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The Effects of Different Pressure Pneumoperitoneum on the Pulmonary Mechanics and Surgical Satisfaction in the Laparoscopic Cholecystectomy

Beyza Küçüköztaş[1], Leyla İyilikçi[2], Sule Ozbilgin[2]*, Mücahit Özbilgin[2], Tarkan Ünek[2], Hülya Ellidokuz[2]

[1] Ege University, School of Medicine, Department of Anesthesiology and Intensive Care, Üniversite Cad. No: 9 Bornova — 35100, Turkey
[2] Dokuz Eylul University, School of Medicine, Department of Anesthesiology and Intensive Care, İnciraltı Mah. Mithatpaşa Cad. No: 1606 Sok. İnciraltı — 35340 İzmir, Turkey

Влияние пневмоперитонеума под различным давлением на показатели легочной механики и удовлетворенность хирурга при лапароскопической холецистэктомии

Б. Кючюкёзташ[1], Л. Ийиликчи[2], С. Озбилгин[2]*, М. Озбилгин[2], Т. Унек[2], Х. Эллидокуз[2]

[1] Университет Эге, медицинский факультет, кафедра анестезиологии и интенсивной терапии, Üniversite Cad. №: 9 Борнова — 35100, Турция
[2] Университет Докуз Эйлул, медицинский факультет, кафедра анестезиологии и интенсивной терапии, İnciraltı Mah. Mithatpaşa Cad. №: 1606 Sok. İnciraltı — 35340 Измир, Турция

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Summary

Objectives. Inspiratory, hemodynamic and metabolic changes occur in laparoscopic surgery depending on pneumoperitoneum and patient position. This study aims to evaluate the effects of intra-abdominal pressure increase based on CO_2 pneumoperitoneum in laparoscopic operations on hemodynamic parameters and respiratory dynamics and satisfaction of surgeon and operative view.

Materials and Methods. A total of 116 consecutive, prospective, ASA class I–III cases aged 18–70 years undergoing laparoscopic cholecystectomy were enrolled in this study. Data of 104 patients were analysed. Patients were divided into two groups as the group Low Pressure (<12 mmHg) (Group LP) (n=53) and the group Standard Pressure (>13 mmHg) (Group SP) (n=51). In this study administration of general anesthesia used total intravenous anaesthesia in both groups. All groups had standard and TOF monitorization applied. The anaesthesia methods used in both groups were recorded. Before, during and after peritoneal insufflation, the peroperative ventilation parameters and hemodynamic parameters were recorded. The adequacy of pneumoperitoneum, gastric and the operative view were evaluated by the operating surgeon and recorded.

Results. The peripheral oxygen saturation showed no significant difference between the low and standard pressure pneumoperitoneum in view of tidal volume, respiratory rate, end tidal CO_2, mean and peak inspiratory pressure, and minute ventilation values. In terms of hemodynamics, when values just after intubation and before extubation were compared, it was observed that in the LP group systolic, diastolic and mean blood pressure values were higher. In terms of heart rate, no significant difference was observed in determined periods between groups. There was no significant difference between the groups in terms of surgical satisfaction and vision.

Conclusion. Low pressure pneumoperitoneum provides effective respiratory mechanics and stable hemodynamics for laparoscopic cholecystectomy. It also provides the surgeon with sufficient space for hand manipulations. Anaesthetic method, TIVA and neuromuscular blockage provided good surgery vision with low pressure pneumoperitoneum.

***Keywords:** laparoscopic cholecystectomy; pneumoperitoneum; surgical vision; surgery satisfaction; low pressure; deep neuromuscular blockage*

Conflict of Interest. The authors declare no conflict of interest. Abstract of this study was presented partly at the Euroanaesthesia Congress 2016, London.

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Correspondence to:

*Sule Ozbilgin
E-mail: ozbilginsule@gmail.com

Адрес для корреспонденции:

*Суле Озбилгин
E-mail: ozbilginsule@gmail.com

Introduction

Cholelithiasis is a common disease of the digestive system treated with surgical methods. With the development of laparoscopy, laparoscopic cholecystectomy has become an accepted surgical intervention. Due to many advantages such as less pain in the postoperative period, small incisions, shorter hospital stay and more rapid return to daily life, it is accepted as the gold standard globally. This minimally invasive technique reduces mortality and morbidity and is a very reliable and effective method [1–3].

Of those with gallstones, each year 2–4% become symptomatic with biliary colic, acute cholecystitis, obstructive jaundice and gallstone pancreatitis [4, 5]. Each year in America more than 1.5 millon cholecystectomies are performed [6]. The incidence of gallstones in the adult population in the West is about 10–15% [5–8].

The insufflation pressure for laparoscopic cholecystectomy is generally 12–15 mmHg. In a review of the Cochrane database. Grusamy et al. [7] defined standard pressure as varying between 12 and 16 mmHg, with low pressure as less than 12 mmHg and high pressure more than 17 mmHg. Volume and pressure studies have been performed and it was found that pressures greater than 15 mmHg did not further expand the operation field [8]. Pneumoperitoneum ensures sufficient visualisation of the abdominal cavity and allows manipulation of the laparoscope. There is some evidence that low pressure pneumoperitoneum is associated with decreased pain for laparoscopic cholecystectomy; however, these results are still open to debate as varies of the clinical studies detailing the benefits were found to be at a high risk of bias and inadequate blinding [2].

Randomised clinical studies using low pressure pneumoperitoneum have shown reduced cardiac changes [9], shoulder pain complaints [10], pain severity and analgesic requirements [10, 11]. The important critical point is that low pressure pneumoperitoneum ensures sufficient surgical view and is safe.

In this study, we have compared various factors like respiratory dynamics and hemodynamic parameters in patients undergoing laparoscopic cholecystectomy under standard pressure versus low pressure. In addition we have aimed to research and discuss the effects in terms of surgeon satisfaction and vision quality.

Materials and Methods

This study was performed after receiving permission from «Dokuz Eylül University, Faculty of Medicine, Non-interventional Research Ethics Committee» (date 29.05.2014, Protocol No. 1538-GOA, Decision No. 2014/21-07) and informed patient consent. The study included patients in ASA classification I–III, from 18–70 years, undergoing elective laparoscopic cholecystectomy surgery and was completed as a prospective observational study.

The records of laparoscopic cholecystectomy patients in 3 months examined. According to these records, we found that low pneumoperitoneum pressure was applied to 53 patients and standard pneumoperitoneum pressure was applied to 51 patients. Then, we continued our evaluations under 2 groups. The study was performed on 116 consecutive patients and data from a total of 104 patients were analysed. Patients were divided into two group as low pressure (< 12 mmHg) (LP) (n=53) and standard pressure (> 13 mmHg) (SP) (n=51). Four patients in LP group and 8 patients in SP group underwent open laparotomy and were excluded from the study.

Exclusion Criteria:

1. Acute cholecystitis
2. Cases with low pulmonary compliance or high airway resistance (chronic pulmonary diseases)
3. Morbidly obese patients (BMI > 35)
4. Malignancy or chronic inflammatory disease
5. Renal or liver disorders
6. Endocrine or immune system disorders
7. Patients receiving immunosuppressive treatment
8. Cases with open laparotomy
9. Any surgical intervention in addition to cholecystectomy
10. Previous abdominal surgery

The demographic characteristics of the patients are shown in Table 1.

Patients in LP and SP groups had standard monitoring (non-invasive blood pressure, electrocardiogram, peripheral oxygen saturation measurements) and neuromuscular junction monitoring with TOF Guard (TOF Guard (TOF-GUARD, Biometer International A.S. DENMARK) applied before anaesthesia induction.

In both groups, for anaesthesia induction 0.2–0.5 mcg/kg/min remifentanil infusion was administered over two minutes followed by intravenous (IV) 1–2 mg/kg propofol and IV 0.5 mg/kg rocuronium. After induction patients had 6 L/min 100% oxygen administered with a face mask for ventilation.

For the anaesthesia maintenance 50% O_2/air mixture and 0.1–0.4 mcg/kg/min remifentanil and 50–150 mcg/ kg/min (3–9 mg/kg/hr) propofol IV infusion was administered. During the surgical procedure when TOF>1 twitch response occurred 0.1–0.15 mg/kg dose of the neuromuscular blocker agent rocuronium was administered. To reverse neuromuscular block, when post-tetanic count (PTC) reached 1–2, 4.0 mg/kg sugammadex IV was administered.

Table 1. Demographic data of patients.

Parameters	Values in groups		*P*-value
	LP, *n*=53	**SP, *n*=51**	
*Age, year	53.00 (38.50–61.00)	50.00 (37.00–62.00)	0.543
Gender Female/Male, *n*	40/13	32/19	0.160
*Body mass index, kg/m^2	27.80 (25.50–30.55)	26.90 (23.40–31.20)	0.390
ASA 1/2/3, *n*	14/29/10	19/28/4	0.191
*Anaesthesia time, min	95.00 (80.00–117.50)	100.00 (90.00–120.00)	0.351
*Insufflation time, min	60.00 (45.00–70.00)	60.00 (45.00–80.00)	0.181

Note. For Tables 1, 2: * — values are median (25–75 percentiles), mean (range) or number (proportion).

Table 2. Surgical and insufflation data.

Parameters	Values in groups		*P*-value
	LP, *n*=53	**SP, *n*=51**	
Attempts to insert Veress needle (1/2/3), *n*	52/0/3	50/1/0	1.00
*Initial intra-abdominal pressure, mmHg	12.0 (11.0–12.0)	14.0 (13.0–15.0)	0.297
*Volume of insufflation CO_2, L	3.2 (2.5–5.1)	3.6 (2.5–5.8)	0.388
Grade of quality of view			
1	1	0	0.781
2	8	8	
3	23	24	
4	21	19	

Positive pressure respiration was begun with 2–4 L/min fresh gas flow and FiO_2 0.5 volume control for 6–8 ml/kg tidal volume and 10–12 respirations/min frequency. PEEP was not used and inspiration:expiration (I:E) ratio was set at 1:2. Mechanical ventilation was performed with the anaesthesia machine (Dräger, Zeus Infinity Empowered; Dräger Medical AG&Co. KG, Germany).

In the peroperative period the ventilation parameters (airway peak pressure, mean airway pressure, tidal end carbon dioxide, tidal volume, minute ventilation volume) and hemodynamic parameters (systolic, diastolic and mean arterial pressure, heart rate) were measured at 4 different times; 2 minutes after intubation (T1), 10 min after peritoneal insufflation (T2), before desufflation (T3) and before extubation (T4).

Pneumoperitoneum pressure values were determined by the surgical team with values of 12 mmHg and below in the low pressure group and 13 mmHg and above included in the standard pressure group [7]. Immediately after intra-abdominal laparoscopic intervention and immediately before the end of peritoneal insufflation, gastric distension was evaluated on a scale of 0–10 (0=empty stomach, 10=distension obstructing the surgical field) by a surgeon blind to the airway device [12].

For surgical satisfaction, surgical view quality was evaluated. To evaluate surgical view quality, the surgeon provided a point value from 1 to 4 (1: bad, 2: acceptable, 3: good, 4: perfect) [13]. All surgical procedures were performed by the same surgical team and view quality was evaluated with points by the same team.

The anaesthesia duration, operation duration and hospital stay of the patients were recorded. In the postoperative period the time when patients returned to physical activities or to work was learned by telephone and recorded.

Statistical Analysis. The data obtained in the research was entered into a database in the SPSS (Statistical Package For Social Sciences) 15.0 program and statistical analyses were performed with this program. Continuous variables and sub groups are presented as mean, standard deviation, median, values, while categorical variables are presented as frequency and percentage. Calculation of sample size has performed by «OpenEpi» program. Margin of error was 5%, safety margin was 95% and frequency was accepted as 50% what unknown frequency of situation. Minimum 73 cases would have included to study: but we have included 104 patients.

The variables specified by the measurement was analyzed after the analysis of conformity to normal distribution for comparison. For comparison of independent groups the «Mann–Whitney *U*» test was used. Paired multiple groups were analysed with the «Friedman Test» method. Categorical variables are presented in diagonal tables as frequency and percentage, and distribution was compared with the chi-square method. Significance value was at $P<0.05$.

Results

There was no significant difference between the groups in terms of surgical satisfaction and vision (Table 2). Results of surgical and insufflation data are showed in Table 2. Stomach distension values medians (25–75 percentiles) are 3.00 (2.00–5.00) in LP Group and 3.00 (2.00–4.00) in SP Group for 10 minutes after insufflation (T2). Stomach distension values medians (25–75 percentiles) are 3.00 (2.00–4.00) in Group LP and 3.00 (2.00–4.00) in Group SP for before desufflation (T3). In both group, 10 minutes after insufflation (T2) (P=0.546) and before desufflation (T3) (P=0.855) there were no statistically significant difference in stomach distension identified.

This study did not observe any significant differences between patients undergoing laparoscopic cholecystectomy with low and standard pressure pneumoperitoneum in terms of peripheral oxygen saturation , tidal volume, respiratory count, end tidal carbon dioxide, mean and peak airway pressure and minute ventilation values. Comparison of ventilation parameters between groups are showed in Table 3.

When hemodynamics are evaluated, when values immediately after intubation (T1) and before extubation (T4) are compared, the systolic, diastolic and mean blood pressure values in the low pressure group were observed to be higher. When these values are examined after insufflation and before desufflation, there was no significant difference between the two groups. There was no significant difference observed in terms of heart rate in the stated periods. Comparison of hemodynamics parameters between groups are presented in figure.

Hospital stay time are 1.51±0.80 days in Group LP and 1.47±1.00 days in Group SP. Beginning daily activities for patients are 3.13±1.09 days in Group LP and 3.25±1.07 in Group SP. Beginning work in the postoperative period for patients are 7.06±4.17 days in Group LP and 6.19±1.67 days in Group SP. When patients are investigated in terms of hospital stay, beginning daily activities and beginning work in the postoperative period, there was no statistically significant difference identified between the low pressure and standard pressure groups (P=0.389, P=0.518, P=0.847, respectively).

This study found no significant difference in respiratory dynamics between patients undergoing laparoscopic cholecystectomy with low and standard pressure pneumoperitoneum. However, in terms of hemodynamic parameters, in the low pressure group immediately after intubation and before extubation the SBP, DBP and MAP values were found to be higher. There was no significant difference between the groups in terms of surgeon satisfaction and vision quality.

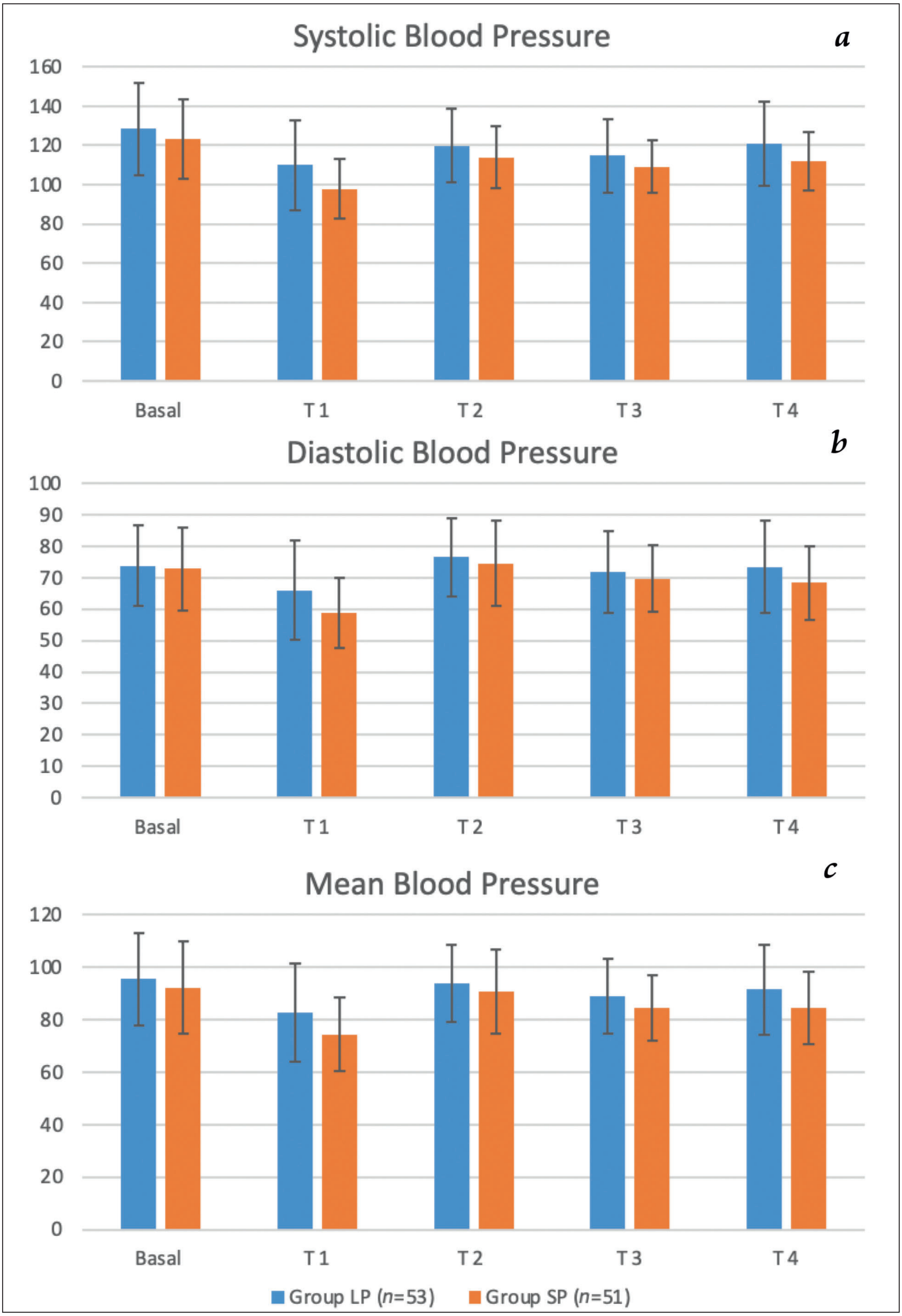
Discussion

Grusamy et al. [7] in a review of the Cochrane database found a total of 15 clinical studies and presented the effects of low and standard pressure

Table 3. Comparison of ventilation parameters between groups at the study stages, median (25–75 percentiles).

Parameters	Values in groups							
	2 minutes after airway device insertion T1		10 minutes after insufflation T2		Before desufflation T3		Before removal airway device T4	
	LP	**SP**	**LP**	**SP**	**LP**	**SP**	**LP**	**SP**
Tidal volume, ml	465.0 (422.5–500.0)	460.0 (425.0–550.0)	480.0 (415.0–540.0)	480.0 (430.0–550.0)	480.0 (402.0–540.0)	490.0 (430.0–580.0)	480.0 (415.0–535.0)	490.0 (430.0–560.0)
Expiratory volume, L.min^{-1}	5.76 (4.82–6.42)	5.72 (5.04–6.72)	6.00 (5.05–6.84)	5.94 (5.20–6.72)	6.00 (5.22–7.00)	6.30 (5.40.7.50)	6.00 (5.18–6.88)	6.00 (5.04–7.20)
Respiratory rate/min	12.0 (12.0–12.0)	12.0 (12.0–13.0)	12.0 (12.0–13.5)	12.0 (12.0–13.0)	13.0 (12.0–14.0)	13.0 (12.0–14.0)	12.0 (12.0–14.0)	12.0 (12.0–14.0)
$ETCO_2$, mmHg	31.0 (28.00–33.00)	31.0 (29.0–34.0)	32.0 (28.5–34.5)	32.0 (30.0–34.0)	33.0 (31.0–36.0)	34.0 (32.0–36.0)	31.00 (30.00–32.50)	32.0 (31.0–34.0)
Peak airway pressure, cmH_2O	20.0 (16.0–22.0)	18.0 (15.0–22.0)	23.0 (19.0–25.0)	21.0 (19.0–24.0)	22.0 (19.0–25.0)	21.0 (18.0–24.0)	20.00 (17.00–22.50)	18.0 (16.0–22.0)
Mean airway pressure, cmH_2O	8.0 (7.0–9.0)	8.0 (7.0–9.0)	9.0 (8.0–10.0)	9.0 (8.0–10.0)	9.0 (8.0–10.0)	9.0 (8.0–10.0)	8.00 (7.00–9.00)	8.0 (7.0–9.0)
SpO_2	100.0 (99.0–100.0)	100.0 (100.0–100.0)	100.0 (100.0–100.0)	100.0 (100.0–100.0)	100.0 (100.0–100.0)	100.0 (100.0–100.0)	100.0 (100.0–100.0)	100.0 (100.0–100.0)

Note. P>0,05; SpO_2 — peripheral oxygen saturation; $ETCO_2$ — end tidal carbon dioxide.



Systolic blood pressure (*a*), diastolic blood pressure (*b*) and mean blood pressure (*c*) in groups.

pneumoperitoneum. This study defined standard pressure as between 12 and 16 mmHg, with low pressure below 12 mmHg and high pressure 17 mmHg. There was no difference between the two groups in terms of postoperative complications, mortality, morbidity and changing to open cholecystectomy [7].

In situations where significant anatomic structures cannot be defined, if the intervention does not advance within a certain time, if there is uncontrolled hemorrhage and bile duct problems that cannot be resolved laparoscopically, the operation should be changed to open surgery. The rate of change from laparoscopic cholecystectomy to open operations is 5% [13–15]. In our study the rate of change to open operations was found to be 10.34%.

In the review by Grusamy et al. [7] the operation duration was found to be mean 2 minutes longer in the low pressure group. Different to this result, the study by Sarli et al. [10] found that low pressure pneumoperitoneum did not increase the operation duration and did not cause peroperative and postoperative complications. They determined that low pressure pneumoperitoneum technique was sufficient. However, these results may vary linked to surgeon experience. At the same time, they may be linked to patient factors like obesity and previous surgery. In a study researching the effects of low (7–8 mmHg) and standard (12–14 mmHg) pressure pneumoperitoneum by Singla et al. [16] they found the surgical durations were similar in both groups. They showed that this result indicated low pressure pneumoperitoneum did not negatively affect surgical success, and that laparoscopic cholecystectomy can be completed in the same duration. In our study, we excluded patient linked factors like obesity and previous surgery and did not observe a significant difference statistically between anaesthesia duration and insufflation duration; similar to the results of the previous study. In our study there was no statistically significant difference in terms of anaesthesia and insufflation durations between the low pressure and standard pressure groups.

Grusamy et al. [7] reported no significant difference between the mean hospital stay and patient satisfaction between the low and standard pressure groups. In our study there was no significant difference observed between the groups in terms of hospital stay. There is no clinical study reporting the duration to return to normal activity or work and surgeon satisfaction. In our study, the return to normal activity and work was investigated and there was no significant difference found between the two groups.

When the literature is examined in terms of additional port requirements, it was reported that there was no requirement for an additional port during surgery in both groups, and that in the low pressure group the requirements for intra abdominal pressure increase was higher to ensure sufficient surgical view [17–19]. In our study in both groups there was no need for additional port in either group. However, in the LP group there was a need for intra abdominal pressure increase. This situation is similar to previous studies [17–19]. In our study initially due to insufficient surgical view in those included in the LP group, a total of 7 patients required increased intra abdominal pressure.

During pneumoperitoneum, reaching high intra abdominal pressures may negatively affect respiratory parameters [20–22]. Makinen et al. [23] stated that 12 mmHg CO_2 pneumoperitoneum reduced respiratory compliance by 30%, while Luis et al. [24] reported a reduction of 40%. Kendal et al. [25] showed that 15 mmHg pneumoperitoneum reduced respiratory compliance by 49%. Another study by Makinen et al. [26] reported a reduction in pulmonary dynamic compliance of 50% with increases in Ppeak and Pplateau. After pneumoperitoneum desufflation they identified a fall in basal values of pulmonary compliance and airway pressures. In our study, in both the low pressure and standard pressure groups, there was an increase observed in Ppeak and Pmean values in the insufflation period and after desufflation there was no significant difference between the basal values of both identified. When low pressure and standard pressue groups are compared, there was no statistically significant difference observed between the groups in terms of Ppeak and Pmean.

The potential benefit of low pressure pneumoperitoneum is a reduction in cardiopulmonary complications. When the literature is examined, many studies assessing the effects of different pressure pneumoperitoneum have reported no cardiopulmonary morbidity. It was observed that the patient population included in these studies were classified as ASA I and II [7, 17, 19]. In a case series comprising 400 patients, the cardiopulmonary complication rate was found to be 0.5% and they reported that 70% of patients were in the low risk group for anaesthesia [9]. The difference in our study is that we included patients in ASA III class. In our study when the groups are compared after intubation and before extubation, the SBP, DBP and MAP values were higher in the low pressure group. These results may be linked to our inclusion of ASA III patients.

Rishimani et al. [27] in a study of laparoscopic cholecystectomy including 30 patients with low (6 mmHg) and high (14 mmHg) intra abdominal pressure values found that in the high pressure group 10 patients had 8–20/min increase in heart rate, 7 patients had 6–12/min decrease and 13 patients had no change. They identified a 15–30% fall in cardiac index. Mean arterial pressure increased by mean 41.15% after insufflation compared to before insufflation. After desufflation there was a 24.94% increase compared to before insufflation. There was no change in heart rate. In our study for hemodynamic data only blood pressure and heart rate were recorded, cardiac index measurements were not performed. Joris et al. [28] reported a reduction in cardiac index of 20% corresponding to an increase of 35% in MAP. The same study found that SCR increased by 65% and pulmonary vascular resistance (PVR) increased by 90%, with no change in HR observed. Marshall et al. [29] reported that hemodynamics varied linked to intra abdominal pressure increase, with CO_2 insufflation causing an increase in HR, MAP and total peripheral resistance, a reduction in beat volume and sympathetic stimulation.

Pneumoperitoneum may cause a variety of arrhythmia like A–V dissociation, nodal rhythm, sinus bradycardia and asystole. This response is a vagal cardiovascular reflex linked to peritonal strain. Hypercarbia may increase these types of effects. In our study when heart rates are compared, there was no difference between the groups. This result may be linked to CO_2 insufflation rate being held constant for all patients.

In our study there was no difference when the groups were compared in terms of surgeon satisfaction. This result may be related to the lack of difference between the groups when stomach distension is assessed. Distended stomach negatively affects the surgical field of view and manipulation of the trochars. Stomach distension was assessed on a scale of 1–10 10 minutes after insufflation and before desufflation by a surgeon blind to the groups. There was no statistical difference between the groups.

A study by Dubois et al. [30] researched the effects of deep neuromuscular blockage on surgical conditions for patients undergoing laparoscopic hysterectomy. With fixed pneumoperitoneum pressure (13 mmHg), surgical view quality was assessed by the surgeon and it was concluded that patients with deep neuromuscular block had better surgical view scores [31, 32]. Staehr-Rye et al. [33] in a study of laparoscopic cholecystectomy with low pressure pneumoperitoneum (8 mmHg) compared the effects of deep neuromuscular block and moderate neuromuscular block on surgical view quality and concluded that deep neuromuscular block provided better surgical view conditions. Martini et al. [31] in a study evaluating the effects of deep neuromuscular blockage on surgical conditions for laparoscopic surgeries found that the significance of the deep neuromuscular blockage effect was large and that it provided sufficient working area in the surgical field and increased view quality.

In our study in spite of low insufflation pressure, the surgical duration, surgical field conditions and complication risks were not greater and this may be linked to standardisation of neuromuscular blockage with TOF monitoring during induction and maintenance.

The study has some limitations; our defined low pressure value of 12 mmHg is higher than in previous studies [10, 16, 34, 35]. This value (12 mmHg) was determined linked to the experience of the clinical surgery team at our hospital. Additionally invasive cardiac monitoring with cardiac index, continuous arterial pressure monitoring and blood gas monitoring were not performed. There was no comorbidities analysis for these patients.

Conclusion

In conclusion, during laparoscopic cholecystectomy surgery, low pressure pneumoperitoneum ensures effective respiratory mechanics and stable hemodynamics. Additionally it provides sufficient surgical area for hand manipulations by the surgeon.

When these results are considered, with TIVA anaesthesia method and deep neuromuscular blockage administration, we believe low pressure pneumperitoneum ensures better surgical view quality and surgeon satisfaction.

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