An-Najah National University

Faculty of Graduate Studies

THE EFFECT OF CO2 INSUFFLATION ON ARTERIAL BLOOD GASES AND END TIDAL CO2 DURING LAPAROSCOPIC SURGERIES IN ADULTS

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Dedication

First, I thank God for everything. Then, I am grateful to my beloved mother and father, brother and sisters, whose love, sacrifice, patience and unwavering support are my source of strength. I will be grateful forever.

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Declaration

I, the undersigned, declare that I submitted the thesis entitled:

THE EFFECT OF CO2 INSUFFLATION ON ARTERIAL BLOOD GASES AND END TIDAL CO2 DURING LAPAROSCOPIC SURGERIES IN ADULTS

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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Date: **14/10/2024**

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Abstract

Theoretical background: During laparoscopic surgeries, surgeons prefer to inflate the abdomen using CO2 gas to make a space between abdominal layers and organs and the " pneumoperitoneum " procedure. Clinical significance was found, and the effect of CO2 insufflation on end-tidal CO2 levels and arterial blood gases was clarified during these procedures, especially in terms of patient ventilation and respiratory function.

Aims: The purpose of the study was to discover the effect of co2 inflation during laparoscopic operations on the end-tidal co2 levels and arterial blood gases for adults patients. The main goal was to evaluate the physiological effects of CO2 insufflation and its connection with respiratory parameters.

Methodology: 60 adult patients who underwent laparoscopic surgery were selected and divided into two groups with 30 participants in each group based on respiratory rate used and the study design was a prospective single-blind quasi-experimental design. Patients were monitored for ABG, vital signs and ETCO2 levels. Subgroup and sensitivity analysis were applied to assess the effect of CO2 insufflation on vital signs and respiratory system functions.

Main results: The results showed significant differences in ABG and ETCO2 levels among the two groups, especially in respiratory rate, duration of CO2 insufflation and venting of CO2. Subgroup analysis showed changes in ABG based on the duration of CO2 insufflation, and sensitivity analysis indicated the possible effect of confounding variables on the study outcomes.

Conclusions: The findings assure on the importance of carefully monitoring and managing CO_2 levels during laparoscopic surgeries to provide optimal patient outcomes and gives important information about the physiological implications of CO_2 insufflation, and emphasizes the need of standardized protocols and continuous monitoring during these surgical procedures.

Keywords: Arterial Blood Gases(ABG), CO2-Insufflation, End-Tidal CO2(ETCO2), Laparoscopic Surgeries and Respiratory Rate(RR).

Chapter One
Introduction and theoretical background

1.1 Brief introduction

In laparoscopic surgeries the surgeons create a small incisions in the abdomen that is slightly invasive and the procedure containing inserting a camera and specialized instruments through the incisions to perform the procedure (Karaveli et al., 2021; Sahay et al., 2017). The CO2 insufflation (pneumoperitoneum) is a common technique used during laparoscopic surgeries to create space in the abdomen and improve visibility for the surgical team but this technique can lead to changes in ABG and EtCO2 levels which can have clinical implications on the patients (Karaveli et al., 2021; Sahay et al., 2017). Therefore a quasi-experimental research design used to investigate the effect of CO2 insufflation on ABG and ETCO2 levels during laparoscopic surgeries in adults.

1.2 The independent and dependent variables

The respiratory rate was the independent variable and 14 breaths per minute were used in the control group and 20 breaths per minute for the experimental group and the dependent variables were the ABG and ETCO2 levels that were measured and monitored during the operation. The study can provide important insights into the safety and satisfaction of this practice, and help guide clinical work and future research in this area (Karaveli et al., 2021; Sahay et al., 2017).

1.3 Theoretical basis

The CO2 insufflation can cause a number of physiological changes such as changes in intrathoracic pressure, venous return, and cardiac output which can lead to alterations in ABG and ETCO2 levels, this study talks about the physiological effects of CO2 insufflation on arterial blood gases and end tidal carbon dioxide levels during laparoscopic surgeries (Eva et al., 2022).

During laparoscopic surgeries the insufflation of CO2 cause an increase of PACO2 and PH of arterial blood caused by the decrease of tidal volume and lung compliance that leads to respiratory acidosis, as a result the respiratory system has an important intervention in regulating CO2 levels in the body (Chen et al., 2021).

The study is supported by previous studies that have reported changes of ABG and ETCO2 levels during laparoscopic operations with CO2 insufflation for example a randomized clinical trial by Chen et al., (2021) found that higher levels of CO2 insufflation pressure during laparoscopic surgery were associated with changes in ABG and cerebral oxygen saturation. Similarly a study of Saad et al., (2020) reported changes of ABG and electrolyte levels during prolonged laparoscopic surgeries and these studies highlight the need for further investigation of the effects of CO2 insufflation on ABG and ETCO2 levels during laparoscopic surgeries.

Also the theoretical basis of the study is to investigate effect of CO2 insufflation on ABG and ETCO2 levels during laparoscopic surgeries and this is based on the understanding of the respiratory system and the potential changes in ABG and ETCO2 levels associated with CO2 insufflation.

1.4 Problem statement

The study is the understanding of the effects of CO2 insufflation on ABG and ETCO2 levels during laparoscopic surgeries because the CO2 insufflation can cause a number of physiological changes such as changes in intra-thoracic pressure, venous return, and cardiac output which can lead to changes in ABG and ETCO2 levels (Kumar et al., 2020). The respiratory system plays an important role in regulating CO2 levels in the body.

During laparoscopic surgery the insufflation of CO2 can cause respiratory acidosis and this can be compounded by the decrease in tidal volume and lung compliance associated with CO2 insufflation and this can cause further alterations in ABG and ETCO2 levels and in addition to respiratory acidosis there is other potential effects of CO2 insufflation during laparoscopic surgeries include decreased oxygen saturation, hypercapnia, and changes in hemodynamic. These changes can cause other complications such as arrhythmias, hypotension, and myocardial ischemia particularly in patients with underlying cardiovascular or pulmonary disease (Jiang et al., 2019).

During laparoscopic surgeries it is important for clinicians to understand the effects of CO2 insufflation on ABG and ETCO2 levels and keep the patients under continuous monitoring for ABG values and ETCO2 levels (Can et al., 2018). The problem addressed by this study is the potential effect of CO2 insufflation on ABG and ETCO2 levels during laparoscopic surgeries and the need for understanding these effects to improve patient safety and gives better outcomes, also gives an impression about the possibility of decreasing the risk of respiratory complications by using the appropriate surgical techniques and suitable insufflation pressure (Wei et al., 2020).

1.5 Study hypotheses

1. There is no significant difference in arterial blood gases ABG between patients undergoing laparoscopic surgeries before and during CO2 insufflation.
2. There is no significant difference in ETCO2 levels between patients undergoing laparoscopic surgeries before and during CO2 insufflation and after venting of CO2 (disinflation).
3. The respiratory rate (14 VS 20 breath/min) during laparoscopic surgeries has no significant effect on ABG before and during CO2 insufflation.
4. The respiratory rate (14 VS 20 breath/min) during laparoscopic surgeries has no significant effect on ETCO2 levels before and during CO2 insufflation and after venting of CO2 (disinflation).

1.6 Significance of the study

The study is important for several reasons.
Firstly: The laparoscopic surgeries are becoming increasingly common and CO2 insufflation is a key component of the procedure so the understanding of the potential risks associated with CO2 insufflation is important for improving patient safety during these surgeries (Srivastava & Niranjan, 2010).

Secondly: The changes in ABG and ETCO2 levels can have significant consequences for patients particularly those with underlying cardiovascular or pulmonary disease and by identifying the potential effects of CO2 insufflation on these parameters as a result the clinicians can better monitor patients during laparoscopic surgeries and intervene if necessary to prevent adverse outcomes (Srivastava & Niranjan, 2010).

Furthermore the study can inform decisions regarding respiratory rate used during laparoscopic surgeries and the choice of insufflation pressure and other surgical techniques to decrease undesirable effect and prevent any complications in respiratory system so that can ultimately improve the quality of care provided to patients undergoing laparoscopic surgeries. Overall the study is important for improving our understanding of the effect of CO_2 insufflation during laparoscopic surgeries and for informing clinical practice to improve patient outcomes.

Also the importance of the study assure on its potential to optimize patient safety and satisfaction and to obtain excellent outcomes during laparoscopic surgeries by examining the effect of CO_2 insufflation on ABG and $ETCO_2$ levels as well as the impact of calibrated respiratory rate during surgery so the study aims to provide valuable insights into how to optimize these parameters for better patient outcomes.

The results of this study could inform clinical practice guidelines for laparoscopic surgeries and possibly can lead to changes in surgical techniques as a result that can improve patient safety and reduce complications. So the study has the potential to benefit both patients and healthcare providers by improving the quality of care during laparoscopic surgeries (Liu Y, 2020; Tsafrakas A et al., 2018).

1.7 Objectives of the study

1. To compare the effects of CO_2 insufflation during laparoscopic surgeries on ABG and $ETCO_2$ levels for two different respiratory rates (14 breaths per minute vs. 20 breaths per minute). It also aims to discover if there is an essential variation between the two groups before and during CO_2 insufflation and after venting of CO_2 (disinflation)**.**
2. To determine the effect of the duration of surgery on ABG and $ETCO_2$ levels during CO_2 insufflation and after venting of CO_2 (disinflation) during laparoscopic surgeries.
3. To know the effects of CO_2 insufflation on peak airway pressure (PAP) between patients undergoing laparoscopic surgeries before and during CO_2 insufflation and after venting of CO_2 (disinflation).
4. To provide evidence-based recommendations for optimizing respiratory management during laparoscopic surgeries to minimize any susceptible complications and improve patient safety.

1.8 keywords and Terminologies

Arterial Blood Gases (ABGs), ASA score, CO_2 disinflation, CO_2 Insufflation, End-Tidal CO_2 (ETCO2), Laparoscopic Surgeries, Peak Airway Pressure (PAP), Pneumoperitoneum, Respiratory Rate.

ABG (Arterial Blood Gas Analysis): A blood test withdrawn from artery to show the percentage of oxygen and carbon dioxide saturation, indicating lung function. It measures acid-base balance too, denoting how kidneys and lungs preserve the equilibrium. In enzymology, it is an important factor in keeping the acid-base balance stable. When imbalances occur, a person may experience acidosis (too much acid) or alkalosis (too much base), both of which can be dangerous and even deadly if left untreated (Yap & Aw, 2011).

The American Society of Anesthesiologists (ASA) score is a risk categorical scale modified by the American Society of Anesthesiologists that anesthesiologists employ to evaluate the pre surgical risks according to the patient's preoperative health status. The system categorizes the patients into six different types depending on their condition and speciality diseases. The new ASA score unveiled in October 2019 contains disease predictors for specific ailments, enabling clinicians to assess them. It assists in assessing and creating anticipation for anaesthetic and surgical intervention (Doyle et al., 2024).

CO_2 disinflation: The procedure of venting CO_2 gas from the abdominal cavity after the completion and finishing of the surgical procedure. During laparoscopic surgery, carbon dioxide gas infiltrates the abdomen to create a pneumoperitoneum, providing adequate space and visibility for the surgeon to operate. Disinflation involves the careful and gradual suctioning of carbon dioxide gas to return the abdominal cavity to its normal state before the insufflation of CO_2 and ensuring patient safety and comfort post-surgery. Proper management of CO_2 disinflation is important to avoid complications such as residual gas pockets, which can cause postoperative discomfort or pain (Yang et al., 2022).

CO_2 insufflation: The method of inflating or infiltrating the abdominal cavity using CO_2 gas, typically the abdominal cavity, during minimally invasive surgery (MIS) to expand the space between the abdominal skin layers and organs for better visibility and access. CO_2 gas is preferred over other gases because it has many characteristics, such as being cheap, non-inflammable, and having a high affinity to solute in the blood, and the lungs can wash it out. This procedure increases intra-abdominal pressure that causes the abdominal wall to increase in size and rise outward; as a result, the diaphragm will rise upward. Also, it will decrease the capacity and compliance of the lungs and reduce intra-thoracic space (Lee-Ong, 2023).

End-tidal carbon dioxide (ETCO2): Ii is the percentage of CO2 gas that is eliminated from the lungs, and it can be measured at the end of the exhalation phase during breathing. ETCO2 level indicates the effectiveness of gas exchange in the lungs and whether the lungs wash out effectively (Pokorná et al., 2010).

Laparoscopic Surgeries: The other name for laparoscopic surgery is keyhole surgery, the least invasive procedure. It is a surgical technique that includes a number of small incisions by surgeons, and these incisions are small in size, which may be between 0.5 to 1 centimetre. After the incisions are made, the surgeons use trocars, which are stainless steel plates. They are about one cm thick and were used to create small, narrow tubes through which endoscopies are passed through incisions made in the abdomen. It is like the pathway the surgeon uses to reach the abdominal organs. These trocars facilitate using a laparoscope, a long and narrow instrument, and a narrow and long fibre optic camera (Patil et al., 2024).

Peak Airway Pressure (PAP): The highest pressure level recorded in patients' airways during mechanical ventilation. This one evaluates the maximum pressure obtained during inspiration in a single ventilatory episode. Peak airway pressure is a key parameter for determining airflow resistance in patients' airways and respiratory system compliance. It is frequently tracked among people receiving mechanical ventilation to determine that the pressure being applied during inspiration is not above safety thresholds and that their lungs are healthy enough. High airway peak pressure can suggest increased respiratory resistance, decreased lung compliance, or other pulmonary conditions and must be countered by adjusting the ventilator settings to provide high-quality ventilation with as few complications as possible (Gertler, 2021).

Pneumoperitoneum: It is the key procedure in laparoscopy, where the abdominal cavity is artificially inflated with CO2 or any other inert gas to provide a working area to the surgeon. This process involves the injection of gas into the abdominal cavity, which makes the abdominal wall outward at the same time as the diaphragm upward. In this case, the intra-abdominal pressure rises, peak airway pressure increases, and the intra-thoracic space and capacity of the lungs are reduced. The enlargement of the abdomen is sufficient to facilitate proper visualization of internal structures and adequately manoeuvre and manipulate with the tools and implements used in operation. This process is crucial before starting laparoscopic surgery to have a clear and unobstructed view of the surgical site to perform safe surgery (Lee-Ong, 2023).

Respiratory Rate: The process of which the air get in and out of the lung termed as respiratory rate. This process called ventilation, and it includes inspiration phase, which allow the air to get in to the lungs, and the expiration phase, which allow the air to get out from the lungs. The adults usually breath between (12-18)breaths/minute and the process of expiration needs twice time of inspiration for example the adult requires 1 second of inspiration and 2 seconds of expiration (Dougherty & Lister, 2015).

Chapter Two

Literature Review

2.1 Introduction

This chapter explore the research that in connection with articles talk about "the effect of CO_2 insufflation on ABG and $ETCO_2$ levels during laparoscopic surgeries in adults". The literature review gives a view about the impacts of CO_2 insufflation and how was the previous studies were done and the clinical implications of these findings so to gather relevant literature a systematic search was conducted using several databases including Google Scholar, PubMed and other trusted medical and scientific websites. These sources containing a huge quantity of reliable articles, clinical studies and meta-analyses that are crucial for research and the search strategy include keywords such as CO_2 insufflation, ABG, $ETCO_2$, laparoscopic surgeries and adults.

The chapter give an impression about how the CO_2 insufflation during laparoscopic surgeries can affect the respiratory system and cardiovascular system. In addition, the chapter containing subsequent parts that explain the connection among $ETCO_2$ and $PACO_2$ and focused on the ways that used to monitor and measure these parameters and the outcomes of previous studies in different site and settings and different surgical techniques of laparoscopic surgeries. The review also examines the clinical implications of CO_2 insufflation, including potential complications and guidelines for optimizing patient safety and outcomes. By synthesizing findings from various studies, this chapter aims to know the limitations in the current informations and to give facilities for new research.

Laparoscopic surgeries in the current years is widely practiced and preferred by the surgeons and the patients rather than the past, because it has many benefits, for example it is less invasive, less pain and patients shows more satisfaction and excellent outcomes for the surgeons. One of the primary principles of laparoscopic surgeries is making a field or space between the abdominal cavity and organs, and this can be done by inflate the abdominal cavity using CO_2 gas to create a pneumoperitoneum.

While pneumoperitoneum is essential for laparoscopic surgery, it is also associated with potential risks, including changes in hemodynamic and arterial blood gas parameters as a result it can cause side effects for example complications in cardiovascular system such as arrhythmia and respiratory system adverse effects such as respiratory distress (Can et al., 2018; Eva et al., 2022; Memon et al., 2018). The objectives of literature review were to explore the effects of CO_2 insufflation on hemodynamic status and ABG readings for patients undergoing laparoscopic surgeries.

This study focused on comparing the effect between two groups for hemodynamic status and ABG readings among patients who underwent laparoscopic surgery with CO_2 insufflation and without CO_2 during laparoscopic cholecystectomy. 60 patients were randomly assigned to either undergo the surgery with CO_2 insufflation group or the gasless group. The researchers take readings of various physiological parameters including HR, BP, ABG and central venous pressure before and after the surgery.

The results showed that the patients in group of CO_2 insufflation had significantly higher peak airway pressures(PAP), higher levels of $ETCO_2$ and lower levels of oxygen saturation than the gasless group and there were no significant differences in the hemodynamic parameters among the two groups. This study suggests that CO_2 insufflation during laparoscopic surgeries may affect ABG readings but not necessarily hemodynamic parameters (Ozkan U et al., 2020). However, it is necessary to note that this is just one study that cannot give a holistic view about the effects of CO_2 insufflation on physiological parameters because it may vary depending on various factors such as the type of surgery, the patient characteristics and the surgical technique used during the surgery (Ozkan U et al., 2020).

A similar study about "The Effect of CO_2 Insufflation on ABG and $ETCO_2$ During Laparoscopic Cholecystectomy". The study published in the Journal of Laparoendoscopic & Advanced Surgical Techniques in 2018 and the study design was prospective randomized control. A total number of 60 participants underwent laparoscopic cholecystectomy divided into two groups with randomization to receive either standard CO_2 insufflation or low-pressure CO_2 insufflation. ABG and $ETCO_2$ levels were measured before insufflation, during insufflation and after insufflation.

The results showed that there was a decrease in arterial oxygen saturation ($SPAO_2$) and an increase of $ETCO_2$ levels in both groups during insufflation but there was a insignificant difference between the standard and low-pressure groups. The low-pressure group had a significantly lower peak airway pressure(PAP) and lower incidence of postoperative shoulder pain. This study gives a suggestion about the use of low-pressure CO_2 insufflation technique may be beneficial in reducing some of side effects of CO_2 insufflation during laparoscopic surgeries and the need of further research to confirm these findings (Şahin et al., 2018).

The study found that pneumoperitoneum had a significant effect on ABG analysis during laparoscopic gynecologic surgery. The authors observed a statistically significant lowering in PH, PAO_2 and HCO_3 levels as well as an increase in $PACO_2$ levels at 10 minutes after CO_2 insufflation and at the end of surgery it returned to baseline. These changes may be caused by decreased cardiac output, increased intra-abdominal pressure and decreased pulmonary compliance (Kim et al., 2016).

Kumar and Jindal aimed to show the effect of CO_2 insufflation on ABG and $ETCO_2$ levels during laparoscopic surgery and the results showed that there was a significant increase in $ETCO_2$ levels post CO_2 insufflation which then gradually decreased over time. Also, a significant lowering was found in PH, PAO_2 and HCO_3 levels after CO_2 insufflation but these levels returned to baseline at the end of surgery. These changes possibly happened as a result of increased intra-abdominal pressure and decreased pulmonary compliance. The study focused on the importance of monitoring ABG and $ETCO_2$ levels during laparoscopic surgeries to ensure patient safety and obtain desirable outcomes (Kumar et al., 2018).

The study of Wang et al (2018) focused on "the effects of CO_2 insufflation on ventilator function and quality of recovery after laparoscopic surgeries". The researchers who conduct the study found that the patients in the group of CO_2 insufflation had a significantly lower forced vital capacity (FVC), decrease in forced expiratory volume at one second (FEV_1) and peak expiratory flow (PEF) immediately after surgery and on the first day postoperative compared to the control group and there was no significant difference in the quality of recovery between the two groups. So the authors suggest that these changes in ventilator function is supposed to be happened because of decreased pulmonary compliance and increased intra-abdominal pressure as a result of CO_2 insufflation during the surgery (Wang et al., 2018).

The study showed that CO_2 insufflation caused a significant decrease in PH, PAO_2 and HCO_3 levels and in contrast, it caused a significant increase in $PACO_2$ levels for both episodes of during and after laparoscopic surgeries. These changes were found in patients with a BMI ≥25 kg/m2 and in surgeries that have a duration of time longer than 120 minutes. These findings is likely occurred by the effects of intra-abdominal pressure on respiratory functions (Jain et al., 2019).

In the study of "the impact of CO_2 pneumoperitoneum on ventilatory and hemodynamic parameters during laparoscopic cholecystectomy". A significant increase was found in the levels of mean arterial pressure (MAP) and heart rate (HR) and on the other hand a decrease in tidal volume (VT), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1) and peak expiratory flow(PEF) values caused by CO_2 insufflation (pneumoperitoneum). These parameters returned to baseline after venting of CO_2 at the end of the operation . The authors suggest that the changes in ventilatory and hemodynamic values are related to increased intra-abdominal pressure and decreased pulmonary compliance that caused by CO_2 insufflation (Pacheco et al., 2020).

This study goal was to investigate "the effect of CO_2 insufflation on blood gases and hemodynamic changes in patients undergoing laparoscopic cholecystectomy". The Pneumoperitoneum caused a significant changes in arterial blood gases including a decrease in PH, PAO2, and HCO_3 levels and an increase in PACO2 levels, which improved after disinflation. Also changes in hemodynamic parameters were seen such as an elevation in mean arterial pressure (MAP) and the patients has an increase of heart beats, which normalized post venting of CO_2. The study concluded that the CO_2 insufflation during laparoscopic cholecystectomy has a significant impact on blood gases and hemodynamic changes (Arslan & Dikmen, 2020).

In this study a sum of 40 participants were included to explore "the effects of pneumoperitoneum on arterial blood gas and hemodynamic parameters in laparoscopic cholecystectomy". The patients divided into two groups: Group P (n=20) underwent laparoscopic cholecystectomy with pneumoperitoneum and Group C (n=20) underwent laparoscopic cholecystectomy without pneumoperitoneum.

Arterial blood gas and hemodynamic parameters were recorded before insufflation (T0), 15 minutes after insufflation (T1), and 60 minutes after insufflation (T2). The researchers found a significant increase in PACO2 levels and a decrease in PAO2 levels in Group P compared to Group C at T1 and T2 ($p < 0.05$). However, there were no significant differences in hemodynamic parameters between the two groups. The authors concluded that pneumoperitoneum during laparoscopic cholecystectomy may cause an elevation of $PaCO_2$ levels and they notice a fall in PaO_2 levels, but it does not have a significant effect on hemodynamic parameters (Ozdil et al., 2020).

A retrospective study in Pakistan aimed to assess the effects of insufflations of CO_2 into the intraperitoneal cavity during laparoscopic surgeries on end-tidal CO_2. The research was long-term and descriptive; therefore, it was approved by the proper ethical standards department. Researchers measured the $ETCO_2$ concentration at various intervals: preoperatively, at the start of CO_2 insufflation at 10mmHg, between 10–15mmHg, at the highest PIP established during surgery, and at the completion of surgery. The research showed a rise in the $ETCO_2$ after the CO_2 insufflation and, more notably, after the incision. Nonetheless, in most patients, it was observed that once the laparoscopic surgery was over, the $ETCO_2$ came back to normal (Irfan et al., 2022).

A study in which changes in $ETCO_2$ together with SPO_2 and ECG during laparoscopic and open cholecystectomy were investigated with reference to the consequences of CO_2 insufflation during laparoscopic surgeries under general anaesthesia (GA). The study design was cross-sectional and conducted at Jorhat Medical College and Hospital in the Department of Anesthesiology for a duration of 12 months from July 2020 to July 2021. Seventy patients were recruited for the study and evenly distributed between head and neck/cervical surgery and thoracic surgery groups (35 patients per group) using Epi-info software. Participants were adults aged 18-60 years with ASA physical status I or II. However, the participants underwent laparoscopic cholecystectomy and were divided into two groups: Group I (open cholecystectomy) and Group II (laparoscopic cholecystectomy).

It was ascertained that patients in Group II showed a noticeable rise in heartbeats, starting at 10, 20, and 60 min, and rose noticeably at 30, 40, and 50 min before returning to the baseline. While comparing the two Groups, SBP in Group II increased significantly at 20 & 60 min significantly, and at 30, 40, and 50 min significantly than in Group I, DBP raised slightly at 20 min and very significantly at 30 as well as 40 and 50 min than Group I respectively, $ETCO_2$ rose significantly at 20 min and highly significantly at 30, 40, 50 (Das, 2024).

The changes in arterial blood gas, $ETCO_2$, PH, and hemodynamic techniques during laparoscopy. This prospective study involved 50 patients, American Society of

Anesthesiologists physical status grade I and II, between the ages of 20 and 65 years, who were posted for same-day laparoscopy. Arterial blood samples were obtained pre-operatively and at defined time points during CO_2 insufflation: 10 minutes, 60 minutes, 120 minutes, and at the end of the procedure following disinflation. Discrete waveform analysis revealed that ETCO2 elevated throughout the surgery and peaked 60 minutes after starting insufflation but reduced to near baseline after disinflation. PACO2 levels, on the other hand, were elevated in both associated affiliated clusters but stayed within the physiological perimeter. PH, in contrast, decreased significantly, the lowest value of which was noted at 120 minutes for affiliated cluster 2. Systolic blood pressure increased from 139 ± 12 mmHg to 166 ± 21 mmHg, while diastolic blood pressure raised from 90 ± 10 mmHg to 98 ± 11 mmHg ($p < 0.05$); volatile anaesthetics controlled this. The analyzed values of EtCO2, PaCO2, and pH considerably changed.

However, the values remained within the physiological range, and a spontaneous increase in MV was observed while the patients were mechanically ventilated. This was supported by the fact that most parameters returned to baseline status in health patients after disinflation, and ETCO2 was a reliable indicator of hypercarbia among the patients (Makwana et al., 2014).

A study explored the relationship between end-tidal carbon dioxide (ETCO2) and arterial carbon dioxide (PaCO2) over time in elective pediatric laparoscopic surgeries. This prospective observational cohort study included 29 children, all classified as ASA I and aged between 12 and 72 months. The study involved 116 paired comparisons of PACO2 and ETCO2. Arterial blood samples were collected at four different time points: before pneumoperitoneum, 15 minutes into pneumoperitoneum, 30 minutes into pneumoperitoneum, and one minute after deflation. Simultaneously, ETCO2 values were recorded during each arterial blood sample withdrawal. Pearson's correlation coefficients and the Bland-Altman method assessed the relationship between PACO2 and ETCO2. The results indicated that in 61.2% of the comparisons, the difference between PACO2 and ETCO2 was within 0 to 5 mmHg, with 29.3% showing a negative difference. A significant positive connection was noticed between (PaCO2) and (ETCO2) pre-pneumoperitoneum ($r = 0.617$, $p < 0.001$) and after 15 min into pneumoperitoneum ($r = 0.582$, $p = 0.001$), but not at 30 min ($r = 0.142$, $p = 0.461$) or post venting (r percentage = 0.108, p rate= 0.577). The Bland-Altman analysis demonstrated an approval among $PaCO_2$ and $ETCO_2$ before pneumoperitoneum, with a mean difference of 0.14±5.6 mmHg (95% borders of approval: -10.84 to 11.2, $p = 0.971$). However, there was no agreement at 15 minutes (mean difference: 0.51±7.15 mmHg, 95% limits: -13.5 to 14.5, $p < 0.001$), 30 minutes (mean difference: 2.62±7.83 mmHg, 95% limits: -12.73 to 17.97, $p < 0.001$), or after deflation (mean difference: 1.81±6.56 mmHg, 95% limits: -10.93 to 14.55, $p = 0.015$) (Abdel-Ghaffar et al., 2021).

A prospective descriptive study from the concerned departments containing 20 participants undergoing laparoscopic surgeries for different pathologies, including Ovarian cystectomy, Cholecystectomy, and Appendectomy, so ($ETCO_2$) was measured before the beginning of the operation and before the insufflation of CO_2. After that, it is measured with an intra-abdominal pressure of 10-mmHg, between 10-15 mmHg, and at 15-mmHg. It is measured at the end of the operation, so $EtCO_2$ increased slightly post-CO_2 insufflation and raised gradually during the operation until the surgeon finished the surgery, and it gradually decreased after venting CO_2 (Farman et al., 2022).

There was an observational study containing 50 participants whose age was more than 18 years, characterized by (ASA) scores of I and II. The study was done to discover the metabolic effects of CO_2 insufflation in laparoscopic operations. The result showed a gradual increase of $ETCO_2$ and a gradual lowering of pH during insufflation. At the end of the operation and the patient started to recover, PH started to rise but did not reach the percent that measured at baseline and was less than it ($p<0.118$). The ($PACO_2$) increased post 15 minutes of carbon dioxide insufflation and reached the highest level at 30 minutes with mean & SD 42.82,2.775 & 46.16,2.909, which means it is significant. According to $ETCO_2$, it is raised up post 15 minutes of insufflation. The same $PACO_2$ reached the highest percentage at 30 mins with a mean of 41.56 & 44.50, which is considered significant. On the other hand, the same as pH happened to HCO_3. It is lowered gradually and reaches the lowest rate at 30 minutes of Co_2 insufflation with a mean of 23.70, SD 1.919 & range of 19-27 (Bachh et al., 2022).

A study included 12 participants who underwent laparoscopic cholecystectomy with Co_2 insufflation and were tested to examine respiratory system function and ABGS. After starting the operation, the respiratory mechanics were continuously monitored and recorded using an in-line spirometer. During the insufflation of CO_2, the researchers noticed a fall in minute ventilation with about 500 ml.min-1. Also, they discover decreasing in the capacity of the lungs and lungs compliance from 49.6 +/- 4.7 to 30.7 +/- 2.3 (mean +/- SEM) ml.cmH2O-1 with a value of ($P < 0.005$), and at the end of the operation and start venting of CO_2 the lung compliance returned to 45.1 +/- 3.1. According to peak inspiratory pressure, they discover an increase in the value from 15.9 +/- 0.9 to 18.9 +/- 1.0 cmH20 with a percentage ($P < 0.05$). ABG readings showed lower pH levels and an increase in $PACO_2$ called CO_2 retention during insufflation and in the recovery room ($P < 0.05$). In the end, the results demonstrated that the percentage of $PACO_2$ in laparoscopic cholecystectomy was higher compared to open cholecystectomy (Iwasaka et al., 1996).

2.2 Literature Review Matrix

2.2.1 The first study

- Title: "Effects of pneumoperitoneum on arterial blood gas and hemodynamic parameters in laparoscopic cholecystectomy".
- Author/Date: Ozdil et al., 2020.
- Purpose: To investigate the effects of pneumoperitoneum on arterial blood gas and hemodynamic parameters in laparoscopic cholecystectomy.
- Methodology: A total of 40 patients were included in the study, and they were divided into two groups: Group P (n=20) underwent laparoscopic cholecystectomy with pneumoperitoneum, and Group C (n=20) underwent laparoscopic cholecystectomy without pneumoperitoneum. Arterial blood gas and hemodynamic parameters were recorded before insufflation (T0), 15 minutes after insufflation (T1), and 60 minutes after insufflation (T2).
- Analysis and Results: There was a significant increase in $PaCO_2$ levels and a decrease in PaO_2 levels in Group P compared to Group C at T1 and T2 ($p < 0.05$). However, there were no significant differences in hemodynamic parameters between the two groups.
- Conclusions: Pneumoperitoneum during laparoscopic cholecystectomy may cause a significant increase in $PaCO_2$ levels and a decrease in PaO_2 levels, but it does not have a significant effect on hemodynamic parameters.

2.2.2 The second study

- Title: "A comparative study of hemodynamic and end-tidal carbon dioxide changes during laparoscopic and open cholecystectomy".
- Author/Date: Das, 2024.
- Purpose: To compare End Tidal Carbon Dioxide (ETCO2) changes during laparoscopic, to compare Saturated Pressure of Oxygen (SpO2) and electrocardiogram changes during laparoscopic and open cholecystectomy and to evaluate any additional effects of the insufflated carbon dioxide during laparoscopic cholecystectomy under general anesthesia.
- Methodology: 3115 participants Adult patients of either sex, between 18-60 years of age, belonging to ASA grade I and II, and scheduled for elective cholecystectomy, were selected. The patients were divided into two groups. Group I (N=35): Patients scheduled for open cholecystectomy. Group II (N=35): Patients scheduled for laparoscopic cholecystectomy.
- Analysis and Results: Patients in Group II, therefore, showed a highly significant increase in heart rate (HR); the increase was highly significant starting at 10, 20, and 60 min and significant at 30, 40, and 50 min before returning to the baseline. While comparing both Groups, SBP in Group II increased significantly at 20 & 60 minutes significantly, and at 30, 40, and 50 minutes minutely significantly than the Group I, DBP raised slightly significantly at 20 minutes and highly significantly at 30 as well as 40 and 50 min than Group I respectively, ETCO2 rose significantly at 20 min and highly significantly at 30, 40, 50.
- Conclusions: There are significant hemodynamic changes and ETCO2 changes even in ASA grade I and II patients during laparoscopic cholecystectomy compared to open cholecystectomy. However, most of these changes are transient and within the normal range, and they become comparable by the end of the surgery. SpO2 and ECG also showed no significant changes between the two groups.

2.2.3 The third study

- Title: "Effect of insufflated CO 2 during laparoscopic surgeries on end tidal CO2 concentration using capnography".
- Author/Date: Farman et al., 2022.
- Purpose: To understand the determination of effect of blowing of CO2 to intraperitoneal cavity during laparoscopic surgeries on end tidal CO2.
- Methodology: A prospective descriptive study in which the author has collected data through convenience include twenty patients (20) undergoing laparoscopic surgeries for different pathologies, including Ovarian cystectomy, Cholecystectomy and Appendectomy provided the consent of the said participants, so the End tidal CO2 (EtCO2) concentration was recorded in intervals at pre-induction of anesthesia before insufflation and termed this as baseline concentration of the said gas, then recorded at 10-mmHg, between 10-15 mmHg, at 15-mmHg of intraperitoneal pressure and at the cessation of the surgery. End tidal CO2 (EtCO2) after CO2 insufflation during laparoscopic surgeries is compared with the baseline EtCO2.
- Analysis and Results: EtCO2 increased slightly after CO2 insufflation and considerably after the surgical incision. After completion of the laparoscopic surgery, the EtCO2 exhibited a trend to baseline value.
- Conclusions: The patients who were otherwise healthy and were just undergoing laparoscopic surgeries, EtCO2 surges slightly subsequent to CO2 insufflation and readily comes to baseline value.

2.2.4 The fourth study

- Title: "Metabolic Effects of Carbon Dioxide Insufflation During Laparoscopic Surgery: Changes in pH, Arterial Partial Pressure of Carbon Dioxide (PaCO2) And End Tidal Carbon Dioxide (ETCO2)".
- Author/Date: Bachh et al., 2022.
- Purpose: To determine the Metabolic effects of carbon dioxide insufflation during laparoscopic surgery.
- Methodology: An observational study on 50 patients above 18 years of age with physical status of American Society of Anesthesiologists (ASA) Class I and II.
- Analysis and Results: A progressive decrease in the pH during pneumoperitoneum in keeping with the hypercarbia. An increase towards baseline was observed during

recovery, but pH was still significantly lower than baseline 15 minutes into recovery ($p<0.118$). The Pco2 increased after 15 mins of Co2 insufflation & peaked at 30 mins with mean & SD 42.82,2.775 & 46.16,2.909, respectively, which was statically significant. Etco2 also increased after 15 mins of Co2 insufflation & peaked at 30 mins with mean 41.56 & 44.50 respectively, which was statistically significant. Similarly, Hco3 decreased over period of time with peak decrease at 30 mins of Co2 insufflation with mean 23.70, SD 1.919 & range 19-27.

- Conclusions: Co2 insufflation does bring metabolic changes in Ph, Pco2, Etco2 & HCO3 but with proper monitoring & management laparoscopic procedure can be safely performed.

2.2.5 The fifth study

- Title: "End-tidal carbon dioxide measurements as a surrogate to arterial carbon dioxide during pediatric laparoscopic surgeries: a prospective observational cohort study".
- Author/Date: Abdel-Ghaffar et al., 2021.
- Purpose: To investigate the correlation and agreement between ETCO2 measured by capnography and arterial PaCO2 measured by arterial blood gas analysis and to calculate the PaCO2– ETCO2 difference during pediatric laparoscopic surgeries.
- Methodology: Prospective observational cohort study included 29 children, all classified as ASA I and aged between 12 and 72 months, Arterial blood samples were collected at four different time points: before pneumoperitoneum, 15 minutes into pneumoperitoneum, 30 minutes into pneumoperitoneum, and one minute after deflation. Simultaneously, ETCO2 values were recorded during each arterial blood sample withdrawal.
- Analysis and Results: Out of the 116 comparisons analyzed, a PaCO2–ETCO2 difference beyond 0 to ≤ 5 mmHg was recorded in 71 comparisons (61.2%) with negative difference in 34 comparisons (29.3%). A positive significant correlation between PaCO2 and ETCO2 was recorded before ($r = 0.617$, $p = 0.000$) and at 15 minutes ($r = 0.582$, $p = 0.001$), with no significant correlation at 30 minutes ($r = 0.142$, $p = 0.461$), either after deflation ($r = 0.108$, $p = 0.577$). Bland-Altman plots showed agreement between ETCO2 and PaCO2 before inflation with mean PaCO2-ETCO2 difference 0.14±5.6 mmHg (limits of 95% agreement -10.84–11.2, simple

linear regression testing p-value 0.971), with no agreement at 15 minutes (0.51 ± 7.15, -13.5–14.5, p = 0.000), 30 minutes. (2.62 ± 7.83, -12.73–17.97, p = 0.000), or after deflation (1.81 ± 6.56, -10.93–14.55, p = 0.015).

- Conclusions: Usage of capnography as a trend monitor in pediatric laparoscopic surgeries may not be a reliable surrogate for PaCO2 levels.

2.2.6 The sixth study

- Title: "Effect of insufflated CO2 during laparoscopic surgeries on end tidal CO2 concentration using capnography".
- Author/Date: Irfan et al., 2022.
- Purpose: To assess the effects of insufflations of CO2 into the intraperitoneal cavity during the procedure of laparoscopic surgeries on end-tidal CO2.
- Methodology: 20 patient prospective descriptive study in which the author has collected data through convenience sampling due to a smaller number of laparoscopic surgeries in the respective healthcare center and shortage of funds, from Rehman Medical Center Peshawar, Pakistan, twenty patients (20) undergoing laparoscopic surgeries for different pathologies, including Ovarian cystectomy, Cholecystectomy and Appendectomy.
- Analysis and Results: PaCO2 increased also in comparison with baseline PaCO2 after insufflation of CO2 and it was slightly greater p value less than 0.01. The fluctuation in EtCO2 due to insufflation with a mean of 28.40±17.57 with p value=0.00.
- Conclusions: Otherwise healthy patients going through only laparoscopic surgeries, the ETCO2 surges slightly following CO2 insufflation. This surged CO2 readily comes to the baseline within a couple of minutes evidencing the rapid excretion of excessive CO2 absorbed during surgical period.

2.2.7 The seventh study

- Title: Respiratory mechanics and arterial blood gases during and after laparoscopic cholecystectomy.
- Author/Date: Iwasaka et al., 1996.
- Purpose: To assess the effects of increased intra-abdominal pressure due to CO_2 insufflation on the mechanical characteristics of the respiratory system and arterial blood gases during and after laparoscopic cholecystectomy.
- Methodology: 12 patients undergoing laparoscopic cholecystectomy with CO_2 insufflation. To examine respiratory mashine and arterial blood gases. Respiratory mechanics were continuously monitored with in-line spirometry. In the recovery room, $PaCO_2$ was measured in this group at 30 min and compared with $PaCO_2$s in 23 patients who had undergone open cholecystectomy retrospectively, to evaluate the effects of insufflation on CO_2 elimination.
- Analysis and Results: Minute ventilation was decreased by about 500 $ml.min^{-1}$ during abdominal insufflation. Dynamic lung compliance decreased from 49.6 +/- 4.7 to 30.7 +/- 2.3 (mean +/- SEM) $ml.cmH_2O^{-1}$ with abdominal insufflation ($P < 0.005$), and returned to 45.1 +/- 3.1 after the release of pneumoperitoneum. Peak inspiratory pressure increased from 15.9 +/- 0.9 to 18.9 +/- 1.0 cmH_2O with abdominal insufflation ($P < 0.05$). Arterial blood gas determinations indicated a decrease in arterial pH, with CO_2 retention during insufflation and in the recovery room ($P < 0.05$). $PaCO_2$ of the laparoscopic patients was higher than that of the open patients in the recovery room.
- Conclusions: Respiratory acidosis was caused during CO_2 insufflation for laparoscopic cholecystectomy, that was due to (1) decreased compliance, (2) increased CO_2 load and (3) insufficient ventilation. Accumulated CO_2 during laparoscopic cholecystectomy increased $PaCO_2$ level in the recovery room.

Chapter Three
Materials and Methods

3.1 Introduction

This chapter describes the approach used to look into these consequences, particularly emphasizing increases in end-tidal CO_2 ($ETCO_2$) and arterial blood gases (ABG) in adult patients with laparoscopic procedures. The methodology section comprehensively details the prospective study design, participant selection criteria, systematic data collection procedures, and statistical analytical approaches employed in this research. Through the analysis of the mentioned variables, the research aims to comprehensively comprehend the effects of CO_2 insufflation, thereby enhancing patient care and the results of laparoscopic procedures.

3.2 Methodology

3.2.1 Study design

A Prospective single-blind Quasi-experimental design aims to find a cause-and-effect relationship between the independent and dependent variables.

3.2.2 Participants

Adult patients undergoing elective laparoscopic surgery.

3.2.3 Sample size

The study includes 60 patients, with 30 patients in each group. The following formula is used to calculate the sample size: $n = 2[(Z\alpha/2 + Z\beta)\sigma/\Delta]^2$ is used. In this formula, n represents the sample size per group, $Z\alpha/2$ is the critical value of the standard normal distribution for a two-tailed test at a significance level of $\alpha/2$, $Z\beta$ is the critical value of the standard normal distribution for the desired power ($1-\beta$), σ is the estimated standard deviation of the outcome variable, and Δ is the minimum clinically important difference in the outcome variable. By dividing the total sample size of 60 by the number of groups (2), we obtain a sample size per group of 30. The desired power level is typically set at 80% or higher.

3.2.4 Site and Setting

Operation Rooms at Darwish Nazzal Governmental Hospital in Qalqilia, Palestine.

3.2.5 Study period

From June 2023 to January 2024.

3.2.6 Intervention

One group received CO_2 insufflation during laparoscopic surgery with an increase of respiratory rate to 20 breaths per minute, while the other group received CO_2 insufflation with a respiratory rate of 14 breaths per minute during surgery.

3.2.7 Blinding

The study was single-blinded, meaning neither the patients nor the surgical team knew which group the patient was assigned to.

3.2.8 Outcome measures

The levels of arterial blood gases (PH, $PACO_2$, PAO_2) and end-tidal CO_2 ($ETCO_2$) were measured at different time intervals before, during, and after surgery for both groups.

3.3 Data Collection

3.3.1 Inclusion criteria

- Adults aged between (18-60) years old, ASA score 1 and 2.
- Scheduled for laparoscopic surgery.
- Able to provide informed consent.

3.3.2 Exclusion criteria

- History of respiratory disease (e.g., asthma, COPD).
- History of cardiac disease (e.g., heart failure, ischemic heart disease).
- History of liver or kidney disease.
- Pregnancy.
- BMI $\geq$ 30 kg/m^2.

- Use of medications that affect respiratory or cardiovascular function (e.g., beta-blockers, opioids).
- History of CO_2 insufflation intolerance or hypersensitivity.

3.3.3 Control Group

The control group received standard laparoscopic surgery with CO_2 insufflation and a respiratory rate of 14 breath per minute. Arterial blood gases and end-tidal CO_2 levels were measured at baseline and at 15-minutes intervals during the surgery.

3.3.4 Experimental Group

The experimental group received standard laparoscopic surgery with CO_2 insufflation and an increase in respiratory rate of 20 breath per minute. ABG and $ETCO_2$ levels were measured before CO_2 insufflation and after 15 minutes of insufflation.

3.3.5 Data Analysis

The appropriate statistical tests and methods were used including the Chi-Square test, the two independent samples T-test, the repeated measures analysis of variance (ANOVA), the paired samples T-test and the Pearson correlation coefficients to determine the effect of CO_2 insufflation on arterial blood gases (ABG) and end-tidal CO_2 ($ETCO_2$) during laparoscopic surgeries in adults. The results reported as the mean values and standard deviations for each group and statistical significance were determined.

3.4 Working Plan

To collect the data for both groups, the following steps were taken:

3.4.1 Participant recruitment

After obtaining institutional review boards (IRB) approval from committee of An-Najah National University for human subjects research and taking the permission from Palestinian Ministry Of Health (PMOH) to conduct the study. The participants selected from list of patients that scheduled for laparoscopic surgery (laparoscopic appendectomy and laparoscopic cholecystectomy) at the study site. Inclusion criteria included adults aged 18 years and older who require laparoscopic surgery under general anesthesia. Exclusion criteria included a history of respiratory or cardiovascular disease, pregnancy, BMI equal or more than 30kg/m2 and any other conditions that may affect ABG and ETCO2 levels.

3.4.2 Data collection

Demographic data and clinical characteristics of the participants were collected, including age, gender, height and weight to calculate the body mass index (BMI), medical history, type of laparoscopy and surgical duration. Arterial line was applied at the beginning of the operation by the anesthesiologist. Vital signs, blood gases, peak airway pressure and end-tidal CO2 levels were measured at baseline and at 15-minute intervals during the surgery.

3.4.3 Ethical considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki and local ethical guidelines. Informed consent was obtained from all participants prior to enrollment in the study, and confidentiality and privacy of the participants' data were ensured.

3.4.4 Reporting and dissemination

The study results will be reported in a scientific manuscript and presented at relevant scientific conferences. The results may also will be disseminated to the wider medical community through publication in relevant journals or online platforms.

3.4.5 Validity and reliability

The reliability of the data sheet was confirmed by determining the reliability coefficient using Cronbach's Alpha Equation. The reliability was equal or up to 77.3%, so Cronbach’s alpha will generally increase when the correlations between the items increase. For this reason, the coefficient measures the internal consistency of the test. The maximum value is one, and usually, its minimum value is zero, although it can be negative (Chen et al., 2021).

3.5 Summary

Our current study had a prospective, single-blind, quasi-experimental design to study the effects of CO2 insufflation on arterial blood gases and end-tidal CO2 during laparoscopic surgeries. The study was conducted in the operating rooms of Darwish Nazzal Governmental Hospital in Qalqilia, Palestine, from June 2023 to January 2024. The primary outcome measures included arterial blood gases and end-tidal CO2 levels.

Chapter Four
Results

4.1 Introduction

This chapter presents descriptive statistics summarising the clinical and patient demographics and then uses inferential statistics to assess the hypotheses. It is anticipated that the results will provide more information on how best to control breathing during laparoscopic procedures and that by customizing insufflation techniques to preserve physiological stability, patient outcomes may be enhanced. Sixty adult patients from governmental hospitals were methodically gathered to provide a large sample size for statistical analysis. ABGS and ETCO2 measurements were made before insufflation periodically during surgery and after disinflation. These measurements included PH, PACO2, PAO2, HCO3, and ETCO2. The significance of the variations between the experimental and control groups was then determined by analyzing these data. This showed how different respiratory rates impact gas exchange during CO2 insufflation.

4.2 Statistical Methods

The Statistical Package for Social Sciences Software (SPSS) Version 23 was used for the data analysis in this study. The researcher conducted descriptive statistics (Frequencies, Percentages, Means, and Standard Deviations) for all the studied variables, indicators, parameters, and measurements related to the study. The statistical tests are used to analyze the results and to test the research hypotheses. We suppose that the P value is significant if it is equal to or less than 0.05, and the analysis runs as follows:

1. The Chi-Square test: It was used to check the differences in rates for the two groups, RR14 & RR20, for the qualitative (categorical) variables like Laparoscopy Type, Gender, Medical history, Smoking history, and Respiratory Rate.
2. The two independent samples T-test: To test the changes in the average between the two study groups (RR14, RR20) for the numeric variables that include Age, Height, Weight, Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure, Arterial Blood Gas (ABG) values, Intra-abdominal pressure, and the duration of the procedure (min).

3. The repeated measures analysis of variance (ANOVA) and the paired samples T-test: To test the differences in means of the Vital Signs, End-Tidal CO2 Levels, and the Arterial Blood Gas (ABG) values between the three or two stages of the study before insufflation, 15 minutes after insufflation (during insufflation), and after venting of CO2 (disinflation).
4. The Pearson correlation coefficients: To test the effect and the relationships between the duration of the procedure and Intra-abdominal pressure from one side, and the End-Tidal CO2 Levels (ETCO2) and also the Arterial Blood Gas (ABG) values (PH, PAO2, PACO2, HCO3) from the other side during insufflation (15 minutes after insufflation).

4.3 Study Sample

The study sample included 60 adult patients undergoing elective laparoscopic surgery. The participants were selected randomly and distributed into two groups. The first group contained 30 patients in the respiratory rate group 14 (RR14), and the second group contained 30 patients in the respiratory rate group 20 (RR20). Generally, the study sample included 22 males (p=36.7%) and 38 females (p=63.3%), and the mean of the ages in the sample was about 36 years. Also, the means of the heights and the weights of the participants are about (170 cm) and about (67 kg) respectively. Most of the patients in the study sample had L.cholecystectomy Laparoscopy Type (p=86.7%). The least had L. appendectomy (p=13.3%), and about 33.3% of the patients in the study sample had a smoking history. However, all of the patients had a free medical history.

The following table shows the results of the statistical testing and comparisons between the study groups (Respiratory Rate Group (RR14) and Respiratory Rate Group (RR20) in the demographic variables:

Table 1
*Comparisons between the study groups in the Demographic Data (N=60)**

Variable	Respiratory Rate Group RR14 (N=30)	RR20 (N=30)	Total (N=60)	P-value
Age	37.53 ± 9.74	34.6 ± 9.81	36.07 ± 9.8	0.250
Gender: Male	13(43.3%)	9(30%)	22(36.7%)	0.284
Female	17(56.7%)	21(70%)	38(63.3%)	
Height	169.53 ± 7.26	169.43 ± 5.41	169.48 ± 6.35	0.952
Weight	67.97 ± 5.97	65.53 ± 4.91	66.75 ± 5.56	0.090
Laparoscopy Type: L.cholecystectomy	27(90%)	25(83.3%)	52(86.7%)	0.448
L.appendectomy	3(10%)	5(16.7%)	8(13.3%)	
Medical history	0(0%)	0(0%)	0(0%)	-----
Smoking history	11(36.7%)	9(30%)	20(33.3%)	0.584

*The P-values are in relation to two independent samples, the T-test for the quantitative variables and the Chi-square test for the categorical variables, and the numbers in the table represent (Mean ± Standard deviation) or N(%).

Table (1) showed that the demographic data of all participants of both groups (RR14, RR20) was not significantly different at 0.05 level. All the P-values of the tests are higher than the 0.05 level.

The following table shows the results of the statistical testing and comparisons between the study groups in the Vital Signs, End-Tidal CO2 Levels, and Peak Airway Pressure before insufflation:

Table 2

*Comparisons between the study groups in the Vital Signs, End-Tidal CO2 Levels, and in the Peak Airway Pressure - before insufflation (N=60)**

Variable	Respiratory Rate Group RR14 (N=30)	RR20 (N=30)	Total (N=60)	P-value
SBP	123.17 ± 9.22	123.87 ± 10.52	123.52 ± 9.82	0.785
DBP	77.3 ± 4.82	76.6 ± 4.23	76.95 ± 4.51	0.552
HR	78.27 ± 7.82	79.53 ± 6.89	78.9 ± 7.33	0.508
SPO2	96.8 ± 1	97.23 ± 1.17	97.02 ± 1.1	0.127
ETCO2	35.87 ± 3	33.97 ± 2.03	34.92 ± 2.71	0.006
Peak Airway Pressure	13.96 ± 1.79	13.77 ± 1.4	13.87 ± 1.6	0.637

According to Table (2), it is noticed that there are significant differences with a value of 0.05 among the study groups (RR14, RR20) only of End-Tidal CO2 Levels (ETCO2) before insufflation. The results show that the mean of the End-Tidal CO2 Levels (ETCO2) of the RR14 group was 35.87, significantly more than the mean of the End-Tidal CO2 Levels (ETCO2) in the RR20 group because it was 33.97, and the P-value I 0.006.

The following table shows the results of the statistical testing and comparisons between the study groups in the Arterial Blood Gas (ABG) values before insufflation:

Figure 1

The Vital Signs, End-Tidal CO2 Levels, and in the Peak Airway Pressure - before insufflation

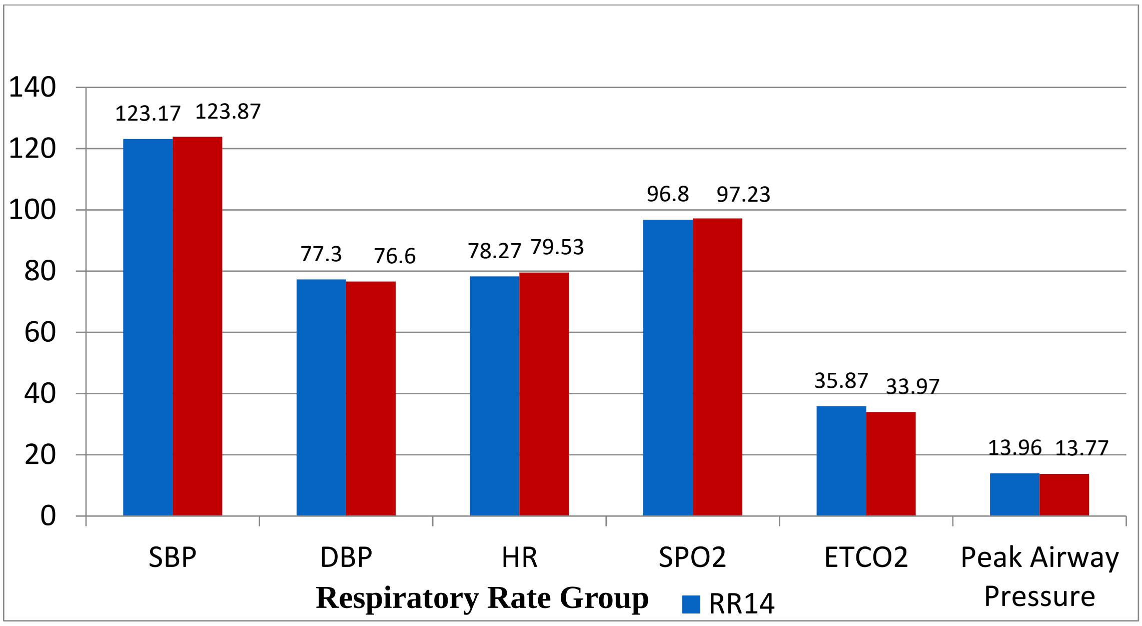


Table 3

*Comparisons among the two groups in the Arterial Blood Gas (ABG) values - before insufflation (N=60)**

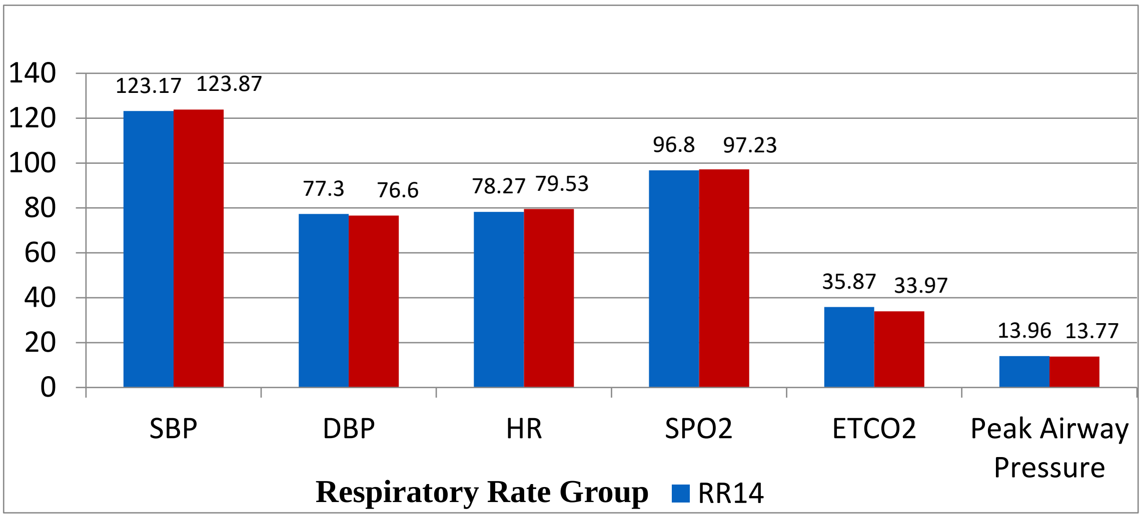
Variable	Respiratory Rate Group RR14 (N=30)	RR20 (N=30)	Total (N=60)	P-value
PH	7.4 ± 0.02	7.39 ± 0.02	7.39 ± 0.02	0.378
PAO2	84.17 ± 3.97	83.74 ± 3.88	83.96 ± 3.9	0.678
PACO2	39.22 ± 3.29	38.45 ± 2.1	38.84 ± 2.77	0.281
HCO3	24.2 ± 1.04	24.38 ± 0.78	24.29 ± 0.92	0.460

Hypothesis (3): The respiratory rate (14 VS 20 breath/min) during laparoscopic surgeries has no significant effect on arterial blood gases (ABGs) before CO2 insufflation.

The results in Table (3) give the impression that the arterial blood gas (ABG) values before insufflation for the study groups (RR14, RR20) did not show a significant difference at 0.05 level between the two groups. All the P-values of the tests are higher than the 0.05 level.

Figure 2

The Vital Signs, End-Tidal CO2 Levels, and in the Peak Airway Pressure - before insufflation



The following Table shows the results of the statistical testing and comparisons between the study groups in the Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure, and Intra-abdominal pressure at 15 minutes after insufflation (during insufflation):

Table 4

*Comparisons between the study groups in the Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure, and Intra-abdominal pressure - 15 minutes after insufflation (during insufflation) (N=60)**

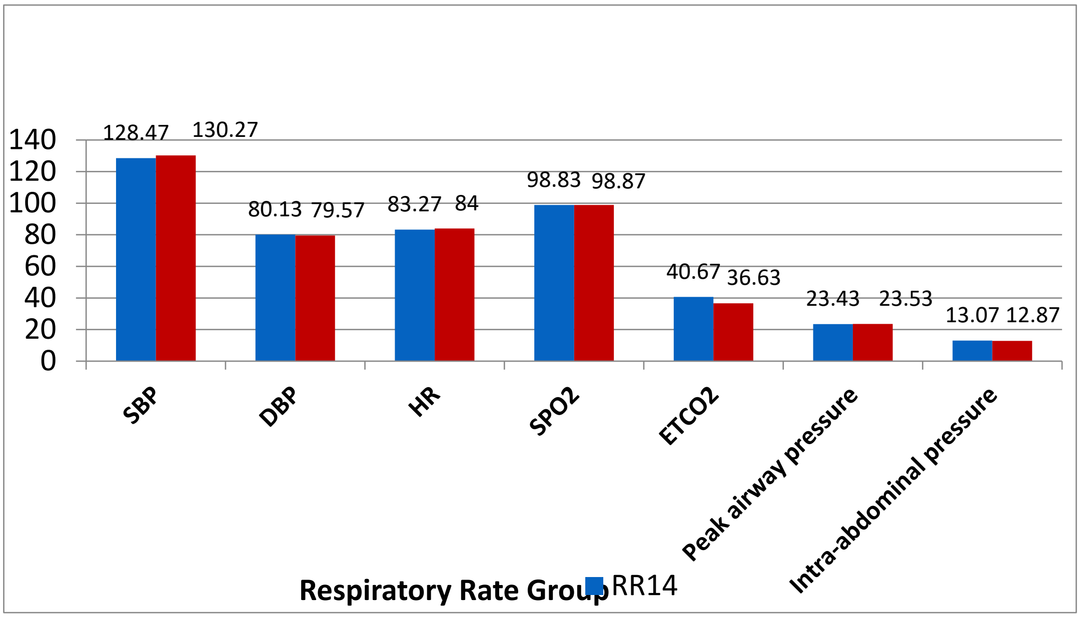
Variable	Respiratory Rate Group RR14 (N=30)	RR20 (N=30)	Total (N=60)	P-value
SBP	128.47 ± 7.89	130.27 ± 11.54	129.37 ± 9.84	0.483
DBP	80.13 ± 3.7	79.57 ± 3.55	79.85 ± 3.61	0.547
HR	83.27 ± 6.58	84 ± 6.28	83.63 ± 6.39	0.660
SPO2	98.83 ± 0.79	98.87 ± 0.82	98.85 ± 0.8	0.873
ETCO2	40.67 ± 3.53	36.63 ± 2.59	38.65 ± 3.68	0.000
Peak airway pressure	23.43 ± 3.42	23.53 ± 3.07	23.48 ± 3.22	0.909
Intra-abdominal pressure	13.07 ± 0.87	12.87 ± 0.94	12.97 ± 0.9	0.395

Hypothesis (4): The respiratory rate (14 VS 20 breath/min) during laparoscopic surgeries has no significant effect on end-tidal CO2 (ETCO2) levels before and during CO2 insufflation and after venting of CO2 (disinflation).

According to Table (4), the researcher discovered a difference at a level of 0.05 among the study groups (RR14, RR20) only in the End-Tidal CO2 Levels (ETCO2) 15 minutes after insufflation (during insufflation), which was significant. The results show that the mean of the End-Tidal CO2 Levels (ETCO2) of the RR14 group (40.67) is more significant than the mean of the End-Tidal CO2 Levels (ETCO2) in the RR20 group because it was equal (36.63). The P-value was less than 0.001.

Figure 3

The Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure, and Intra-abdominal pressure - 15 minutes after insufflation (during insufflation)



The following Table shows the results of the statistical testing and comparisons among the two groups in the Arterial Blood Gas (ABG) values at 15 minutes after insufflation (during insufflation):

Table 5

*Comparisons among the two groups in the Arterial Blood Gas (ABG) values - 15 minutes after insufflation (during insufflation) (N=60)**

	Respiratory Rate Group			
Variable	RR14 (N=30)	RR20 (N=30)	Total (N=60)	P-value
PH	7.36 ± 0.03	7.37 ± 0.02	7.36 ± 0.03	0.008
PAO2	91.19 ± 4.61	89.24 ± 3.64	90.22 ± 4.23	0.074
PACO2	44.08 ± 4.27	41.28 ± 2.88	42.68 ± 3.88	0.004
HCO3	23.89 ± 1.01	24.2 ± 0.74	24.04 ± 0.89	0.185

Hypothesis (3): The respiratory rate (14 VS 20 breath/min) during laparoscopic surgeries has no significant effect on arterial blood gases (ABGs) before and during CO2 insufflation" because this hypothesis can be rejected regarding the PH and the PACO2.

The results in Table (5) showed the following:

1- The pH and PACO2 values after 15 minutes of insufflation (during insufflation) were significantly different at 0.05 level among the study groups (RR14, RR20).
2- The mean of PH values in the RR14 group was (7.36), which is significant in value and lower than the mean of PH values in the RR20 group (Mean=7.37), the measured P-value=0.008.
3- The mean of the PACO2 values of the RR14 group was (44.08), which is significant and more than the value of the RR20 group because it was (41.28), the tested P-value=0.004.

The following Table shows the results of the statistical testing and comparisons between the study groups in the Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure, and the Duration of the procedure (min) after venting of CO2 (disinflation):

Table 6

*Comparisons between the study groups in the Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure, and the Duration of the procedure (min) – after venting of CO2 (disinflation) (N=60)**

Variable	Respiratory Rate Group		Total	P-value
	RR14 (N=30)	RR20 (N=30)	(N=60)	
SBP	120.43 ± 6.76	122.2 ± 8.64	121.32 ± 7.74	0.381
DBP	75.83 ± 4.17	75.77 ± 3.16	75.8 ± 3.67	0.945
HR	78.17 ± 6.52	78.8 ± 5.55	78.48 ± 6.01	0.687
SPO2	98.27 ± 0.78	98.13 ± 0.86	98.2 ± 0.82	0.533
ETCO2	38.7 ± 3.09	34.03 ± 1.92	36.37 ± 3.47	0.000
Peak airway pressure	16.9 ± 2.01	17.28 ± 2.26	17.09 ± 2.13	0.498
Duration of the procedure (min)	56.77 ± 7.05	54.93 ± 6.38	55.85 ± 6.73	0.295

Figure 4

The Arterial Blood Gas (ABG) values - 15 minutes after insufflation (during insufflation)

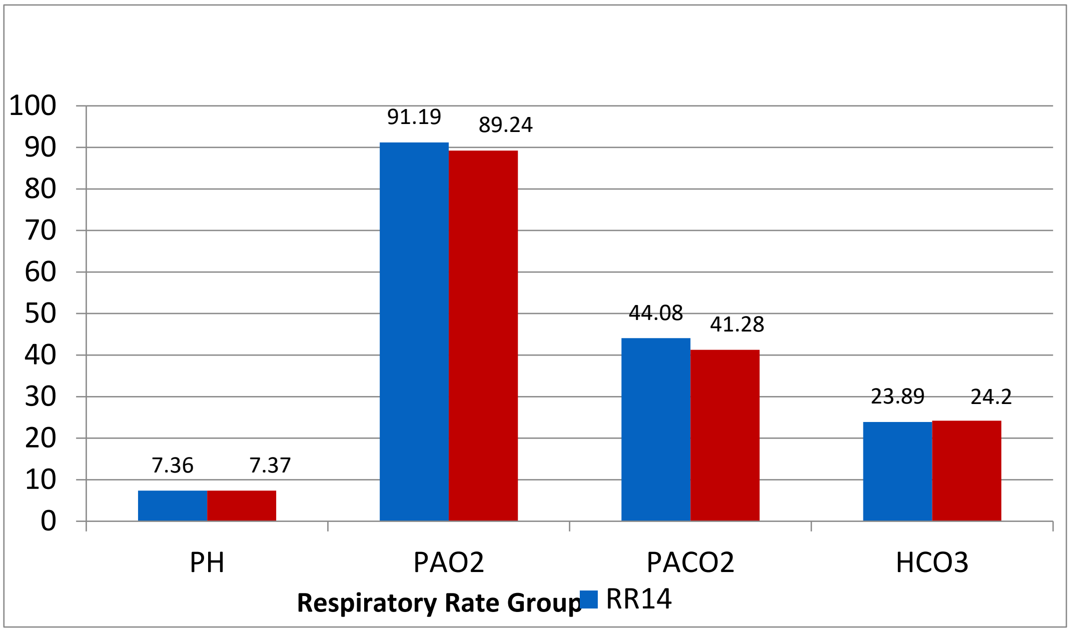
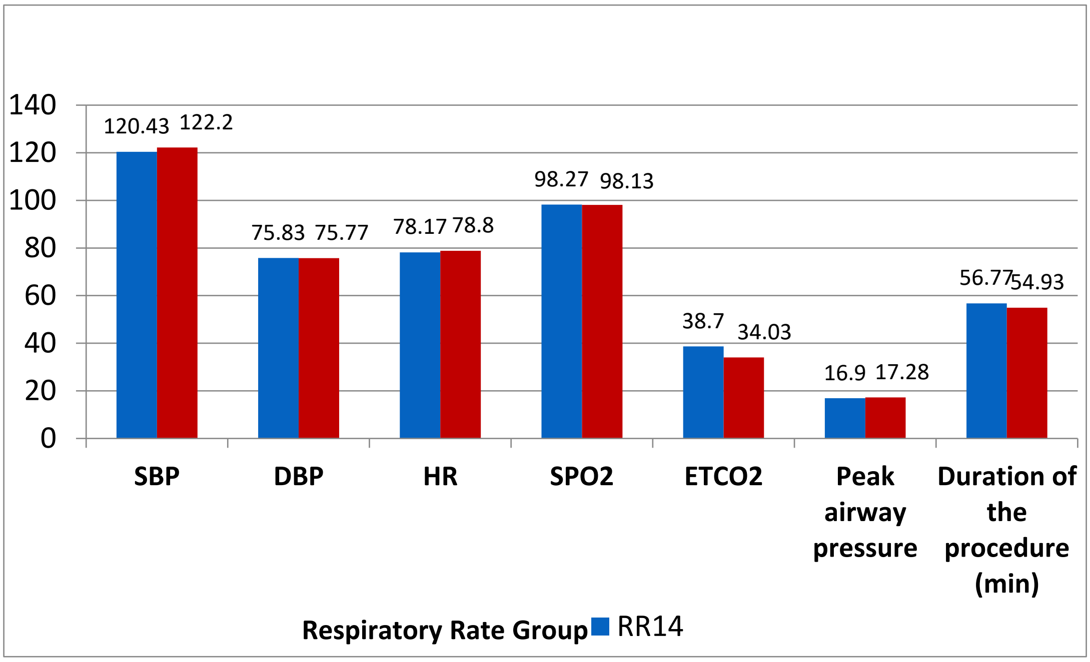


Table (6) shows a difference between the two groups (RR14, RR20) with a level of 0.05 only of End-Tidal CO2 Levels (ETCO2) after venting of CO2 (disinflation). The results show that the mean of the End-Tidal CO2 Levels (ETCO2) of the RR14 group was (38.7) which is more than the mean of the End-Tidal CO2 Levels (ETCO2) of the RR20 group (34.03), the tested P-value is less than 0.001.

Figure 5

The Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure and the Duration of the



procedure (min) – after venting of CO2 (disinflation)

The following Table shows the results of the statistical testing and comparisons in the Vital Signs, End-Tidal CO2 Levels, and Peak Airway Pressure before insufflation, during insufflation, and after venting of CO2 (disinflation):

Table 7

*Comparisons in the Vital Signs, End-Tidal CO2 Levels, and Peak Airway Pressure before insufflation, during insufflation, and after venting of CO2 (disinflation) (N=60)**

Variable	Before Insufflation (N=60)	During Insufflation (N=60)	After venting of CO2 (disinflation) (N=60)	P-value
SBP	123.52 ± 9.82	129.37 ± 9.84	121.32 ± 7.74	<0.001
DBP	76.95 ± 4.51	79.85 ± 3.61	75.8 ± 3.67	<0.001
HR	78.9 ± 7.33	83.63 ± 6.39	78.48 ± 6.01	<0.001
SPO2	97.02 ± 1.1	98.85 ± 0.8	98.2 ± 0.82	<0.001
ETCO2	34.92 ± 2.71	38.65 ± 3.68	36.37 ± 3.47	<0.001
Peak Airway Pressure	13.87 ± 1.6	23.48 ± 3.22	17.09 ± 2.13	<0.001

* The P-values are related to the repeated measures analysis of variance (ANOVA) test for the repeated quantitative variables; the table containing numbers indicating (Mean ± Standard deviation).

Hypothesis (2): There is no significant difference in the end-tidal CO2 (ETCO2) levels between patients undergoing laparoscopic surgeries before and during CO2 insufflation and after venting of CO2 (disinflation).

In Table (7), the researcher found a difference with a level of 0.05 before insufflation, during insufflation, and after venting of CO2 (disinflation) in all Vital Signs, End-Tidal CO2 Levels, and Peak Airway Pressure. The p-values for all variables were lower than 0.05.

According to SBP, the outcomes of the post-hoc pairwise comparisons tests in Table (A.1) show that the mean of the SBP after venting of CO_2 (disinflation) (Mean=121.32) is significantly lower than the mean of the SBP before insufflation (Mean=123.52) which is itself also significantly lower than the mean of the SBP during insufflation (Mean=129.37), the P-value of the test is less than 0.001. (See Table A.1 in Appendix A).

Regarding the DBP, the results of the post-hoc pairwise comparisons tests in Table (A.1) show that the mean of the DBP after venting of CO_2 (disinflation) (Mean=75.8) is significantly lower than the mean of the DBP before insufflation (Mean=76.95) which is itself also significantly lower than the mean of the DBP during insufflation (Mean=79.85), the P-value of the test is less than 0.001. (See Table A.1 in Appendix A).

Regarding the HR, the results of the post-hoc pairwise comparisons tests in Table (A.1) show that the mean of the HR after venting of CO_2 (disinflation) (Mean=78.48) and the mean of the HR before insufflation (Mean=78.9) is significantly lower than the mean of the HR during insufflation (Mean=83.63), the P-value of the test is less than 0.001. (See Table A.1 in Appendix A).

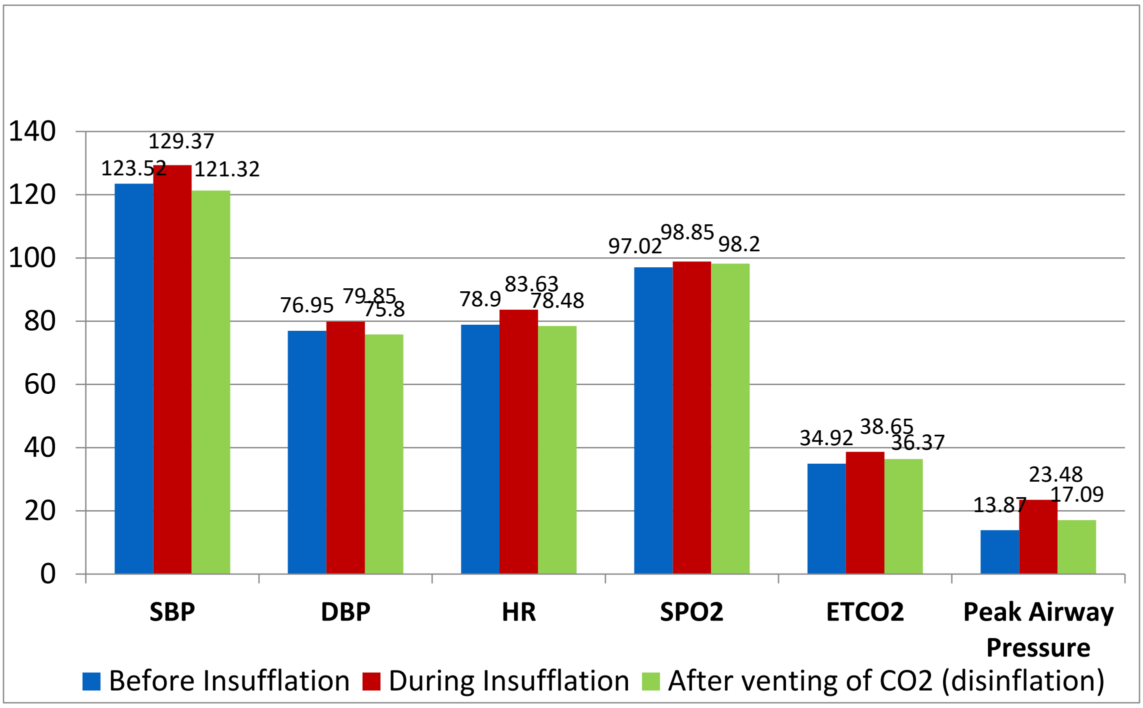
Regarding the SPO_2, the results of the post-hoc pairwise comparisons tests in Table (A.1) show that the mean of the SPO_2 during insufflation (Mean=98.85) is significantly higher than the mean of the SPO_2 after venting of CO_2 (disinflation) (Mean=98.2) which is itself also significantly higher than the mean of the SPO_2 before insufflation (Mean=97.02), the P-value of the test is less than 0.001. (See Table A.1 in Appendix A).

Regarding the $ETCO_2$, the results of the post-hoc pairwise comparisons tests in Table (A.1) show that the mean of the $ETCO_2$ during insufflation (Mean=38.65) is significantly higher than the mean of the $ETCO_2$ after venting of CO_2 (disinflation) (Mean=36.37) which is itself also significantly higher than the mean of the $ETCO_2$ before insufflation (Mean=34.92), the P-value of the test is less than 0.001. (See Table A.1 in Appendix A).

Regarding the Peak Airway Pressure, the results of the post-hoc pairwise comparisons tests in Table (A.1) show that the mean of the peak airway pressure during insufflation (Mean=23.48) is significantly higher than the mean of the peak airway pressure after venting of CO2 (disinflation) (Mean=17.09) which is itself also significantly higher than the mean of the peak airway pressure before insufflation (Mean=13.87), the P-value of the test is less than 0.001. (See Table A.1 in Appendix A).

Figure 6

The Vital Signs, End-Tidal CO2 Levels, Peak Airway Pressure before insufflation, during insufflation, and after venting of CO2 (disinflation)



The following Table shows the results of the statistical testing and comparisons in the Arterial Blood Gas (ABG) values before Insufflation and during Insufflation:

Table 8

*Comparisons in the Arterial Blood Gas (ABG) values between before Insufflation and during Insufflation (N=60)**

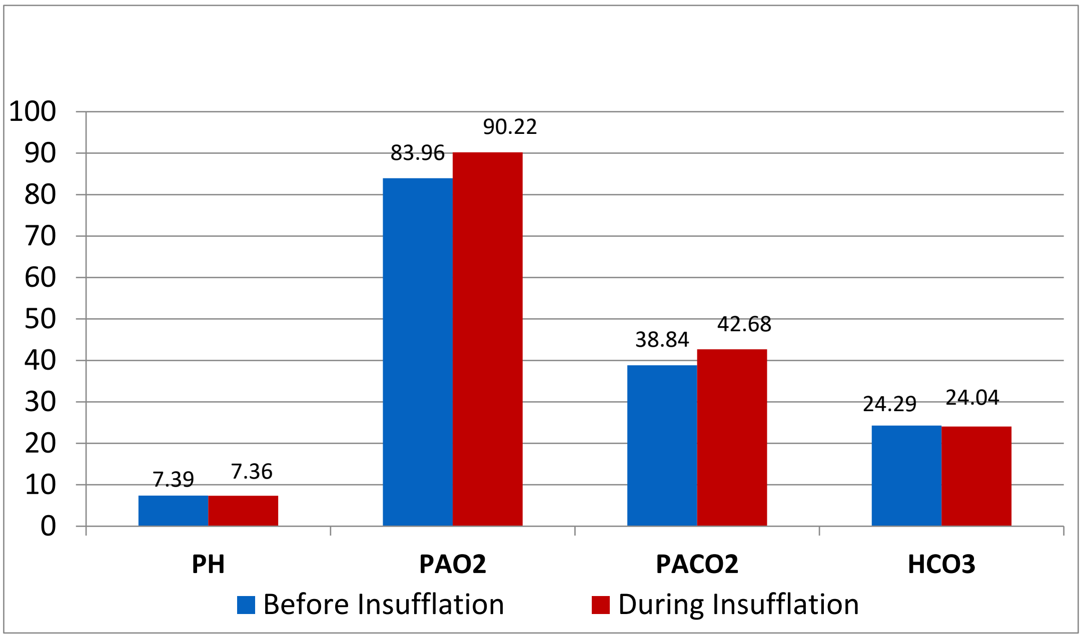
Variable	Before Insufflation (N=60)	During Insufflation (N=60)	P-value
PH	7.39 ± 0.02	7.36 ± 0.03	<0.001
PAO2	83.96 ± 3.9	90.22 ± 4.23	<0.001
PACO2	38.84 ± 2.77	42.68 ± 3.88	<0.001
HCO3	24.29 ± 0.92	24.04 ± 0.89	<0.001

Hypothesis (1): There are no significant differences in arterial blood gases (ABGs) between patients undergoing laparoscopic surgeries before and during CO2 insufflation.

Table (8) shows a variation of 0.05 before and during insufflation in arterial blood gas (ABG) values. All the p-values were lower than 0.05.

Figure 7

The Arterial Blood Gas (ABG) values before Insufflation and during Insufflation



Related to the PH values, the mean of the PH values during insufflation (Mean=7.36) is significantly lower than the mean of the PH values before insufflation (Mean=7.39), and the P-value of the test is less than 0.001.

Regarding the PAO2 values, the results show that the mean of the PAO2 values during insufflation (Mean=90.22) is significantly higher than the mean of the PAO2 values before insufflation (Mean=83.96), the P-value of the test is less than 0.001.

Regarding the PACO2 values, the results show that the mean of the PACO2 values during insufflation (Mean=42.68) is significantly higher than the mean of the PACO2 values before insufflation (Mean=38.84), the P-value of the test is less than 0.001.

Regarding the HCO3 values, the results show that the mean of the HCO3 values during insufflation (Mean=24.04) is significantly lower than the mean of the HCO3 values before insufflation (Mean=24.29), the P-value of the test is less than 0.001.

The following Table shows the results of Pearson correlation coefficients to test the relationships between the duration of the procedure and Intra-abdominal pressure from one side, and the End-Tidal CO2 Levels (ETCO2) and also the Arterial Blood Gas (ABG) values (PH, PAO2, PACO2, HCO3) from the other side during insufflation (15 minutes after insufflation):

Table 9
Pearson correlation coefficients between the study valuables at 15 minutes after insufflation (during insufflation) (N=60)

Variables at 15 minutes after insufflation (during insufflation)	Pearson Correlation (R) and its P-value	Duration of the procedure (min)	Intra-abdominal pressure
ETCO2	R	0.376**	0.369**
	P-value	0.003	0.004
PH	R	-0.294*	-0.308*
	P-value	0.023	0.017
PAO2	R	0.006	-0.173
	P-value	0.962	0.185
PACO2	R	0.368**	0.481**
	P-value	0.004	0.000
HCO3	R	-0.063	-0.129
	P-value	0.630	0.326

According to Table (9), we found a significant positive relationship with a level of 0.05 level among the duration of the procedure and ETCO2 (R=0.376, P-value=0.003) and also between the Duration of the procedure and PACO2 (R=0.368, P-value=0.004). Also, there is a significant negative relationship at 0.05 level between the Duration of the procedure and PH (R=-0.294, P-value=0.023), so the conclusion from these results is that there are significant positive effects of the Duration of the procedure on the ETCO2 and on the PACO2. However, the duration of the procedure has a significant negative effect on the PH.

Also, a significant positive relationship with a level of 0.05 among the Intra-abdominal pressure and ETCO2 (R=0.369, P-value=0.004), and also between the Intra-abdominal pressure and PACO2 (R=0.481, P-value=0.000), and also there are significant negative relationships at 0.05 level between the Intra-abdominal pressure and PH (R=-0.308, P-value=0.017). Hence, the conclusion from these results is that there are significant positive effects of the Intra-abdominal pressure on the ETCO2 and on the PACO2, but there is a significant negative effect of the Intra-abdominal pressure on the PH.

The following table shows the results of the statistical testing and comparisons between the smoking history groups in the End-Tidal CO2 Levels and in the Arterial Blood Gas (ABG) values before insufflation:

Table 10

*Comparisons between the smoking history groups in the End-Tidal CO2 Levels and in the Arterial Blood Gas (ABG) values before insufflation (N=60)**

Variable	Smoking history			P-value
	Yes (N=20)	No (N=40)	Total (N=60)	
ETCO2	37.7 ± 2	33.53 ± 1.8	34.92 ± 2.71	<0.001
PH	7.38 ± 0.02	7.4 ± 0.02	7.39 ± 0.02	<0.001
PAO2	81.91 ± 3.97	84.98 ± 3.47	83.96 ± 3.9	0.003
PACO2	41.78 ± 1.77	37.37 ± 1.84	38.84 ± 2.77	<0.001
HCO3	24.59 ± 0.96	24.14 ± 0.87	24.29 ± 0.92	0.076

Depending on table(10) we found the following:

1. ETCO2, PH, PAO2, and PACO2 were significantly different, using a level of 0.05 for the smoking history groups (Yes, No).
2. The mean of ETCO2 values for the positive smoking history group=37.7 is more significant than the negative smoking history group=33.53. The P-value of the test is lower than 0.001.

3. The mean of PH values for the positive smoking history group=7.38 is significantly lower than the negative smoking history group=7.4, and the P-value of the test is lower than 0.001.
4. The mean of PAO2 values for the positive smoking history group=81.91 is significantly lower than the negative smoking history group=84.98. The P-value of the test is 0.003.
5. The mean of the PACO2 values for the positive smoking history group=41.78 is significantly more than the negative smoking history group=37.37, and the P-value of the test is less than 0.001.

4.4 Summary

This study involved 60 adult patients undergoing elective laparoscopic surgery in Palestine from June 2023 to January 2024 and divided participants into two groups: The number of patients in the respiratory rate group 14 (RR14) was 30, and in the respiratory rate group 20 (RR20) was 30. The majority of the patients had laparoscopic cholecystectomy done, 33.3% of the patients in the study sample have a smoking history, and all of the patients have free medical history. CO2 insufflation was applied during the operation, and the patients in the first group received 14 breaths per minute and 20 breaths per minute in the second group. The weight, age, gender, height, blood pressure, heart rate, and hematologic profile in the preoperative assessment of the patients did not reflect any variance among the two groups ($P > 0$. However, the RR14 group had higher mean ETCO2 values of 35.87, whereas the RR20 mean was 33.97 before the initiation of insufflation. Some differences in the ETCO2 after the insufflation were marked when the RR14 group had ETCO2 levels of 40.67 while the RR20 group had 36.63, with a P-value of < 0. 001. The PH and PaCO2 were significantly different, with the PH of the RR14 group being 7.36 while for the RR20 group, it was 41.28. By the time of the end of insufflation, there were perceived significant differences in RR14 ETCO2, which was $P < 0.001$. The vital signs, ETCO2, and peak airway pressure demonstrated differences before, during, and after the insufflation procedures following CO2 venting. The subjects had lower SBP, DBP, HR, SPO2 and ETCO2 levels. There was a decrease in PH, an increase in PAO2, PACO2, and a decrease in HCO3 during insufflation compared to ABG prior to insufflation with a ‘P’ value < 0.05. Preliminary results of the study show a positive relationship between the procedure time and ETCO2 and PACO2 but were inversely related to PH. A positive correlation was observed regarding the correlation of intra-abdominal pressure with ETCO2, while the correlation between IAP and PACO2 was negative. A negative correlation of PH with IAP was observed. They also found that smokers had a higher mean ETCO2 of 37.7%, lower PH of 7.38, lower PAO2 of 81.91, and higher PACO2 of 41.78 than non-smokers, which was statistically significant.

Chapter Five
Discussion and Conclusion

5.1 Introduction

The study explores the impact of respiratory rate on arterial blood gas (ABG) responses and other physiological parameters in patients undergoing laparoscopic surgery with CO_2 insufflation. It investigates how respiratory rate interacts with CO_2 insufflation to influence blood gas levels, end-tidal CO_2 ($ETCO_2$), and other vital signs. The research aims to answer questions about baseline respiratory rate, CO_2 insufflations, effects on ABG and $ETCO_2$ levels, relationships between duration of surgery, intra-abdominal pressure, baseline blood gas, $ETCO_2$ levels, and the influence of smoking habits.

The study found significant differences in arterial blood gases (ABG) and $ETCO_2$ before and during CO_2 insufflation, regardless of respiratory rate. This rejects the null hypothesis that there is no change in ABG and $ETCO_2$. The focus was on how CO_2 insufflation affects these values rather than the lack of significant difference in ABG and $ETCO_2$ across respiratory groups at baseline.

5.2 Hypotheses Discussion

Hypothesis (1):" There is no significant difference in arterial blood gases (ABG) between patients undergoing laparoscopic surgeries before and during CO_2 insufflation". The results supported the null hypothesis, so it is accepted because there were no statistically significant variations in the pre-insufflation ABG (PH, $PACO_2$ and HCO_3) between the two different respiratory rate groups. This is consistent with other studies that found baseline ABG before CO_2 introduction is not significantly affected by small changes in respiratory rate within a healthy range (O'Malley & Cunningham, 2001). To preserve the acid-base balance, homeostatic processes probably make up for these differences. The study aimed to focus on how ABGs were affected by respiratory rate during laparoscopic procedures (Eva et al., 2022). The arterial blood gases (ABG) before CO_2 insufflation are not significantly affected by respiratory rate (14 vs. 20 breaths/min), according to the first null hypothesis (H0). Our results are supported by a study investigating how three different breathing rates—12, 16, and 20 breaths per minute—affect blood gas levels and ventilation during laparoscopies. The results show a direct relationship between respiratory rate and specific findings. Peak airway pressure increased in response to reduced respiratory rates, indicating that slower respiratory rates might not be sufficient for proper ventilation.

Furthermore, in contrast, the 20 breaths/min group showed an increase in PACO2 and a drop in blood PH, indicating that faster respiratory rates may be less efficient in removing CO2, which might lead to abnormalities in blood gas levels. The research points to a connection between these results and respiratory rate. The study provides important information supporting a connection between specific characteristics of respiratory function during a laparoscopy and respiratory rate (Hon, 2011).

Hypothesis (2): "There is no significant difference in end-tidal CO2 (ETCO2) levels between patients undergoing laparoscopic surgeries before and during CO2 insufflation and after venting of CO2 (disinflation)" was rejected because our study found a slight increase in ETCO2 levels after CO2 insufflation in laparoscopy. A study conducted in the Department of Anesthesiology found that patients under spinal anesthesia and general anesthesia experienced a significant increase in end-tidal CO2 (PETCO2) after CO2 insufflation during laparoscopic surgery(Klopfenstein et al., 2008). The text also mentions a return to baseline after surgery, indicating a complex relationship between CO2 insufflation and observed changes and a return to baseline post-surgery (Klopfenstein et al., 2008). Another study supports the link between CO2 insufflation and end-tidal CO2 (ETCO2) during laparoscopy in healthy patients. The study showed a slight rise in ETCO2 after insufflation, indicating that some CO2 has been absorbed into the circulation. However, the increase was insignificant and eventually recovered to baseline post-surgery, suggesting that CO2 may be efficiently eliminated after a laparoscopy in healthy individuals. The focus on healthy patients without underlying medical issues increases the generalizability of the findings (Irfan et al., 2022).

Hypothesis (3):" The respiratory rate (14 VS 20 breath/min) during laparoscopic surgeries has no significant effect on arterial blood gases (ABG) before and during CO2 insufflation" was rejected, because, in this study, there was a significant difference of PH and PCO2 before and during insufflation. A study shows that respiratory rate would not significantly affect ABGs before or during CO2 insufflation. Nevertheless, only the 20 breaths/min group (Group C) demonstrated statistically significant changes in PH and PACO2 levels following CO2 injection. Only Group C had a substantial fall in blood PH and an increase in PACO2 following CO2 introduction, suggesting that the greater respiratory rate (20 breaths/min) was less successful in maintaining acid-base balance than a lower rate (14 breaths/min) during CO_2 insufflation. It supported the connection between elevated intra-abdominal pressure (produced by CO_2 insufflation) and elevated catecholamine levels, although it did not directly measure blood gas tensions. The indirect effects of catecholamines on blood gas control may enhance our findings of altered acid-base balance (Mikami et al., 1998). Evidence of the effect of CO_2 pneumoperitoneum on CO_2 elimination efficiency might affect blood gas tensions (Bhavani-Shankar et al., 2000) supports our findings about the potential impact of respiratory rate on ABGs during laparoscopy. The study gives direct details on the connection between methods of breathing, blood gas dynamics, and CO_2 pneumoperitoneum during laparoscopy to understand the mechanisms investigated in the study, and these investigations strengthen it (Jo et al., 2016).

Hypothesis (4): "The respiratory rate (14 VS 20 breath/min) during laparoscopic surgeries has no significant effect on end-tidal CO_2 ($ETCO_2$) levels before and during CO_2 insufflation, and after venting of CO_2 (disinflation)" was rejected, because in this study it is found a significant difference of $ETCO_2$ between the two groups during insufflation. A study found a positive correlation between CO_2 insufflation and end-tidal CO_2 ($ETCO_2$) levels during laparoscopic cholecystectomy under controlled ventilation. Also, the study showed a 21% increase in $ETCO_2$ levels after 20 minutes of CO_2 insufflation, indicating that CO_2 insufflation leads to a measurable elevation in $ETCO_2$(Noor et al., 2011).

5.3 Demographic Data

The effects of CO_2 pneumoperitoneum on physiological parameters may vary depending on various factors, such as the type of surgery, patient characteristics, and the specific surgical technique used (Ozkan U et al., 2020). This is in contrast with this study that there are no significant differences between the study groups (RR14, RR20) in all the demographic variables for the participants.

5.4 During Insufflation

The current study shows that the mean of the PH values in the RR14 group (Mean=7.36) is significantly lower than the mean of the PH values in the RR20 group (Mean=7.37), the P-value of the test is 0.008, which compatible with a significant decrease in PH in another multiple studies during laparoscopic surgery (Arslan & Dikmen, 2020; Kumar et al., 2018; Makwana et al., 2014).

In the recent trial, there are no significant differences at 0.05 level between the study groups (RR14, RR20) in the PAO2 with p value 0.074 in contrast with a study of the effect of CO2 insufflation on arterial blood gases and end-tidal CO2 during laparoscopic cholecystectomy that shows a significant decrease in arterial oxygen saturation (SPAO2) (Şahin et al., 2018). It also disagrees with another study that observed a significant decrease in PAO2 (Arslan & Dikmen, 2020; Jain et al., 2019; Kim et al., 2016; Kumar et al., 2018). The results show significant differences in end-tidal CO2 (ETCO2), with the mean in the RR14 group (Mean=40.67) being higher than the mean of the End-Tidal CO2 Levels (ETCO2) in the RR20 group (Mean=36.63), agree also with a significant increase of ETCO2 levels after CO2 insufflation during laparoscopic surgery (Kumar et al., 2018; Şahin et al., 2018), also rise in the ETCO2 after the CO2 insufflation and more notably after the incision in various intervals in retrospective, long-term, and descriptive study (Farman et al., 2022; Irfan et al., 2022), as similar increase of ETCO2 significantly at 20 min and highly significantly at 30, 40, 50 min during insufflation (Bachh et al., 2022; Das, 2024) in another study peaked at 60 min (Makwana et al., 2014).

A statistically significant increase in PACO2 levels, for both levels during and after insufflation in laparoscopic surgeries of patients with a BMI ≥25 kg/m2 and in surgeries lasting longer than 120 minutes (Jain et al., 2019), similar to our result of significant differences in the mean of PACO2 values for RR14 group=44.08 which is more than the mean of the PACO2 values of RR20 group=41.28, with P-value of 0.004. In addition, it agrees with a significant increase in PACO2 levels of participants having laparoscopic cholecystectomy during insufflation (Arslan & Dikmen, 2020). The same study for investigating the effects of pneumoperitoneum on arterial blood gas and hemodynamic parameters in laparoscopic cholecystectomy showed a significant increase of PACO2 at 15 and 60 min after insufflation and in the same with elevated PACO2 in all defined time points during insufflation in a prospective study which involved 50 patient (20-65 years) in same day laparoscopy (Makwana et al., 2014). Similarly, an observational study to determine the Metabolic effects of carbon dioxide insufflation during laparoscopic surgery shows that PCO2 increased after 15 mins Co2 insufflation & peaked at 30 mins (Bachh et al., 2022).

The current result for HCO3 shows no significant differences between RR14 and RR20 groups with a p-value of 0.185 in contrast with multiple studies that show a significant decrease in HCO3 (Arslan & Dikmen, 2020), especially a decrease in 10 min after insufflation (Kim et al., 2016).

The study found that a slower respiratory rate (RR14) group had a significantly higher baseline End-Tidal CO2 (ETCO2) level compared to a faster breathing group (RR20). This suggests a potential effect of respiratory rate on baseline CO2 elimination. During CO2 insufflation, the RR14 group maintained a higher ETCO2 level compared to the faster breathing group. However, there were significant differences in PH and PACO2 levels, suggesting a potential respiratory acidosis effect in the slower breathing group. After venting CO2, the RR14 group continued to have a higher ETCO2 level. All vital signs showed a significant decrease after CO2 was vented compared to both baseline and during insufflation.

Likewise, the current finding shows a significant difference in peak inspiratory pressure before insufflation with a mean and standard deviation of 13.87 ± 1.6 and during insufflation with a mean and standard deviation of 23.48 ± 3.22 with a p-value of 0.000. This is similar to a study conducted on 12 patients undergoing laparoscopic cholecystectomy with Co2 insufflation which showed increased Peak inspiratory pressure from 15.9 +/- 0.9 to 18.9 +/- 1.0 cmH20 with abdominal insufflation ($P < 0.05$) (Iwasaka et al., 1996).

In a recent study, there is a significant difference in vital signs during insufflation with SPB mean of 129.37, DPB mean of 79.85, HR mean of 83.63and SPO2 mean of 98.85 compared to after venting with SPB mean of 121.32, DPB mean 75.8, HR mean 78.48 and SPO2 mean 98.2 with p value 0.000 for all parameters so they return to normal range. These results are similar to the impact of CO2 pneumoperitoneum on ventilatory and hemodynamic parameters during a laparoscopic cholecystectomy study that found a significant increase in mean arterial pressure (MAP) and heart rate (HR), as well as a decrease in tidal volume (VT), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1). Peak expiratory flow (PEF) values due to pneumoperitoneum. However, these parameters returned to baseline after deflation of the pneumoperitoneum (Pacheco et al., 2020), also with a cross-sectional study that shows a highly significant increase in heart rate (HR) starting at 10, 20, and 60 min and significant at 30, 40, and 50 min before returning to the baseline for laparoscopic cholecystectomy group. While comparing both Groups, SBP in the laparoscopic cholecystectomy increased at 20 & 60 min significantly, and at 30, 40, and 50 minutes significantly than the open cholecystectomy Group, DBP raised slightly at 20 min and highly significantly at 30 as well as 40 and 50 min than Group open cholecystectomy respectively (Das, 2024).

After venting the results, it is observed that all parameters had been returned to the baseline range by the end of the surgery, which is compatible with multiple studies that show the same as our recent result (Arslan & Dikmen, 2020; Kumar et al., 2018; Makwana et al., 2014).

5.5 Conclusion

The current study focuses on the impact of CO2 insufflation during laparoscopic surgeries in adult patients. The study aimed to assess the effects of CO2 insufflation on ABG and ETCO2 levels. It involved 60 adult patients and used a prospective, single-blind quasi-experimental design. The results indicated significant differences in ABG and end-tidal CO2 levels (ETCO2) between study groups based on respiratory rate, the duration of insufflation, and venting of CO2. Subgroup and sensitivity analyses were conducted to explore the impact of CO2 insufflation on respiratory parameters. The study concluded that careful monitoring and management of CO2 levels during laparoscopic surgeries are crucial for ensuring optimal patient outcomes. The findings emphasize the need for standardized protocols and continuous monitoring during these surgical procedures.

5.6 Limitations

1. Lack of previous reviews that dealt with the subject of our study.
2. ABG sampling involves an invasive procedure, which can be uncomfortable and distressing for patients. The increased risk of complications and the required specialized staff may contribute to patients' hesitance to undergo subsequent testing and may affect the data gathering and accuracy of measurements concerning CO2 insufflation in laparoscopic surgeries.
3. Single-center studies may limit the generalizability of the results to the population of patients and the variability of surgical practices in different healthcare environments.
4. Difficulty in collecting data from the respondents.
5. Shortage and limitations of ABG test in the hospital laboratory.

5.7 Recommendations

1. Encourage constant and frequent checks of arterial blood gases and end-tidal CO2 in patients, especially when they are undergoing laparoscopic surgery to observe abnormality and apply the necessary measures easily.
2. Sometimes, prolonged CO2 insufflation may have an adverse effect on the patient. To this end, institutions should adopt standard guidelines regarding the time taken for insufflation, methods of venting, and monitoring timelines.
3. For the training of the surgical teams and anesthesiologists, the possible physiological effects of CO2 insufflation during surgery and guidelines of interpreting ABG and ETCO2 levels should be provided, focusing on improving the effectiveness of the teams in the management of surgeries.
4. It is suggested that more funding should be directed to future studies focusing on the effects of CO2 insufflation in patients undergoing laparoscopy, the relationship between respiratory parameters and clinical outcomes, as well as other investigations involving larger populations of patients and longer observation in order to delineate the long term consequences of this intervention.
5. Promote communicative and collaborative relations between anesthesiologists, surgeons, and respiratory therapists to elaborate on patients' care plans that will cover the effects that CO2 insufflation has on patients' ventilation and respiratory function.

6. To define guidelines for the adaptation of healthcare workers to CO2 insufflation during laparoscopic surgeries, including adjustments of arterial blood gas and end-tidal CO2. Further research must be conducted to establish the resultant common practice guidelines.
7. Make sure to explain to the patients the potential physiologic effects in relation to CO2 pneumoperitoneum during laparoscopic procedures and leave no doubt in their minds that they can appreciate your efforts to alleviate their concerns.
8. Ensure that quality improvement measures are taken within the health care organizations to look into the matter concerned with CO2 insufflation mechanism frequently and critique it scientifically in terms of its efficiency, effectiveness, and impact on patients' safety and surgery results while recommending modifications, if any.

5.8 Implication of the study

The study gives feedback to the anaesthesia team in clinical practice about the effect of CO2 insufflation on ABG and ETCO2 during laparoscopic surgeries and the appropriate anaesthetic technique for respiratory parameters to be used for optimum patient outcomes and to avoid any complications. In addition, monitoring ABG and ETCO2 levels during the operation is important because the patient may be affected by respiratory acidosis.

List of Abbreviations

Abbreviation	Meaning
ETCO2	End-Tidal CO2 Levels
ABG	Arterial Blood Gases
PH	Potential or Power of Hydrogen
PAO2	Partial Pressure Of Oxygen In Arterial Blood
PACO2	Partial Pressure Of Carbon Dioxide In Arterial Blood
HCO3	Bicarbonate
SPO2	Oxygen saturation for peripheral tissues
PAP	Peak Airway Pressure
MIS	Minimally Invasive Surgery
IRB	Institutional Review Boards
ASA	American Society of Anesthesiologists
GA	General Anesthesia
VS	Versus
RR	Respiratory Rate
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
HR	Heart Rate
KG	Kilogram
Kg/m2	Kilogram Per Square Meter
COPD	Chronic Obstructive Pulmonary Disease
PIP	Peak Inspiratory Pressure
BMI	Body Mass Index
IAP	Intra-Abdominal Pressure
e.g.	For Example
L.	Laparoscopic
BMI	Body Mass Index
PMOH	Palestinian Ministry Of Health

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Appendices

Appendix A

Tables

Table A.1

The Post-hoc pairwise comparison tests based on Bonferroni Adjustment

Variable	Insufflation (I)	Insufflation (J)	Mean Difference (I-J)	P-value
SBP	before	during	-5.850	0.000
		after	2.200	0.000
	during	before	5.850	0.000
		after	8.050	0.000
	after	before	-2.200	0.000
		during	-8.050	0.000
DBP	before	during	-2.900	0.000
		after	1.150	0.009
	during	before	2.900	0.000
		after	4.050	0.000
	after	before	-1.150	0.009
		during	-4.050	0.000
HR	before	during	-4.733	0.000
		after	0.417	1.000
	during	before	4.733	0.000
		after	5.150	0.000
	after	before	-0.417	1.000
		during	-5.150	0.000
SPO2	before	during	-1.833	0.000
		after	-1.183	0.000
	during	before	1.833	0.000
		after	.650	0.000
	after	before	1.183	0.000
		during	-.650	0.000
ETCO2	before	during	-3.733	0.000
		after	-1.450	0.000
	during	before	3.733	0.000
		after	2.283	0.000
	after	before	1.450	0.000
		during	-2.283	0.000
Peak Airway Pressure	before	during	-9.617	0.000
		after	-3.223	0.000

	during	before	9.617	0.000
		after	6.393	0.000
	after	before	3.223	0.000
		during	-6.393	0.000

Appendix B

IRP Approval Letter

An-Najah National University
Faculty of Medicine & Health Sciences
Institutional Review Board

جامعة النجاح الوطنية
كلية الطب وعلوم الصحة
لجنة اخلاقيات البحث العلمي

Ref: Mas. July. 2023/3

IRB Approval Letter

Title of Research:

The effect of CO2 insufflation on arterial blood gases and end tidal CO2 during laparoscopic surgeries in adults

Submitted by:
Mohammad Jamal Souqi

Supervisor:
Mohammed Hayek, Nizar Said

Aproved:
10th July. 2023

Your Study Title "***The effect of CO2 insufflation on arterial blood gases and end tidal CO2 during laparoscopic surgeries in adults.***" reviewed by An-Najah National University IRB committee and was approved on *10th* July. 2023

Hasan Fitian, MD

IRB Committee Chairman

IRB Institutional Review Board

Nablus - P.O Box :7 or 707 | Tel (970) (09) 2342902/4/7/8/14 | Faximile (970) (09) 2342910| E-mail : IRB@najah.edu

Appendix C

Data Sheet

Part 1: Demographic data of the participant:

Patient's number	Age	Gender	Height	Weight	Type of laparoscopy	Medical history	Smoking history

Part 2 : Vital Signs, Peak Airway Pressure and Arterial Blood Gases – before insufflation:

Blood pressure	Heart rate	Respiratory rate	Oxygen saturation	Etco2 level	Peak airway pressure

• Arterial Blood Gases (ABG) values: pH, PaO2, PaCO2, HCO3

PH	PAO2	PACO2	HCO3

Part 3: During Insufflation: 15 minutes after beginning of insufflation

• Arterial Blood Gas (ABG) values: pH, PaO2, PaCO2, HCO3

PH	PAO2	PACO2	HCO3

Blood pressure	Heart rate	Respiratory rate	Oxygen saturation	Etco2 level	Intra-abdominal pressure	Peak airway pressure

Part 4: after venting of co2 (disinflation)

Blood pressure	Heart rate	Respiratory rate	Oxygen saturation	Etco2 level	Duration of surgery	Peak airway pressure

Appendix D

The ASA score

The American Society of Anesthesiologists (ASA) score is a subjective assessment of a

ASA SCORE	**Physical Status**
ASA I	I.A normal healthy patient.
ASA II	A patient with mild systemic disease.
ASA III	A patient with severe systemic disease.
ASA IV	I.A patient with severe systemic disease that is a constant threat to life.
ASA V	I.A moribund patient who is not expected to survive without the operation.
ASA VI	I.A declared brain-dead patient.

patient's overall health that is based on 6 classes**:**

Appedix E

Certificate of English Proofreading and Editing

Certificate of English Proofreading and Editing

This certificate confirms that the thesis mentioned below was proofread by an expert in academic English and edited by a native speaker.

The following issues were corrected: grammar, punctuation, sentence structure, and phrasing.

Faculty of Graduate Studies at An-Najah National University can contact us for a copy of the edited document that the author submitted.

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جـامعـــة النجاح الوطنية

كليـــة الدراســـات العليـــا

تأثير نفخ ثاني أكسيد الكربون على غازات الدم الشرياني ومستوى ثاني أكسيد الكربون في نهاية الزفير أثناء العمليات الجراحية بالمنظار عند البالغين

إعداد

محمد جمال حسن سوقي

إشراف

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د. نزار سعيد

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في تمريض التخدير، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

2024

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الملخص

خلفية الدراسة والأهداف: تتضمن العمليات الجراحية باستخدام المنظار نفخ بطن المريض باستعمال غاز ثاتي أكسيد الكربون لجعل فراغ بين جدار البطن والأعضاء الداخلية، حيث ان عملية النفخ تؤثر على مستوى غاز ثاني أكسيد الكربون في الدم الشرياني وفي نهاية الزفير مما يؤثر على وظيفة الجهاز التنفسي للمريض. حيث ان الدراسة تهدف الى قياس مدى تأثير نفخ ثاني أكسيد الكربون على غازات الدم الشرياني ومستوى ثاني أكسيد الكربون في نهاية الزفير أثناء العمليات الجراحية بالمنظار عند البالغين، حيث أن الهدف الأساسي من الدراسة هو تقييم التأثير الفسيولوجي لعملية النفخ باستخدام غاز ثاني أكسيد الكربون على وظائف الجهاز التنفسي للمريض.

منهجية البحث: تم اجراء دراسة بحثية تجريبية، حيث تضمن البحث 60 مريض ممن خضعوا لعمليات جراحية باستعمال المنظار، وتم تقسيم المرضى الى مجموعتين، حيث احتوت كل مجموعة على 30 مريض، وتم قياس مستوى غازات الدم الشرياني ومستوى ثاني أكسيد الكربون في نهاية الزفير خلال مدة نفخ بطن المريض، وبعد جمع البيانات تم تحليلها لتقييم تأثير نفخ بطن المريض باستعمال غاز ثاني أكسيد الكربون على وظائف الجهاز التنفسي.

النتائج: أظهرت البيانات أن هناك فرق واضح في مستوى ثاني أكسيد الكربون في نهاية الزفير وأيضا على غازات الدم الشرياني خلال مدة نفخ بطن المريض باستعمال غاز ثاني أكسيد الكربون، وأبرز التحليل للبيانات احتمالية تأثير المتغيرات المربكة على نتائج الدراسة.

الاستنتاج والتوصية: تؤكد نتائج الدراسة على أهمية مراقبة وإدارة مستويات غاز ثاني أكسيد الكربون في الدم الشرياني خلال العمليات الجراحية باستعمال المنظار، وتقدم الدراسة توصيات قيمة حول التأثير الفسيولوجي على وظائف الجهاز التنفسي نتيجة نفخ بطن المريض باستعمال غاز ثاني أكسيد الكربون، وتؤكد على الحاجة الى إجراء بروتوكولات موحدة ومراقبة مستمرة خلال هذه العمليات الجراحية.

الكلمات مفتاحية: غازات الدم الشرياني، نفخ غاز ثاني أكسيد الكربون، مستوى ثاني أكسيد الكربون في نهاية الزفير، العمليات الجراحية باستعمال المنظار، معدل التنفس.