A Prospective Observational Study: The Effects of Carbon Dioxide Pneumoperitoneum in Paediatric Laparoscopic Surgery

Dr. H N Madhusudana¹, Dr. Aditya Sapra², Dr. A B Tiwari*³

¹(Dept of Anaesthesiology) Air Force Hospital, Kanpur India: 208004
²(Head of Dept, Anaesthesiology) Air Force Hospital, Kanpur India: 208004
³(Sr Consultant Anaesthesiologist) Ghaziabad India: 201007

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ABSTRACT

Paediatric laparoscopic surgery is currently an established and the most preferred surgical technique owing to reduced morbidity, mortality and health care costs. The anaesthetic management is the most critical step in paediatric laparoscopic surgery, particularly owing to crowded viscera in a small space, high intra-abdominal pressure and higher vagal tone. These are also a critical determinants of cardiovascular stability in anesthesia. The other concerns are the effects on pulmonary and systemic vascular resistance and sudden severe bradycardia during creation of pneumoperitoneum. The present study is a prospective observational study conducted to quantify the effects of carbon dioxide pneumoperitoneum in paediatric laparoscopy. The parameters monitored are pulse oximetry, basal heart rate, blood pressure (automated NIBP), temperature, continuous electrocardiography, End tidal carbon dioxide pressure, airway pressure, pH of blood and Partial pressure of carbon dioxide in venous blood.

Key words: Arterial Oxygen Saturation(SpO₂)–Intra-abdominal pressure(IAP)–Systemic vascular resistance(SVR)–End tidal carbon-dioxide(EtCO₂)–Partial pressure of venous carbon-dioxide(PvCO₂)–Arterial Blood Gas(ABG) and Hydrogen Ion Concentration (pH).

1 INTRODUCTION

Gaskin TA et al had a genuine future prediction of developments in video-controlled operations i.e. laparoscopy. [1] Controlled intra-abdominal pressure (IAP) within the abdominal cavity is used to facilitate smooth operation by raising the anterior abdominal wall up and suppressing the other abdominal organs and soft tissues of the back. Georg Kelling first described this technique of establishing pneumoperitoneum, which was then named after him celioscopy. [2] The first clinical laparoscopic surgery performed on human in Stockholm was reported by Hans Christian Jacobaeus in 1910, who pioneered the laparoscopy and thoracoscopy. [3] With the introduction of insufflator by Goetze(1921) and later development of a spring loaded insufflation needle for the safe introduction of gas into the abdomen by Later Janos Veress of Hungary, the creation of pneumoperitoneum become an ease. Richard Zollikofer, a Swiss gynaecologist, was one of the first to recognize the benefits of using carbon dioxide to create pneumoperitoneum and introduced in 1924. [4] However, invention of automatic CO2 insufflator by Kurt Karl Stephan Semm opened a new chapter in operative laparoscopy. [5] Stephen Gans opened the new chapter of paediatric laparoscopy by publishing the first case report on paediatric laparoscopy.

He termed it peritoneoscopy in his landmark publication “Advances in Endoscopy of Infants and Children”. [6] The paediatric laparoscopic surgery is now an established and most preferred surgical technique due to reduced morbidity, mortality and health care costs. [7] A laparoscopic approach reduces the surgical stress, fluid shifts and need for postoperative analgesia. There are additional advantages are reduced respiratory and wound complications and decreased overall hospital stay. [8] The ideal gas for insufflation of the abdominal cavity should be cheap, non-sparking, colourless, non-flammable, non-inexplosive, increase the working
and viewing space, easily removed from the body, minimal effect after embolization, completely non-toxic and highly soluble in blood. [9] The Cochrane Database of Systematic Reviews 2017, published a variable result on gases used to create pneumoperitoneum. [10] Though helium, argon, krypton and xenon meet the most criteria of an ideal gas for pneumoperitoneum, but these are very expensive and have a very low blood gas solubility (0.00018). [11] Carbon dioxide pneumo-peritoneum is the hallmark of laparoscopy, because of its cost very, being relatively inert, non-sparking, non-flammable and in abundance in the body that diffuses and decomposes easily. It does not pose a risk of embolism, since that its elimination from the body via the lungs physiological. However longer laparoscopic procedures with carbon dioxide may lead to peritoneal irritation and postoperative pain. Though, laparoscopic surgery has several advantages over conventional surgery, but is associated with several systemic adverse effects. The cardiovascular adverse effects are increase in pulmonary and systemic vascular resistance, sudden bradycardia during pneumoperitoneum with blow-up of in gas, penetration by trocars and laparoscopes and even by raised intra abdominal pressure(IAP). [12] This can be minimised by limiting the IAP to 6mmhg in infants and to 12mmHg. [13] The reduced diaphragmatic excursion, reduced thoracic compliance & functional residual capacity; early closure of smaller airways and increased peak airway pressures have adverse pulmonary effects, resulting into significant ventilation perfusion mismatch. There may be carbon dioxide embolism, increased bronchial secretion and atelectasis. [14] The carbon dioxide pneumoperitoneum has several other systemic effects such as rise in ICP and CBF, risk of regurgitation, venous stasis, reduction in splanchic, hepatic, and renal blood flow, oliguria, metabolic acidosis and increase in the plasma concentrations of catecholamines, cortisol, insulin, epinephrine, prolactin, growth hormone, and glucose levels. [15] When absorbed in large amount can lead to respiratory acidosis and cardiac arrhythmias. [16, 17] The surgical concern is crowding of viscera in a small space and risk of injury to umbilical vessels, stomach and bladder puncture, thus limiting the access of periumbilical area for port. [15, 18]

The present, prospective study was designed to quantify the haemodynamics, pH and partial pressure of venous carbon dioxide changes in paediatric patients undergoing laparoscopic surgery.

2 MATERIAL & METHOD

After permission from Hospital Ethics Committee, 60 paediatric patients in ASA Grade I / II, scheduled to undergo elective laparoscopic abdominal surgery under general anaesthesia were enrolled in study. All the patient listed were aged below 05 years and weighing less than 20 kg. The patient selected were exposed to standard anaesthesia practice. They had been premedicated with midazolam 0.10 mg/kg intravenous and fentanyl 02 μg/kg. They were induced with propofol 2.0–2.5 mg/kg and endotracheal intubation and muscle relaxation was facilitated with vecuronium 0.1 mg/kg with an appropriate size of an endotracheal tube. Anaesthesia was maintained with oxygen, nitrous oxide, and sevoflurane (0.8%–1.2%). Patients were mechanically ventilated using oxygen and nitrous oxide, end-tidal CO2 was maintained below 30–35 mmHg. The parameters recorded and compiled for study were pulse oximetry, basal heart rate, blood pressure (automated NIBP), temperature, continuous ECG, EtCO2, airway pressure, arterial blood gas and Pvo2 of blood. The parameters were recorded i) at induction to serve as a basal parameter ii) at start with creation of pneumoperitoneum, iii) at end of surgery and iii) post-operatively. The effects of CO2 pneumoperitoneum was statistically analysed. Data variables were expressed as mean ± standard deviation. Student’s t-test and Chi-square test were applied to compare different variables. P < 0.05 was considered statistically significant. The statistical analysis was done using IBM SPSS (Statistical Package for the Social Sciences) Statistics for Mac version: Statistics Standard 22.

3 RESULT

All patients included in present study had identical demographic distribution with respect to their age, height, weight and gender. Table 1

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Distribution (n=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Yrs.)</td>
<td>2.92± 1.09</td>
</tr>
<tr>
<td>Sex</td>
<td>Male 40/66.6%</td>
</tr>
<tr>
<td></td>
<td>Female 20/34.3%</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>12.58 ± 1.84</td>
</tr>
<tr>
<td></td>
<td>Herniectomy 28</td>
</tr>
<tr>
<td></td>
<td>Orchidopexy 25</td>
</tr>
<tr>
<td></td>
<td>Nephrectomy 04</td>
</tr>
<tr>
<td></td>
<td>Splenectomy 03</td>
</tr>
</tbody>
</table>

The common paediatric laparoscopic surgical procedures done were herniotomy, orchidopexy nephrectomy and splenectomy. The pre-induction parameters recorded as basal parameters were within a normal limit. These parameters were heart rate, SpO2, systolic blood pressure, diastolic blood pressure, EtCO2, Pvo2, peak inspiratory pressure (PIP) cm H2O and arterial blood gas(ABG).Table 2

The vital parameters recorded after creation of pneumoperitoneum at start of surgery were excessively noticeable. There was statistically significant rise in heart rate, systolic blood pressure, end tidal carbon dioxide level and mixed venous carbon dioxide pressure (p-value < 0.05). There was a significant rise in peak inspiratory pressure. The arterial blood gas has a significant rise in partial pressure of carbon dioxide and serum bicarbonate level. There was a fall in pH and rise in serum lactate level but these were statistically not significant. The changes in rest of haemodynamic and arterial blood gas parameters were not significant. Tables 2, 3, 6 and 7

The vital parameters recorded immediately at the end of surgery also has similar changes as compared to basal value, except the rise in heart rate was statistically not significant. There was a significant rise in systolic blood pressure, end tidal carbon dioxide, partial pressure of mixed venous carbon dioxide and peak inspiratory pressure. Similarly, there was significant rise in partial pressure of carbon dioxide and serum bicarbonate level in arterial blood gas analysis. The changes in rest of the haemodynamic and arterial blood gas parameters were not significant. Tables 2, 4, 6 and 7

The changes in haemodynamic parameters and arterial blood gas recorded post-operatively were identical and statistically not significant. Tables 2, 5, 6 and 7

4 DISCUSSION
This was an observational study conducted to quantify the effects of carbon dioxide pneumoperitoneum in paediatric laparoscopy. Paediatric laparoscopic surgery, a minimal access surgery is now accountable for great majority of surgical procedures in infants and young children owing to inherent safety and cost effectiveness. [8] However, laparoscopic surgery has got inherent limitations owing to crowding of viscus in small space and restricted access of periumbilical area for port. The laparoscopic procedure in paediatric age group is further associated with hemodynamic alterations, raised intra-abdominal pressure and an alteration in arterial blood gas following absorption of carbon dioxide and circulatory pressure changes. [19]

The observations showed that there was significant difference in haemodynamics and arterial blood gas study in patients when compared to their basal values at creation.
of pneumoperitoneum and at the end of surgery but these parameters returned to their basal values in post-operative period. At any time during the course of pneumoperitoneum the intra-abdominal pressure was never allowed to go beyond 12 mm of Hg. Several studies have revealed that pneumoperitoneum results in elevated intra-abdominal pressure and shifts the diaphragm upwards. The intrathoracic pressure increases, the abdominal part of the chest wall stiffens and expansion of the lungs is restricted. This is followed by a significant decrease up to 50% in pulmonary dynamic compliance and an increase in peak and plateau airway pressures [20, 21] There was significant tachycardia, rise in systolic blood pressure, end tidal carbon dioxide level and mixed venous carbon dioxide pressure at the creation of pneumoperitoneum. The cardiovascular changes occurring during laparoscopic procedure are because of both mechanical and chemical effects of CO₂-induced pneumoperitoneum, results into significant tachycardia and rise of systemic vascular resistance, the effect have been ascribed to raised catecholamine release and mechanical effects of pneumoperitoneum. [22, 23]. Joris et al. using invasive monitoring, observed a significant increase in mean arterial pressure (35%) after peritoneal insufflations, along with an increase of systemic vascular resistance (65%). [24] Branche et al. observed a 25.7% increase in mean arterial pressure, a 49% increase in left ventricular end-systolic wall stress. [25] De Waal observed a 21% increase in mean arterial pressure and a 17% increase in heart rate. [26] Pelsis et al observed a rise in end tidal carbon dioxide and mixed venous carbon dioxide that closely co-related with rise in PaCO₂, following carbon dioxide insufflation. [27] Mullett et al observed a continued increase in mixed venous carbon dioxide and end tidal carbon dioxide throughout the CO₂ insufflation during creation of carbon dioxide pneumoperitoneum. [28] The fall in pH along with a rise in EtCO₂ and a corresponding rise in PvCO₂ was in consistent with the animal model study in pH along with a rise in EtCO₂ and a corresponding rise creation of carbon dioxide pneumoperitoneum. [28] The fall tidal carbon dioxide throughout the CO₂ insufflation during continued increase in mixed venous carbon dioxide and end carbon dioxide insufflation. [27] Mullett et al observed a dioxide that closely co-related with rise in PaCO₂, followed rise in end tidal carbon dioxide and mixed venous carbon dioxide pressure at the creation of pneumoperitoneum. [30, 31] Wittgen et al also observed in patients with normal cardio-respiratory system had increased EtCO₂, PvCO₂ and decreased pH in laparoscopic surgery. [32] Mutetwa et al observed a significant elevation in PaCO₂ (p<0.001) and a fall in pH (p <0.001), rise in ion bicarbonate (HCO₃-) (p = 0.011), and base excess (ABE) (p <0.001), consistent with the rise in EtCO₂ and PaCO₂ during pneumoperitoneum. [33] Postoperatively, all parameters were identical to pre-induction values and statically the changes were non-significant.

### 5 CONCLUSION

The study concludes that haemodynamic changes (heart rate, systolic and diastolic blood pressure), ventilatory pressure dynamics, carbon dioxide pneumoperitoneum are consistent with paediatric laparoscopy. These parameters can be managed and kept within physiological limits by limiting the depth of anaesthesia, optimal analgesia, control of intra-abdominal pressure to a maximum of 12cm H2O, optimal tidal volume, by judicious increase of peak inspiratory pressure to about 5-8 cm H2O and increased rate of ventilation. The maintenance of these parameters, within the physiological limits, prevents significant clinical changes in haemodynamics and pH due to hypercarbia and acidosis.

### REFERENCES


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Table 6. Peri-Operative Comparative Vital Parameters (P-Value)

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Parameters (p-value)</th>
<th>Heart Rate</th>
<th>Blood Pressure</th>
<th>SpO₂</th>
<th>EtCO₂</th>
<th>pH</th>
<th>PvCO₂</th>
<th>PIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>After Creation of Pneumoperitoneum</td>
<td>0.017</td>
<td>0.005</td>
<td>0.437</td>
<td>1.000</td>
<td>0.002</td>
<td>1.000</td>
<td>0.001</td>
<td>0.012</td>
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<tr>
<td>At End of surgery</td>
<td>0.385</td>
<td>0.003</td>
<td>1.000</td>
<td>1.000</td>
<td>0.005</td>
<td>1.000</td>
<td>0.020</td>
<td>0.104</td>
</tr>
<tr>
<td>Post-operatively</td>
<td>0.064</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table 7. Peri-Operative Arterial Blood Gas Statistical Significance

<table>
<thead>
<tr>
<th>Variables at</th>
<th>Arterial Blood Gas</th>
<th>pH</th>
<th>PaO₂</th>
<th>O₂ saturation</th>
<th>PaCO₂</th>
<th>HCO₃⁻</th>
<th>BE</th>
<th>Lactate</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Pneumoperitoneum</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.003</td>
<td>0.002</td>
<td>1.000</td>
<td>0.066</td>
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<tr>
<td>At the end of Surgery</td>
<td>1.000</td>
<td>0.788</td>
<td>0.698</td>
<td>0.002</td>
<td>0.031</td>
<td>1.000</td>
<td>0.101</td>
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<tr>
<td>At Post-operative</td>
<td>1.000</td>
<td>0.943</td>
<td>0.937</td>
<td>0.318</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>

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33. Mutetwa EN, Shumbairerwa S, Crawford, Madzimbamuto, Chimova T, Morang-Chikuni D. Metabolic effects of Carbon Dioxide (CO2) insufflation during laparoscopic surgery: changes in pH, arterial partial Pressure of Carbon Dioxide (PaCO2) and End Tidal Carbon Dioxide (EtCO2). Cent Afr J Med. 2015 Sep-Dec;61(9-12):61-5.