

The Effect of Intra-abdominal Carbon Dioxide Pressure on Blood Pressure in Laparoscopic Surgeries

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Abstract

Backgrounds: The high intra-abdominal carbon dioxide (CO₂) gas pressure of the pneumoperitoneum may result in physiological changes. **Objectives:** This study aimed to examine the impact of high CO₂ pressure on intraoperative blood pressures (BPs) in patients undergoing laparoscopy surgeries. **Materials and Methods:** In this quasi-experimental clinical trial, 36 patients diagnosed with different intra-abdominal diseases were undergone laparoscopic surgeries under a standard of CO₂ pressure (≥ 13 mmHg). In another group, 39 patients who were matched in age and gender were undergone laparoscopic surgeries under low CO₂ pressure (≤ 12 mmHg). **Results:** The patients in both high and low CO₂ pressure groups were comparable in age (37.65 vs. 42.37 years; $P = 0.114$), gender ($P = 0.212$), and operation time (36.18 vs. 34.64 min), respectively. The patients underwent high CO₂ pressure had significantly lower levels of diastolic BP after anesthesia (72.28 vs. 77.89; $P = 0.020$), lowest systolic BP (SBP) (94.69 vs. 102.26; $P = 0.006$), and lowest diastolic BP (DBP) (59.00 vs. 68.36; $P < 0.001$) in contrast with higher level of postoperative diastolic BP in high CO₂ group (111.23 vs. 78.11; $P < 0.001$). SBP and DBP and heart rate were decreased significantly from preoperative to postanesthesia and postoperative surgery in groups. **Conclusion:** The present study showed that BP parameters were decreased following laparoscopy surgeries (higher pneumoperitoneal CO₂ pressure has lower BP in comparison to lower pneumoperitoneal CO₂ pressure). Low CO₂ pressure is recommended during laparoscopic surgeries as much as possible, especially in patients with comorbidities such as heart diseases, old ages, and for operations that take longer time.

Keywords: Blood pressure, complication, heart rate, laparoscopy cholecystectomy

INTRODUCTION

Laparoscopy surgeries are now widely used in medicine. The advantages of this technique are a reduction of postoperative pain, improvement of cosmetic results, lesser wound-related complications and infection, and patient satisfaction and reduction in hospital stay time. The procedure of laparoscopy involves insufflation of carbon dioxide (CO₂) gas into the peritoneal cavity to produce a pneumoperitoneum and provide access for work or surgical operation. This procedure leads to intra-abdominal pressure (IAP). In the procedure, CO₂ is insufflated into the peritoneal cavity at a rate of 2–20 L/min to a pressure of 10–20 mmHg. The pneumoperitoneum is maintained by a constant gas flow of 200–400 ml/min.^[1]

The high intra-abdominal gas pressure of the pneumoperitoneum, changing the patient's position results in physiological changes, particularly in the cardiovascular and respiratory systems.

These changes and the direct effect of gas insufflation may have substantial impacts on a patient.

The surgeons need to be aware of physiological changes caused by CO₂ insulation and elevated IAP to treat the laparoscopy surgery challenge.^[2] The effects of pneumoperitoneum on intraoperative adverse cardiovascular, respiratory, and renal systems were reported in the literature.^[3,4]

The reasons for using CO₂ gas to create pneumoperitoneum are inexpensiveness, highly solubility, chemical stability, rapid elimination, physical insertion, suppression of combustion, and also proper illumination. In addition, it is a normal product of human metabolism, and it is nontoxic at physiologic levels.^[5-7]

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To prevent the onset of intraoperative complications of laparoscopic procedures, surgeons need to be aware of pathophysiological effects of laparoscopic procedures, especially the effects of CO₂ pneumoperitoneum on the human body.^[8]

This study aimed to examine the effect of high CO₂ pressure on intraoperative and postoperative blood pressures (BPs) and heart rate (HR) in patients undergoing laparoscopy surgeries.

MATERIALS AND METHODS

Study design and sampling

In this quasi-experimental clinical trial, 40 patients who diagnosed with intra-abdominal problems were underwent a laparoscopic cholecystectomy, laparoscopic sleeve gastrectomy, ascending colon cancer laparoscopic right hemicolectomy, laparoscopic removal for esophagus cancer, diagnostic laparoscopy for fertility, laparoscopic cholecystectomy, laparoscopic bilateral inguinal hernia mesh repair following exhaustive endocrinological, and imaging assessment under standard CO₂ pressure (high CO₂ pressure). In another group, 40 patients who were matched in age and gender and were diagnosed with intra-abdominal medical conditions were undergone laparoscopic cholecystectomy or sleeve gastrectomy under low CO₂ pressure.

The patients in high CO₂ pressure were underwent 13 and above CO₂ pressure in mmHg, while the patients in low CO₂ pressure were underwent 12 and lower CO₂ pressure.

The patients were matched in age and gender before data analysis. The surgery was performed between February 2, 2018 and April 7, 2019, in Rizgary Teaching and Hawler Teaching and Erbil Private Hospitals in Erbil city.

Ethical consideration

The operation was performed for the patients following taking ethical approval from the Kurdistan Board for Medical Specialties and verbal consent from the patients. The required information about the operation was presented to the patients before surgery.

Inclusion and exclusion criteria

The following patients were excluded from the study; patients with uncontrolled hypertension, heart failure, pregnancy, hypovolemic status, and severe comorbidities such as renal failure, adrenal gland diseases, and some others. The patients who were taking antihypertensive or HR regulating medications are also excluded.

Intervention

Patients were nonrandomly assigned to two groups.

The laparoscopy was performed by the same team of surgeons in each case, using the same surgical technique (lateral flank approach) and three or four trocars. CO₂ pneumoperitoneum was established. In the standard laparoscopy group, IAP of 10–14 mmHg was maintained throughout the procedure, whereas in patients from the second group, the pressure of 6–8 mmHg

was applied to perform surgery. There were no differences in total dose (volume) of insufflated CO₂ between the two groups.

Clinical procedures

The surgeon performed detailed physical and clinical examinations for all patients. The laboratory investigations were complete hemogram, blood group and Rh test, renal function test, and liver function test. The surgery was performed by the study surgeon with the cooperation of a senior house officer and one nurse. The patients in two study groups stayed at the hospital for at least 12 h.

CO₂ gas and Veress needle placement were used to create pneumoperitoneum followed by insertion of a transumbilical/subumbilical/supraumbilical 10-mm port with pressure at abdominal cavity maintained at 12 mmHg, and the 10-mm laparoscope was passed.

Laparoscopic cholecystectomy

In this method, the patient was located in reverse and left Trendelenburg position. In the epigastrium located in the right side of the falciform ligament, a 10-mm trocar was placed and one or two additional 5-mm ports in the right upper side of the abdomen just with two fingers width under the costal margin in midclavicular line and anterior/midaxillary line through or slightly under the umbilicus [Figure 1].^[9] The technique was performed by dissection of the gallbladder by the first grasping and lifting fundus. Subsequently, the cystic duct and artery were dissected. Using electrocautery, the gallbladder was removed from its bed, and it was retrieved through the epigastric port.^[10]

Laparoscopic sleeve gastrectomy

It is a surgical weight loss procedure. In a sleeve gastrectomy, also known as vertical sleeve gastrectomy or gastric sleeve procedure, the outer margin of the stomach is removed, about 75% of the stomach, to restrict food intake, leaving a sleeve of stomach. In this method, the operation is performed with the patient supine, with open legs in reverse Trendelenburg position (inclined) in operating table with angle of 30°. The main surgeon is positioned between the lower limbs; the assistant surgeon and the scrub nurse are on his right side. To prevent fall injuries and poor positioning, patients are attached to the operating table with the use of special braces in the abdomen and lower limbs.

Pneumoperitoneum was performed with direct abdominal puncture with a Veress needle in the left upper quadrant, along the costal margin in the midclavicular line, kept up with inflation pressure of 16 mmHg and flow 20–40 l/min of CO₂. Before the operation is applied, antibiotic prophylaxis is given. Taking as reference the average anatomical xipho-umbilical line, the first trocar (10 mm, permanent) is inserted at the intersection of two-thirds with the lower upper-third of about 3 cm to the left of the patient. This position allows frontal approach to gastroesophageal transition without the risk of puncture stand in the middle of the round ligament (trocar 1 – T1). The second trocar (5 mm, permanent) is placed next to the xiphoid process (trocar 2 – T2) for removal of the liver. The third (12 mm, disposable) is positioned on the right

side of the patient, at the right midclavicular line in parallel to the T1 (trocar 3 – T3). The fourth (5 mm, permanent) is placed in the left anterior axillary line along the costal margin (trocar 4 – T4). The last trocar (12 mm, disposable) is placed at the level of the left midclavicular line, also near the costal margin (trocar 5 – T5) [Figure 2].^[11]

The operation began with the dissection and removal of the fat pad of the esophagogastric junction, to allow complete visualization of the left face of the left diaphragmatic crus, and then proceeds to release and ligation of the great gastric curvature with ultrasonic energy (Ultracision Harmonic Ace Plus, Ethicon, Johnson and Johnson Corporation, USA) starting at the distal portion of the gastric body, continuing proximally into the esophagus, and subsequently along distal to the pylorus. Part of the gastric fundus adhered to the diaphragmatic crus is totally loose in its posterior portion, freeing up all the adhesions to complete dissection of the diaphragmatic crus with ligation of the posterior gastric artery. With the entire dissected stomach starts clipping about 2 cm from the pylorus with green load stapler 60 mm using Echelon (Echelon Flex Endopath, Ethicon, Johnson and Johnson Corporation, USA) and without introduction of the gastric tube for this first clipping. The usual sequence is to follow with a golden cargo and complete the staple line with blue charges, all of 60 mm. From the second shot, all subsequent steps are done with the calibration done by gastric probe number Fr 32 inside the gastric tube, guiding the positioning direction parallel to the stapler. In the last shot you need to pay attention to maintain approximately 0.5–0.8 cm of stomach near the esophagogastric angle to avoid inadvertent clipping of the abdominal esophagus.

By conducting the second and third shots, it should be observed carefully the position of the angular notch, thereby avoiding narrowing or rotation of the gastric tube at this point. Before each shot, it must be evaluated properly position the stapler in reference to the anterior and posterior stomach wall in order to construct fully symmetrical gastric tube. After leak testing of the staple line with methylene blue solution, the stomach

is removed by incision of the T3 after digital dilation. After review of hemostasis, surgical gauze, and needles counting, the trocars are removed with direct visualization to evaluate the presence of bleeding in the holes of the portals. The skin is sutured.

The intraoperative complications were: complications related to port insertion (in two cases), port reinsertion at different parietal peritoneum site (three cases), minor omentum injury (one case by the port tracker).

The complications during surgical procedure were bleeding: Injury to cystic artery before ligation in one case, injury to gastric arteries in one case, notable bleeding from the liver bed of gall bladder in two cases, gall bladder perforation in three cases, and minor liver injury with cautery scalpel in two cases at site of bed of gall bladder (one case) outside the bed of gall bladder (one case).

The anesthesia-related complications were: difficult endotracheal intubation in two cases, minor controlled allergy to medication in one case, excess bronchial secretions in two cases, and delay recovery in one case. The complications of the procedure were managed appropriately in site.

Diagnostics and measurement criteria

The diagnosis of the disease was created based on the suspicion for positivity for one item in local signs of inflammation and one item in systemic signs of inflammation and definitive criteria, including positivity for one item in local signs of inflammation, one item in systemic signs of inflammation, and findings on imaging characteristic of acute cholecystitis.^[12]

Statistical methods

The descriptive purposes of the study were presented in mean and standard deviation or frequency and percentage. To make matching in age, gender, and BP between high and low CO₂ pressure, independent *t*-test, Pearson Chi-squared, or Fishers' exact tests were performed. The comparison of clinical information and BP between high and low CO₂ pressure was performed in independent *t*-test. The comparison of BP

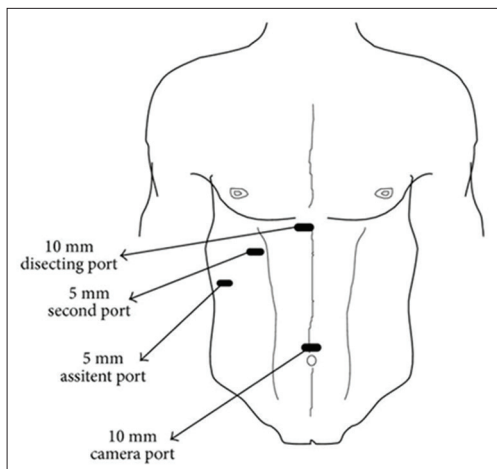


Figure 1: Position of the trocars for laparoscopic cholecystectomy^[9]

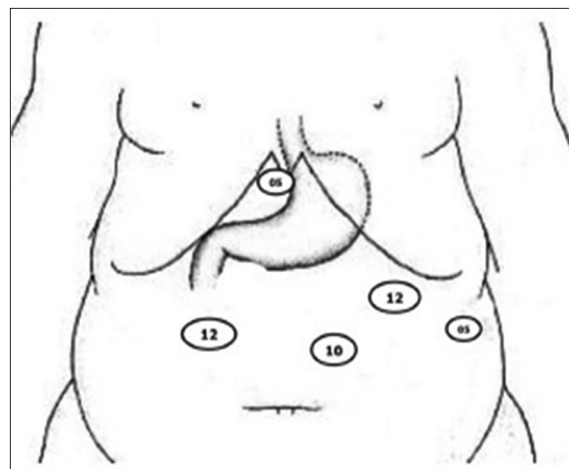


Figure 2: Positioning of the trocars for laparoscopic sleeve gastrectomy^[11]

parameters between preoperative and postoperative stages was examined in a paired *t*-test. $P < 0.05$ was considered a statistically significant difference. The statistical calculations were performed by Statistical Package for the Social Sciences 24 (SPSS 24; IBM Corp; USA; Washinton).

RESULTS

The study revealed that the patients underwent high CO₂ pressure and low CO₂ pressure for laparoscopic surgeries were comparable in age (37.65 vs. 42.37 years; $P = 0.114$), gender (female: 75.0% vs. 61.5%; $P = 0.212$), and chronic diseases (2.8% vs. 0.0%; $P = 0.480$). While the patients in high CO₂ pressure had a higher body mass index (32.02 vs. 26.34; $P = 0.003$). The patients in high CO₂ pressure were mostly graded as the American Society of Anesthesiologists (ASA) I (52.8%) and ASA II (41.7%) in contrast with ASA I (84.6%; $P = 0.003$). Most of the patients in high CO₂ pressure were underwent laparoscopic cholecystectomy (47.2%) and laparoscopic sleeve gastrectomy (25.0%) in contrast laparoscopic cholecystectomy (97.4%) in low CO₂ pressure group [Table 1].

The study showed that the patients in high CO₂ pressure group were more likely to undergo four ports for laparoscopy (47.2%) in contrast with four-port (43.6%) and three-port operation (53.8%) in low CO₂ pressure ($P < 0.001$). The patient position in most of the subjects in high CO₂ pressure group was

supine with head up and left lateral tilting (50.0%) and lithotomy (36.1%) in contrast with supine with head up and left lateral tilting in 97.4% in low CO₂ pressure group ($P < 0.001$). The levels of respiratory pressure, CO₂ set pressure, and CO₂ flow rate in high CO₂ pressure group were 16.25 versus 14.95; 14.42 versus 10.97; and 16.69 versus 5.08 compared to low CO₂ pressure groups, respectively. The operation time in patients underwent high CO₂ pressure (36.18 min) compared to 34.64 min in low CO₂ pressure ($P = 0.315$), [Table 2].

The comparison of BP between the patients underwent high CO₂ pressure and low CO₂ pressure was shown in Table 3. The study showed that the patients underwent high CO₂ pressure had significantly lower levels of diastolic BP after anesthesia (72.28 vs. 77.89; $P = 0.020$), lowest systolic BP (SBP) (94.69 vs. 102.26; $P = 0.006$), and lowest diastolic BP (DBP) (59.00 vs. 68.36; $P < 0.001$). While the patients in high CO₂ pressure group had a significantly higher postoperative diastolic blood pressure (111.23 vs. 78.11; $P < 0.001$). No significant difference was found in other items between the two study groups [Table 3].

The comparison of HR between the patients underwent high CO₂ pressure and low CO₂ pressure showed that the lowest HR was found in patients in low CO₂ pressure (74.0 bit/min) compared to high CO₂ pressure (79.0 bit/min; $P = 0.047$). The study did not find the significant difference in preoperative HR ($P = 0.909$), postanesthesia HR ($P = 0.171$),

Table 1: General information between high and low carbon dioxide pressure groups

Patients' characteristics	Study group		P (two-sided)
	High CO ₂ pressure (n=36)	Low CO ₂ pressure (n=39)	
Age (years)	37.65 (10.63)	42.37 (14.29)	0.114*
Range: 17-70	17-55	20-70	
Gender			
Male	9 (25.0)	15 (38.5)	0.212**
Female	27 (75.0)	24 (61.5)	
BMI	32.02 (10.14)	26.34 (2.67)	0.003*
ASA grading			
ASA I	19 (52.8)	33 (84.6)	0.003***
ASA II	15 (41.7)	4 (10.3)	
ASA III	2 (5.6)	2 (5.1)	
Operation type			
Ascending colon cancer laparoscopic right hemicolectomy	1 (2.8)	0 (0.0)	<0.001***
Ca esophagus	1 (2.8)	0 (0.0)	
Diagnostic laparoscopy for fertility	3 (8.3)	0 (0.0)	
Laparoscopic cholecystectomy	3 (8.3)	0 (0.0)	
Laparoscopic bilateral inguinal hernia mesh rep	1 (2.8)	0 (0.0)	
Laparoscopic cholecystectomy	17 (47.2)	38 (97.4)	
Laparoscopic cholecystectomy for gall stone	1 (2.8)	0 (0.0)	
Laparoscopic sleeve gastrectomy	9 (25.0)	0 (0.0)	
Sleeve gastrectomy	0 (0.0)	1 (2.6)	
Chronic illness			
Yes	1 (2.8)	0 (0.0)	0.480***
No	35 (97.2)	39 (100.0)	

*Independent *t*-test, **Pearson Chi-squared, ***Fishers' exact tests were performed for statistical analyses. CO₂: Carbon dioxide

Table 2: Comparison of clinical information between high and low carbon dioxide pressure groups

Patients' characteristics	Study group		P (two-sided)
	High CO ₂ pressure (n=36)	Low CO ₂ pressure (n=39)	
Port number			
3.00	4 (11.1)	21 (53.8)	<0.001**
4.00	17 (47.2)	17 (43.6)	
5.00	12 (33.3)	1 (2.6)	
6.00	2 (5.6)	0 (0.0)	
7.00	1 (2.8)	0 (0.0)	
Patient position			
Lithotomy	13 (36.1)	1 (2.6)	<0.001**
Supine	5 (13.9)	0 (0.0)	
Supine with head up and left lateral tilting	18 (50.0)	38 (97.4)	
Respiratory pressure	16.25 (4.99)	14.95 (3.86)	0.213*
CO ₂ set pressure	14.42 (0.69)	10.97 (1.55)	<0.001*
CO ₂ flow rate	16.69 (5.15)	5.08 (2.49)	<0.001*
Operation duration	36.18 (6.19)	34.64 (6.78)	0.315*

*Independent *t*-test and, **Fishers' exact tests were performed for statistical analyses. CO₂: Carbon dioxide

and postoperative HR ($P = 0.503$) between high and low CO₂ pressure, respectively [Table 4].

The study showed that SBP and DBP and HR were decreased significantly from preoperative to postanesthesia and postoperative surgery in both high and low CO₂ pressure groups ($P < 0.05$), [Table 5].

DISCUSSION

This clinical study showed that the BP parameters were decreased statistically significant from preoperative to postoperative stages. There was a significant difference between two study groups in postanesthesia DBP, lowest SBP and DBP (in high CO₂ pressure group), and postoperative DBP.

The physiological changes that occur in the body during laparoscopy could be due to different factors. Some of these factors are increasing IAP on the body, impacts of gas absorption, and surgical trauma.^[13,14] The degree to which cardiac output is reduced depends on several variables, including volume status insufflating gas, patient position, and IAP.^[15]

Increased IAP during pneumoperitoneum develops many pathophysiological mechanisms. Intraoperative pressure support splanchnic vasoconstriction and reduction in blood flow through the inferior cava vein and renal and portal vein, all lead to decreased venous flow to the heart. The central venous pressure (CVP) increases with IAP. CO₂ pneumoperitoneum with moderately elevated IAP raises intrathoracic pressure that leads to increased CVP.^[8]

The effects of CO₂ pneumoperitoneum on physiological changes have reported in the literature by several investigations. For example, a study investigated the hemodynamic effects of high (15 mmHg) and low (7 mmHg) IAP during laparoscopic cholecystectomy. They included 20 patients randomly to either high- or low-pressure pneumoperitoneum. The arterial BP, HR,

Table 3: Comparison of blood pressure between high and low carbon dioxide pressure groups

BP	Study groups		P (two-sided)
	High CO ₂ pressure (n=36)	Low CO ₂ pressure (n=39)	
Preoperative SBP	127.17 (9.07)	123.62 (8.52)	0.087
Preoperative DBP	84.89 (8.25)	87.43 (5.28)	0.130
Preanesthesia SBP	111.59 (7.67)	113.82 (8.06)	0.230
Postanesthesia DBP	72.28 (12.36)	77.89 (6.88)	0.020
Lowest SBP	94.69 (13.66)	102.26 (8.32)	0.006
Lowest DBP	59.00 (9.90)	68.36 (6.90)	<0.001
Postoperative SBP	116.59 (6.77)	114.08 (6.21)	0.105
Postoperative DBP	111.23 (18.12)	78.11 (8.90)	<0.001

Independent *t*-test was performed for statistical analyses. The bold numbers show a significant difference. BP: Blood pressure, SBP: Systolic BP, DBP: Diastolic BP, CO₂: Carbon dioxide

Table 4: Comparison of heart rate between high and low carbon dioxide pressure groups

HR	Study groups		P (two-sided)
	High CO ₂ pressure (n=36)	High CO ₂ pressure (n=36)	
Preoperative HR	76.92 (14.25)	76.54 (14.33)	0.909
Postanesthesia HR	72.57 (12.98)	76.62 (12.06)	0.171
Lowest HR	79.00 (11.46)	74.00 (9.54)	0.047
Postoperative HR	78.29 (12.91)	76.29 (12.37)	0.503

Independent *t*-test was performed for statistical analyses. The bold numbers show a significant difference. HR: Heart rate, CO₂: Carbon dioxide

stroke volume, and cardiac output were measured. The HR and mean arterial BP was increased during insufflation in high CO₂ pressure group. In the low-pressure group, insufflation raised mean arterial BP and a peak rise in both stroke volume and cardiac output by 10% and 20%, respectively.^[15]

Table 5: Comparison of blood pressure parameters between pre- and postoperative steps in high and low carbon dioxide pressure groups

BP parameters	High CO ₂ pressure	P (two-sided)
Preoperative SBP	127.00 (9.32)	0.003
Postanesthesia SBP	111.79 (7.70)	
Preoperative SBP	127.00 (9.32)	0.001
Postoperative SBP	116.64 (6.87)	
Preoperative DBP	84.89 (8.25)	<0.001
Postanesthesia DBP	71.63 (11.90)	
Preoperative DBP	85.32 (7.95)	<0.001
Postoperative DBP	110.53 (17.91)	
Preoperative HR	76.80 (14.44)	0.008
Postoperative HR	78.29 (12.91)	
BP parameters	Low CO ₂ pressure	P (two-sided)
Preoperative SBP	123.62 (8.52)	<0.001
Postanesthesia SBP	113.82 (8.06)	
Preoperative SBP	123.62 (8.52)	<0.001
Postoperative SBP	114.08 (6.21)	
Preoperative DBP	87.43 (5.28)	<0.001
Postanesthesia DBP	78.80 (6.37)	
Preoperative DBP	87.43 (5.28)	<0.001
Postoperative DBP	78.94 (8.67)	
Preoperative HR	76.66 (14.50)	0.900
Postoperative HR	76.29 (12.37)	

CO₂: Carbon dioxide, BP: Blood pressure, HR: Heart rate, SBP: Systolic BP, DBP: Diastolic BP

The findings reported in this study are similar to those reported in other clinical settings.^[3,4] One study reported 20% of the decrease in cardiac output.^[4]

A controlled IAP facilitates the operation of a surgeon within the abdominal cavity.

The complications of the patient in this study were not fatal. However, their cases in this study developed gallbladder preformation. Many of these complications could be prevented with increasing clinical experience and appropriate anesthesia. Lower intra-abdominal CO₂ pressure during laparoscopic surgeries is safer in terms of better cardiac output and tissue perfusion. Lower CO₂ pressure is advised, especially in elderly patients, patients with comorbidities such as heart disease, pregnancy, and for procedures that take longer time. However, the use of CO₂ pressure set is up to surgeon's preference and experience. The complications develop based on the IAP, the amount of CO₂ absorbed, the technique of ventilation, the circulatory volume of the patient, the pathologic conditions of the patient, and the anesthesia type. To prevent the development of the complications during laparoscopy, sufficient monitoring and correct management are required.^[16]

Limitations of the study

The finding reported in this clinical study must be used with caution since the patients were underwent different types of laparoscopic surgeries and positions. Moreover, the patients were selected from two clinical settings in Erbil City that make

a difficulty in generalizing the findings to other settings across the country. It is hard to make between-study comparison, as the surgeons have used different CO₂ pressure in the literature.

CONCLUSION

The present study showed that BP parameters were decreased following laparoscopy surgeries (higher pneumoperitoneal CO₂ pressure has lower BP in comparison to lower pneumoperitoneal CO₂ pressure). Low CO₂ pressure is recommended during laparoscopic surgeries as much as possible, especially in patients with comorbidities such as heart diseases, old ages, and for operations that take longer time.

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Conflicts of interest

There are no conflicts of interest.

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