Original Research Article

Effect of carbon dioxide pneumoperitoneum on acid base balance during laparoscopic surgeries

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Abstract

Background: Carbon dioxide is the most commonly used gas to induce pneumoperitoneum during laparoscopic surgeries, as CO_2 levels in blood and expiratory gas can be easily measured and monitored. However, insufflations of carbon dioxide into the peritoneum may lead to alteration in the acid-base balance. **Aim:** To study the effect of carbon dioxide pneumoperitoneum on acid-base balance during laparoscopic surgeries. **Material and Methods:** The study included 40 adult patients of either sex, scheduled to undergo elective laparoscopic surgical procedures. Measurement and comparison was done between preinsufflation and predesufflation values of arterial blood gas analysis. **Results:** Comparison of arterial blood gas analysis of preinsufflation and predesufflation sample indicated that pneumoperitoneum originated a definite and significant fall in mean arterial pH from 7.41±0.03 to 7.37±0.04 ($p < 0.001$), significant decrease in mean base excess from -1.36±1.53 mmol/lit to -2.32±2.08 mmol/lit ($p < 0.001$) and elevation in mean $PaCO_2$ from 36.73±3.96 mmHg to 40.52±4.19 mmHg ($p < 0.001$); with no significant change in bicarbonate concentration ($p > 0.05$). These changes were seen inspite of ventilatory adjustment to maintain $etCO_2$ within acceptable range. We found no actual acid base abnormality but definite acidotic trend with statistical significance and this trend was of mixed type i.e. respiratory with metabolic component. **Conclusion:** Pneumoperitoneum during laparoscopic surgery is associated with alteration in acid base balance and significant decrease in arterial pH during pneumoperitoneum with development of mild mixed respiratory and metabolic acidosis in healthy adults. These acid base changes during laparoscopy may even be more exaggerated in patients with cardiovascular and pulmonary diseases with significant anaesthetic implications.

Key Words: Laparoscopic surgeries, pneumoperitoneum, acid base balance, respiratory acidosis, metabolic acidosis.

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INTRODUCTION

Over the last two decades, laparoscopy has shown appreciable growth in its clinical application, gained worldwide acceptance and has become a frequently performed surgery due to its various advantages over the open-technique. This minimally invasive procedure requires pneumoperitoneum for adequate visualization and operative manipulation.[1] Carbon dioxide is the most commonly used gas to induce pneumoperitoneum, as CO_2 is highly soluble in blood because of rapid buffering, it is rapidly removed in lung, also it diffuses into the tissues rapidly, thus decreasing the risk of gas embolism. In addition, CO_2 levels in blood and expiratory gas can be easily measured and monitored. Elimination of CO_2 can be augmented by increasing ventilation.[2] However, insufflations of carbon dioxide into the peritoneum may lead to alteration in the acid-base balance and causes hypercarbia, respiratory acidosis, and peritoneal reaction leading to shoulder pain.[3] The present study was carried out to study the effect of carbon dioxide pneumoperitoneum on acid-base balance during laparoscopic surgeries.

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MATERIAL AND METHODS

The present prospective controlled clinical study was carried out in the Department of Anaesthesiology, Tertiary Care Hospital, after approval by the hospital's ethics committee. Patients posted for elective laparoscopic surgery, which included laparoscopic appendicectomy, cholecystectomy, adhesiolysis, hydatide cysts removal, or aspiration, abdominoperineal resection, and gonadal vein ligation were studied.

Inclusion Criteria

- Patients posted for elective laparoscopic surgery.
- ASA physical status I/II.
- Age from 18-60 years
- Patients of either sex.

Exclusion Criteria

- Patient's refusal.
- Significant cardiovascular morbidity (ASA III and IV).
- Patients with respiratory disorders e.g. asthma, chronic-obstructive-pulmonary disorder, pulmonary tuberculosis, history of pulmonary resection.
- Abnormal modified Allen's test suggestive of inadequate collateral circulation in the hand.
- Coagulopathy or patients on anti-coagulant therapy.
- Chronic smokers
- Obese patients with BMI > 25 Kg / m^2.

Sample Size: Hirvonen EA *et al* (1994)[8] studied ventilatory effects, blood gas changes and oxygen consumption during laparoscopic hysterectomy. Based on this study, estimation of sample size for our study was done. With reference to this study and using the relative precision formula with confidence level - 90%; level of significance - 5% and relative precision - 5%, sample size of 40 was decided.

Methodology: A detailed pre-anaesthetic evaluation including history of present illness, general examination, systemic examination, airway assessment was carried out in each patient. Appropriate laboratory tests and radiological investigations were carried out and results noted. Patients were premedicated with i.v. Ranitidine 50mg and i.v. Glycopyrrolate 0.004mg/kg .Sedation given with i.v. Midazolam 0.02mg/kg, i.v. Fentanyl 2µg/kg. Baseline vital parameters were noted after premedication and sedation, but before induction. Patients were preoxygenated with 100% O_2 on mask for 3 min. Induction of general anaesthesia was done with i.v. Propofol 2mg/kg and i.v. Vecuronium 0.15mg/kg and the patient was ventilated for 3 min on mask on O_2 + N_2O + Sevoflurane / Isoflurane. Intubation was done with the appropriate sized cuffed endotracheal tube. After inflating the cuff and securing the tube, controlled mechanical ventilation was started and anaesthesia was maintained on O_2 and N_2O in ratio of 50:50 along with inhalational anaesthetic agent (2% Sevoflurane or 1.2% Isoflurane) on semiclosed circle system with CO_2 absorber and flow rate of 4 lit/min. Mechanical ventilation was adjusted by changing respiratory rate (R.R.) to maintain $etCO_2$ between 30 to 40 mmHg while tidal volume was kept constant at 10 ml/kg. Intraoperatively, intermittent doses of I.V. Vecuronium bromide 0.02 mg/kg were used for muscle relaxation according to neuromuscular monitoring. Maintenance doses of i.v. Fentanyl 0.5 µg/kg were given Intraoperatively at every 60 min. Baseline arterial blood sample was taken anaerobically after intubation but before carbon dioxide insufflation through 22 gauge Jelco in 3 ml preheparinized syringe by standardized arterial blood sampling technique. $etCO_2$ value was noted down at the time of arterial blood sampling. Sample kept in container with ice, deep enough to immerse syringe beyond level of specimen i.e. barrel of syringe containing the blood sample and was sent for ABG analysis. At the time of sampling, vital parameters like heart rate (ECG), blood pressure, SPO_2 were also noted down. ABG analysis was done on Cobas B-121 ABG analyzer, Roche Company. After arterial sampling, pneumoperitoneum was created with carbon dioxide. Intra-abdominal pressure was maintained between 12 – 16 mm Hg and was monitored, and recorded. Apart from this, other parameters recorded during pneumoperitoneum were (1) Rate of CO_2 insufflation and (2) patient positioning. Second arterial blood sample was taken just before carbon-dioxide desufflation by the above-mentioned technique with simultaneous recording of $etCO_2$ at the time of sampling. Any intraoperative complications were managed accordingly. At the end of surgery, reversal of neuromuscular blockade was done with i.v. Neostigmine 0.05 mg/kg and i.v. Glycopyrrolate 10 µgm/kg. Extubation was done after thorough oropharyngeal suctioning, return of reflexes and muscle power. Postoperatively, vital parameters like respiratory rate, heart rate, and blood pressure were monitored and any complaints including nausea, vomiting managed accordingly before the patients were shifted to ward.

Statistical Analysis: Continuous variables were presented as mean ± standard deviation, categorical variables were expressed in percentage (%). All Continuous variables were compared by paired t-test. p value < 0.05 was considered as statistically significant. Data was analyzed on statistical software STATA 10.0. Correlation between change in pH with PaO_2 and $HCO3^-$ assessed by calculating correlation coefficient ''r''. Association between number of patient and acid base alteration was assessed by chi-square test.

RESULTS

The study included 40 adult patients of either sex, scheduled to undergo elective laparoscopic surgical procedures. Measurement and comparison was done between preinsufflation (P.I.) and predesufflation (P.D.) values of arterial blood gas analysis.

Table 1: Characteristics of study population

Characteristics	Value
Age (yrs)	
Mean ± SD	34.85±12.08
Range	18-60
Sex	
Male	13(32.5 %)
Female	27(67.5 %)
BMI, kg/m²	
Mean ± SD	19.6 ± 2.65
BMI, kg/m²n (%)	
<18.5	18(45%)
18.6-24.99	22(55%)
>25	---
ASA status	
ASA I	40(100%)
ASA II	---

In present study, age group ranged from 18-60 years with mean age of study population was 34.85 ± 12.08 years. All patients of both sexes belonged to ASA-I category. Study involved more number of females, 27(67.5 %) as compared to males, 13 (32.5%).

Table 2: Type of procedures carried out in study population

Laparoscopic appendicectomy	19 (47.5%)
Laparoscopic adhesiolysis	2 (5%)
Laparoscopic APR	2 (5%)
Laparoscopic cholecystectomy	15 (37.5%)
Laparoscopic cyst aspiration	1 (2.5%)
Laparoscopic gonadal vein ligation	1 (2.5%)
Total	**40(100%)**

Laparoscopic appendicectomy (47.5%), Laparoscopic cholecystectomy (37.5%), formed the major bulk of procedures.Average duration of laparoscopic surgery was 81.45 ± 51.38 min with range of 30 to 250 min.Average duration of pneumoperitoneum was 68.62 ± 48.10 min, ranging from 20 to 218 min.

Table 3: Comparison of mean Arterial blood gas values of preinsufflation and predesufflation sample

	Preinsufflation (P.I.) (Mean ± SD)	Predesufflation (P.D.) (Mean ± SD)	Change Mean ± SD (%)	p value
pH	7.41±0.03	7.37±0.04	0.04±0.03 (0.54%)	p < 0.001 HS
PaO_2, (mmHg)	251.25±66.42	234.64±84.72	16.61±60.04 (6.61%)	P > 0.05 NS
$PaCO_2$, (mmHg)	36.73±3.96	40.52±4.19	3.78±4.11 (10.32%)	p < 0.001 HS
$HCO3^-$,(mEq/lit)	22.83±1.57	22.70±1.78	0.13±1.40 (0.57%)	p > 0.05 NS
B.E., (mmol/lit)	-1.36±1.53	-2.32±2.08	0.96±1.48 (56.30 %)	p < 0.001 HS

NS-Non-significant, S- Significant, HS- Highly significant

Mean arterial pH of 7.41±0.03 at preinsufflation sample decreased to 7.37±0.04 at predesufflation sample during pneumoperitoneum. Decrease in mean arterial pH was of 0.04±0.03 which is highly significant statistically ($p<0.001$). Mean arterial pH value was well within normal range of 7.35 to 7.45, but had decreasing or acidotic trend with pneumoperitoneum. Mean arterial O_2 concentration (PaO_2) also showed slight decrease during pneumoperitoneum as compared to preinsufflation value, decrease was by 6.61% which is not significant statistically ($p > 0.05$).There was highly significant increase ($p<0.001$) in mean $PaCO_2$ during pneumoperitoneum to 40.52 ± 4.19 mmHg as compared to preinsufflation value of 36.73±3.96 mmHg. The change was 3.78±4.11 mmHg (10.32%). Mean $HCO3^-$ concentration showed statistically non-significant change ($p>0.05$) during pneumoperitoneum (-0.57%) as compared to before insufflation value. Highly significant decrease ($p<0.001$) in mean base excess (-56.30%) by 0.96 ± 1.48mmol/lit (increase in base deficit) was seen during pneumoperitoneum as compared to before insufflation value. Decrease in mean B.E. was seen without change in bicarbonate.

Table 4: Interpretation of Arterial blood gas values and significance of change

ABG values	Preinsufflation	Predesufflation	Significance
Normal	36	27	p<0.05, S
Acidosis			
Respiratory	---	1	
Metabolic	---	---	
Mixed	---	11	
Total	**---**	**12**	**p<0.001, HS**
Alkalosis	**4**	**1**	**p>0.05, NS**

NS- Non-significant, S- Significant, HS- Highly significant

Analysis of individual ABG values showed that before CO_2 insufflation, 36 patients had normal ABG values with pH in normal range, and 4 patients had alkalosis (pH>7.45).Analysis of predesufflation ABG values showed that 12 patients had acidosis (pH<7.35), in which 11 had mixed respiratory and metabolic component derangement with acidosis, while one patient had respiratory acidosis. 27 patients had ABG values within normal range. One patient had alkalosis. Before pneumoperitoneum, 36 patients had pH in normal range while this number decreased to 27 at predesufflation sample time, this decrease in number of patients with normal pH was a significant change ($p<0.05$).Before pneumoperitoneum, no patient had pH <7.35 i.e. no patient had acidosis, but this number increased to 12 at predesufflation sampling time, this increase was highly significant statistically ($p<0.001$).Alkalosis or pH > 7.45 was seen in 4 patients before pneumoperitoneum, while, at predesufflation sampling time alkalosis was seen in one patient only, but this change was not significant statistically ($p > 0.05$).

Table 5: Correlation between changes in pH with $PaCO_2$ and $HCO3^-$

Variable	Coefficient of correlation	Significance
pH and $PaCO_2$	r = - 0.7612	p<0.001, HS
pH and $HCO3^-$	r = 0.0004	p> 0.05, NS

NS- Non-significant, S- Significant, HS- Highly significant

Significant negative correlation was seen between pH and $PaCO_2$ ($p<0.001$), while pH and $HCO3^-$ did not show any kind of positive or negative correlation. During laparoscopy procedure we observed 4 patients having heart rate less than 50 beats per min, out of them 3 patient had bradycardia at the start of pneumoperitoneum and one at 50 min of pneumoperitoneum. Out of these 4 patients, one underwent laparoscopic hydatid cyst aspiration, two underwent laparoscopic appendicectomy, and one underwent laparoscopic cholecystectomy. All patients were treated successfully with i.v. Atropine 0.3 mg. Two patients showed intraoperative increase in blood pressure during Pneumoperitoneum above 160 mmHg, and required intraoperative treatment with i.v. NTG infusion for short period. Remaining 34 patients showed no complication intraoperatively, and even during pneumoperitoneum. Nausea was complained by five patients post operatively which was treated with repeat i.v. Ondansetron 4 mg. One patient who complained of pain in abdomen and incision site, was treated with i.v. Pentazocine 0.5 mg/kg. Another one who complained of both nausea and pain, was managed as mentioned above. No arterial line related complications were seen during or after completion of laparoscopy.

DISCUSSION

Acid-base changes following CO_2 absorption are the primary derangement with laparoscopy. Changes can be of respiratory or metabolic origin. These changes depend upon the patient's underlying respiratory status as the lung eliminates absorbed CO_2 buffered by the blood. In otherwise healthy patients, an increase in minute ventilation is sufficient, but for those with COPD, elimination of CO_2 is less efficient causing them to suffer from more significant and prolonged CO_2 retention and derangement in acid base balance i.e. respiratory acidosis. Laparoscopy with CO_2 insufflation causes a mild respiratory acidosis due to the absorption of CO_2.[4] Although, some authors have reported consistent associated mild metabolic acidosis.[5,6] Experimentally, this trend towards metabolic acidosis is noted at gas insufflation pressures >20 mmHg.[7] Lactic acidosis results from splanchnic hypoperfusion following mechanical effect of raised intraabdominal pressure and CO_2 absorption and hypercarbia from CO_2 pneumoperitoneum.[8] There are reports of frank metabolic acidosis in laparoscopic surgeries with high I.A.P.[9] In present study, with comparison between two samples, definite change was observed in mean values of acid base status of predesufflation sample as compared to preinsufflation sample and this change was towards acidotic side. In present study, ASA-I patients undergoing laparoscopic surgeries with I.A.P. of 12 to 16 mmHg and mean duration of pneumoperitoneum about 68.62 ± 48.10 min, has shown no frank acid base abnormality in mean values of arterial acid base status. However, pneumoperitoneum caused a definite fall in pH ($p<0.001$), base excess ($p<0.05$) and elevation in $PaCO_2$ ($p<0.001$); with no significant change in bicarbonate concentration ($p> 0.05$), indicating change towards acidotic side. These changes were seen inspite of ventilatory adjustment to maintain $etCO_2$ within acceptable range. We have not done extensive invasive hemodynamic monitoring, so inspite of hemodynamic stability, subtle changes in systemic circulation or peritoneal circulation in our study may not have been detected by non-invasive cardiac monitoring. These changes were detected by invasive cardiovascular monitoring in various studies.[5,7] Further invasive studies by E. Eleftheriadis*et al*,[10]found significant decrease in hepatic microcirculation and gastric intramural pH (7.15±0.16 vs. 7.37±0.02, P = 0.003) in patients operated for cholecystectomy, in first group subjected to CO_2 pneumoperitoneum for laparoscopy as compared to second group patients undergoing open procedure. Anna-Maria Koivusalo *et al*,[11] found increase in gastric mucosal PCO_2 and decrease in gastric intramucosal pH during CO_2 pneumoperitoneum for laparoscopic cholecystectomy as compared to the gasless procedure. In addition, we have not analyzed blood lactate values because of non-availability of facility. So, metabolic component cannot be evaluated in further details. In our study, there was a definite decrease in pH. Though mean change was not acidotic, mean pH has an acidotic trend. Mean pH change has respiratory component with minor metabolic constituent. This increase in $PaCO_2$ and decrease in pH was seen inspite of respiratory adjustments. Though their predesufflation arterial blood gas values were within normal range, it was highly significant change from preinsufflation value and clinically important as change in $PaCO_2$ correlated with pH change. Increase in $PaCO_2$ after CO_2 pneumoperitoneum indicates extra CO_2 load from CO_2 absorption from pneumoperitoneum and hypercapnia, inspite of increase in Minute Ventilation. In our study, mean arterial pH has decreased with pneumoperitoneum even after increase in ventilation to maintain $etCO_2$, which indicates acid-base change inspite of attempted ventilatory compensation even in healthy patients (ASA-I status), and these changes may be more significant in compromised patients. Thus, when we compared mean blood gas values of arterial blood sample taken just before CO_2 pneumoperitoneum with mean arterial blood gas values of predesufflation sample, we found no actual acid base abnormality but definite acidotic trend in predesufflation arterial sample with statistical significance and this trend was of mixed type i.e. respiratory with metabolic component. Acid base changes in our study occurred secondary to pathophysiological effect of CO_2 pneumoperitoneum. Respiratory and metabolic component of mixed acid base alteration can be explained by CO_2 absorption and direct mechanical effect of raised intraabdominal pressure on organ perfusion that occurred during CO_2 pneumoperitoneum. A mild metabolic acidosis sometimes occurs in patients undergoing general anaesthesia usually after period of extracorporeal perfusion, after circulatory arrest and hypothermia or immediately following the temporary occlusion of major vessels such as aorta, massive blood transfusion, hypoxia, and low cardiac output. Neither of these factors are present in our study and so metabolic acidosis found in our study signifies the presence of different cause. Various authors studied acid base changes during pneumoperitoneum in ASA I, II, III patients, with different IAP and duration of pneumoperitoneum. Out of them, metabolic acidosis was observed by Ibraheim *et al*[8] in ASA-I/II patients, Taura *et al*[9] in ASA-II/III patients, all of them observed increase in blood lactate levels as marker of metabolic acidosis. Respiratory acidosis was observed by Eila A. Hirvonen *et al*[12] in ASA-I/II patients, Hong *et al*[13] in ASA-I patients, Uen *et al*[14]in ASA-I/II patients, Aoki A[15]in ASA-I/II patients. In their study decrease in pH was linked to correspondingly increasing $PaCO_2$. Mixed respiratory and metabolic acidosis observed by V. Ga´ndara *et al*[6] in ASA-I/II patients. Wittgen *et al*[16]compared acid base changes in ASA-I patients with ASA-II/III patients, who found significant acid base alterations in ASA-II/III patients as compared to non-significant changes in ASA-I patients even with same ventilatory and anaesthetic management which emphasized hazards of CO_2 pneumoperitoneum in ASA-II/III patients. We have studied acid base changes in ASA-I patients only, but significant changes even in these healthy patients' marks their importance in ASA-II/III patients. Some authors studied acid base changes during CO_2 pneumoperitoneum for laparoscopy and compared it with acid base changes during gasless laparoscopy or open procedures. These authors found significant acid base alterations during CO_2 pneumoperitoneum as compared to non-significant changes in other groups. Uen *et al*[14] found significant ($p<0.01$) decrease in pH in CO_2 pneumoperitoneum group as compared to gasless laparoscopy group. Schulze *et al*[17] found significant increase in $PaCO_2$ but non-significant change in pH during CO_2 pneumoperitoneum as compared to gasless laparoscopy. In present study, we evaluated acid base changes in ASA-I patients, though we have not studied acid base alterations in ASA-II/III patients, but significant acid base alteration even in ASA-I patients in our study indicates chances of their exaggeration in ASA-II/III patients. Some authors, who have studied acid base changes in control group (open procedure or gasless laparoscopy group); found non-significant acid base changes in open procedure or in gasless laparoscopy group[16,17]as compared to CO_2 pneumoperitoneum group.

CONCLUSION

Pneumoperitoneum during laparoscopic surgery is associated with, alteration in acid base balance and significant decrease in arterial pH during pneumoperitoneum with development of mild mixed respiratory and metabolic acidosis. These acid base changes during laparoscopy may even be more exaggerated in patients with cardiovascular and pulmonary diseases with significant anaesthetic implications.

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