



# Influence of laparoscopic carbon dioxide pneumoperitoneum on neonate circulation and respiration

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## Abstract

**Objective:** This study investigated the influence of laparoscopic carbon dioxide (CO<sub>2</sub>) pneumoperitoneum on neonate circulation and respiration.

**Methods:** The study included neonates undergoing elective laparoscopic abdominal surgery. CO<sub>2</sub> insufflation pressure was maintained within 8–14 mmHg for pneumoperitoneum creation. Heart rate (HR), mean arterial pressure (MAP), peripheral oxygen saturation (SpO<sub>2</sub>), partial pressure of end-tidal carbon dioxide (P<sub>ET</sub>CO<sub>2</sub>) and maximum inspiratory pressure were monitored continuously. Arterial blood samples were collected: 5 min before pneumoperitoneum creation (baseline); 5, 10, and 20 min after CO<sub>2</sub> insufflation; 10 min after CO<sub>2</sub> exsufflation; 10 min after surgery. pH, partial pressure of CO<sub>2</sub> (PaCO<sub>2</sub>) and arterial oxygen saturation (SaO<sub>2</sub>) were also measured.

**Results:** Thirty-six neonates were included. HR and MAP significantly increased after pneumoperitoneum creation, then decreased to baseline after CO<sub>2</sub> exsufflation. PaCO<sub>2</sub> and P<sub>ET</sub>CO<sub>2</sub> were significantly higher after pneumoperitoneum creation, whereas pH was significantly lower 20 min after pneumoperitoneum creation compared with baseline. No significant differences were observed in SpO<sub>2</sub> and SaO<sub>2</sub>.

**Conclusion:** CO<sub>2</sub> pneumoperitoneum had a significant effect on neonatal circulation and respiration, suggesting that the pneumoperitoneal pressure should be limited within a certain range in neonates undergoing laparoscopic surgery.

## Keywords

Neonate, laparoscopy, circulation, respiration

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## Introduction

Laparoscopic surgery provides several advantages compared with open surgical procedures: it results in only minor surgical trauma; the anaesthetic and operative procedures usually have a better safety profile; patients experience shorter postoperative recovery periods and hospital stays; patients usually have lower levels of postoperative pain.<sup>1</sup> Thus, laparoscopic surgery is widely used in clinical practice.<sup>2-4</sup> However, carbon dioxide (CO<sub>2</sub>) pneumoperitoneum interferes with the circulation and respiration during laparoscopic surgery.<sup>5</sup> Given that neonates have a different anatomy, physiology, and pharmacology from children,<sup>6</sup> the procedures used and the effects of anaesthesia in neonates are more varied and challenging, limiting the exploration of laparoscopic surgery in neonates.<sup>7</sup> This current study was designed to observe the influence of laparoscopic CO<sub>2</sub> pneumoperitoneum on circulation and respiration, as well as to explore the safety of anaesthesia, in neonates during laparoscopic surgery.

## Patients and methods

### *Patient population*

This study sequentially recruited neonates undergoing elective laparoscopic abdominal surgery at the Department of Anaesthesiology, The First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan Province, China between January 2010 and December 2012. The indication for surgery was either hypertrophic pyloric stenosis or laparoscopic-assisted Hirschsprung's disease. All patients were of American Society of Anesthesiologists physical status levels 1–2. No other cardiovascular, respiratory, hepatic or renal diseases were found in the patients. Moreover, no patient had evident electrolyte imbalance. Age, sex and body weight were recorded for each neonate.

This study was conducted in accordance with the Declaration of Helsinki and with the approval of the Ethics Committee of The First Affiliated Hospital of Zhengzhou University. Written informed consent was obtained from the parent(s) or legal guardian(s) of all participants.

### *Anaesthetic and surgical procedures*

All patients were kept nil by mouth for 4 h before anaesthesia induction. Premedication included intramuscular injection of 0.01 mg/kg atropine and 10 mg vitamin K<sub>1</sub>. Anaesthesia was induced with an intravenous injection of 2 mg/kg ketamine, 1–2 mg/kg propofol, and 0.05–0.1 mg/kg vecuronium (a muscle relaxant). After tracheal intubation, the patients were mechanically ventilated (tidal volume [ $V_T$ ] = 6–7 ml/kg; inspiration time:expiration time = 1 : 1.5). The respiratory rate was adjusted to maintain the partial pressure of end-tidal carbon dioxide ( $P_{ET}CO_2$ ) at 35–45 mmHg without the use of positive-end-expiratory pressure. The CO<sub>2</sub> insufflation pressure was kept within 8–14 mmHg. Radial or femoral artery catheterization was performed for invasive blood-pressure monitoring. During the operation, anaesthesia was maintained with an intravenous injection of 6–9 mg/kg propofol and 1% sevoflurane inhalation. After surgery, extubation was performed after recovery of the throat reflex, suction and adequate ventilation.

All surgical procedures were undertaken with the neonates in the supine position. All surgical procedures were performed by Dr Jia-Xiang Wang and an assistant, from the Department of Paediatric Surgery, The First Affiliated Hospital of Zhengzhou University. A 3 mm-long umbilical incision was made and the laparoscope was inserted into the incision. A CO<sub>2</sub> pneumoperitoneum was created by the open method. The insufflation pressure was maintained within 8–14 mmHg. Two other trochars were

inserted, based on need. After the laparoscope was withdrawn, the residual CO<sub>2</sub> was evacuated (i.e. exsufflated).

### Patient monitoring

A Dräger Primus® anaesthesia machine (Dräger, Lübeck, Germany) and a Philips IntelliVue MP60 monitor (Philips, Andover, MA, USA) were used during the operation. Heart rate (HR), mean arterial pressure (MAP), electrocardiogram, peripheral oxygen saturation (SpO<sub>2</sub>),  $P_{ET}CO_2$  and maximum inspiratory pressure were monitored continuously. Arterial blood samples were collected at the following timepoints: 5 min before pneumoperitoneum creation (baseline); 5, 10, and 20 min after CO<sub>2</sub> was insufflated; 10 min after CO<sub>2</sub> was exsufflated; 10 min after surgery. Blood samples were mixed with heparin (2–3 IU/ml) and used immediately for analysis. The pH, partial pressure of CO<sub>2</sub> (PaCO<sub>2</sub>) and arterial oxygen saturation (SaO<sub>2</sub>) of the blood were measured at the above timepoints using a blood gas analyser (ABL800 FLEX; Radiometer Medical, Brønshøj, Denmark).

### Statistical analyses

All data were expressed as the mean  $\pm$  SD. All statistical analyses were performed using the SPSS® statistical package, version 13.0 (SPSS Inc., Chicago, IL, USA) for Windows®. Comparisons with the baseline values were made using Student's *t*-test. A *P*-value < 0.05 was considered statistically significant.

### Results

A total of 36 neonates undergoing elective laparoscopic abdominal surgery were included in the study, with a mean  $\pm$  SD age of  $24 \pm 6$  days (range 1–28 days) and a mean  $\pm$  SD body weight of  $3.4 \pm 1.2$  kg (range 2.7–3.8 kg). The indication for

surgery was hypertrophic pyloric stenosis in 10 cases and laparoscopic-assisted Hirschsprung's disease in 26 cases.

The HR and MAP significantly increased 5, 10, and 20 min after pneumoperitoneum creation compared with the baseline value ( $P < 0.05$  for all comparisons), then both HR and MAP decreased to the baseline values 10 min after the pneumoperitoneum was exsufflated (Table 1). PaCO<sub>2</sub> and  $P_{ET}CO_2$  were significantly higher at 5, 10, and 20 min after pneumoperitoneum creation compared with the baseline value ( $P < 0.05$  for all comparisons), whereas the pH was significantly lower than the baseline value at 20 min after pneumoperitoneum creation ( $P < 0.05$ ). No significant changes were observed for SpO<sub>2</sub> and SaO<sub>2</sub> at any time-points after pneumoperitoneum creation.

### Discussion

Compared with laparotomy, which involves a large incision through the abdominal wall, laparoscopic surgery provides many advantages. For example, surgical trauma is usually reduced, postoperative pain is eased, the surgical field of view is clearer, postoperative bowel function resumes earlier and abdominal adhesions are reduced.<sup>1</sup> Therefore, laparoscopic surgery is a better option for neonatal abdominal surgery.<sup>8</sup>

During a laparoscopic procedure, increased CO<sub>2</sub> pneumoperitoneum, intra-abdominal pressure and CO<sub>2</sub> absorption may increase PaCO<sub>2</sub>, which can induce a number of pathophysiological changes.<sup>9</sup> First, lung compliance decreases and substantial changes in the haemodynamics ensue.<sup>10</sup> Secondly, a series of stress reactions is induced, manifested by a stimulated sympathetic system and the release of catecholamine.<sup>11</sup> The present study showed that, during laparoscopic pneumoperitoneum, a number of indicators in neonates were significantly changed, compared with the

**Table 1.** Respiratory, circulatory and blood-gas changes before and after carbon dioxide pneumoperitoneum in neonates undergoing elective laparoscopic abdominal surgery (n = 36).

| Parameter                              | Baseline   | After pneumoperitoneum  |                         |                         | After exsufflation<br>10 min | After surgery<br>10 min |
|----------------------------------------|------------|-------------------------|-------------------------|-------------------------|------------------------------|-------------------------|
|                                        |            | 5 min                   | 10 min                  | 20 min                  |                              |                         |
| HR, beats per min                      | 126 ± 10   | 153 ± 10 <sup>a</sup>   | 159 ± 10 <sup>a</sup>   | 148 ± 10 <sup>a</sup>   | 133 ± 10                     | 131 ± 9                 |
| MAP, mmHg                              | 57 ± 7     | 77 ± 8 <sup>a</sup>     | 80 ± 8 <sup>a</sup>     | 78 ± 8 <sup>a</sup>     | 61 ± 8                       | 59 ± 6                  |
| SpO <sub>2</sub> , %                   | 98 ± 4     | 98 ± 3                  | 97 ± 4                  | 96 ± 6                  | 98 ± 8                       | 98 ± 6                  |
| PaCO <sub>2</sub> , mmHg               | 37.2 ± 1.7 | 40.6 ± 1.7 <sup>a</sup> | 41.9 ± 1.8 <sup>a</sup> | 45.4 ± 1.8 <sup>a</sup> | 38.8 ± 1.9                   | 38.6 ± 1.9              |
| P <sub>ET</sub> CO <sub>2</sub> , mmHg | 34 ± 6     | 38 ± 5 <sup>a</sup>     | 39 ± 6 <sup>a</sup>     | 40 ± 7 <sup>a</sup>     | 35 ± 5                       | 34 ± 4                  |
| pH                                     | 7.4 ± 0.4  | 7.4 ± 0.3               | 7.4 ± 0.5               | 7.3 ± 0.6 <sup>a</sup>  | 7.3 ± 1.0 <sup>a</sup>       | 7.4 ± 0.4 <sup>a</sup>  |
| SaO <sub>2</sub> , %                   | 99.9 ± 0.4 | 99.8 ± 0.5              | 99.7 ± 0.3              | 99.6 ± 0.5              | 99.8 ± 0.4                   | 99.8 ± 0.6              |

Data presented as mean ± SD.  
<sup>a</sup>P < 0.05 compared with baseline values (i.e. the value monitored 5 min before pneumoperitoneum creation); Student's t-test.  
HR, heart rate; MAP, mean arterial pressure; SpO<sub>2</sub>, peripheral oxygen saturation; PaCO<sub>2</sub>, partial pressure of carbon dioxide; P<sub>ET</sub>CO<sub>2</sub>, partial pressure of end-tidal carbon dioxide; SaO<sub>2</sub>, arterial oxygen saturation.

baseline value. Sustained abdominal hypertension may also cause diaphragmatic hernia, perforation of the diaphragm, pneumothorax, subcutaneous and mediastinal emphysema, as well as other complications.<sup>12</sup> A small abdominal pressure has minimal effects on respiration and circulation. Thus, the abdominal pressure was maintained within 8–14 mmHg in the present study. The surgeon was requested to operate cautiously, to avoid repeated pneumoperitoneum needle punctures. Muscle relaxants can decrease the intra-abdominal pressure, increase the abdominal capacity and accommodate a high volume of CO<sub>2</sub> at low abdominal pressure. Consequently, the surgical field exposure increases and the side-effects of the pneumoperitoneum decrease.<sup>13</sup>

Few reports have been published on the effects of laparoscopic surgery on neonatal respiration.<sup>12–14</sup> During laparoscopic surgery, CO<sub>2</sub> pneumoperitoneum causes CO<sub>2</sub> to be absorbed into the circulation. The pushed-up diaphragm decreases the lung capacity and functional residual capacity.<sup>15</sup> These factors lead to hypercapnia.<sup>16</sup> Given that the neonatal respiratory system is not

completely developed, the functional residual capacity is small and the closed volume level is high. Therefore, their respiratory reserve capacity is small and the neonate can easily develop hypoxia.<sup>17</sup> In this current study, the V<sub>T</sub> and respiratory rate were adjusted using pure oxygen based on the neonatal physiology. SaO<sub>2</sub> did not change significantly, whereas P<sub>ET</sub>CO<sub>2</sub> increased and pH decreased significantly after pneumoperitoneum creation.

During pneumoperitoneum creation, the cardiovascular responses of neonates are complex.<sup>18</sup> Systemic vascular resistance increases because of the increased intra-abdominal pressure. The afterload increases and the ventricular function curve shifts to the right side. Venous return decreases because of increased systemic pressure. All these factors lead to decreased cardiac output.<sup>19</sup> Neonatal cardiac compliance is worse than that of adults and systolic efficiency is lower in the neonatal than in the adult myocardium.<sup>18</sup> Moreover, the Frank–Starling mechanism is not evident.<sup>20</sup> Therefore, the HR must increase to maintain cardiac output.<sup>20</sup> The blood pressure increases because of the increased intra-

abdominal pressure or increased  $\text{PaCO}_2$ , which causes systemic vascular resistance to increase.<sup>21</sup>

In this current study, the inflation pressure was limited within 8–14 mmHg during laparoscopic surgery.  $\text{PaCO}_2$  increased significantly after pneumoperitoneum creation. Respiratory and circulatory functions had varied maxima within 10 min and  $P_{\text{ETCO}_2}$  decreased to the baseline after  $\text{CO}_2$  was exsufflated. No hypoxaemia was observed throughout the entire process. Therefore, adequate preoperative preparation (correction of acidosis and electrolyte balance), restriction of abdominal pressure within a low range, strengthening of intraoperative monitoring and proper adjustment of respiratory and circulatory indicators during anaesthesia are vital, to ensure safe anaesthesia during neonatal laparoscopic surgery.

### Declaration of conflicting interest

The authors declare that there are no conflicts of interest.

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