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Coagulation Dynamics in Laparoscopic Cholecystectomy: Investigating the Impact of Carbon Dioxide Pneumoperitoneum

Prithvinathan.V, Raghupathy Thirunavikkarasu*
Department of General Surgery, Sree Balaji Medical College & Hospital, Chennai, India

Abstract

Laparoscopic cholecystectomy is the widely used procedure to treat various gall bladder pathologies, During the procedure, pneumoperitoneum is created with carbon dioxide (CO_2) to improve visualization. This study investigates the impact of CO_2 pneumoperitoneum on coagulation dynamics in patients undergoing the procedure. Fifty-four patients were observed to assess preoperative and postoperative changes in coagulation parameters, including prothrombin time (PT) and D-dimer levels. The study found that postoperative PT changes were minimal, with a mean decrease from 11.83 to 11.7 seconds. D-dimer levels significantly increased, indicating heightened fibrinolytic activity, which can cause deep vein thrombosis (DVT) in high-risk individuals. The study highlights the importance of monitoring coagulation profiles during laparoscopic procedures and suggests that prophylactic anticoagulation should be considered for high-risk patients. Further large-scale investigations are recommended to quantify thrombotic risks associated with CO_2 pneumoperitoneum.

Keywords: *Carbon Dioxide, D-Dimer, Laparoscopic Cholecystectomy, Pneumoperitoneum, Prothrombin time (PT).*

Introduction

Laparoscopy is widely employed in modern surgical practice for both diagnostic and therapeutic purposes, offering numerous benefits such as enhanced cosmetic outcomes, reduced postoperative discomfort, shorter hospital stays, and quicker recovery times [1,2]. Advances in technology and surgical instruments have integrated laparoscopy into various surgical specialities, including gynaecology, urology, and colorectal surgery.

Creating a working space is crucial in laparoscopy, typically achieved through positive pressure pneumoperitoneum using carbon dioxide (CO_2) [3]. Richard Zollinger of Switzerland first proposed CO_2 for pneumoperitoneum in 1924 due to its noncombustible properties, which facilitate safe electrocoagulation during surgery. CO_2 is preferred over other gases like nitrous oxide and helium because it is readily absorbed and exhaled by the body, minimizing the risk of gas embolism.

CO_2 pneumoperitoneum [13,14] alters normal physiology by a rapid absorption into circulation from the peritoneal cavity, potentially affecting cardiovascular, respiratory [3,11], and coagulation systems. Increased intra-abdominal pressure (IAP) [4] can lead to decreased venous return, reduced cardiac output, and increased systemic vascular resistance, posing a challenge for patients with preexisting cardiovascular conditions [8,9]. Respiratory effects include elevated peak inspiratory pressure, reduced functional residual capacity, and hypercapnia, necessitating careful intraoperative monitoring and ventilation adjustments.

Despite its advantages, laparoscopy poses certain risks including increased intra-abdominal pressure, CO_2 absorption during insufflation, and the adoption of the reverse

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****Corresponding Author: drtraghupathy@gmail.com***

Trendelenburg position during surgery. The reverse Trendelenburg position, commonlyused to improve surgical field visibility, can exacerbate pneumoperitoneum's effects on hemodynamics and respiratory function [5], particularly in obese patients.

The inaugural laparoscopic cholecystectomy took place in Germany in 1986, marking a transformative shift over the past three decades. Methodological advancements, such as the development of advanced imaging systems (e.g., high-definition cameras and 3D visualization), improved trocar design, and the introduction of energy devices (e.g., ultrasonic and bipolar coagulators), have significantly reduced surgical duration [15] and complications. These innovations have established laparoscopic cholecystectomy as the standard procedure [6,10] in general surgery, with over 500,000 cases performed annuallyin the United States alone.

The impact of CO_2 pneumoperitoneum on various physiological systems, particularly coagulation, warrants comprehensive investigation. Studies have shown that pneumoperitoneum can induce a hypercoagulable state due to increased intra-abdominal pressure and systemic inflammatory response [7]. This is of particularconcern in patients with a history of thromboembolic events or coagulation disorders. Additionally, the effects of CO_2 insufflation on peritoneal microcirculation and tissue perfusion remain an area of ongoing research.

This study aims to assess these effects in patients undergoing laparoscopic cholecystectomy, providing valuable insights to surgeons regarding potential adverse outcomes. By understanding the physiological alterations induced by CO_2 pneumoperitoneum, surgeons can implement strategies to mitigate risks, such asoptimizing patient positioning, intraoperative fluid management, and the use of adjunctive therapies to enhance patient safety and surgical outcomes [12].

Methodology

This observational study was conducted at the Department of General Surgery and Department of Surgical Gastroenterology, Sree Balaji Medical College and Hospital, Bharath University, Chennai, India. The study population comprised patients attending the outpatient clinic and inpatients of the aforementioned departments. Data collection occurred over 12 months, from March 2023 to March 2024. Participants were selected using purposive sampling, a non-probability sampling method. This study was approved by the Institutional Ethics Committee (IHEC) of Sree Balaji Medical College and Hospital with Ref.No. 002/SBMCH/IHEC/2023/1909.

Sample size: 54

Sample Size Calculation

Hypothesized % frequency of outcome in a population (p) is 4%Confidence limits as % of 100 (d): 5%

Design effect:2

Sample Size

$$\boldsymbol{n} = [\mathbf{DEFF} * \mathbf{Np}(\mathbf{1}-\mathbf{p})]/[(\mathbf{d2}/\mathbf{Z21}-\boldsymbol{\alpha}/\mathbf{2} * (\mathbf{N}-\mathbf{1}) + \mathbf{p} * (\mathbf{1}-\mathbf{p})]$$

Confidence interval 99%

Data Analysis

Data collected are tabulated and analysed using IBM SPSS computer softwarepackage version 21. The chi-square test will be used to find the significance ofstudy parameters on a categorical scale between two or more groups.

Inclusion and Exclusion Criteria

The study population consisted of patients who underwent laparoscopic cholecystectomy, including both genders, aged 18-60 years, with diagnosed gallstones, gallbladder polyps, chronic cholecystitis, or relief stages of acute cholecystitis and had a surgical duration of 60-180 minutes.

Patients were excluded from the study if their surgical time exceeded three hours or if the procedure was converted to open surgery.

Additionally, individuals with associated hypertension, those on anticoagulant or antiplatelet therapy, and patients with known malignancies were also excluded. Furthermore, patients with a history of bleeding or clotting disorders, deep venous thrombosis, or pregnant women were not eligible for participation.

Operative Procedure

The procedure was carried out under general anaesthesia, using standard laparoscopic equipment in all patients, with carbon dioxide pneumoperitoneum. The pneumoperitoneum pressure was maintained at 13 mmHg ± 1 mmHg. Patients were positioned supine with the table tilted to a 30-degree head-up and 15-degree right-up angle to improve visualization of the gallbladder and Calot's triangle. This positioning allowed the colon and duodenum to fall away from the liver edge. The surgeon operated from the patient's left side, with the monitor positioned near the right shoulder. A nasogastric tube and Foley catheter were placed to deflate the stomach and empty the bladder.

The pneumoperitoneum was established using the open Hasson's method, starting with a supra-umbilical incision of 1 to 1.5 cm. Dissection proceeded through the rectus sheath and peritoneum, layer by layer. Once entry into the peritoneal cavity was confirmed, a 10 mm port was inserted, and carbon dioxide was insufflated to maintain pressure between 12 and 14 mmHg, at a flow rate of 3 to 3.5 litres per minute. A 30-degree, 10 mm telescope attached to a light source and endoscopic camera was introduced through the 10 mm port. Laparoscopic inspection ensured no injuries occurred during port insertion, detected any associated or suspected pathologies, and assessed the feasibility of continuing laparoscopically. Additional ports were inserted under direct vision.

A 10 mm working port was placed in the epigastric region to the right of the falciform ligament, and two 5 mm ports were positioned in the midclavicular and anterior axillary lines to facilitate gallbladder retraction and better visualization of Calot's triangle. The cystic pedicle was exposed, and dissection created a window around the cystic duct. Three clips were applied to the cystic duct, which was then divided between them. The cystic artery was similarly isolated, clipped, and divided. The gallbladder was dissected from the liver bed by separating the loose fibrous layer between the gallbladder and the fascia over the liver bed. It was extracted through either the epigastric or umbilical port. Hemostasis was confirmed, and all ports were removed under direct visualization. The pneumoperitoneum was released, and the wound was closed in layers. Post-operatively, the patient received analgesics for pain control. The gallbladder specimen was sent for histopathological analysis, and any stones were sent for biochemical examination [18].

Result

In a cohort of 54 patients undergoing laparoscopic cholecystectomy, demographic and clinical parameters were evaluated to assess surgical outcomes and perioperative changes. The patient population consisted of 34 females and 20 males, with the predominant age group being 41-50 years. Surgical duration ranged from 1 hour 25 minutes to 2 hours 50 minutes (Table 1), with prolonged durations attributed to dense adhesions in Calot's triangle.

Perioperative coagulation profile changes were observed. Preoperative prothrombin time (PT) ranged from 11 to 13.5 seconds, while postoperative PT ranged from 10.5 to 14 seconds, with a statistically significant mean difference of 0.130 ($p < 0.05$) (Table 2). Additionally, D-dimer levels demonstrated a substantial increase, with preoperative values ranging from 99 to 178 and postoperative values ranging from 199 to 506, yielding a mean difference of 220.44 (95% CI) (Table 3). No cases of deep vein thrombosis (DVT) [14] were reported during the two-week follow-up period

Table 1. Master Chart

S. No	Sex	Age	Duration of Surgery	Complications During Surgery	Pre-OP PT	Post-OP PT	Pre-OP D-Dimer	Post OP D-Dimer
1	Female	40	80min	Nil	11	11.8	110	310
2	Female	44	80 min	Nil	13.3	12	154	354
3	Female	43	90 min	Nil	11.9	12.3	132	332
4	Female	46	120 min	Nil	11.5	12	143	323
5	Female	48	90 min	Nil	12.7	13	146	246
6	Female	51	80 min	Nil	13	13.9	170	370
7	Female	38	80 min	Nil	13.5	14	144	409
8	Female	44	80 min	Nil	12.8	13.8	139	500
9	Female	45	80 min	Yes	12	13	159	490
10	Female	41	80 min	Nil	11.7	12.9	130	438
11	Female	40	180 min	Nil	13.3	12.3	171	354
12	Female	49	90 min	Nil	11.9	12	154	332
13	Female	47	120 min	Nil	11.5	13	167	323
14	Female	40	180 min	Nil	12.7	13.9	132	246
15	Female	50	90 min	Nil	13.5	14	141	370
16	Female	55	90 min	Nil	12.8	14	146	501
17	Female	41	170 min	Nil	13.5	11.9	170	498
18	Female	44	180 min	Yes	11	13.2	144	354
19	Female	43	90 min	Nil	12.5	13.9	177	504
20	Female	46	180 min	Nil	11	14	169	330
21	Female	48	170 min	Nil	12.7	12	171	387
22	Female	51	90 min	Nil	13	13	154	343
23	Female	49	120 min	Nil	13.5	13.9	167	465
24	Female	47	170 min	Nil	12.8	14	132	225
25	Female	40	180 min	Nil	12	14	143	354
26	Female	41	80 min	Nil	13.5	11.9	159	278
27	Female	40	80 min	Yes	12.8	14	130	386
28	Female	49	80 min	Nil	13.5	13.8	111	457
29	Female	47	80 min	Nil	11	13	134	370
30	Female	49	80 min	Nil	12.5	12.9	151	294
31	Female	51	80 min	Yes	13.5	13	146	499
32	Female	38	80 min	Nil	12.8	13.9	170	408
33	Female	44	80 min	Nil	12	14	144	386
34	Female	45	80 min	Nil	13.5	14	177	457
35	Male	41	80 min	Nil	12.8	11.9	169	370
36	Male	40	80 min	Nil	13.5	14	111	354
37	Male	49	80 min	Nil	11	14	134	332
38	Male	47	80 min	Nil	12.6	14	151	323
39	Male	40	170 min	Nil	12.9	11.9	108	246
40	Male	41	120 min	Nil	13.1	13	99	370

S. No	Sex	Age	Duration of Surgery	Complications During Surgery	Pre-OP PT	Post-OP PT	Pre-OP D-Dimer	Post OP D-Dimer
41	Male	40	170min	Nil	13.5	14	144	499
42	Male	49	120 min	Nil	12.8	11.8	177	408
43	Male	47	170 min	Nil	13.5	13	169	386
44	Male	40	80 min	Nil	11	11.9	111	457
45	Male	50	170 min	Nil	12.5	14	134	370
46	Male	55	170 min	Nil	13.5	11.9	151	434
47	Male	41	80 min	Yes	11	13.2	134	392
48	Male	44	80 min	Nil	12.6	13.9	151	294
49	Male	43	80 min	Nil	12.9	14	108	396
50	Male	46	80 min	Nil	13.1	14	99	465
51	Male	48	80 min	Nil	12.8	14	111	221
52	Male	51	80 min	Nil	12	11.9	134	453
53	Male	42	180 min	Yes	13.5	13	151	199
54	Male	46	120 min	Nil	12.8	14	134	209

Table 2. Prothrombin Time

Prothrombin Time		
	Before Surgery	**After surgery**
MEAN	11.83	11.7
STANDARD DEVIATION	1.008	0.898
STANDARD ERROR OF MEAN	0.143	0.127

Table 3. D-dimer Ratio

D DIMER		
	Before Surgery	**After Surgery**
Mean	129.78	350.22
Standard Deviation	21.01	73,21
Standard Error of Mean	2.97	10.35

Discussion

In our retrospective analysis of 54 patients undergoing laparoscopic cholecystectomy, we observed distinct patterns in coagulation profiles and thromboembolic risks associated with the procedure. Our study revealed a predominance of female patients (62%) undergoing surgery, consistent with global and regional trends indicating a higher incidence of gallbladder pathologies among females [20].

Demographic and Surgical Characteristics

The majority of patients operated fell within the age groups of 41-50 years and 51-60 years, collectively constituting 76% of the cohort. This demographic distribution underscores the increasing prevalence of gallbladder diseases beyond the age of 40 years. Surgical durations ranged from 1 hour 25 minutes to 2 hours 50 minutes, highlighting variability in procedural times influenced by factors such as adhesions andsurgical complexity.

Prothrombin Time (PT) and D-dimer Analysis

Analysis of PT before and after surgery indicated varied responses among patients, with some showing increased PT (indicating hypercoagulability) and others with decreased PT (indicating hypercoagulability). Despite these individual variations, the overall mean PT decreased insignificantly from 11.83 to 11.7 seconds postoperatively, suggesting a minimal impact on average coagulation times (SEM = 0.143 vs. 0.127) [Fig. 1]. D-dimer levels, however, exhibited a significant increase postoperatively (mean increase of 220.44), reflecting heightened fibrinolytic activity (SEM = 2.97 before surgery, 10.35 after surgery) [Fig.2]. This finding aligns with similar studies by Amin et al.and underscores the potential thrombotic risk associated with laparoscopic procedures.

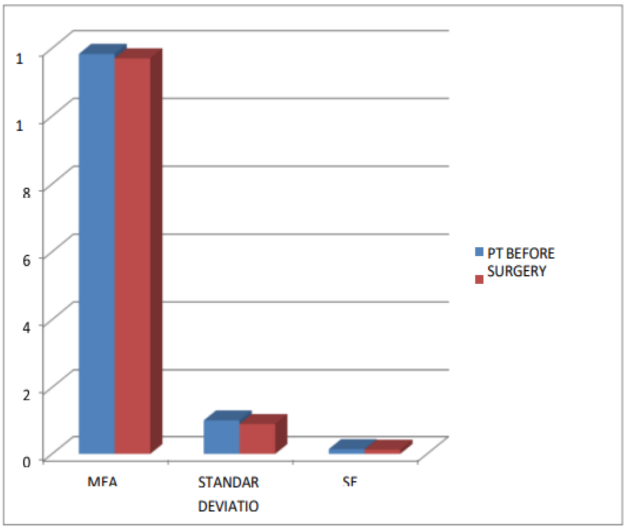

Figure 1. Prothrombin Time Analysis Before and After Surgery

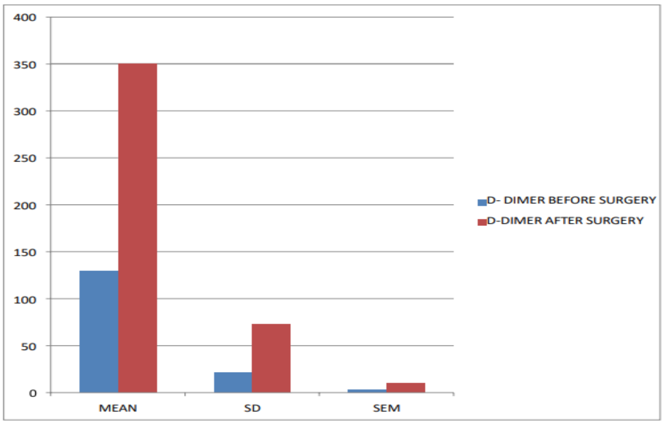

Figure 2. D-dimer Analysis

Comparison with Literature and Contradictory Findings

Our findings corroborate studies by Hans et al., Garg et al., and Schietroma et al., which also reported hypercoagulable states post-laparoscopic surgery. Conversely, studies by Rahr et al., Yan et al., and Martinez et al. suggested hypercoagulability or no significant change in coagulation profiles postoperatively, highlighting conflicting observations in the literature.

Factors Influencing Coagulation Profiles

The alteration in coagulation profiles post-surgery cannot be attributed solely to carbon dioxide pneumoperitoneum. Factors such as patient positioning (reverse Trendelenburgwith a right tilt), intra-abdominal pressure dynamics (12-14 mmHg during surgery), and surgical stress contribute significantly. These factors may induce stasis, a component of Virchow's triad [19], potentially initiating coagulation cascades despite the absence of thrombotic events observed in our study cohort.

Clinical Implications and Prophylactic Measures

Despite observed changes in coagulation markers, none of our patients developed clinically evident thrombosis postoperatively. However, given the inherent thrombotic risk associated with increased D-dimer levels, consideration of prophylactic measures,such as low molecular weight heparin, should be evaluated on a case-by-case basis, especially in patients with additional risk factors. In conclusion, our study underscores the complex interplay of surgical factors and patient physiology influencing postoperative coagulation profiles in laparoscopic cholecystectomy [16]. While the study supports the activation of coagulation and fibrinolytic systems, further large-scale investigations are warranted to quantify thrombotic risks accurately. Surgeons should carefully weigh the risk-benefit ratio of prophylactic anticoagulation in high-risk patients undergoing laparoscopic cholecystectomy to mitigate potential thromboembolic complications effectively [17].

Limitations

This study is limited by its small sample size of 54 patients, which may not fully represent broader population trends. Additionally, the study exclusively focused on patients undergoing laparoscopic cholecystectomy, potentially limiting the generalizability of findings to other surgical procedures using carbon dioxide pneumoperitoneum. Patients undergoing similar procedures for different medical conditions may exhibit varied changes in their coagulation profiles. Furthermore, the timing of blood sample collection, specifically at 6 hours post-pneumoperitoneum onset, introduces a temporal limitation; varying sampling times could potentially yielddifferent coagulation profile outcomes.

Conclusion

Laparoscopic cholecystectomy in this cohort demonstrated favourable outcomes with minimal complications. PT and D-dimer analyses indicated significant postoperative changes, highlighting the importance of monitoring coagulation parameters. Continued vigilance in thromboembolic risk assessment and management remains crucial in the postoperative care of these patients.

Conflict of interest

There is no conflict of interest

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