PERIODICUM BIOLOGORUM
VOL. 127, No 1–2, 149–155, 2025
DOI: 10.18054/pb.v127i1-2.35361

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

Original research article

The effects of low-pressure and standard-pressure pneumoperitoneum on parameters of mechanical ventilation and pain after laparoscopic nephrectomy

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Keywords: nephrectomy; laparoscopy; postoperative pain; analgesia; artificial respiration

Abbreviations

ASA – American Society of Anesthesiologists
BMI – body mass index
COPD – chronic obstructive pulmonary disease
$ETCO_2$ – end-tidal carbon dioxide
IAP – intra-abdominal pressure
PIP – peak inspiratory pressure
SpO_2 – peripheral oxygen saturation
PNP – pneumoperitoneum
PLSP – post-laparoscopy shoulder pain
PONV – postoperative nausea and vomiting
VAS – Visual Analogue Scale

Received March 2, 2025
Revised June 19, 2025
Accepted June 25, 2025

Abstract

Background and purpose: *Pneumoperitoneum (PNP) insufflation during laparoscopic surgery may affect respiratory function and postoperative pain. The aim of the study is to investigate the effects of PNP pressure on artificial respiration and early postoperative pain in patients undergoing transperitoneal laparoscopic nephrectomy.*

Materials and methods: *In a retrospective study low (8 mmHg, N=16) and standard-pressure PNP (12 mmHg, N=30) were compared. Peripheral oxygen saturation (SpO_2), end-tidal carbon dioxide ($ETCO_2$) and peak inspiratory pressure (PIP) were recorded at the beginning and 30 minutes after PNP insufflation. The intensity of pain was assessed with a visual analog scale (VAS) up to 4 hours, 4-8 hours, and 9-24 hours postoperatively. Analgesics given were recorded 24 hours postoperatively.*

Results: *The median age and body mass index (BMI) did not differ between the groups. Duration of the operation (minutes) was significantly shorter in the group with low-pressure PNP (P=0.020). In the standard-pressure PNP group, PIP was significantly higher 30 minutes after PNP insufflation (P=0.003). There was no difference in postoperative pain and postoperative opioid consumption and non-opioid analgesics between groups.*

Conclusions: *Although the intensity of pain and consumption of analgesics between the groups with low and standard- pressure PNP did not differ significantly, there was a trend towards more favorable outcome on postoperative pain when using low-pressure PNP. In the group with standard-pressure PNP, PIP was significantly higher 30 minutes after PNP insufflation. A prospective study with a larger number of patients could provide better data on the effect of the level of PNP.*

INTRODUCTION

Total and partial nephrectomy can be performed by transperitoneal or retroperitoneal approaches. The transperitoneal approach is more commonly used due to well-recognizable anatomical landmarks, a larger working space, and more frequent choice of operators. On the other hand, the retroperitoneal approach minimizes the risk of injury to intraperitoneal organs *(1)*. The pressure at which gas is insufflated into the abdominal cavity to create a PNP can affect the cardiopulmonary system and postoperative recovery. In most institutions, there is a consensus that 12 mmHg is the standard-pressure for laparoscopy *(2)*. In addition to the pathophysiological changes in the cardiovascular system during CO_2 pneumoperitoneum, significant respiratory changes such as hypercapnia, hypoxemia, and barotrauma can occur during laparoscopy, but these are rare due to the use of effective ventilation techniques. In patients with compromised cardiopulmonary function, ventilation may be difficult due to increased intra-abdominal pressure (IAP), Trendelenburg position, and cranial displacement of the diaphragm *(3,4,5).* Pain after laparoscopic surgery is predominantly visceral, and PNP affects the visceral pain component and lower IAP should result in less pain *(6).* In a study conducted one year after surgery, Nikolajsen et al. confirmed that poorly controlled acute postoperative pain can result in chronic pain *(7).* Pain after laparoscopic procedures occurs secondary to the creation of PNP and is mainly manifested as abdominal pain and post-laparoscopy shoulder pain (PLSP). Studies have shown that lower-pressure PNP reduces postoperative pain, analgesic consumption and shortens recovery time after general surgical procedures *(8).* Although laparoscopic surgery reduces postoperative pain, it is still significant and represents a clinical problem in laparoscopic urological procedures. Performing laparoscopic urological procedures with lower-pressure PNP appears to be as safe as standard or high-pressure PNP and there are some reports of good clinical outcomes with the use of low-pressure PNP *(9).* However, there is little research on the effect of PNP in urological procedures, especially cystectomy and nephrectomy *(9).*

The hypothesis of this study is that patients with higher PNP will have higher values of $ETCO_2$ and PIP. We expect that, due to the increased pressure of the pneumoperitoneum, patients with higher pneumoperitoneum will have stronger postoperative pain.

MATERIALS AND METHODS

This retrospective study was conducted at the Department of Urology, University Hospital Center Osijek, Croatia. Approval for the study was obtained from the Ethics Committee of the parent institution in accordance with the ethical principles of the Declaration of Helsinki. (January 17, 2025 - R1-398/2025).

We included a total of 46 adult patients (32 men and 14 women) who underwent elective transperitoneal laparoscopic nephrectomy between April 2023 and February 2025 for renal tumor/dysfunction. The following parameters were recorded: age, sex, type and duration of surgery/PNP. Patients were divided into two groups according to the insufflated PNP pressure. Group I consisted of patients with a low PNP pressure of 8 mmHg, and group II consisted of patients with a standard PNP pressure of 12 mmHg. There were 16 patients in group I (8 total and 8 partial nephrectomies), and 30 patients in group II (21 total and 9 partial nephrectomies). The exclusion criteria were patients with chronic pain, a history of major abdominal surgery, renal procedures, and incomplete data required for the study. Data were taken from the anesthesia charts and the hospital information system. In all cases, general anesthesia protocol was used to anesthetize the patients. After the patient was brought into the operating room, intravenous access was secured. Monitoring included blood pressure measurement, pulse oximetry and capnography. Neuromuscular blockade monitoring was not included. All patients received 3 mg of midazolam and 10 μg of sufentanil for premedication. Patients were preoxygenated via face mask with an oxygen flow for 3 minutes. Anesthesia was induced with propofol at a dose of 2 mg/kg and rocuronium at 0.6 mg/kg. After the cessation of spontaneous breathing, mask ventilation was performed with oxygen flow of 6 L/min for 2 minutes to achieve complete muscle relaxation necessary for tracheal intubation. The trachea was intubated with a cuffed endotracheal tube with an internal diameter of 7-8 mm. Patients were ventilated with a fresh gas flow of 4 L/min using an oxygen:air mixture of 33:67% and sevoflurane at 2 vol%. Before the first incision, 0.4 μg/kg of sufentanil was administered. Additional boluses of 10 μg of sufentanil were given based on clinical signs of inadequate analgesia (mean arterial pressure >100 mmHg or pulse >100/min). Muscle relaxation was maintained with 20 mg boluses of rocuronium every 20 minutes. Ephedrine in a dose of 10 mg was given when the mean arterial pressure dropped below 70 mmHg, and atropine 0.5 mg was prescribed when the pulse was lower than 50/min. After the induction of anesthesia, a urinary catheter and a orogastric tube were introduced. All patients received ondansetron 4 mg and dexamethasone 2 mg for postoperative nausea and vomiting (PONV) prophylaxis.

Patients were ventilated with pressure-controlled ventilation with PEEP od 5 cm H_2O. Ventilation was adjusted according to the $ETCO_2$ level. SpO_2, $ETCO_2$ and PIP were recorded in the anesthesia sheet at the beginning and 30 minutes after PNP insufflation. Patients were placed in a modified lateral decubitus position. PNP was induced using a Veress needle, and CO_2 was insufflated at a rate of 2 L/min until an IAP of 8 or 12 mmHg was achieved. Intraperitoneal insufflation at these pressures was kept constant by automatic CO_2 flow regulation. Operations were performed using 4 trocars. At the end of the operation, the remaining CO_2 from the peritoneum was evacuated by abdominal compression and a drainage tube was placed through the lower trocar. After the final surgical suture, inhalational anesthetics were discontinued, and patients were ventilated with 100% oxygen. Reversal of neuromuscular blockade was achieved using 2.5 mg of neostigmine and 1 mg of atropine**.** Patients were extubated in the operating room after achieving an adequate level of consciousness and muscle strength. Upon reaching an Aldrete score of ≥9, patients were transferred to the recovery room and in case of PONV, 10 mg of Reglan was given intravenously. Also, all patients were routinely prescribed postoperative analgesia: metamizole 2.5 grams and paracetamol 1 gram immediately after the end of anesthesia. If postoperative pain ?4 on VAS was registered in the postoperative recovery unit, meperidine 20 mg or tramadol 50-100 mg was given. If pain was <4 non-opioid analgesics (metamizole, paracetamol) were given intravenously on the patient's request. In the recovery room, the nurse recorded the time of onset and intensity of the pain according to VAS, the localization of pain, the amount and type of analgesic given, and PONV in the first 24 hours postoperatively. The duration of the operation was calculated as skin-to-skin time, and the duration of the PNP from the insertion of the first trocar to the removal of the last trocar. The intensity of pain was assessed with a 10-point VAS in the period up to 4 hours, 4-8 hours and 9-24 hours postoperatively. The amount and the analgesics given, as well as PONV were recorded 24 hours postoperatively.

Statistical analysis was done using Statistical Package for Social Sciences (SPSS) for Windows, version 20.0 (SPSS Inc., IL, USA). For statistical analysis differences between groups were analyzed using the Mann-Whitney *U*-test for continuous variables, and expressed as median and interquartile range (IQR). Nominal variables were analyzed using the χ^2 test or Fisher's exact test, depending on the number of patients. An association between data was done using Pearson's or Kendall's correlation. Statistically significant differences were considered with P <0.05.

RESULTS

There were no significant differences in sex, age, history of chronic obstructive pulmonary disease (COPD), BMI, and type of surgery (total vs. partial) between the two groups (Table 1). ASA physical status was higher in the standard-pressure PNP group, as was duration of surgery and PNP in the standard-pressure PNP group (Table 1).

Intraoperative respiratory parameters and opioid consumption of patients undergoing nephrectomy with low-pressure PNP and standard-pressure PNP are presented in Table 2. There were no differences in $ETCO_2$ and SpO_2 between groups. The only difference between the groups

Table 1. *Baseline characteristics and intraoperative data of patients undergoing laparoscopic nephrectomy with low-pressure (8 mmHg) and standard-pressure (12 mmHg) PNP.*

Characteristic	Low-pressure PNP (N=16, Group I)	Standard-pressure PNP (N=30, Group II)	P value
Sex (male : female)	12 : 4	20 : 10	0.903†
ASA (2 : 3)	9 : 7	7 : 23	**0.026***
Age	67 [56.75-69.75]	65 [54.5-71.5]	0.972
COPD	16 : 0	26 : 3	0.542†
BMI (kg/m^2)	27 [26-30.4]	28.8 [26.1-32.7]	0.356
Type of surgery (total vs. partial nephrectomy)	8 : 8	21 : 9	0.180*
Duration of the PNP (min)	107.5 [88.75-140]	140 [113.75-201.25]	**0.015**
Duration of the surgery (min)	135 [116.25-157.5]	170 [130.5-240]	**0.020**

Variables are expressed as median and interquartile range [IQR]; data were analyzed using the Mann-Whitney U-test, *χ^2-test and †Fisher's exact test; statistically significant differences are in bold (P<0.05). ASA, American Society of Anesthesiologists; COPD, Chronic Obstructive Pulmonary Disease; BMI, Body Mass Index; PNP, Pneumoperitoneum; min, minutes.

Table 2. *Intraoperative respiratory parameters and opioid consumption in two groups of patients undergoing laparoscopic nephrectomy with low-pressure PNP and standard-pressure PNP.*

Characteristic	Low-pressure PNP (N=16)	Standard-pressure PNP (N=30)	P value*
$ETCO_2$ – 1 (mmHg)	32 [28-35.75]	30.5 [28-32.25]	0.365
PIP – 1 (cm H_2O)	13 [12.25-14]	14 [13-15]	0.077
$ETCO_2$ – 2 (mmHg)	36 [33.5-38.25]	36 [32.75-38.25]	0.754
PIP – 2 (cmH_2O)	18.5 [17-20]	20 [19.75-22]	**0.003**
SpO_2 (%)	98 [97-99]	98.5 [97-99]	0.516
Sufentanil intraoperatively (µg)	500 [412.5-500]	475 [400-562.5]	0.679

Data were analyzed using the Mann-Whitney U-test, and variables were expressed as median and interquartile range [IQR]; statistically significant differences between groups are in bold (P<0.05). PNP, pneumoperitoneum; $ETCO_2$ – 1, end-tidal carbon dioxide at the beginning of PNP insufflation; $ETCO_2$ – 2, end-tidal carbon dioxide 30 minutes after PNP insufflation; PIP – 1, peak inspiratory pressure at the beginning of the PNP insufflation; PIP – 2, Peak inspiratory pressure 30 minutes after the PNP insufflation; SpO_2, peripheral oxygen hemoglobin saturation 30 minutes after PNP insufflation; µg, microgram.

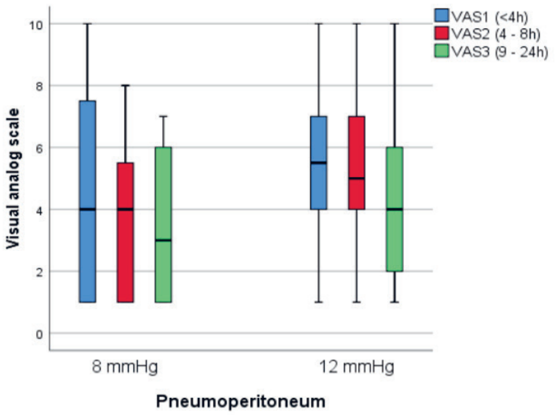

Figure 1. *Pain in patients after laparoscopic nephrectomy with low-pressure pneumoperitoneum (8 mmHg) and standard-pressure pneumoperitoneum (12 mmHg) within the first 24 postoperative hours; the Mann-Whitney U-test; P>0.05. VAS, Visual Analogue Scale.*

was noted in the PIP 30 minutes after PNP insufflation, which was significantly higher in the standard-pressure PNP group (Table 2).

There was no difference in intraoperative sufentanil consumption between the low and standard-pressure PNP groups (Table 2; P=0.679).

Data on the intensity of postoperative pain in the first 24 hours after surgery were measured by VAS and are shown in Figure 1. Although pain was slightly higher in the group with standard-pressure PNP, the difference between the groups was not statistically significant in any measurement (P>0.05 in all measurements) (Figure 1).

According to the pain intensity ≥4 on the VAS scale, 4 patients in each group received opioids in the first 24 hours postoperatively (χ2 test; P=0.330). There was no significant difference in the first onset of pain (in minutes after surgery) between the two groups regarding PNP pressure levels (P=0.374). However, the first postoperative pain occurred earlier in the standard-pressure PNP group (Table 3).

In our study, no significant difference was found in the postoperative consumption of opioid and non-opioid analgesics between the two groups (Table 3; P=0.330). In our patients, postoperative pain was mostly managed with non-opioid analgesics. Regarding the localization of pain, there was no statistically significant difference between the groups (P=0.830). The majority of patients had localized pain in the abdominal area (11 patients in the group with low versus 26 patients in the group with standard-pressure PNP), pain in the wound was recorded in 1 patient in the group with low-pressure and in 4 with standard-pressure PNP. A total of 5 patients had localized pain in other areas, such as the shoulder, catheter or drain (Table 3). PLSP was recorded in two patients who underwent right-sided laparoscopic nephrectomy, in a 52-year-old female patient with BMI=39.1, total nephrectomy

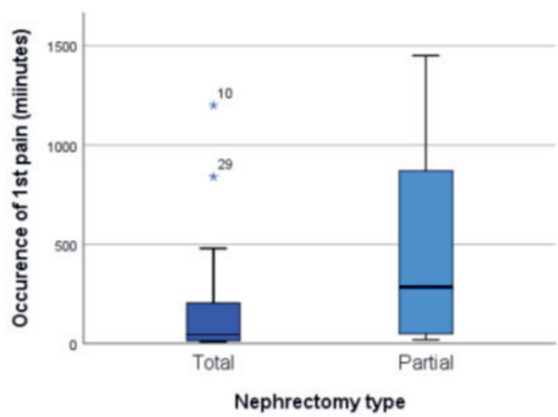

Figure 2. *Graphic presentation of the first postoperative pain occurrence in patients who underwent total and partial laparoscopic nephrectomy (patients undergoing nephrectomy with low-pressure and standard-pressure PNP); the Mann-Whitney U-test; P=0.060.*

Table 3. *Postoperative pain characteristics and opioid consumption in patients undergoing laparoscopic nephrectomy with low-pressure PNP (8 mmHg) and standard-pressure PNP (12 mmHg).*

Characteristic	Low-pressure PNP (N=16)	High-pressure PNP (N=30)	P value
The first pain occurrence (minutes after surgery)	240 [30-310]	80 [17.5-260]	0.374
Pain localization			
Abdomen	11	26	0.830*
Wound	1	4	
Other	1	4	
Postoperative opioid -morphine equivalents	4	4	0.330†
Metamizole (g)	2.5 [0-5]	2.5 [2.5-5]	0.693
Paracetamol (g)	1 [1-2]	1 [1-1]	0.593

Data were analyzed using the Mann-Whitney U-test and variables were expressed as median and interquartile range [IQR]; *χ^2-test; †Fisher's exact test; P>0.05. PNP, pneumoperitoneum; g, gram.

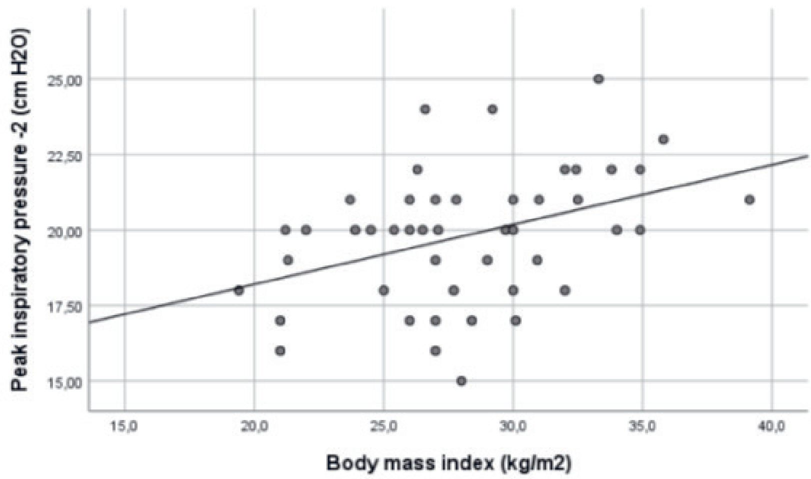

Figure 3. *A positive correlation of body mass index and peak inspiratory pressure 30 minutes after pneumoperitoneum insufflation in the patients undergoing total and partial laparoscopic nephrectomy with low-pressure and standard-pressure pneumoperitoneum; Pearson's correlation, r= 0.395; P=0.007.*

lasting 210 minutes with right shoulder abduction during surgery, and in a 63-year-old male patient with BMI=26.0, who underwent partial nephrectomy lasting 180 minutes, with right shoulder abduction during surgery.

The intensity of pain measured by the VAS scale was reported to be stronger in patients who underwent total nephrectomy compared to patients who underwent partial nephrectomy, regardless of whether they had low or standard-pressure PNP, although differences are not significant (5.5 [1-8.5] vs. 5 [1-6.25]; the Mann-Whitney *U*-test; P=0.060). The pain occurred earlier in the patients undergoing total nephrectomy (after 45 minutes [15-212.5 minutes] vs. 285 minutes [47.5-877.5 minutes] in patients with partial nephrectomy; P=0.009) (Figure 2).

Furthermore, one patient in the low-pressure PNP group and 7 patients in the standard-pressure PNP group had PONV and this was not statistically significant (Fisher's exact test; P=0.23).

A correlation analysis in the whole population confirmed lower SpO_2 values in patients with higher ASA status (Kendall's τ =-0.360; P=0.007).

A statistically significant correlation was confirmed between BMI and PIP-2, as shown in Figure 3.

DISCUSSION

Transperitoneal laparoscopic upper urinary tract surgery (TLUS) offers numerous advantages compared to open surgery. Although the length of hospitalization and recovery time is usually shorter compared to open surgery, postoperative pain remains one of the most common complaints and a source of stress following laparoscopic urological procedures *(10). The European Association for Endoscopic Surgery* recommends the use the lowest abdominal pressure that allows adequate exposure of the surgical field during laparoscopy *(11).* Post-laparoscopy pain can manifest as deep abdominal (visceral) pain, incisional (parietal) pain, and post-laparoscopy shoulder pain (PLSP) (likely visceral) *(11,12).* Possible causes of PLSP include the effect of CO_2 pneumoperitoneum, stretching of the peritoneum, irritation of the diaphragm, diaphragmatic injury, and shoulder abduction during the operation *(13,14,15).* Deep intraabdominal pain is primarily caused by traction of the intestines, stretching of the abdominal wall, and compression of the intraabdominal organs. However, according to the results of the meta-analysis by Ortenzi et al. such symptoms can be attributed to the pressure of the PNP *(16).* A prospective study on pain characteristics after laparoscopic hysterectomy showed that incisional and visceral pain were most intense 30 minutes after surgery and then gradually decreased, while PLSP was less intense on the day of surgery but increased to its maximum intensity after 24 hours postoperatively. PLSP developed in 90% of all patients, with right shoulder pain being more pronounced and intensifying more during rest *(17).* In our study, there was no difference in pain localization between the two groups. The majority of patients complained of abdominal pain (11 in the low-pressure PNP group and 26 in the standard-pressure PNP group), while in both groups a total of 5 patients experienced pain at the wound site, and 5 patients reported other pain (mostly discomfort due to the catheter). Some patients experienced pain in two or more locations simultaneously. Two patients reported right shoulder pain during the first 24 hours postoperatively. In our study, shoulder pain in the male patient could be associated with shoulder abduction and the duration of the operation, while in the female patient it was associated with higher $ETCO_2$, shoulder abduction, and duration of the operation. A meta-analysis of results at various time points during laparoscopic procedures showed that overall pain was significantly lesser in the low PNP pressure group, but this difference became clinically significant only after 2 and 3 days. After 1 and 3 days, PLSP was significantly lower in the low-pressure group, with this difference being clinically significant after 3 days. The researchers concluded that the most significant advantage of low-pressure PNP is the reduced postoperative pain; however, recommendations for its use are weak, and further studies are needed to determine the safety of low-pressure *PNP (18).* Furthermore, it was determined that low-pressure laparoscopic cholecystectomy significantly reduces the frequency and intensity of PLSP, decreases the need for postoperative analgesics, and shortens hospitalization *(13).* In a comparison between open and laparoscopic nephrectomy, similar average outcomes of acute postoperative pain were observed, with the difference in pain intensity reaching significance at only one-time point (2 hours postoperatively). The highest pain scores were recorded at 30 minutes and 1 hour after surgery in both groups. Patients had an equal risk for developing chronic pain *(19).* In our study, although the initial postoperative pain occurred 160 minutes earlier in the standard-pressure PNP group, this was not statistically significant. Additionally, pain was stronger in the group of patients who underwent total laparoscopic nephrectomy compared to those who underwent partial laparoscopic nephrectomy, regardless of PNP pressure, but even that was not statistically significant. Although pain was stronger in the standard PNP group at each measurement point (VAS1, VAS2, VAS3), the VAS did not differ significantly between the groups at any measurement point. Our results could be attributed to the relatively small number of patients included in the study and the fact that patients were not separated based on the type of surgery (total vs. partial) but only based on the level of PNP pressure. Low-pressure peritoneum (8 mmHg) in general surgical procedures has been shown to reduce postoperative pain and analgesic consumption; however, it may also compromise visibility in the operative field and decrease working space *(8,20).* Furthermore, there are conflicting results regarding surgeon satisfaction, intraoperative blood loss, postoperative pain, postoperative opioid demand, and patient satisfaction. One study determined that low-pressure peritoneum is safe and provides nearly the same operative time as standard-pressure PNP in cholecystectomy *(21).* In contrast, a study on the effect of PNP during laparoscopic hysterectomy found that lower insufflation pressure negatively affected surgeon satisfaction, with a trend toward longer operative time and greater blood loss, and did not positively affect patient satisfaction, postoperative pain, opioid demand, or discharge time *(22).* In our study, no significant difference was found in the postoperative consumption of opioid and non-opioid analgesics between the two groups. In our patients, postoperative pain was mostly managed with non-opioid analgesics. Additionally, there was no difference in intraoperative opioid consumption (sufentanil) between the low and standard-pressure PNP groups. It has been established that during laparoscopic cholecystectomy, lower PNP pressure leads to reduced postoperative pain, but significantly prolongs the operative time. However, the effect of prolonged operative time with low-pressure peritoneum on clinical outcomes could not be determined from the studies included in the meta-analysis *(16).* In contrast, although not statistically significant, our study determined a longer operative time in the standard-pressure PNP group. The mean operative time was 35 minutes, and the duration of PNP was 32.5 minutes longer in the standard-pressure PNP group. A possible explanation for the longer operative time when using standard PNP pressure is that, in our study, the operators used standard-pressure for more challenging procedures. In our study, we compared the level of PNP and BMI and did not find a significant difference between the groups in terms of BMI and the PNP pressure used, but we did find that patients with higher BMI had higher PIP 30 minutes after insufflation regardless of low or standard-pressure PNP pressure. According to the literature, the use of low PNP pressure in laparoscopic procedures, especially laparoscopic robotic prostatectomy, could be prioritized over standard- pressure in obese patients and those with COPD *(23).* Furthermore, in our study we did not find a significant difference in postoperative nausea and vomiting (PONV) during the first 24 hours postoperatively between the two groups. The relatively low incidence of PONV could be attributed to PONV prophylaxis and the use of non-opioid analgesics for managing postoperative pain. Considering that the study by Özdemir-van Brunschot et al. showed that the use of low PNP pressure compared to standard-pressure has no clinical advantages on cardiac and pulmonary function, but that for ASA III and ASA IV patients further studies are necessary *(18),* we also compared the effect of low and standard PNP pressure on respiratory parameters during the operation. In our study we confirmed significantly lower SpO_2 in patients with higher ASA status. The levels of PIP 30 minutes after insufflation was higher in the group with standard PNP pressure compared to low PNP pressure. Accordingly, the PNP pressure should be maintained at the lowest possible level that does not compromise the surgeon's view of the operative field. Furthermore, we did not find a significant difference in the effect of low versus standard PNP pressure on $ETCO_2$ and SpO_2. A possible reason for the lack of difference between the two groups is the adjustment of ventilation during laparoscopy so that these parameters $ETCO_2$ and SpO_2 remain within the reference values.

The limitation of our study is its retrospective nature and the fact that patients were monitored for only 24 hours postoperatively. Another drawback of the study is the small number of patients included and the lack of randomization. The results would have been more significant or might have been different if a randomized controlled trial with a larger patient sample had been conducted.

CONCLUSION

The review of the published literature indicates that performing laparoscopic urological procedures under low-pressure PNP appears to be safe and results in lower postoperative pain compared to standard and high PNP pressure. In our study, although we did not find significant differences in the occurrence of initial pain, pain intensity, and postoperative consumption of opioid and non-opioid analgesics, there was a trend toward a significantly more favorable outcome regarding postoperative pain when using low-pressure PNP during laparoscopic nephrectomy. Furthermore, we found a significant increase in PIP 30 minutes after insufflation in the standard PNP group. A prospective study with a larger number of patients could provide better data on the effect of the level of PNP.

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