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The cardiorespiratory effects of laparoscopic procedures in infants

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Summary

We assessed the cardiorespiratory effects of laparoscopic procedures in 27 infants aged between 36 and 365 days. Infants were monitored and anaesthetised in a standardised manner. Heart rate, mean arterial pressure, end-tidal carbon dioxide and oxygen saturation were recorded, and blood gases were measured at 5 min after intubation, 15 and 30 min after carbon dioxide pneumoperitoneum, 5 min after desufflation and after extubation. The pH, P_aO_2, base excess, S_aO_2 and S_pO_2 decreased, and PCO_2 increased by insufflation of carbon dioxide intraperitoneally, and improved following deflation. Changes in pH and P_aO_2 during the study were statistically significant ($p < 0.0001$). The increase in P_aCO_2 30 min after pneumoperitoneum was statistically significant when compared with initial values. Transient arrhythmias were observed in 10 infants 1 min after pneumoperitoneum. There were no statistically significant alterations in heart rate and systolic blood pressure.

Keywords *Surgery*; laparoscopy, paediatric. *Complications*; cardiorespiratory.

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Recent technological advances have led to a surge of interest in minimally invasive procedures. Paediatric surgeons have been involved with this technique since the early 1970s. With the success of laparoscopy, the demands and applicability of this technique in children have been increasing [1]. As a result, paediatric anaesthetists are facing increasing numbers of children requiring anaesthesia during laparoscopy. Despite the benefits of laparoscopy, insufflation of carbon dioxide causes intra-operative ventilatory and haemodynamic changes [2–4]. Data on the effects of laparoscopy in infants are limited [5, 6].

The purposes of this study were to investigate respiratory changes, to ascertain the complications of pneumoperitoneum in infants, and to clarify the safety of the procedure from an anaesthetist's perspective.

Methods

Following institutional approval and informed consent from parents, 36 infants with various diagnoses have undergone elective laparoscopic procedures under general anaesthesia in the Department of Pediatric Surgery, Istanbul University Cerrahpasa Medical Faculty since 1992.

Twenty-seven of these patients, whose ages ranged between 36 and 365 days [mean (SD) = 116.8 (89.8) days], ASA physical status I–III, weighing 2.7–13 kg [5.71 (2.77) kg], were monitored and anaesthetised in a standardised manner.

No infant received premedication and all fasted for at least 4 h before operation. Anaesthesia was induced with 2% halothane or 2.5% isoflurane in 50% oxygen. Tracheal intubation was facilitated by atracurium 0.5 $mg.kg^{-1}$ and muscle relaxation was maintained with additional doses throughout the procedure. Morphine 0.1 $mg.kg^{-1}$ was given intravenously and anaesthesia was maintained using an air/oxygen mixture to achieve an inspired oxygen concentration of $\approx 50\%$ and up to 1% halothane or 1.5% isoflurane given via a Jackson Rees system. The fresh gas flow rate was 4 $l.min^{-1}$ and infants were ventilated manually by the same anaesthetist throughout the laparoscopy at a respiratory rate of ≈ 20.

The patients were monitored by electrocardiogram. Blood pressure was measured noninvasively during the awake state and following intubation, an arterial cannula was placed in the radial artery for invasive blood pressure monitoring and sampling of arterial blood gases. The end-tidal carbon dioxide ($F_{E'}CO_2$) was monitored (Criticare 1100) in eight infants with the tube sampling located between the tracheal tube adaptor and the breathing system.

Peritoneal insufflation was performed with a 7204 Wisap CO_2-Pneu insufflator. Intra-abdominal pressure was not permitted to rise above 10 mmHg. All patients were placed in the supine position and a maximum of 10° Trendelenburg ($n = 2$) or 30° head-up (Fowler) ($n = 4$) position allowed.

At the end of surgery, neuromuscular blockade was reversed by atropine 0.01 $mg.kg^{-1}$ and neostigmine 0.02 $mg.kg^{-1}$. Patients were extubated and oxygen was given via a mask. Full monitoring continued into the early postoperative period.

Arterial blood samples were obtained 5 min after intubation (t_0), 15 min (t_1) and 30 min (t_2) after carbon dioxide insufflation, 5 min after desufflation (t_3) and after extubation (t_4). Samples were analysed using the Ciba Corning 860 blood gas analyser. Any changes in cardiac rhythm were recorded.

Statistical analysis

Results are expressed as mean (SD). Repeated measures ANOVA and the Dunnett multiple comparison test were used for statistical analysis. A p-value < 0.05 was considered significant.

Results

Demographic data for the infants are listed in Table 1. Two of the infants were born prematurely at 30 and 32 weeks gestational age (46 and 52 weeks postconceptual age at the time of laparoscopy, respectively). One infant had a history of congenital heart insufficiency and sepsis at birth and had been in the intensive care unit for a month, another infant had been in the intensive care unit because of convulsions during early infancy.

Respiratory parameters

Seven of the infants had mild metabolic acidosis at the start of the study. The pH, P_aO_2, S_aO_2 and S_pO_2 decreased, and P_aCO_2 increased by insufflation of carbon dioxide intraperitoneally, and improved following deflation. The changes in base excess and bicarbonate were minimal, statistically and clinically insignificant. The changes in pH and P_aO_2 during the study were statistically significant ($p < 0.0001$ with repeated measurements ANOVA). The increase in P_aCO_2 at 30 min after pneumoperitoneum was statistically significant when compared with values obtained 5 min after intubation (t_0) (Table 2). An infant with primary biliary atresia (PBA) and prior bronchopneumonia showed persistent hypercapnia following desufflation. Another infant with PBA had an S_pO_2 of 92% when awake but better S_pO_2 values during laparoscopy. S_pO_2 decrease (lowest 90%) was observed in an infant with pyloric stenosis when intra-abdominal pressure (IAP) rose to 10 mmHg.

Table 1 Demographic characteristics. Results are presented as mean (SD) and [range] or number.

Age; days	116.8 (89.8)	36–365
Weight; kg	5.71 (2.77)	2.7–13
M:F	15:12	
ASA physical scores	I 8	
	II 16	
	III 3	
Duration of anaesthesia; min	142.5 (112.33)	30–400
Duration of CO_2 insuflation; min	35 (12.48)	25–65
Indications		
Evaluation of primary biliary atresia	13	
Choledochal cyst	3	
Impalpable undescendent testis	4	
Ovarian cyst	2	
Pyloric stenosis	1	
Hydatid cyst	1	
Neuroblastoma	1	
Hepatoblastoma	1	
Duplication cyst	1	
Procedures		
Lap. Cholangiography + Lap. Biopsy	6	
Lap. Cholangiography + Kasai procedure	7	
Lap. Cholangiography + Lap. Cyst resection	1	
Laparoscopic exploration	4	
Lap. resection of ovarian cyst	2	
Lap. Pyloromyotomia	1	
Lap. Cystic drainage	1	
Lap. Biopsy	3	

Hemodynamic parameters

Transient tachycardia (heart rate increased 20% above the awake recording) was observed in four infants, and transient bradycardia (heart rate decreased 20% below the awake recording) in six infants, 1 min after pneumoperitoneum. There were no statistically significant changes in heart rate and systolic blood pressures (Table 3).

Discussion

Laparoscopic surgery introduces new problems, mainly due to physiological changes produced by the patient's position and the pneumoperitoneum [2–5, 7]. Although sufficient data are not yet available, the respiratory and cardiac alterations in children were supposed to be similar to, or slightly more than, those seen in adults [6, 8].

Several factors are responsible for hypercarbia during laparoscopy following carbon dioxide insufflation,

Table 2 Results of blood gases. Results are expressed as mean (SD)

	t_0	t_1	t_2	t_3	t_4
pH	7.41 (0.1)*	7.36 (0.1)†	7.34 (0.1)‡	7.36 (0.1)†	7.35 (0.1)†
P_aCO_2; mmHg	30.7 (7.5)	35.7 (8.9)	37.1 (12.9)†	33.7 (11.2)	35.95 (10.1)
P_aO_2; mmHg	189.7 (59.3)*	140.1 (29)‡	144.8 (51.7)‡	159.1 (66.1)†	155.8 (72.01)†
HCO_3; mmol.l^{-1}	19.4 (3.57)	20.2 (2.9)	20.3 (4.4)	19.1 (4.5)	18.5 (3.4)
BE; mmol.l^{-1}	−4.8 (3.3)	−5.2 (2.4)	−6.1 (4.4)	−5.4 (3.2)	−7.2 (2.9)
S_aO_2; %	99.6 (0.3)	99 (1)	98.4 (2.6)	99 (0.2)	98.9 (1.4)
S_pO_2; %	98.9 (1.9)	97.6 (2.7)	97.1 (3)	98.2 (2.2)	98.1 (1.2)
$F_{E'}CO_2$; mmHg ($n=8$)	27.1 (9.2)	29.2 (8.55)	34.2 (9.2)	30.3 (8.4)	32.3 (8)

†$p<0.05$, ‡$p<0.001$ when compared with t_0, *$p<0.0001$ in ANOVA for repeated measurements.

Table 3 Heart rate and mean arterial pressures. Results are expressed as mean (SD)

	Awake	t_0	1 min after pneumoperitoneum	t_2	t_3	t_4
Heart rate; beat.min^{-1}	135.05 (18.9)	133.3 (16.8)	134.2 (18.06)	132.5 (15.9)	132.5 (15.9)	134.06 (15.45)
Mean arterial pressure; mmHg	55.4 (9.99)	54.38 (12.47)	63.7 (14.44)	58.45 (15.93)	57.92 (15.5)	59 (17.48)

including the absorption of carbon dioxide, alterations in respiratory function and cardiac output [2–5, 8].

Insufflation of carbon dioxide into the peritoneal cavity creates a high carbon dioxide gradient between the peritoneum and the blood perfusion to the peritoneum. Carbon dioxide is absorbed in considerable amounts into the bloodstream resulting in significant hypercarbia and a decrease in pH [4, 10, 11]. Tan *et al.* [12] demonstrated a 30% increase in carbon dioxide load due to absorption in young, healthy adults. Our previous study, and a study by Remeso *et al.* had shown that carbon dioxide insufflation during paediatric laparoscopy results in a significant increase of P_aCO_2 due to absorption [13, 14]. As in Remeso *et al.*'s study, the initial P_aCO_2 in our infants was low. The increases in P_aCO_2 did not reach unphysiological levels. Keeping a constant intracranial pressure is more important in infants than in children and adults. Hypercarbia and increased IAP give rise to increased intracranial pressures and intracranial haemorrhage in infants.

Other respiratory derangements during laparoscopy are cephalad displacement of the diaphragm due to pneumoperitoneum resulting in reduction in lung volume and ventilation perfusion mismatch, as well as altering gas exchange [15]. Abdominal distention stiffens the diaphragm/abdomen part of the chest wall and restricts lung expansion [16]. A 20% decrease in functional residual capacity (FRC) occurs under general anaesthesia with controlled ventilation [17] and a further 20% decrease in FRC has been reported during laparoscopic surgery in adults [3, 18]. The well-known feature of paediatric respiratory physiology is a low FRC (10% of total lung capacity) and high closing volume. These characteristics change during growth [3, 19–22]. The decrease in FRC increases the ventilation/perfusion mismatch and alveolar deadspace. Anatomical deadspace is also altered with diaphragmatic shift and general anaesthesia [3]. The significant decreases in P_aO_2 confirm a decrease in FRC in infants. This means that infants are more severely effected by the respiratory effects of pneumoperitoneum than adults.

Because of the high inspired oxygen concentration we used during laparoscopy, the P_aO_2 decreased along the flat portion of the oxyhaemoglobin dissociation curve; hence the saturation of arterial haemoglobin, whether monitored by arterial blood gas analysis or pulse oximetry remained above 95% throughout the procedure. Noninvasive monitoring during paediatric laparoscopy such as S_pO_2 and $F_{E'}CO_2$ are practical methods but $F_{E'}CO_2$ monitoring is unreliable with rapid respiratory rates, low tidal volumes and the Jackson Rees system [5, 23].

Alterations in cardiac rhythm may also be seen during laparoscopy and are related to increased intra-abdominal pressure, hypercarbia, wakefulness and surgical stimulation. The cardiac output decreases when intra-abdominal pressure exceeds 20 mmHg. Also inferior vena cava obstruction exaggerates the decrease in cardiac output [24]. Another consistent effect of pneumoperitoneum on the cardiovascular system is an increase in systemic vascular resistance (SVR) as a result of compression of the aorta and increase in splanchnic arteriolar vasoconstriction due to increased IAP [25]. These derangements are more significant in the presence of hypovolaemia [25].

Gueugniaud *et al.* [6] reported a decrease in aortic blood flow and stroke volume and an increase in systemic vascular resistance in healthy male infants similar to those seen in adults. In our study, cardiac output and systemic vascular resistance were not monitored for ethical reasons. It is usually thought that simple clinical measurements of blood pressure and heart rate might give a misleading impression of cardiovascular status; although the stability of these parameters during this study could be attributed to first restricting the increase in IAP (kept below 10 mmHg throughout the pneumoperitoneum) and to the normovolaemic state of the patients [26].

Anaesthetic management of infants undergoing laparoscopic surgery must take account of surgical requirements and the physiological changes due to pneumoperitoneum. Improved understanding of the potential problems will allow appropriate anaesthetic management.

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