Original Research Article

Correlation between arterial and end tidal carbon dioxide partial pressure during laparoscopic surgeries

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Abstract

Background: End-tidal carbon dioxide pressure ($etCO_2$) monitoring is used as an indirect measure of arterial carbon dioxide partial pressure ($PaCO_2$). To prevent hypercapnia, close intraoperative monitoring of $etCO_2$ or $PaCO_2$ and appropriate ventilatory changes are necessary. **Aim:** To evaluate the correlation between arterial and end-tidal carbon dioxide during laparoscopic surgeries. **Material and Methods:** A total of 40 non-obese adult patients of either sex, between 18 to 60 years of age and ASA status I, posted for elective laparoscopic surgery were included. Measurement and comparison done between preinsufflation values of $etCO_2$, a-$etCO_2$ gradient and their respective predesufflation values. **Results:** In present study, a-$etCO_2$ gradient increased with pneumoperitoneum to 7.58±2.11 mmHg at predesufflation period as compared to 5.55±2.07 mmHg at preinsufflation period and this change of 2.03±1.35 mmHg was found to be highly significant ($p<0.001$). We observed change in a-$etCO_2$ gradient to be more in Trendelenburg position (2.20±1.51 mmHg) as compared to antitrendelenburg position (1.82±1.15 mmHg); however, this difference is not significant statistically. Change in a-$etCO_2$ gradient has highly significant, positive correlation with duration of pneumoperitoneum ($p< 0.001$). **Conclusion:** Increase in a-$etCO_2$ gradient with pneumoperitoneum indicating loss of correlation between $etCO_2$ and $PaCO_2$ during pneumoperitoneum and thus $etCO_2$ is less accurate in reflecting $PaCO_2$.

Key Words: Laparoscopic surgeries, pneumoperitoneum, End-tidal carbon dioxide pressure, arterial carbon dioxide partial pressure.

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INTRODUCTION

Laparoscopy is a minimally invasive surgery and promoted as gentle surgery, still the procedure is not risk free. Reduction in functional residual capacity (FRC) occurs with general anaesthesia is compounded by CO_2 induced pneumoperitoneum and Trendelenburg positioning of patients.[1]End-tidal carbon dioxide pressure ($etCO_2$) monitoring is used as an indirect measure of arterial carbon dioxide partial pressure ($PaCO_2$). To prevent hypercapnia, close intraoperative monitoring of $etCO_2$ or $PaCO_2$ and appropriate ventilatory changes are necessary. There is some disagreement whether $etCO_2$ is reliable in predicting the $PaCO_2$ in laparoscopic procedures with CO_2 insufflations. Although $etCO_2$ is an easily accessible monitoring parameter, it often underestimates the true level of PaCO2.[2] Thus, relying on $etCO_2$, anaesthesiologist may not be able to execute appropriate ventilatory changes to eliminate increased CO_2 load to prevent systemic acidosis. Keeping in mind all these controversies regarding dependence on $etCO_2$ for monitoring of $PaCO_2$ during laparoscopic surgeries even in healthy patients and necessity of their anticipation in compromised patients, the present study was conducted to

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evaluate the correlation between arterial and end-tidal carbon dioxide during laparoscopic surgeries.

MATERIAL AND METHODS

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

Inclusion Criteria

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

Exclusion Criteria

- 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 $Kg/m^{2.}$
- Patient's refusal.

Sample Size: Based on a previous study,[3] a sample size of 40 patients was calculated using values of confidence level = 90%, level of significance=5% and relative precision= 5%.

Methodology: A detailed preanaesthetic 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 withi.v. Ranitidine 50mg andi.v.Glycopyrrolate 0.004mg/kg. Sedation given with i.v. Midazolam 0.02mg/kg and 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, 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 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. All patients received i.m. Diclofenac sodium 75 mg after endotracheal intubation. Maintenance doses of i.v. Fentanyl 0.5 µg/kg were given intraoperatively at every 60 min. Baseline arterial blood sample was taken anaerobically. $etCO_2$ value was noted down at the time of arterial blood sampling. After arterial sampling, pneumoperitoneum was created with carbon dioxide.Intra-abdominal pressure [**I.A.P.**] was maintained between 12-16 mmHg, 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. 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. Intra and postoperative complications were noted.

Statistical Analysis: Data was analyzed on statistical software STATA 10.0.Continuous variables were presented as mean ± standard deviation, categorical variables were expressed in percentage (%). All Continuous variables were compared by paired t-test. Mean change in a-$etCO_2$ gradient as compared to I.A.P. at 3 levels was compared by analysis of variance (ANOVA) with multiple comparison test of Bonferroni; correlation between duration of pneumoperitoneum and a-$etCO_2$ gradient was assessed by calculating correlation coefficient "r". Association between number of patients and acid base alterations was assessed by chi-square test.p value < 0.05 was considered as statistically significant.

RESULTS

The study included 40 adult patients of either sex, scheduled to undergo elective laparoscopic surgical procedures. In present study, age group ranged from 18-60 years, mean age of study population was 34.85±12.08 years. Study involved 13 male and 27 female patients. Mean BMI of study population was 19.6±2.65 kg/m^2 which indicated weight distribution in the patient group.

Study involved 45% patients with BMI <18.5 kg/m^2, while 55% patients were with BMI between 18.6 to 24.99 kg/m^2.There were no over-weight patients (BMI > 25 kg/m^2) in the study. All patients of both sexes belonged to ASA-I category. Laparoscopic appendicectomy19 (47.5%), Laparoscopic cholecystectomy 15 (37.5%) were the major surgeries performed followed by Laparoscopic adhesiolysis and Laparoscopic APR in 2 (5%) patients each, Laparoscopic cyst aspiration and Laparoscopic gonadal vein ligation in one (2.5%) patient each. 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 1: Comparison of Mean etCO_2during pneumoperitoneum (mmHg) with Preinsufflation value

Interval	Mean etCO_2 (Mean ± S.D.)	Baseline etCO_2 (Mean ± S.D.)	Significance
Preinsufflation, n= 40	31.18±3.45	---	p>0.05, NS
Pneumoperitoneum			
5 min, n= 40	32.12±2.83	31.18±3.45	p<0.001,HS
10 min, n= 40	32.58±2.83	31.18±3.45	p<0.001, HS
20 min, n= 39	32.63±3.42	31.16±3.49	p<0.001, HS
30 min, n= 37	32.87±2.93	30.98±3.49	p<0.001, H.S
40 min, n= 29	32.90±3.19	31.11±3.48	p<0.001, HS
50 min, n= 22	32.82±3.78	30.67±3.73	p<0.05, S
60 min, n= 17	33.55±3.15	30.75±4.06	p<0.001, HS
90 min, n= 10	33.41±3.64	29.96±3.67	p<0.05, S
120 min, n= 7	32.87±2.97	28.44±3.93	p<0.05, S
150 min, n= 3	33.37±4.15	30.37±2.51	---
180 min, n =2	32.50±3.54	30.50±3.54	---
210 min, n= 1	36.00±0.00	33.00±0.00	---
Predesufflation, n=40	32.93±3.69	31.18±3.45	p<0.05, S

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

Duration of pneumoperitoneum varied in different patients in our study and affected the baseline value for mean etCO_2 at different time intervals. Mean preinsufflation etCO_2 was 31.18 ± 3.45 mmHg at time of sampling; it showed highly significant increase from baseline at 5, 10, 20, 30, and 40 min. of insufflation (p< 0.001). Again, at 60 min, mean etCO_2 increased highly significantly to 33.55 ± 3.14 mmHg from baseline (p <0.001). At 50, 90, 120 min change was significant (p <0.05). During rest of pneumoperitoneum we may not able to comment on significance of change in mean etCO_2 at time interval of 150, 180 and 210 min as only 3, 2 and 1 patients respectively, had this much period of pneumoperitoneum. etCO_2 showed a tendency to increase with duration of pneumoperitoneum. etCO_2 increased significantly at predesufflation arterial sampling time as compared to preinsufflation arterial sampling time. A total of 18 (45%) patients were in reverse trendelenburg position (head high) during procedure and 22 (55%) patients were in trendelenburg position (head low) during procedure.

Table 2: Comparison of changes in mean Arterial to end tidal CO_2gradient (mmHg) between preinsufflation and predesufflation value

	Pre-insufflation (P.I.) (Mean ± SD)	Predesufflation(P.D.) (Mean ± SD)	Change Mean ±SD (%)	p value
$PaCO_2$ (mmHg)	36.73±3.96	40.52±4.19	3.78±4.11 (10.32 %)	p <0.001 HS
etCO_2 (mmHg)	31.18±3.45	32.93±3.69	1.76±3.61 (5.61 %)	p <0.05 S
a-etCO_2 Gradient (mmHg)	5.55±2.07	7.58±2.11	2.03±1.35 (36.58 %)	p <0.001 HS

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

Highly significant (p<0.001) increase in mean $PaCO_2$ was seen during pneumoperitoneum as compared to preinsufflation value with a mean change of 3.78±4.11mmHg. Mean etCO_2 has shown significant change (p < 0.05) of 1.76 ± 3.61 during pneumoperitoneum from 32.93 ± 3.69 mmHg as compared to preinsufflation value of 31.18 ± 3.45 mmHg. Mean a-etCO_2 gradient changed highly significantly (p < 0.001) by 2.03 ± 1.35 mmHg during pneumoperitoneum as compared to before insufflation value. Mean a-etCO_2 gradient was 5.55 ±2.07 mmHg before pneumoperitoneum, which increased highly significantly to 7.58 ± 2.11 mmHg during pneumoperitoneum. In trendelenburg position, mean a-etCO_2 gradient was on higher side i.e.2.20 ± 1.51 mmHg as compared to 1.82 ± 1.51 mmHg in antitrendelenburg position, but this was not a significant difference statistically (p>0.05). Coefficient of correlation r = +0.6303, and p < 0.001, showed highly significant positive correlation between duration of pneumoperitoneum and a-etCO_2 gradient. Mean a-etCO_2 value showed persistently increasing trend with duration of pneumoperitoneum. The mean a-etCO_2 value was always above the baseline value of a-etCO_2 gradient, during pneumoperitoneum. No significant (p > 0.05) correlation was seen between I.A.P. and mean

change in a-etCO_2 gradient with pneumoperitoneum. The change in PaCO_2 has significant positive correlation with change in a-etCO_2 gradient and the change in etCO_2 does not have any significant correlation with change in a-etCO_2 gradient. No major hemodynamic or anaesthesia related complication encountered during operative procedure or pneumoperitoneum.

DISCUSSION

End-tidal carbon dioxide pressure(etCO_2) monitoring is increasingly used during anaesthesia as an indirect measure of PaCO_2. Routinely anaesthesiologists rely on etCO_2 monitoring for detection of hypercarbia. Value of a-etCO_2 depends on many factors including ventilation – perfusion distribution within lung (V/Q), changes in FRC and changes in CO_2 production (V_{CO2}). In many countries, etCO_2 monitoring has been made mandatory for laparoscopic surgeries. During laparoscopic surgery, Trendelenburg position together with peritoneal insufflation of CO_2 reduces FRC and increases V_{CO2}, and leads to changes in V/Q distribution due to basal lung compression and redistribution of hydrostatic forces. Thus, a-etCO_2 is expected to change further during laparoscopy. Many studies concluded that, a-etCO_2 gradient increased with pneumoperitoneum and etCO_2 measurements grossly underestimate PaCO_2 levels and are unreliable for ventilatory adjustments because of increased dead space ventilation secondary to V-Q mismatching.[4-7] In present study, we have analyzed a-etCO_2 gradient before and during CO_2 pneumoperitoneum and evaluated changes in it with pneumoperitoneum in laparoscopic surgeries. We also assessed correlation of a-etCO_2 gradient with duration of pneumoperitoneum, I.A.P., and patients positioning. To study a-etCO_2 gradient in present study, we analyzed arterial blood sample taken before CO_2 insufflation (preinsufflation sample) and just before CO_2 desufflation (predesufflation sample) for PaCO_2 and these values were compared with etCO_2 value at the time of arterial blood sampling. Arterial to end tidal carbon dioxide gradient calculated from this data. In present study, etCO_2 was monitored and maintained constantly between 30 to 40 mmHg during procedure, i.e. before and during CO_2 pneumoperitoneum by increasing respiratory rate and minute ventilation. It is well known fact that, CO_2 absorption and finally its elimination through lung during CO_2 pneumoperitoneum had persistently shown increase in CO_2 concentration in expired tidal volume. Studies have shown persistent increasing trend of etCO_2 value with duration of pneumoperitoneum[4,8,9] Other studies[10,11]found an increase in etCO_2 concentration maximum up to 40 to 60 min of pneumoperitoneum, and thereafter it becomes stable. Duration of pneumoperitoneum varied in different patients in our study. Mean etCO_2 values at any period represents only specific number of patients and not all the patients. In our study mean etCO_2 measurement showed increasing trend with duration of pneumoperitoneum but was not significant statistically. Some authors found increase in gradient[4-7] while others found no significant change in it[1,12-14] Preinsufflation values of a-etCO_2 gradients in our patients were similar to other studies[1,15-17]and increase in gradient with laparoscopy was only approximately 2.03 mmHg, but still highly significant ($p<0.001$) change from preinsufflation value. This increase in gradient may have occurred secondary to increase in dead space ventilation following CO_2 pneumoperitoneum and cephalad shift of diaphragm leading to decreased pulmonary compliance or decrease in cardiac output and resultant altered V-Q perfusion relationship. There were no negative values of gradient during laparoscopy among our patients. Several reports[18,19]have indicated that a-etCO_2 gradient has tendency to increase or to become unpredictable with time in prolonged laparoscopies and especially in patients with pulmonary disorders, where authors recommended radial artery cannulation and frequent blood gas analysis. In our study, 18 patients are in anti-Trendelenburg position and 22 patients in Trendelenburg position. Mean a-etCO_2 gradient was on higher side i.e. 2.20±1.51 mmHg with Trendelenburg position, as compared to 1.82±1.51 mmHg in anti-Trendelenburg position, which may have occurred because of more decrease in F.R.C. in Trendelenburg positioning, but this was not a significant difference statistically ($p>0.05$). Analysis of data indicates positioning of patient has minor but non-significant effects on a-etCO_2 gradient. Some other studies, where author studied effect of position on a-etCO2 gradient found that, different patient positioning during pneumoperitoneum does not affect a-etCO_2 gradient significantly.[4] Increase in mean a-etCO_2 gradient in our patients was 2.03 ± 1.35 mmHg (35%), this much increase was seen in healthy patients. Even higher increase in gradient is expected in patients with cardiac or pulmonary diseases; undergoing laparoscopy[6]. This makes ventilatory adjustments of these patients, based on etCO_2 measurements, difficult and at times dangerous retention of CO_2 with hazardous complications may occur.

CONCLUSION

Increase in a-etCO_2 gradient with pneumoperitoneum indicates loss of correlation between etCO_2 and PaCO_2 during pneumoperitoneum and thus etCO_2 is less accurate in reflecting PaCO_2. The loss of correlation between etCO_2 and PaCO_2 during laparoscopy may even be more exaggerated in patients with cardiovascular and

pulmonary diseases with significant anaesthetic implications.

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