ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.5336/medsci.2021-84276

Comparison of the Effects of Positive End-Expiratory Pressure and Recruitment Manoeuvre Applied in Laparoscopic Surgeries on Respiratory Mechanics and Arterial Oxygenation: Randomized Clinical Trial

Laparoskopik Ameliyatlarda Uygulanan Pozitif Ekspirasyon Sonu Basıncı ve Recruitment Manevrasının Solunum Mekanikleri ve Arteriyel Oksijenizasyon Üzerine Etkilerinin Karşılaştırılması: Randomize Klinik Çalışma

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ABSTRACT Objective: In patients undergoing mechanical ventilation in laparoscopic surgeries, pulmonary gas exchange and oxygenation are impaired due to many reasons, especially atelectasis. In this study, it was aimed to compare the effects of positive end-expiratory pressure (PEEP) and recruitment practices on respiratory mechanics and oxygenation in patients undergoing laparoscopic surgery. **Material and Methods:** This prospective study was performed with 60 American Society of Anesthesiologists I-II patients who underwent laparoscopic cholecystectomy. After induction of anaesthesia, the patients were randomly divided into three groups as the patients who were applied +10 cmH_2O PEEP during pneumoperitoneum (Group P), patients who were applied 40 cmH2O continuous positive airway pressure (Group S) after desufflation and the control group (Group C). Arterial blood gas values before anesthesia, before insufflation, after insufflation, desufflation and postoperative, respiratory mechanics values during operation [dynamic lung compliance (Cdyn), airway resistance, peak and mean airway pressure] were compared with the relevant time data. **Results:** While there was a significant decrease in PaO_2 in Group C in the post-desufflation period compared to the pre-insufflation period, an increase in PaO_2 was observed in both the groups wherein the manoeuvre was applied, especially in Group S. The increase in Group S was significantly higher than Group P. In all postoperative periods, arterial oxygenation values were significantly higher in groups wherein manoeuvre was applied (Group P: p=0.006, p<0.001, p<0.001; Group S: p=0.042, p<0.001, p=0.004). Dynamic compliance values decreased in all groups after insufflation. During the desufflation period, Cdyn values were significantly higher in Group P and especially in Group S compared to Group C (p<0.001). **Conclusion:** Recruitment manoeuvres are effective and safe in preventing impairment of blood gas and respiratory mechanics in patients undergoing laparoscopic surgery.

Keywords: Anaesthesia, general; laparoscopic surgery; positive-pressure respiration; pulmonary atelectasis; respiratory mechanics

ÖZET Amaç: Laparoskopik ameliyatlarda mekanik ventilasyon uygulanan hastalarda pulmoner gaz değişimi ve oksijenasyon başta atelektazi olmak üzere birçok nedenden dolayı bozulmaktadır. Bu çalışmada, laparoskopik cerrahi geçiren hastalarda pozitif ekspirasyon sonu basıncı [positive end-expiratory pressure (PEEP)] ve recruitment uygulamalarının solunum mekaniği ve oksijenasyon üzerine etkilerinin karşılaştırılması amaçlanmıştır. **Gereç ve Yöntemler:** Bu prospektif çalışma, laparoskopik kolesistektomi uygulanan 60 Amerikan Anestezistler Derneği I-II hasta ile gerçekleştirildi. Anestezi indüksiyonu sonrası hastalar pnömoperiton sırasında +10 cmH_2O PEEP (Grup P), desüflasyon sonrası 40 cmH2O sürekli pozitif hava yolu basıncı uygulanan hastalar (Grup S) ve kontrol grubu (Grup C) olarak randomize gruplara ayrıldı. Anestezi öncesi, insüflasyon öncesi, insüflasyon sonrası, desüflasyon ve postoperatif arteriyel kan gazı değerleri, operasyon sırasındaki solunum mekanik değerleri [dinamik akciğer kompliyansı (Cdyn), hava yolu direnci, tepe ve ortalama hava yolu basıncı] ilgili zaman verileri ile karşılaştırıldı. **Bulgular:** Grup C'de PaO_2'de desüflasyon sonrası dönemde, insüflasyon öncesi döneme göre anlamlı bir düşüş olurken, manevranın uygulandığı her 2 grupta özellikle de Grup S'de PaO_2'de artış gözlendi. Grup S'deki artış, Grup P'den anlamlı derecede yüksekti. Tüm postoperatif dönemlerde manevra uygulanan gruplarda arteriyel oksijenasyon değerleri anlamlı olarak yüksekti (Grup P: p=0,006, p<0,001, p<0,001; Grup S: p=0,042, p<0,001, p=0,004). İnsüflasyon sonrası tüm gruplarda Cdyn değerleri azaldı. Desüflasyon döneminde Cdyn değerleri Grup P'de ve özellikle Grup S'de Grup C'ye göre anlamlı olarak yüksekti (p<0,001). **Sonuç**: Recruitment manevraları, laparoskopik cerrahi geçiren hastalarda kan gazı ve solunum mekaniğinin bozulmasını önlemede etkili ve güvenlidir.

Anahtar Kelimeler: Anestezi, genel; laparoskopik cerrahi; pozitif basınçlı solunum; pulmoner atelektazi; solunum mekaniği

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Peer review under responsibility of Turkiye Klinikleri Journal of Medical Sciences.

Received: 04 May 2021 ***Received in revised form:*** 15 Jun 2021 ***Accepted:*** 05 Jul 2021 ***Available online:*** 21 Dec 2021

Several factors can cause impairment in pulmonary gas exchange and arterial blood oxygenation in patients who are mechanically ventilated during general anaesthesia. The main reason for this is the atelectasis that develops during surgery.[1] Studies have shown that, following anaesthesia induction in patients who are applied neuromuscular block and mechanical ventilation, lung compliance and functional residual capacity (FRC) decreased because of the pushing of the diaphragm, and atelectatic areas developed in the lung areas close to the diaphragm.[2,3] Gas resorption accompanied by compression of the lung tissue due to decreased respiratory tone is also involved in the development of atelectasis. There is a relationship between the volume of atelectasis and the size of the shunt.[3-5]

In laparoscopic surgery, carbon dioxide insufflation into the abdomen with positive pressure is essential.[6] Factors such as atelectasis, decreased FRC and lung compliance resulting from increased intraabdominal pressure may affect the respiratory system and make the impairment in gas exchange more pronounced.[7] Carbon dioxide absorption from the intraperitoneal cavity and the change in the dead space volume may also affect this disorder.[6,8] It has been shown that adverse effects on respiratory mechanics and oxygenation continue even in the periods after desufflation in patients treated with pneumoperitoneum.[9]

Many different ways such as preserving respiratory muscle tone, reducing resorption atelectasis, applying positive end-expiratory pressure (PEEP) and recruitment manoeuvres are used to prevent the development of atelectasis. Recruitment is a series of breathing manoeuvres applied to open closed alveoli and is defined at different durations and pressures.[2,10]

The goal of our study is to compare the effects of PEEP and recruitment manoeuvres on respiratory mechanics and oxygenation in patients undergoing laparoscopic surgery.

MATERIAL AND METHODS

After obtaining the concent of the Clinical Studies Ethics Committee of İstanbul University Cerrahpaşa Faculty of Medicine (06/04/2002, Number: 10800), the present study was conducted prospectively with 60 adult patients of American Society of Anesthesiologists (ASA) I-II who were scheduled to undergo laparoscopic cholecystectomy in the general surgery operating room within İstanbul University Cerrahpaşa Medical Faculty. This study was conducted in accordance with the Declaration of Helsinki. Patients with chronic or acute lung, heart, kidney, metabolic and endocrine diseases and using a drug that would impair the acid-base balance and cause electrolyte disturbances were excluded from the study. The patients were randomly separated into three groups; as the patients who were applied 10 cmH_2O PEEP during pneumoperitoneum (Group P), patients who were applied 40 cmH_2O continuous positive airway pressure (CPAP) (Group S) after desufflation and the control group (Group C).

Patients who were taken to the operating room were sedated with intravenous (IV) 0.03 mg/kg midazolam after their standard monitoring. Invasive arterial pressure monitoring was performed by placing a 20G cannula in the radial artery under local anaesthesia in patients who had the Allen test performed preoperatively.

In the induction of anesthesia, 2 mg/kg propofol, 2 µgr/kg fentanyl and 0.2 mg/kg cisatracurium were used. Orotracheal intubation was performed with 8 and 7.5 size intubation tubes in male and female patients, respectively after adequate muscle relaxation was achieved in patients who were oxygenated with mask. Mechanical ventilation was applied with the Drager Sulla 808 V device (Dräger, Germany) with a tidal volume of 8 mL/kg and a respiratory frequency of 12 per minute. Additionally, 2% volume sevoflurane and 50% O_2/air mixture were used for maintenance of anaesthesia. At certain times, 1 µgr/kg fentanyl and 0.03 mg/kg cis-atracurium were repeated. Ventilation parameters held steady throughout in this study. CO_2 pneumoperitoneum was created with a laparoscopic insufflator device to maintain the intraabdominal pressure constant at 12 mmHg during the operation. During the operation, the operating table was kept in a 15 head-up position.

Patients were intraoperatively monitored for heart rate (ECG), invasive arterial pressure (systolic,

diastolic and mean arterial pressure values), peripheral oxygen saturation (SpO_2), $EtCO_2$ using the Millenia monitor (Millenia, Orlando, USA) and for dynamic lung compliance (Cdyn), airway resistance (Raw), peak inspiratory pressure (PIP) and mean airway pressure (P_{mean}) using the Ventrak monitor (Respiratory Mechanics Monitoring System, Novametrix medical systems, Wallingford, Connecticut, USA).

We determined the principles of PEEP and recruitment that we will apply to the groups in the study, by making use of previous studies.[1,2] In Group P, +10 cmH_2O PEEP was applied during pneumoperitoneum. In Group S, after desufflation, 40 cmH_2O CPAP was applied for 15 seconds with the cessation of breathing, and ventilation was continued for 45 seconds and the same procedure was repeated (recruitment was achieved by applying apnea for three breath periods during a one-minute breathing period and it was performed 2 times in a total of 2 minutes). In Group C, no additional procedure was applied during mechanical ventilation.

Patients were monitored for their hemodynamic values before (A) anaesthesia induction, before insufflation (B), 10 minutes after insufflation (C), 10 minutes after desufflation (D), and postoperatively at minute 30 in the recovery unit (E), at hour 12 (F) and at hour 24 (G). Arterial blood gas samples were collected simultaneously at all of the above-mentioned times and analysed in the Ciba Corning 890 blood gas device (East Walpole, MA, US) without delay. After the induction of anaesthesia, the values of respiratory mechanics were recorded synchronously before insufflation (B), 10 minutes after insufflation (C) and 10 minutes after desufflation (D) (after recruitment manoeuvres in Group S).

Diclofenac sodium 75 mg intramuscular and ondansetron 4 mg IV were administered intraoperatively to all patients. At the end of the anesthesia, neuromuscular block was terminated with 0.01 mg/kg atropine and 0.02 mg/kg neostigmine IV. At the end of the operation, the patients were followed up in the recovery room. The modified Aldreate score was followed and when it reached 9, they were allowed to exit the recovery room.

STATISTICAL ANALYSIS

As a result of the pilot study conducted to calculate the sample size, the influence quantity calculated in the comparison of the Cdyn measurements of the three groups was found to be 0.041. As a result of the power analysis, a total of 60 patients were included in the study, 20 in each group for a significance level of 0.05, 80% power.

Descriptive statistics are expressed as mean and standard deviation for quantitative data, and as frequency and percentage for qualitative data. One-way analysis of variance was used for the intergroup comparisons of the data. Bonferroni test, one of the multiple comparison tests, was used in the presence of significance. To compare the groups in terms of the repeated measurements being analysed, the percentage change value [percentage change=(last measurement-first measurement)/first measurement] compared to the initial measurement was calculated and compared between the groups. Paired t-test was used to examine the variance of each measurement from the initial measurement in the intragroup comparison of time-dependent measurements. Fisher-Freeman-Halton test was used to analyse the categorical data. The level of significance was determined as $\alpha=0.05$. The statistical analysis of data was conducted using IBM SPSS 23.0 (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.) statistics package programme.

RESULTS

Sixty ASA I-II patients, including 47 women and 13 men aged between 23-70, were included in the study. There was no significant difference between the groups in terms of gender, age, body mass index (BMI) and duration of operation (Table 1).

During the operation, heart rate and mean arterial pressure values of the groups were within normal limits and stable. There was no significant difference between the groups in terms of changes in mean arterial pressure and heart rate during the operation and postoperative period ($p>0.05$).

TABLE 1: Demographic data of the groups.

	Group C (n=20) Mean (SD)	Group P (n=20) Mean (SD)	Group S (n=20) Mean (SD)	p value
Gender:				
F/M (n) (%)	16 (80%)/4 (20%)	16 (80%)/4 (20%)	15 (75%)/5 (25%)	1.000[a]
Age (years)	52.5 (12.46)	51.15 (9.81)	51.2 (12.24)	0.916[b]
BMI (kg/m^2)	28.4 (3.5)	27.3 (4.2)	27.4 (4.9)	0.68[b]
Duration of operation (minutes)	74 (24.37)	70.95 (15.85)	73.25 (18.23)	0.879[b]

[a]Fisher-Freeman-Halton test; [b]One-way analysis of variance; SD: Standard deviation; F: Female; M: Male; BMI: Body mass index.

TABLE 2: Mean (standard deviation) intraoperative values of PaO_2, $PaCO_2$, pH and HCO_3.

	B	C	D
PaO_2 (mmHg)			
Group C	163.42 (28.51)	138.24 (40.71)*	142.67 (29.44)*
Group P	153.64 (35.4)	141.98 (28.65)	177.79 (32.65)*&
Group S	175.88 (43.68)	167.2 (42.19)&	224.47 (35.36)*&#
$PaCO_2$ (mmHg)			
Group C	36.35 (3.52)	38.87 (3.61)	40.43 (4.68)*
Group P	36.23 (2.59)	40.17 (4.08)*	39.06 (5.45)
Group S	34.28 (2.75)	36.99 (4.14)*	36.92 (4.64)
pH			
Group C	7.40 (0.03)	7.36 (0.04)*	7.36 (0.04)*
Group P	7.40 (0.04)	7.37 (0.05)*	7.37 (0.06)*
Group S	7.42 (0.04)	7.39 (0.04)*	7.38 (0.05)*
HCO_3 (mmol/L)			
Group C	21.93 (1.97)	22.11 (1.36)	21.49 (1.40)
Group P	22.72 (1.61)	22.45 (1.54)	21.67 (1.78)*
Group S	22.49 (1.39)	22.44 (1.59)	21.26 (1.54)*

*($p<0.05$) significant with period B; &($p<0.05$) comparison with the control group; #($p<0.05$) comparison of the recruitment and positive end-expiratory pressure groups; One-way analysis of variance was used for intergroup comparisons, and paired t-test was used for in-group comparisons; B: Pre-insufflation; C: Post-insufflation; D: Post-desufflation; PaO_2: Partial arterial oxygen pressure; $PaCO_2$: Partial arterial carbon dioxide pressure; HCO_3: Bicarbonate.

1) Intraoperative Arterial Blood Gas Changes (Table 2);

PaO_2 level in Group C was found to be significantly lower after insufflation and desufflation compared to the pre-insufflation period (p=0.027, p=0.012, respectively). In Group P and S, the increase in the post-desufflation period compared to the pre-insufflation period was significant (p=0.013, p=0.011, respectively). In the intergroup comparisons, the post-insufflation decrease in PaO_2 was in Group C, was significant compared to Group S (p=0.026). The post-desufflation increase in PaO_2 was significant in Group P compared to Group C (p=0.002), and in Group S compared to both Group P and Group C (p=0.006, p<0.001).

$PaCO_2$ values increased in the post-insufflation period compared to the pre-insufflation levels in all groups. This increase was found to be significant in Group P and Group S (p<0.001). The increase in $PaCO_2$ in the post-desufflation period was found to be significant in Group C (p<0.001).

There was a significant decrease in pH values in all groups in the post-insufflation period and the post-desufflation period compared to the pre-insufflation period (post-insufflation period compared to pre-insufflation, p<0.001 in all groups; post-desufflation

period compared to pre-insufflation, p<0.05 in all groups). A significant decrease was observed in HCO_3 values in Group P and Group S in the post-desufflation period compared to the pre-insufflation period (p<0.05).

2) Pre-and Postoperative Arterial Blood Gas Changes (Table 3);

A significant decrease was observed in the PaO_2 value in Group C at the postoperative hours 12 and 24 compared to the pre-induction period (p=0.010, p=0.001, respectively). In the intergroup comparisons, PaO_2 values were found to be significantly higher in Group P and Group S compared to Group C in all postoperative periods (Group P p=0.006, p<0.001, p<0.001; Group S p=0.042, p<0.001, p=0.004, respectively).

A significant increase was observed in the $PaCO_2$ value in Group C in the postoperative recovery period compared to the pre-induction period (p=0.002). In the intergroup comparison, $PaCO_2$ value in the recovery period was found to be significantly lower in Group P and Group S compared to Group C (p=0.014, p=0.023, respectively).

A significant decrease was observed in pH and HCO_3 values in Group C, Group P and Group S in the postoperative recovery period when compared with the pre-induction period (pH, p<0.001; HCO_3 p<0.05). There was no significant difference between the groups.

3) Changes in Respiratory Mechanics Values During Surgery (Table 4);

A significant decrease was observed in the dynamic compliance values in Group C, Group P and Group S in the post-insufflation period when compared with the pre-insufflation period (p<0.001). In the post-desufflation period, a significant decrease was observed in Group C compared to pre-insufflation (p<0.001), while the increase in Group P and Group S was significant (p<0.001). In comparison between groups; Cdyn values after desuflation were significantly higher in Group P and Group S than Group C (p<0.001). In Group S, it was found to be significantly higher than Group P (p=0.001).

There was a significant increase in airway resistance values in the post-insufflation period in all three groups compared to pre-insufflation (p<0.001). After

TABLE 3: Pre and postoperative mean (standard deviation) values of PaO_2, $PaCO_2$, pH and HCO_3.

	A	E	F	G
PaO_2 (mmHg)				
Group C	80.93 (7.25)	75.14 (10.61)	69.23 (10.38)*	72.63 (6.47)*
Group P	76.69 (7.77)	83 (13.08)*&	79.44 (7.88)&	81.6 (8.53)&
Group S	79.85 (10)	83.92 (13.34)&	82.84 (14.47)&	81.23 (12.51)&
$PaCO_2$ (mmHg)				
Group C	39.05 (4.67)	46.26 (5.4)*	41.34 (4.6)	39.47 (3.47)
Group P	39.34 (3.23)	41.29 (4.01)&	38.27 (2.66)	38.97 (2.68)
Group S	38.86 (3.76)	40.99 (3.49)&	38.48 (4.18)	38.23 (3.29)
pH				
Group C	7.38 (0.04)	7.30 (0.04)*	7.36 (0.03)	7.39 (0.02)
Group P	7.39 (0.04)	7.33 (0.04)*	7.40 (0.02)	7.41 (0.02)
Group S	7.38 (0.02)	7.32 (0.03)*	7.37 (0.04)	7.39 (0.02)
HCO_3 (mmol/L)				
Group C	23.1 (1.4)	21.78 (1.55)*	22.8 (1.35)	23.57 (1.25)
Group P	23.14 (1.96)	21.42 (1.76)*	23.4 (1.31)	23.03 (1.39)
Group S	23.12 (1.87)	21.11 (1.67)*	22.3 (2.1)	23.52 (1.91)

*(p<0.05) significant with period A; &(p<0.05) comparison with control group; One-way analysis of variance was used for intergroup comparisons, and paired t-test was used for in-group comparisons; A: Pre-induction; E: Postoperative recovery; F: Postoperative 12th hour; G: Postoperative 24th hour.

TABLE 4: Cdyn, Raw, PIP and Pmean, mean (standard deviation) values during surgery.

	B	C	D
Cdyn (mL/cmH_2O)			
Group C	52.01 (5.39)	32.21 (4.41)*	44.44 (5.18)*
Group P	51.75 (7.89)	34.9 (6.09)*	57.23 (10.26)*&
Group S	55.65 (5.94)	36.68 (5.28)*	68.49 (11.41)*&#
Raw (cmH_2O/lt/sec)			
Group C	17.91 (2.54)	23.4 (2.86)*	18.97 (2.36)*
Group P	17.74 (3.73)	21.98 (3.9)*	17.35 (3.63)
Group S	17.09 (4.27)	22.55 (4.93)*	16.22 (3.8)&
PIP (cmH_2O)			
Group C	18.05 (3.81)	24.58 (4.25)*	19.06 (3.89)*
Group P	15.78 (4.06)	21.96 (4.49)*	15.16 (3.5)&
Group S	18.56 (4.32)	23.08 (3.96)*	17.55 (4.06)&
Pmean (cmH_2O)			
Group C	6.73 (1.57)	8.91 (2.26)*	7.3 (1.62)
Group P	6.32 (1.26)	7.87 (1.24)*	6.18 (1.65)
Group S	7.32 (1.85)	8.31 (1.84)	6.7 (2.17)&

#(p<0.05) Comparison of the recruitment and positive end-expiratory pressure groups; *(p<0.05) significant with period B; &(p<0.05) comparison with control group; One-way analysis of variance was used for intergroup comparisons, and paired t-test was used for in-group comparisons; B: Pre-insufflation; C: Post-insufflation; D: Post-desufflation; Cdyn: Dynamic compliance; Raw: Airway resistance; PIP: Peak inspiratory pressure; Pmean: Mean airway pressure.

desufflation, the increase in Group C was significant compared to the pre-insufflation period (p=0.029). In comparison between groups; after desufflation, Raw value was significantly lower in Group S than Group C (p=0.044).

There was a significant increase in PIP values in the post-insufflation period in all three groups when compared with pre-insufflation period (p<0.001). In comparison between groups, PIP in the post-desufflation period was found to be significantly lower in Group P and Group S when compared with Group C (p=0.024; p=0.005, respectively).

A significant increase was observed in the P_{mean} values in Group C and Group P in the post-insufflation period when compared with pre-insufflation period (p<0.001). In the desufflation period, the decrease in the P_{mean} value in Group S was significant when compared with Group C (p=0.037).

DISCUSSION

Different applications have been used to increase the partial pressure of arterial oxygen by reopening the lungs that collapse under general anaesthesia.[9] Recruitment manoeuvres and PEEP are among such applications.[10] In our study, we tried to determine the effectiveness of the PEEP and recruitment manoeuvre methods by measuring respiratory mechanics values and partial arterial oxygen pressure.

In the present study, while there was a significant decrease in the partial arterial oxygen pressure value in the control group in the post-desufflation period compared to the pre-insufflation period, the partial arterial oxygen pressure increased in the manoeuvre group, particularly in those who were applied the recruitment manoeuvre. Intraoperative compliance values decreased with pneumoperitoneum in all three groups. While this decrease continued in the control group, it improved with PEEP and recruitment applications in the other two groups. We observed that this improvement was more pronounced especially in the group in which we applied recruitment.

Various studies have been conducted on the effectiveness of PEEP and recruitment manoeuvres in patients undergoing prolonged mechanical ventilation.[10,11] Rothen et al. compared the cases where they gradually increased airway pressure to 10, 20, 30 and 40 cmH_2O during general anaesthesia and those who were applied a one-time inflation (vital capacity ma-

noeuvre) with a pressure of 40 cmH_2O. They stated that vital capacity manoeuvre with a pressure of at least 40 cmH_2O opens all atelectatic lung tissues and provides a significant reduction in the amount of shunt.[12] In another study, Rothen et al. observed that when they applied the apnoea time for 7-8 seconds in the recruitment manoeuvre, the atelectatic areas formed by general anaesthesia were completely opened and oxygenation significantly improved.[13] In our study, we performed a 40 cmH_2O recruitment manoeuvre with an apnoea duration of 15 seconds.

Kim et al. reported that in laparoscopic cholecystectomies, 5 cmH_2O PEEP application during pneumoperitoneum preserves arterial oxygenation without affecting hemodynamic parameters and is useful in preventing atelectasis.[14] Choi et al. demonstrated by computed tomography that PEEP along with recruitment manoeuvre during robotic surgery reduces the development of atelectasis due to pneumoperitoneum and general anaesthesia when compared with PEEP application alone. They stated that the application of PEEP along with recruitment was beneficial in providing intraoperative oxygenation and preventing postoperative pulmonary complications.[3] Claxton et al. reported in their study that recruitment application is a useful method to correct arterial oxygenation, especially in the early postoperative period, compared to 5 cmH_2O PEEP application alone.[15] Unlike these studies, Arora et al. reported that 10 cmH_2O PEEP application in laparoscopic cholecystectomies did not increase intraoperative oxygenation compared to traditional ventilation strategies.[16] In our study, we applied 10 cmH_2O PEEP level. Compared to the pre-insufflation period, we observed a post-desufflation increase in the PaO_2 value, especially in the recruitment group, in both groups that we applied the manoeuvre.

Futier et al. reported in their study that the administration of 10 cmH_2O PEEP alone during pneumoperitoneum improved respiratory mechanics but did not provide a significant improvement on oxygenation. In addition, they showed that recruitment was beneficial in improving oxygenation with respiratory mechanics.[17] Nguyen et al. reported that there is a decrease in compliance with pneumoperitoneum in laparoscopic abdominal surgeries, and recruitment application with a gradual increase until 20 cmH_2O PEEP level is effective in improving intraoperative oxygenation and compliance, but they stated that it does not prevent the formation of postoperative atelectasis.[4] In our study, we observed a significant decrease in oxygenation in the control group at the postoperative hours 12 and 24. Arterial oxygen values were significantly higher in the manoeuvre groups than the control group in all postoperative periods. Based on our findings, we can conclude that PEEP and recruitment manoeuvres are effective in improving postoperative oxygenation when compared with the control group.

In our study, there was a decrease in dynamic compliance with pneumoperitoneum in all our patients. We observed a significant improvement in Cdyn values with PEEP and especially recruitment applications. While airway resistance, peak and mean airway pressure values increased with pneumoperitoneum in all patients, they decreased with desufflation. We observed that PEEP and especially the recruitment manoeuvre were effective in reducing Raw during this period. In their study, Maracajá-Neto et al. observed an increase of 19.6% and 23.2% in peak and plateau pressures, respectively, due to pneumoperitoneum. They reported that 10 cmH_2O PEEP application during pneumoperitoneum reduced respiratory resistance and respiratory system elastance and positively affected respiratory mechanics.[18] In their study, Weingarten et al. compared the control group with the patients who were applied the recruitment manoeuvre followed by 12 cmH_2O PEEP, and reported an increase in Cdyn and a decrease in Raw with the recruitment application.[19]

During pneumoperitoneum, factors such as the absorption of carbon dioxide from the intraperitoneal cavity, decreased FRC and lung compliance as a result of the diaphragm being pushed due to increased intraabdominal pressure, can lead to the development of hypercapnia by affecting the respiratory system.[20,21] Iwasaka et al. reported that $PaCO_2$ and $EtCO_2$ increased, pH decreased, and HCO_3 concentration remained constant during insufflation in patients in laparoscopic cholecystectomy.[19-21] Park et al. reported that $PaCO_2$ increased and pH decreased with pneumoperitoneum in both recruitment and PEEP

groups in laparoscopic cholecystectomies.[22] In our study, we observed an increase in $PaCO_2$ and a decrease in pH with pneumoperitoneum in all patients. Although there was no significant difference in the early recovery period, $PaCO_2$ values were higher in the control group when compared with the patients who were applied PEEP and recruitment manoeuvre. We observed that $PaCO_2$ and pH returned to normal values in all patients at the postoperative hours 12 and 24.

Computed tomography or X-ray techniques have been used as the most appropriate method to determine the amount of atelectasis in similar studies. A limitation of our study is that, since we could not afford the cost of additional imaging for each patient, we tried to determine the effectiveness of PEEP and recruitment manoeuvres by measuring respiratory mechanics values and partial arterial oxygen pressure.

CONCLUSION

In conclusion, based on the findings obtained in the study, it can be claimed that recruitment manoeuvres are an effective and safe method to prevent the impairment in blood gas and respiratory mechanics that occurs in patients who undergo laparoscopic surgery.

Acknowledgements

We thank Güven Özkaya, Ph.D. from Bursa Uludağ University Faculty of Medicine Biostatistics Department for statistical analysis and Enago (www.enago.com) for English language editing.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **Design:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **Control/Supervision:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **Data Collection and/or Processing:** Öznur Demiroluk, İsmail Şener Demiroluk, Ziya Salihoğlu; **Analysis and/or Interpretation:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **Literature Review:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **Writing the Article:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **Critical Review:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **References and Fundings:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk, Ziya Salihoğlu; **Materials:** Öznur Demiroluk, Yalım Dikmen, İsmail Şener Demiroluk.*

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