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Original Research Article

Complications of CO_2 Pneumoperitoneum in Patients Undergoing Elective Laparoscopic Cholecystectomy

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Abstract

Background: The gold standard for treating symptomatic gallstone disease is laparoscopic cholecystectomy (LC), which offers advantages like less pain, shorter hospital stays, and improved esthetic results. Nevertheless, certain pathophysiological alterations are introduced when pneumoperitoneum is created using carbon dioxide (CO_2) to see the surgical field. These include potentially fatal hemodynamic instability and benign shoulder tip pain following surgery.

Objective: This study's main goal was to assess the frequency and range of complications that were specifically linked to the use of carbon dioxide pneumoperitoneum in patients having elective laparoscopic cholecystectomy at a tertiary care facility. These complications included hemodynamic changes, respiratory changes, and postoperative shoulder pain.

Methods: Over the course of six months, Teerthanker Mahaveer Medical College (TMMC) undertook this retrospective observational study. An analysis was conducted on 204 patients receiving elective laparoscopic cholecystectomy. We gathered and examined information on patient demographics, intraoperative vitals (heart rate, mean arterial pressure, $EtCO_2$), and postoperative problems that were especially related to pneumoperitoneum.

Results: The study population (N=204) was predominately female (68.6%) and had an average age of 42.5 years. Shoulder tip discomfort was the most common consequence noted (34.3%). In 18.6% of instances, there was intraoperative hypercarbia ($EtCO_2 > 45$ mmHg). In 2.9% of patients, subcutaneous emphysema was observed. During insufflation, hemodynamic parameters increased in a statistically significant but clinically acceptable way. Pneumoperitoneum problems did not result in any recorded deaths or conversions to open surgery.

Conclusion: Although CO_2 pneumoperitoneum is generally safe, it is linked to a particular set of consequences, including temporary hypercarbia and referred shoulder pain. To reduce these hazards, intra-abdominal pressure must be closely monitored.

Introduction

With the introduction of laparoscopic surgery, cholecystectomy was no longer performed through a huge subcostal incision but rather using keyhole ports, marking a paradigm shift in general surgery. The insufflation of gas, or pneumoperitoneum, is necessary to produce the appropriate working area inside the abdominal cavity. The universal gas of choice for this purpose is carbon dioxide (CO_2) because of its special qualities: it is inexpensive, colorless, non-combustible, and extremely soluble in blood, which lowers the risk of protracted gas embolism as compared to air or nitrous oxide [1]. Nevertheless, there are physiological costs associated with the formation of a "gas cavity" inside the abdomen.

When CO_2 is insufflated, the intra-abdominal pressure (IAP) usually increases to 12–15 mmHg. Together with the chemical consequences of absorbed CO_2, this increase in pressure generates a unique physiological milieu that puts the patient's respiratory and cardiovascular systems to the test [2]. Given that laparoscopic cholecystectomy is one of the most common elective operations worldwide, both anesthesiologists and surgeons

must be aware of the risks associated with using CO_2.

Pathophysiology of Carbon Dioxide Pneumoperitoneum: Pneumoperitoneum-related problems are caused by two different mechanisms: the systemic effects of CO_2 absorption and the mechanical consequences of elevated intra-abdominal pressure (IAP).

The diaphragm's mechanical elevation results in a decrease in pulmonary compliance and functional residual capacity (FRC). Patients may be more vulnerable to hypoxemia as a result of ventilation-perfusion (V/Q) mismatching [3]. Additionally, venous return and systemic vascular resistance (SVR) might be affected by compression of the abdominal aorta and inferior vena cava. Compensatory mechanisms sustain cardiac output in healthy persons, but these alterations may cause hemodynamic instability in patients with impaired cardiovascular function [4].

Chemically, the peritoneal surface quickly absorbs CO_2. Respiratory acidosis results from this absorption, which raises the arterial partial pressure of carbon dioxide ($PaCO_2$). In order to "blow off" the extra CO_2,the body often adjusts by buffering with bicarbonate and increasing minute ventilation [5]. Significant hypercarbia and acidosis may result from insufficient ventilation or an extremely high absorption rate (for example, from subcutaneous emphysema), which may cause sympathetic activation, tachycardia, and perhaps arrhythmias [6].

Cardiorespiratory Consequences: A complicated clinical picture is produced by the combination of chemical absorption and mechanical pressure. Although it helps move abdominal viscera away from the liver, the "reverse Trendelenburg" position which is frequently employed during cholecystectomy may make venous pooling in the lower limbs worse. On the other hand, capacitance vessels can be compressed by the pneumoperitoneum itself.

Post-laparoscopic shoulder pain (PLSP) is one of the most upsetting, but typically not fatal, after effects. The stretching of the diaphragmatic peritoneum and the local acidosis brought on by CO_2 contact with the nerve endings are the causes of this type of referred pain, which is mediated by the phrenic nerve ($C3-C5$) [7]. It is still an underappreciated part of postoperative healing despite its great occurrence.

The purpose of this study is to assess the prevalence and range of these consequences in a tertiary care setting at Teerthanker Mahaveer Medical College. These complications can be mechanical (emphysema), physiological (hypercarbia), or symptomatic (shoulder discomfort).

Methodology

Study Design and Setting: This study was conducted at Teerthanker Mahaveer Medical College's (TMMC) Department of General Surgery and Anesthesiology and was planned as a retrospective observational study. Six months of surgical patients were included in the study period. To guarantee adherence to ethical norms, the procedure was carefully examined and then approved by the institutional ethics committee prior to the start of data extraction. All data points taken from the medical records were anonymized to ensure patient anonymity.

Study Population and Selection Criteria: 204 individuals who had elective laparoscopic cholecystectomy during the allotted six-month period made up the study cohort. To guarantee a homogeneous sample that would fairly represent the consequences of pneumoperitoneum on a typical population, a strict selection procedure was used. Patients between the ages of 18 and 70 who were undergoing surgery especially for symptomatic cholelithiasis and were categorized as ASA (American Society of Anesthesiologists) Physical Status I or II met the inclusion criteria.

Several exclusion criteria were used in order to separate the variables related to elective pneumoperitoneum. Because the inflammatory state could confuse physiological responses, patients with acute cholecystitis or those in need of emergency surgery were excluded. Cases that needed to be converted to open surgery right away due to anatomical issues were also eliminated from the dataset. Additionally, patients who had several prior abdominal surgeries, were pregnant, or had serious pre-existing cardiopulmonary disease (ASA III or IV) were not included. Because adhesions from previous surgeries can change the kinetics of peritoneal gas absorption and the mechanical compliance of the abdominal wall, the latter exclusion was crucial.

Anaesthetic and Surgical Protocol: For every patient in the group, the management procedure adhered to a uniform approach. Propofol (2 mg/kg) and fentanyl (2 mcg/kg) were used to induce general anesthesia, guaranteeing a seamless transition to unconsciousness. Non-depolarizing medications like Vecuronium or Atracurium were used to promote muscle relaxation, which is necessary for abdominal compliance, and a cuffed endotracheal tube was used to secure the airway. In order to keep end-tidal CO_2 ($EtCO_2$) within the normocapnic range of 35 to 45 mmHg, mechanical ventilation was carefully titrated.

Depending on the patient's habits and the operating surgeon's preferences, either the open Hasson technique or the closed Veress needle approach was used to establish pneumoperitoneum. Carbon dioxide was insufflated to achieve an intra-abdominal pressure (IAP) that was tightly maintained between 12 and 14 mmHg after access was obtained. After insufflation, patients were placed with a left lateral tilt in the reverse Trendelenburg position to maximize surgical exposure. Critical parameters such as $EtCO_2$, heart rate (HR), non-invasive blood pressure (NIBP), and oxygen saturation (SpO_2) were continually recorded and monitored during the process.

Data Collection and Analysis: Anaesthesia charts, operating notes, and postoperative recovery records were all thoroughly reviewed as part of the data extraction procedure. The main intraoperative variables examined were respiratory alterations such as hypercarbia ($EtCO_2 > 45$ mmHg) and episodes of hemodynamic fluctuation, notably hypotension (defined as MAP < 60 mmHg), hypertension, bradycardia, and arrhythmia. Following surgery, attention turned to issues that were directly related to gas insufflation, including the frequency and intensity of shoulder tip pain (measured at 6, 12, and 24 hours), the existence of subcutaneous emphysema (detected by palpable crepitus), postoperative nausea and vomiting (PONV), and any indications of respiratory distress. After that, statistical analysis was carried out using SPSS version 26.0, where categorical variables were displayed as frequencies and percentages and continuous variables were summarized as mean $\pm$ standard deviation.

Results

Demographic Characteristics: The demographic profile of the 204 patients in the final analysis was in line with the overall epidemiology of gallstone disease in this area. With 140 female patients (68.6%) and 64 male patients (31.4%), the cohort clearly showed a female majority. With a mean age of (42.5 ± 12.3) years, the age distribution was rather wide. The population is mostly overweight but not extremely morbidly obese, as indicated by the mean Body Mass Index (BMI) of 26.4 ± 4.1 kg/m^2. In terms of physical status, most patients were in good health; 154 patients (75.5%) were categorized as ASA I, and the remaining 50 patients (24.5%) were classified as ASA II.

Intraoperative Hemodynamic and Respiratory Changes: Measurable alterations in vital markers were caused by the physiological stress of pneumoperitoneum. The most common intraoperative change, affecting 38 patients (18.6%), was transient hypercarbia, which is defined as an $EtCO_2$ greater than45 mmHg.

In each case, the attending anesthesiologist was able to effectively control this by modifying minute ventilation, either by raising the tidal volume or breathing rate, without requiring the surgical procedure to be stopped.

In certain cases, the insufflation of gas caused a sympathetic reaction hemodynamically. Following the development of pneumoperitoneum, 22 patients (10.8%) experienced a brief increase in Mean Arterial Pressure (MAP) of more than 20% of baseline. On the other hand, 8 patients (3.9%) had hypotension, which was probably caused by vagal stimulation or decreased venous return from caval compression. These patients responded quickly to fluid boluses or a brief drop in IAP.

Only two patients (0.98%) experienced premature ventricular contractions (PVCs), which went away when the intra-abdominal pressure was lowered. Clinically relevant arrhythmias were uncommon.

Table 1: Comparison of Mean Pre-operative and Intra-operative Hemodynamic Parameters

Parameter	Pre-operative Baseline (Mean $\pm$ SD)	Intra-operative Peak (Mean $\pm$ SD)	p-value
Heart Rate (bpm)	76 ± 12	88 ± 14	< 0.05
MAP (mmHg)	84 ± 10	96 ± 11	< 0.05
$EtCO_2$ (mmHg)	34 ± 4	41 ± 6	< 0.05
SpO_2 (%)	99 ± 1	98 ± 2	> 0.05

(MAP = Mean Arterial Pressure; EtCO2 = End-Tidal Carbon Dioxide; SpO2 = Oxygen Saturation.)

Postoperative Complications: A particular range of problems related to the usage of CO_2 were discovered during the postoperative phase. The most common complaint, reported by 70 individuals (34.3%), was shoulder tip soreness. Usually described as a dull ache in the right shoulder, this pain peaked 6–8 hours after surgery and then drastically decreased by the 24-hour mark. Six patients (2.9%) had subcutaneous emphysema, which was mostly limited to the lower abdomen wall and port insertion sites. Massive emphysema affecting the face or neck has not been documented. Every case of emphysema was self-limiting and went away on its own in 48 hours. Pneumoperitoneum is not the only cause of postoperative nausea and vomiting (PONV), which affected 48 patients (23.5%).

Table 2: Incidence of Postoperative Complications (N=204)

Complication	Number of Patients (n)	Percentage (%)
Shoulder Tip Pain	70	34.3%
Postoperative Nausea/Vomiting (PONV)	48	23.5%
Subcutaneous Emphysema	6	2.9%
Respiratory Distress (Mild)	4	1.9%
Pneumothorax	0	0.0%

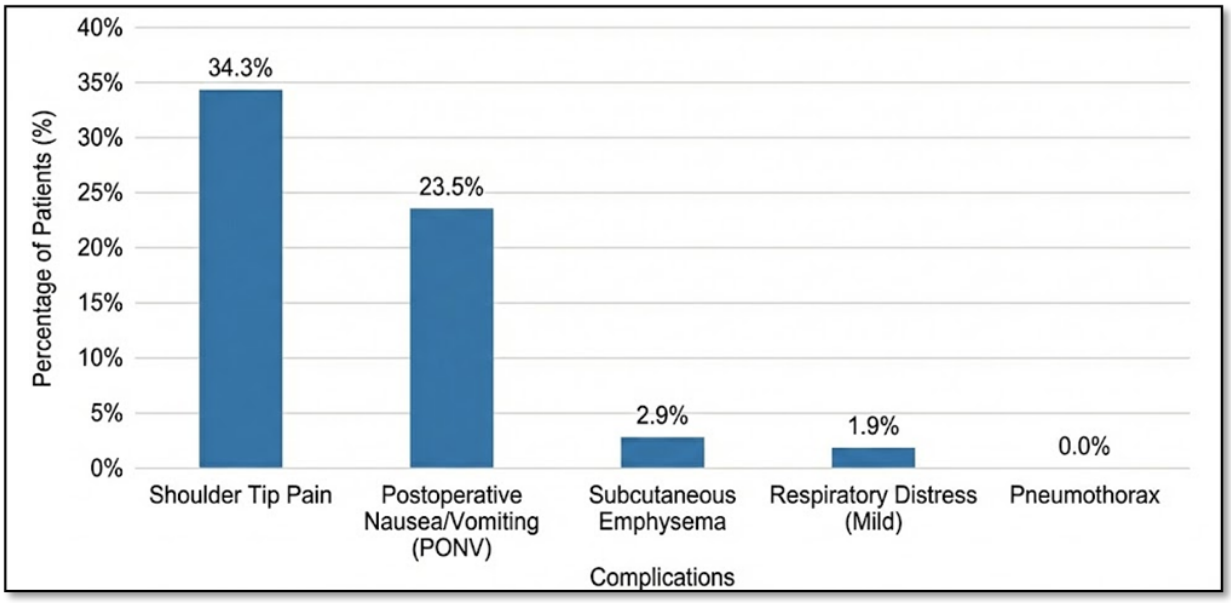

Figure 1: **Relative Frequency of Postoperative Complications**

Discussion

Hemodynamic Perturbations and Safety: The findings of this retrospective investigation at TMMC confirm that although CO_2 pneumoperitoneum causes quantifiable physiological changes, ASA I and II patients tolerate it well. The recognized mechanical effects of elevated intra-abdominal pressure (IAP) are consistent with the observed incidence of transitory hypertension (10.8%). The compression of the abdominal aorta increases afterload when IAP surpasses10 mmHg, and systemic vasoconstriction is facilitated by the release of neurohumoral substances such as vasopressin and catecholamines [8].

The worldwide literature typically reports a rate of 1-2% for healthy patients, which is in line with our observation of a 0.98% incidence of arrhythmia. Hypercarbia, which makes the heart more sensitive to catecholamines, and vagal reflexes brought on by peritoneal stretching are the main causes of arrhythmia during LC [9]. Our study's low incidence indicates that the anesthetic strategy of regulated breathing to maintain normocapnia was successful.

The Burden of Shoulder Tip Pain: Shoulder tip discomfort (STP) is arguably the most common "minor" side effect following laparoscopic surgery. 34.3% of participants in our research had STP. It is still a major cause of patient discomfort, even though it is less common than the historical rates of 60–80% documented in early laparoscopic literature [2].

Mechanism: According to the accepted idea, STP is caused by phrenic nerve irritation. The diaphragmatic peritoneum is irritated and the local pH is lowered when the insufflated CO_2 and peritoneal moisture mix to generate carbonic acid (H_2CO_3).

The brain interprets this nociceptive input as pain originating from the dermatomes supplied by these spinal roots, notably the shoulder area, because the phrenic nerve originates from $C3-C5$ [10].

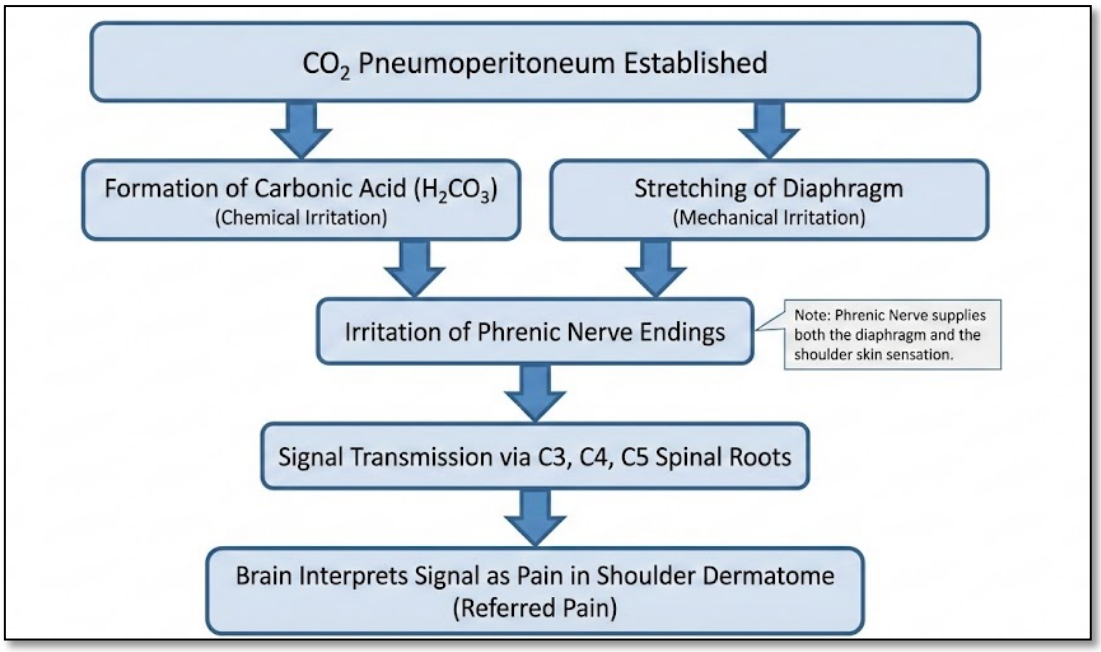

Figure 2: **Proposed Mechanism of Post-Laparoscopic Shoulder Pain (PLSP)**

The incidence is on the lower end of the global range (30–50%), which may be explained by strategies used at our center, such as vigorous aspiration of gas at the end of operation. The recurrence of this discomfort, however, emphasizes the necessity of multimodal strategies, such as the intraperitoneal administration of local anesthetics or the pulmonary recruitment technique, which were not consistently standardized in this retrospective cohort [11].

Subcutaneous Emphysema and Hypercarbia: 2.9% of our patients had subcutaneous emphysema (SE). This complication typically results from the unintentional insufflation of gas into the tissues of the abdominal wall instead of the peritoneal cavity, frequently as a result of trocar or Veress needle malposition. Additionally, if the IAP is too high, gas may be forced through fascial flaws along the port sites [12].

Despite being moderate and self-limiting, the SE seen in our study is a warning indicator. Because CO_2 is absorbed from loose subcutaneous tissue far more quickly than from the peritoneum, extensive SE can result in hypercarbia [13]. In extreme circumstances, this may result in "masked" respiratory acidosis, in which the $PaCO_2$ dramatically increases even with standard breathing settings. The early discovery of hypercarbia (18.6% occurrence) made possible by our approach of monitoring $EtCO_2$ allowed the anesthetist to quickly modify breathing parameters [14].

Comparison with Global Data: The safety profile at TMMC closely matches recognized international criteria when considering our findings in the context of international medical literature. For example, pertinent research by Gutt et al. has long highlighted that, as long as the intra-abdominal pressure is kept below 15 mmHg, the circulatory alterations brought on by pneumoperitoneum are usually well tolerated [2]. Additionally, our complication rates are comparable to those of groups with comparable demographics. In particular, our study's 34.3% incidence of shoulder tip pain is similar to the 30–40% range noted by Sarli et al. in their low-pressure pneumoperitoneum studies [16].

Nonetheless, there are certain differences that could be related to patient demographics or local surgical methods. Our reduced rate of about 1% may be due to the stringent intraoperative management of normocapnia and the strict exclusion of ASA III/IV patients, even though the global literature frequently indicates a somewhat higher frequency of arrhythmias (near to 2-3%). Additionally, Neudecker et al. observed that although biochemical evidence of hepatic and renal stress is widespread during pneumoperitoneum, clinical manifestations are uncommon in elective settings [4]. Our investigation confirms this result because no significant organ failure was found in our postoperative data. The notion that laparoscopic cholecystectomy is a mature, safe treatment when standard protocols are followed is reinforced by the lack of mortality and conversion to open surgery in our group.

Limitations: Despite the promising findings, there are a number of design-related problems with this study. Since this was a retrospective analysis, the accuracy and completeness of the current medical records were the only factors that could be used to

gather data. This raises the possibility of information bias, especially when it comes to subjective, small symptoms. For instance, patients or nursing personnel may have underreported mild shoulder discomfort or brief nausea if they didn't require medication. Furthermore, the study's single-center design at TMMC restricts the findings' applicability to larger populations who may have different demographics or access to other medical resources.

Furthermore, our results cannot be extended to high-risk populations due to the stringent exclusion criteria, even if they are essential for internal validity. The venous return decrease and hypercarbia linked to pneumoperitoneum are known to be considerably less tolerable in patients with pre-existing severe cardiopulmonary compromise (ASA III and IV) [17]. As a result, the safety profile presented here only applies to relatively healthy people undertaking elective procedures; it does not account for the risks involved in performing an emergency laparoscopy or performing surgery on patients with complicated medical conditions.

Conclusion

In conclusion, this retrospective research demonstrates that, for elective ASA I and II patients, laparoscopic cholecystectomy using CO_2 pneumoperitoneum is a very safe technique with a controllable complication profile. According to statistics gathered at Teerthanker Mahaveer Medical College, although physiological disruptions are frequent, they seldom develop into potentially fatal situations. Referred shoulder tip discomfort (34.3%) and temporary intraoperative hypercarbia (18.6%) were the most common problems; these are both well-known side effects of carbon dioxide insufflation and abdominal distension. In this cohort, severe sequelae including hemodynamic collapse, malignant arrhythmias, or extensive subcutaneous emphysema were quite uncommon.

The study's conclusions highlight how crucial it is to be alert in the operating room. End-tidal CO_2 must be closely monitored in order to identify and treat hypercarbia before it causes acidosis. Similarly, a straightforward but efficient way to reduce hemodynamic stress is to keep intra-abdominal pressure as low as possible (preferably between 12 and 14 mmHg). Lastly, rather of treating postoperative shoulder pain as a problem to be disregarded, doctors must actively manage it as a normal physiological consequence of the procedure. Future studies should preferably be prospective in character, possibly concentrating on the effectiveness of certain therapies in lessening the burden of these post-surgical discomforts, such as the use of heated and humidified CO_2 or low-pressure pneumoperitoneum ($8-10$ mmHg).

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