin, can aid clinicians in evaluating treatment efficacy, adjusting interventions accordingly, and potentially improving patient survival rates. These tools, when used together, offer a more comprehensive approach to managing septic shock and other critical conditions, ensuring timely and effective care.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the Ankara University ethic committee (Decision No: 154-4922, Date: 29.06.2009).

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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Sciatic nerve pulsed radiofrequency treatment in coccydynia

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ABSTRACT

Aims: Coccydynia is a pain felt around the coccyx that limits functionality. Interventional treatment options are available in cases that do not respond to conservative methods. This study is aimed to reduce pain by retrograde neuromodulation of the sciatic nerve with pRF in coccydynia.

Methods: 22 patients with coccydynia were treated with bilateral sciatic nerve pRF. Followed for 8 weeks. Visual analog scale measurements were performed before and 2-4-6-8 weeks after the procedure.

Results: At 4 weeks in 16 (73%) patients and at 8 weeks in 11 (27%) patients, pain had decreased by 50% compared to baseline. When the changes in the VAS scale over 8 weeks were analyzed, the change in baseline-2,4,6 weeks was statistically significantly reduced ($p<0.001$).

Conclusion: Interventional methods have been described in the treatment of coccydynia and retrograde neuromodulation of the peripheral nerve pRF was tried for the first time. The fact that the perforating cutaneous branches and sciatic nerve originate from common nerve roots explains the pain reduction with pRF applied to the sciatic nerve. Randomized controlled trials are needed to evaluate the efficacy of treatment.

Keywords: Coccydynia, radiofrequency, sciatic nerve, coccyx pain, pain treatment

INTRODUCTION

Coccydynia is a condition marked by discomfort around the coccyx, which can result from musculoskeletal issues, infection, or cancer. Trauma or childbirth is often identified as a contributing factor. Additional risk factors include gender, obesity, rapid weight loss, variations in coccygeal morphology, and coccygeal hypermobility. It is more prevalent in middle-aged women.[1,2]

In refractory patients to conservative treatment, interventional procedures such as steroid injections, caudal epidural injection, impar ganglion block, spinal cord stimulation can be performed prior to coxigectomy.[3] Successful results with coccygeal nerve block and pRF have been reported in recent publications.[4,5]

The coccygeal nerve is composed of the coccygeal plexus and is responsible for receiving sensation from the coccyx region. The coccygeal plexus is formed within ischiococcygeus from the ventral rami of S4, S5, and Co1 with a contribution (gray rami communicantes) from the sacral sympathetic trunk. It gives rise to anococcygeal nerves which pierce ischiococcygeus and the sacrospinous ligament to supply the subcutaneous tissue on the dorsal aspect of the coccyx.[6]

The perforating cutaneous nerve is the other nerve responsible for the sensory innervation of this region. The perforating cutaneous nerve, usually arising from the posterior aspects of the S2 and S3 ventral spinal rami, supplies the skin over the inferomedial aspect of the gluteus maximus muscle.[7-9]

Since these are thin and scattered nerve branches, it is very unlikely that the nerve can be identified and blocked. However, it originates from common roots with the sciatic nerve, the largest nerve in the human body. The sciatic nerve is derived from spinal nerves L4 to S3. Since S2 and S3 share roots with perforating cutaneous branches, we aimed that retrograde neuromodulation of the sciatic nerve with pRF may reduce coccygeal pain.

pRF is a method of neuromodulation in which a cannula electrode is used to approach the nerve with imaging methods such as ultrasound or fluoroscopy and conducts from a generator that produces an electric field to reduce pain expression in the central nervous system through a series of reactions occurring in neural substrates. In unlike conventional radioofrequency, pulsed mode does not cause

permanent damage to the nerve as the heat does not exceed 42 degrees.[10-12]

In this study, we aimed to evaluate the improvement in coccydynia pain with sciatic nerve pRF. Our findings are promising and are reported in the following.

METHODS

This study was conducted as a retrospective clinical trial. Ethics committee approval was obtained from the local hospital. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Pre-procedure and post-procedure VAS scores were obtained from patient file records. Missing data were completed by a telephone call.

Participants

Between January-June 2024, 28 patients who underwent pRF to the sciatic nerve due to coccydynia were evaluated. Twenty-two patients who met the diagnostic criteria were included in the study. Patients with coccydynia for more than 3 months were evaluated by physical examination. Pathologies such as trigger points, L5-S1 radiculopathy, rheumatic diseases were excluded. Imaging modalities were used to evaluate the associated anatomical regions in the coccyx region that may cause pain or reflected pain. Causes such as malignancy, mass, abscess, systemic infection were excluded.

Inclusion criteria; age between 18-70 years, Coccydynia >3 months, unresponsive to conservative treatment. Confirmation of the diagnosis of coccydynia by MRI. Exclusion criteria; concomitant malignancy, infection, pregnancy, rheumatological diseases, L4-L5-S1 discopathy, the addition of oral medication or other interventional procedures after treatment of sciatica pRF.

The study design is described in **Figure 1**.

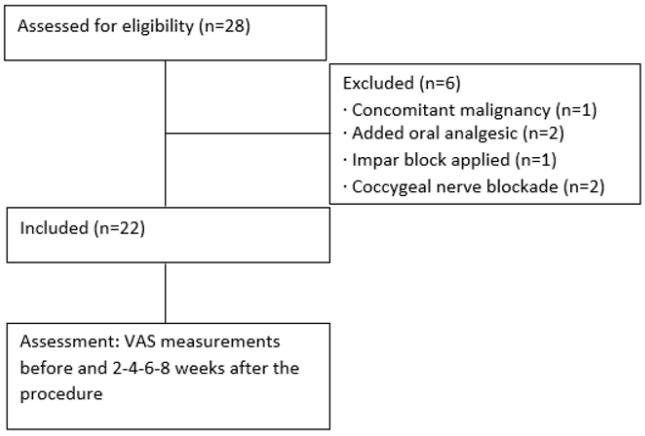

Figure 1. Study design

Intervention

All procedures were performed without sedation, under local anesthesia, with full patient monitoring, under sterile conditions. Under US guidance, bilateral sciatic nerve pRF was performed in the intervention room. The patient was positioned prone and covered with a sterile drape. Using a curve US probe (LOGIQ P9, GE Ultrasound, Sunhwan-ro, Jungwon-gu, Seongnam-si, Gyeonggi-do, Korea), the ischial tuberosity and thoracanter major are visualized at the transgluteal level. The most superficial muscle connecting these two hyperechoic bone images is the gluteus maximus. The sciatic nerve is located just deep to the gluteus maximus muscle and on the surface of the quadratus femoris muscle. It appears as an oval or triangular hyperechoic structure and is closer to the ischial tuberosity.

Using the in-plane technique, a 22-gauge 10 cm 5 mm active hybrid electrode (Equip, FIAB SPA, Italy) was inserted. After confirming that we are close to the sciatic nerve with sensory and motor stimuli a pRF current was applied for 8 minutes (5 Hz at 45 V, 5 ms at a temperature of 42 °C). Since the procedure was performed bilaterally, the same procedure was applied to the other sciatic nerve 8 minutes later. Patients were monitored for possible complications for 2 hours after the procedure (Figure 2).

Radiofrequency therapy was applied by means of a device that produces radiofrequency waves and a cannula electrode connected to it with a cable.

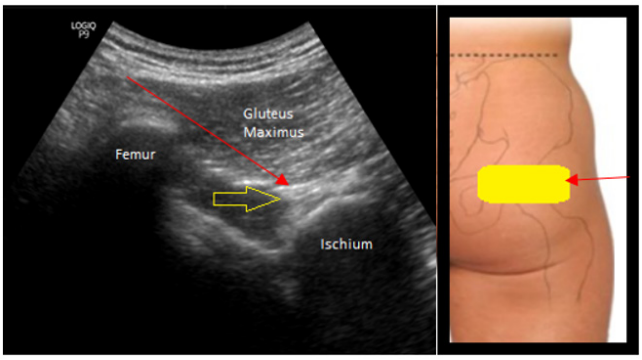

Figure 2. Intervention of Sciatic pRF treatment
Yellow arrow: Sciatic nerve, Red arrow: Needle tracing, Yellow rectangle: Linear probe

Outcome Assessment

We assessed all patients using the VAS scores before and 2-4-6-8 weeks after treatment. Our primary objective was to ascertain the impact of treatment on pain intensity using VAS scores.

Statistical Analysis

All analyses were conducted using Jamovi Project (2022, Jamovi Version 2.3, Computer Software). The findings of this study are expressed as frequencies and percentages. Normality analysis was performed using the Shapiro-Wilk test, skewness kurtosis, and histograms. Normally distributed variables are presented as means and standard deviation (SD). Categorical variables were compared using the chi-square test. Repeated measures were analyzed using Friedmann test. Statistical significance was set at $p<0.05$.

RESULTS

Seventeen of the participants were female and 5 were male. The mean age was 43.36±10.43 years. When classified according to etiology, 10 patients were idiopathic, 12 were traumatic and 2 were due to rapid and excessive weight loss. When comorbidities were evaluated, 8 patients had diabetes mellitus, 5 had hypertension, 2 had cardiovascular disease and 3 had obesity. When continuous analgesic treatment for at least three months was questioned, 8 patients were using NSAIDs, 4 patients were using gabapentinoids and 6 patients were using duloxetine (Table 1).

When the VAS scale change was analyzed, the change found within 8 weeks was statistically significant (Friedman test; $p<0.001$). When all measurement times were analyzed separately, baseline-2. Week, basal-4. Week and basal-8. The decrease in VAS between basal-2 weeks and basal-4 weeks

Table 1. Clinical and demographic data

Variables			
Age		43.36±10.43	45.50(29-63)
Gender	Female	17 (77.27%)	
	Male	5 (22.72%)	
Etiology	Idiopathic	10 (45.45%)	
	Trauma	12 (54.54%)	
	Weight loss	2 (9.09%)	
Comorbidity	DM	8 (36.36%)	
	HT	5 (22.72%)	
	CAD	2 (9.09%)	
	Obesity	3 (13.63%)	
Analgesic usage	NSAID	8 (36.36%)	
	Gabapentinoid	4 (18.18%)	
	Duloksetin	6 (27.27%)	
VAS basal		8.64±1.00	9.00(7-10)
VAS week2		4.27±2.60	3.00(1-9)
VAS week4		3.91±2.65	3.00(1-9)
VAS week6		4.09±2.75	3.00(1-9)
VAS week8		5.32±2.35	5.00(2-10)

mean±standart deviation, median(minimum-maximum), n(%)

and between basal-8 weeks was statistically significant (Bonferroni correction; p<0.001) The change in VAS between other times was not significant.

When the VAS scale change was analyzed, the change found within 8 weeks was statistically significant (Friedman test; p<0.001). When all measurement times were analyzed separately, baseline-2. Week, basal-4. Week and basal-8. The decrease in VAS between basal-2 weeks and basal-4 weeks and between basal-8 weeks was statistically significant (Bonferroni correction; p<0.001) The change in VAS between other times was not significant (Table 2,3).

Table 2. Temporal change of VAS variable

	Median(min-max)	Mean rank	test st	p
VAS basal	9.00(7-10)	4.68		
VAS week 2	3.00(1-9)	2.50		
VAS week 4	3.00(1-9)	2.11	52.931	<0.001
VAS week 6	3.00(1-9)	2.27		
VAS week 8	5.00(2-10)	3.43		

Related Samples Friedman's two-way analysis of variance by ranks

The lowest mean VAS was obtained at the 4th week after treatment. At weeks 6 and 8, VAS measurements increased, even though they remained below baseline. At 4 weeks in 16 (73%) patients and at 8 weeks in 11 (27%) patients, pain had decreased by 50% compared to baseline (Figure 3).

No side effects or complications were observed in any patient.

DISCUSSION

With sciatic nerve pRF treatment, 73% of 22 patients improved more than 50% at week 4 and 27% at week 8. This is the first study to evaluate the effect of sciatic nerve pRF in the treatment of coccidynia.

Peripheral nerve pRF treatments are a widely used method for chronic pain relief. Applications to the greater occipital nerve

Table 3. Change in VAS between two measurement time points

VAS average ranks	Test st.	p
Basal-week 2	-4.577	<0.001
Basal-week 4	-5.387	<0.001
Basal- week 6	-5.053	<0.001
Basal - week 8	-2.622	0.087
Week 2-week 4	-0.810	1.000
Week 2-week 6	-.0.477	1.000
Week 2-week 8	-1.955	0.506
Week 4-week 6	-0.334	1.000
Week 4-week 8	-2.765	0.057
Week 6- week 8	-2.431	0.150

Asymptotic significances (2-sides tests) are displayed. The significance level is 0.05. Significance values have been adjusted by the Bonferroni correction for multiple tests.

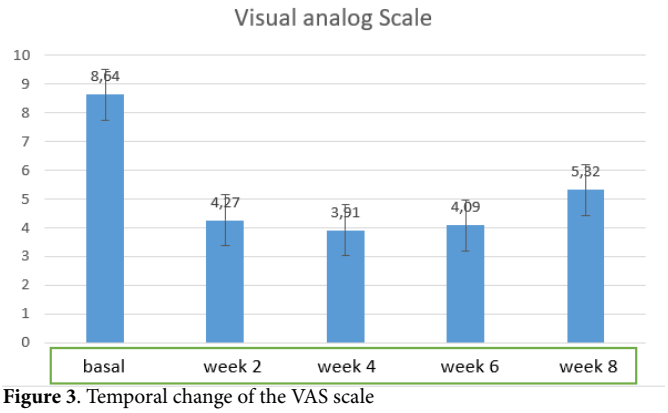

Figure 3. Temporal change of the VAS scale

in chronic migraine, median nerve in carpal tunnel syndrome, posterior tibial nerve in heel spurs, and dorsal root ganglion in radicular pain have taken their place in the literature and clinical practice.[13-17]

Neuromodulation mechanisms of pRF have been implicated in nociceptive signalling. This modification occurs through a variety of mechanisms, including neurotransmitters, ion channels, postsynaptic receptors, immune activity, microglial markers, inflammatory cytokines and intracellular proteins.[11]

In animal studies, histological and biochemical changes in both sciatic nerve and dorsal root ganglia were emphasized with pRF application to the sciatic nerve.

In these studies, changes in calcitonin gene-related peptide, brain-derived neurotrophic factor, substance P, transient receptor potential vanilloid subtype-1 receptors and histochemical improvement in axon diameter, number and myelin sheaths were found after pRF applied to the sciatic nerve. Sciatic nerve pRF applications, which are very rich in terms of experimental animal studies in the literature, have not been so popular in the treatment of chronic pain.[18-21]

There is a case report of successful treatment of phantom pain with sciatic nerve pRF. There is a case report on the treatment of complex regional pain syndrome after femoral fracture. In a 4-week follow-up of 25 patients, pRF was found to be effective in the treatment of chronic knee pain. In a case with sciatic neuropathic pain due to a lesion in the sciatic nerve in the priformis muscle shiza, the pain was relieved.[22-25]

In a case report, sciatic nerve pRF application was reported to be successful in the treatment of femoral pain due to sacral bone metastasis.[26]

It remains unclear which of the interventional methods for coccydynia is the most effective. There are conflicting data in the literature on this subject. Pericoccygeal injections are easy to administer and can be performed with blind technique or US. The efficacy of this treatment with local anesthetics and steroids around the coccyx is controversial.[27,28]

Caudal epidural block and ganglion impar block are methods that can be applied with fluoroscopy and USG. However, fluoroscopy is preferred for safety. Ganglion impar block has been found more effective than caudal epidural block.[29,30]

Recently, there have been reports in the literature on the treatment of coccydynia with coccygeal nerve blockade and conventional radiofrequency.[4,31,32]

The perforating cutaneous nerve, which we targeted, is responsible for the sensory innervation of the coccyx region like the coccygeal nerve. This nerve originates from the S2-S3 spinal roots and we tried to retrograde modulate it with pRF via the sciatic nerve. Our results showed a decrease in coccygeal pain with sciatic nerve pRF. We only utilized the pRF effect during this treatment, which stands as a clinical indicator of retrograde neuromodulation.

Limitations

The limitations of this study were the lack of a comparison group and the failure to analyse the change in analgesic consumption of the patients.

CONCLUSION

Sciatic pRF applied from the transgluteal level under ultrasound guidance is a safe and easy method. It may be an alternative to caudal epidural steroid injection, impar ganglion block, pericoccygeal injection and coccygeal nerve block for coccydynia. These findings should be supported by randomized controlled trials.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Ethical Committe of Etlik City Hospital (Date:26.06.2024, Decision No: 2024-438).

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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Unexpected laryngeal lesion in an expected difficult airway

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ABSTRACT

According to clinical guidelines, a difficult airway is a clinical situation in which an expected or unexpected difficulty in management is encountered or this difficulty and failure is experienced by an anesthesiologist. These situations are difficulties and failures encountered in face mask ventilation, laryngoscopy, ventilation with supraglottic airway equipment, tracheal intubation, extubation or invasive airway. We presented a 47-year-old male case, who was admitted to our center with the diagnosis of Type 1 aortic dissection and who eventually underwent emergency tracheostomy due to difficult airway, in the light of the literature. According to clinical guidelines, a difficult airway is a clinical situation in which an expected or unexpected difficulty in management is encountered or this difficulty and failure is experienced by an anesthesiologist. These situations are difficulties and failures encountered in face mask ventilation, laryngoscopy, ventilation with supraglottic airway equipment, tracheal intubation, extubation or invasive airway. We presented a 47-year-old male case, who was admitted to our center with the diagnosis of Type 1 aortic dissection and who eventually underwent emergency tracheostomy due to difficult airway, in the light of the literature.

Keywords: Aortic dissection, difficult airway, laryngeal lesion, tracheostomy

INTRODUCTION

Difficult airway is a significant cause of morbidity and mortality in anesthesia management.[1] An unexpected difficult airway can be quite challenging for the anesthesiologist and can expose the patient to significant risks if not managed appropriately. Apart from the demographic characteristics of the person, various anatomical and pathological defects in the upper airway are the most common causes of difficult airway.[1,2] Its incidence varies between 1-13%, and it is estimated that half of these are unexpectedly difficult intubations.[3] The patient's previous anesthesia experience allows us to obtain information about the airway and can guide a detailed evaluation of unexpected difficult airway and difficult intubation.

Although it is a foresight, we may encounter situations that we would not have noticed before anesthesia induction. Here, we aimed to present the airway management that was reshaped for unexpected reasons in our case where a difficult airway was expected due to aortic dissection.

CASE

Our case, a male patient aged 47 years, 172 cm, 70 kg, in the American Society of Anesthesiologists (ASA) 5 E risk group, was admitted to our emergency clinic with severe chest pain. Emergency surgery was planned with the diagnosis of Type I aortic dissection. The patient had a history of chronic obstructive pulmonary disease (COPD) and previously had obstructive sleep apnea syndrome (OSAS) surgery. GCS was 15, blood pressure was 150/80 mmHg, heart rate was 108/min, and SpO_2 was 92%. The patient, who had a Mallampati score of II, normal thyromental distance (normal value ≥6.5 cm), normal sternomental distance (normal value ≥12.5 cm), normal neck mobility and adequate mouth opening in the airway evaluation, was prepared for difficult intubation due to tracheal deviation in the chest radiography and thorax computed tomography (Figure 1). The patient was monitored in accordance with ASA standards. Additionally, invasive arterial blood pressure, central venous pressure, temperature, NIRS, BIS and urine output were also monitored. After adequate preoxygenation, midazolam 0.01mg/kg, propofol 2mg/kg, fentanyl 1mcg/kg were administered for anesthesia induction. After effective mask ventilation was confirmed, 0.6mg/kg rocuronium was administered. During video laryngoscopy epiglottis couldn't be visualised. Infected, fragile and edematous tissues were observed in the larynx, and the vocal cord could not be seen (Figure 2). The endotracheal tube could not be advanced through the areas

considered as airway passage by the anesthesia and ear-nose-throat team on video laryngoscopy. Multiple attempts were avoided due to fragility. The patient's Cormack-Lehane score was 4 and airway was secured with an LMA Fastrach. Since the vocal cords could not be visualized with fiberoptic bronchoscopy performed through the LMA Fastrach due to edematous and infective tissues, an emergency tracheostomy was performed by the ENT team. Ascending aorta graft surgery was performed with cross clamp time of 115 minutes, cardiopulmonary bypass time of 162 minutes and a total operation time of 450 minutes. The patient was monitored in the postoperative intensive care unit under mechanical ventilation support for 9 hours (Figure 3). The patient was started on antibiotics. Upon subsequent evaluation by the ENT team, improvement was observed in the infected and fragile structures and the patient was decannulated after 5 days of surgery and discharged after 8 days of surgery day without any problems.

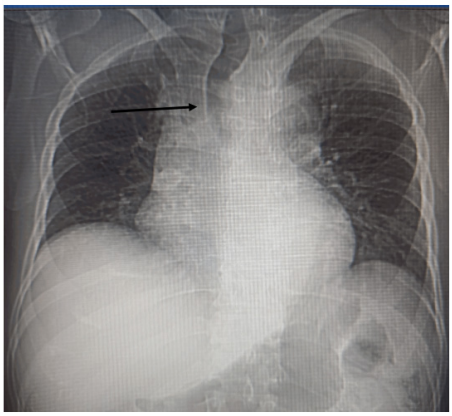

Figure 1. Tracheal deviation in the chest radiography marked with an arrow.

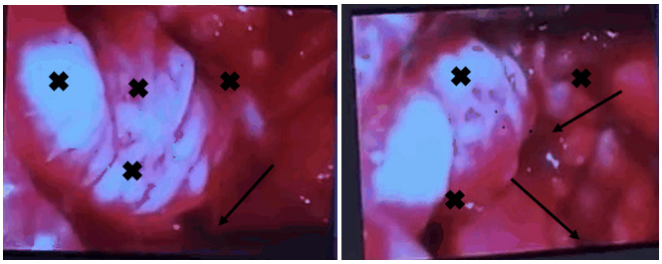

Figure 2. Infected and fragile structures are marked with an X, areas thought to be airway openings are marked with an arrow

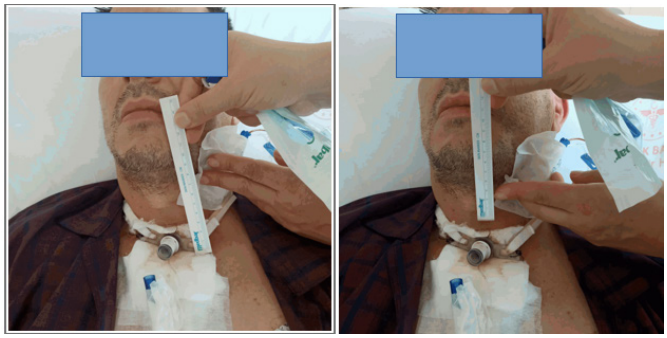

Figure 3. Postoperative period. The patient with tracheostomy cannula and has normal thyromental distance and normal sternomental distance values.

DISCUSSION

Airway management is the most fundamental part of anesthesia practice and a vital skill for the anesthesiologist. Major complications of airway management are very rare but can be life-threatening. According to the ASA guideline, a difficult airway includes the clinical situation in which anticipated or unanticipated difficulty or failure is experienced by a physician trained in anesthesia care, including but not limited to one or more of the following: facemask ventilation, laryngoscopy, ventilation using a supraglottic airway, tracheal intubation, extubation, or invasive airway.[4]

Before anesthesia induction, airway evaluation is very important to determine the presence of upper respiratory tract pathologies or anatomical anomalies. The most important risk factors for difficult airway include advanced age, obesity, Mallampati classification III-IV, chin protrusion, short thyromental distance, and limited head and neck movement.[4] Some of the most important causes of unexpected difficult airway are oropharyngeal infection, laryngeal mass or deformities such as lingual tonsillar hypertrophy, lingual thyroid, thyroglossal cysts and tumors. Patients with these abnormalities may have symptoms such as sore throat, Globus sensation, dysphagia, snoring, and obstructive sleep apnea. However, the patient may be asymptomatic and it may be difficult to identify abnormalities with routine external physical evaluation of the airway.[1,5,6]

Tracheal compression or deviation due to aortic dissection is a situation that requires difficult airway preparation.[4,7] However, the expected difficult airway in our patient made intubation completely impossible due not only to the inability to advance the endotracheal tube in the trachea because of the tracheal pressure caused by aortic dissection, but also due to unpredicted abnormal tissues in the larynx.

According to the ASA difficult airway algorithm, in patients who can be ventilated with a mask but cannot be intubated, it is recommended to limit the number of attempts and consider waking the patient, to consider alternative intubation options (video laryngoscopy, trying different laryngoscope blades, combined techniques, flexible bronchoscopy, introducer, lighted stylet), to evaluate invasive airway intervention or other options (ventilation with a face mask, supraglottic airway devices).[4] In our case, alternative airway equipment was used since it was not possible to wake the patient and postpone the case due to the emergent nature of the medical condition. In our case, video laryngoscopy was used first instead of direct laryngoscopy, as it was anticipated that a difficult airway would be encountered due to tracheal deviation. Since the Cormack-Lehane score was 4 during video laryngoscopy, LMA Fastrach, one of the supraglottic airway devices, was used. Repeated attempts for intubation were avoided because the vocal cords could not be visualized with fiberoptic bronchoscopy through the LMA Fastrach and the airway was extremely fragile. In addition, since it was anticipated that the duration of the case would be long, the invasive airway method was preferred for airway safety.

Difficult airway preparation and the presence of the ENT team allowed us to ensure the patient's airway safety with tracheostomy without any problems.

CONCLUSION

While the expected difficult airway preparation reduces mortality and morbidity in such complex, multidisciplinary cases, we think that we can safely manage the process by following the steps in the guides for unexpected difficult airway.

ETHICAL DECLARATIONS

Informed Consent Form

The patient 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 recieved no financial support.

Author Contributions

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

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