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Original Article

Perioperative parameter analysis of neonates and infants receiving laparoscopic surgery

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Abstract

Background: The field of laparoscopic surgery in neonates or younger infants has benefitted from recent progress. This study aimed to determine the correlation between patient characteristics and perioperative parameters, and to explore the feasibility of laparoscopic surgery in neonates and infants.

Methods: We retrospectively collected and analyzed data on neonates and infants who received laparoscopic surgery at our institute between January 2007 and August 2015. Perioperative data, surgical outcomes, and related complications were analyzed using Spearman rank correlation coefficient.

Results: A total of 82 patients (42 male and 40 female) were included in this study. The median operative age and the median operative body weight were 2.2 months and 4.2 kg, respectively. The median operative time was 3.5 hours, and the median insufflation time was 2.0 hours. The mean intraoperative end-tidal carbon dioxide ($EtCO_2$) level was 37.6 mmHg, the median body temperature (BT) was 35.8°C, and the mean peak inspiratory pressure was 23.3 cmH_2O. The median follow-up duration was 23.4 months. The intraoperative BT was significantly influenced by the operative age ($p < 0.001$, $r_s = 0.52$) and body weight ($p < 0.001$, $r_s = 0.59$). The intraoperative $EtCO_2$ level was higher for longer operative time ($p = 0.01$, $r_s = 0.28$) and insufflation time ($p < 0.001$, $r_s = 0.39$); however, all values returned to normal when the CO_2 insufflation was stopped.

Conclusion: Laparoscopic surgery for neonates and infants can be safely performed by experienced surgeons. However, transient hypercarbia may rapidly ameliorate after CO_2 insufflation is stopped.

Keywords: infants; laparoscopic surgery; neonates; perioperative parameter

1. Introduction

Minimally invasive surgery (MIS) in children, particularly in those under the age of 1 year, requires sophisticated equipment and techniques and has been developed since the late 1990s.[1−3] In neonates and infants, friable and delicate tissue, a small intra-abdominal or intrathoracic space, a steep learning curve, and distinct anesthetic deliberation for dissimilar physiological characteristics have resulted in MIS being utilized less frequently than other techniques.[1,3−5] In addition to technological limitations and the need for precise surgical skills, MIS in neonates and infants is challenging because of their vulnerability to hypothermia and hypercarbia, which may lead to acidosis, reduced cerebral perfusion, and other unfavorable outcomes.[2,4]

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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Although heat loss caused by large incisions is averted in neonates and infants receiving MIS, extended surgical duration with prolonged exposure to the environment, the use of dry and cold carbon dioxide (CO_2) gas, and gas leaks from port sites or instruments all contribute to hypothermia.[2,4] A small airway and large dead space may result in reduced gas exchange. Furthermore, a high peritoneal absorption surface per unit of weight, little peritoneal fat, and thin vessel walls leading to rapid CO_2 diffusion all contribute to hypercarbia in neonates and infants undergoing MIS.[2,4,6] We retrospectively collected clinical data of neonates and infants who received laparoscopic surgery at our institute and analyzed their perioperative data, surgical outcomes, and related complications to clarify the safety and feasibility of MIS in such patients.

2. Methods

Between January 2007 and August 2015, 82 patients (42 male and 40 female) less than 1 year of age who received laparoscopic surgeries at our institute were included. All of the neonates and infants received laparoscopic-related interventions for various diseases. In a typical laparoscopic procedure, the patient was placed in the supine or lithotomy position. The first transumbilical port was introduced using the open Hasson technique. A 5-mm 30° endoscope (KARL STORZ-Endoskope, Surgimed Corporation, Taichung, Taiwan) was inserted via a transumbilical port, and the positions of the other two or three work ports (5 mm or 3 mm) were determined according to operational needs. The pneumoperitoneal space was maintained using CO_2 insufflation, and the pressure was 8−10 mmHg in neonates and 10−12 mmHg in infants.

The patients' medical charts were reviewed to obtain data on general information, diagnosis, perioperative parameters, surgical outcomes, complications, and follow-up durations. The perioperative parameters were the operative age, operative body weight, operative time, CO_2 insufflation time, intraoperative end-tidal CO_2 ($EtCO_2$) levels, body temperature (BT), and peak inspiratory pressure (PIP). Among these factors, $EtCO_2$ was monitored using a capnometer, which continuously measured the concentration of CO_2 in exhaled air via the endotracheal tube connecting to the respirometer of the anesthesia machine. The data were analyzed using the Spearman rank correlation coefficient. The procedure for enrolling all patients in this research was approved by the Institutional Committee on Human Research of Taichung Veterans General Hospital (TCVGH), according to the guidelines of the Declaration of Helsinki and the International Conference on Harmonisation for Good Clinical Practice (Institutional Review Board TCVGH No. CE15260B).

3. Results

The definite diagnoses and corresponding operative procedures of the included patients are listed in Table 1. The central measurement results of the preoperative data of these patients are shown in Table 2. The operative age ranged from 1 day to 11.4 months (median 2.2 months), and the operative weight ranged from 2 kg to 11 kg (median 4.2 kg). The operative time ranged from 1.0 hours to 7.5 hours (median 3.5 hours), and CO_2 insufflation time ranged from 0.2 hours to 5.0 hours (median 2.0 hours). The mean intraoperative $EtCO_2$ level was 37.6 mmHg, the median BT was 35.8°C, and the mean PIP was 23.3 cmH_2O. Although the $EtCO_2$ level increased and BT was reduced at the start of insufflation, in most patients the $EtCO_2$ level was maintained below 42.1 mmHg, PIP was below 26.3 cmH_2O, and BT was above 35.1°C, as shown in Table 2. Hypercarbia-related intraoperative respiratory acidosis and transient hypothermia (BT<35°C) were observed in three and four patients, respectively. All of these

Table 1
Diagnosis, patient number, and operative procedures of patients.

Diagnosis	Operative procedure	Patient No.
Adrenal cortical adenoma	Partial adrenalectomy	1
Anorectal malformation	Laparoscopic-assisted pull-through	3
Biliary atresia	Kasai operation	6
Choledochal cyst	Excision of choledochal cyst and roux-en-y hepaticojejunostomy	9
Congenital duodenal stenosis	Duodenoduodenostomy	1
Congenital diaphragmatic hernia	Primary repair	1
	Patch repair	1
Diaphragmatic eventration	Plication of diaphragm	2
Feeding intolerance in neurologically impaired children with/without gastroesophageal reflux disease	Nissen fundoplication and gastrostomy	1
	Gastrostomy	2
Hirschsprung disease	Swenson procedure	10
Hiatal hernia	Primary repair and Toupet fundoplication	5
Infantile hypertrophic pyloric stenosis	Pyloromyotomy	5
Ileal atresia	Segmental resection and anastomosis	3
Intra-abdominal lymphangioma	Excision of intra-abdominal tumor	1
Intussusception	Surgical reduction	5
Liver cysts	Unroofing of the cyst	2
Neonatal cholestasis	Intraoperative cholangiogram	1
Nonfunctional kidney in duplex collecting system	Partial nephrectomy	5
Ovarian cyst/teratoma	Partial/total oophorectomy	4
Undescended testis	Laparoscopic-assisted orchiopexy	6
Ureteropelvic junction stenosis	Dismembered pyeloplasty	7
Vesicoureteral reflux	Ureteral reimplantation	1

Table 2
Measurement results of preoperative data for patients.

Parameters	Median	Q1	Q3
Operative age (mo)	2.25	0.60	7.38
Operative weight (kg)	4.25	3.42	7.44
Operative time (h)	3.50	2.00	5.00
Carbon dioxide insufflation time (h)	2.00	1.00	3.00
End-tidal carbon dioxide (mmHg)	37.60 (mean)	32.73	42.13
Body temperature (°C)	35.80	35.18	36.31
Peak inspiratory pressure level (cmH_2O)	23.30 (mean)	20.58	26.38
Follow-up (mo)	23.40	8.43	41.53

Table 3
Spearman rank correlation coefficient results of various preoperative parameters.

Spearman rho	Operative age (mo)		Follow-up (mo)		Operative weight (kg)		Operative time (h)		CO_2 insufflation time (h)		$EtCO_2$ (mmHg)		BT (°C)	
	Rho	*p*	Rho	*p*	Rho	*p*	Rho	*p*	Rho	*p*	Rho	*p*	Rho	*p*
Follow-up (mo)	−0.030	0.792	1.000											
Operative weight (kg)	0.878	<0.001	−0.069	0.544	1.000									
Operative time (h)	−0.231	**0.036**	0.072	0.523	−0.322	**0.003**	1.000							
CO_2 insufflation time (h)	−0.078	0.484	0.058	0.604	−0.168	0.130	0.859	<0.001	1.000					
$EtCO_2$ (mmHg)	0.117	0.295	0.109	0.331	0.061	0.586	0.285	**0.010**	0.397	**<0.001**	1.000			
BT (°C)	0.527	**<0.001**	−0.249	0.024	0.596	**<0.001**	−0.215	0.052	−0.024	0.829	0.178	0.110	1.000	
PIP (cmH_2O)	−0.128	0.253	−0.421	<0.001	−0.111	0.319	0.164	0.140	0.147	0.187	0.098	0.383	0.138	0.216

$p < 0.05$ was statistically significant.
BT = body temperature; $EtCO_2$ = end-tidal carbon dioxide; PIP = peak inspiratory pressure level.

patients recovered soon after CO_2 insufflation was temporarily stoppedorthepressuregradientwasloweredbyabout2mmHg,andno unfavorable outcomes were observed until the end of the post-operativefollow-upperiod.

The results of perioperative parameters analyzed using the Spearman rank correlation coefficients are listed in Table 3. Patients at a younger operative age or with lower operative weight had longer operative time than did those at an older operative age or with higher operative weight; however, this correlation was not statistically significant ($p = 0.03$, $r_s = -0.23$ and $p < 0.001$, $r_s = -0.32$, respectively). Prolonged operative or CO_2 insufflation time depends on the surgeon's experience and the corresponding operative procedures. The intraoperative $EtCO_2$ level seemed to be higher for longer operative time ($p = 0.01$, $r_s = 0.28$) and CO_2 insufflation time ($p < 0.001$, $r_s = 0.39$), but with poor correlation. It seems significant that lower intraoperative BT may occur in those patients with lower operative age ($p < 0.001$, $r_s = 0.52$) and lower body weight ($p < 0.001$, $r_s = 0.59$). The mean ventilator PIP levels did not correlate with the other preoperative parameters. The scatter graph of the operative weight and other preoperative parameters is shown in Fig. 1. The operative weight significantly influenced intraoperative BT with favorable negative correlation. No hypotension was observed in any of the patient, even during CO_2 insufflation.

Immediate operative complications were observed in five patients. One patient with colorectal anastomotic leakage (Hirschsprung disease) received diversion ileostomy, whereas one patient with Y-enteroenterostomy leakage (biliary atresia) received exploratory laparotomy for anastomosis revision. Urine leakage (ureteropelvic junction stenosis) was spontaneously resolved through local drainage in one patient and percutaneous nephrostomy in another patient, and the patient with (anorectal malformation) urine retention recovered gradually 1 month after surgery. Blood loss was minimal in most patients, except in one patient who received partial nephrectomy; in this case, the estimated blood loss was 40 mL, and thus the patient required blood transfusion. The follow-up duration ranged from 1 month to 102.6 months (median 23.4 months). One patient died 1 month after laparoscopic surgery for hiatal hernia due to severe sepsis caused by central venous catheter infection. Another patient died of congenital heart disease 1 year after laparoscopic surgery for Hirschsprung disease.

4. Discussion

During the early development of pediatric MIS, traditional pediatric surgeons claimed that they consistently used small wounds in open surgery. Therefore, the benefits of MIS (such as minimal postoperative pain, early mobilization, and early restoration of normal activities) were not apparent in infants and young children, and a lack of appropriate instruments and surgical skills restricted the development of pediatric MIS.[7] With the advancements of instruments and enhanced surgical and anesthetic techniques, increasingly more endoscopic surgeries have been performed in neonates and infants, despite the steep learning curve. MIS procedures are safe and feasible, even in young children and infants, as reported in the literature,[8–11] and these features were observed in our study. The most challenging task is to perform intestinal anastomosis in the small pneumoperitoneal space; however, this concern may be resolved by introducing surgical robots or using alternative devices for anastomosis.[8,9,12] In our series, the umbilical trocar wound was enlarged slightly to perform extracorporeal anastomosis, thereby yielding favorable cosmetic results, shortening CO_2 insufflation time, and saving the additional cost of alternative devices for anastomosis.

Hypothermia and hypercarbia are the most crucial and noteworthy concerns in pediatric MIS, because systemic hypothermia and hypercarbia may lead to arrhythmias and acidosis, respectively. Furthermore, these conditions may subsequently yield irrevocable results, such as brain injury or even death.[2,4,13] However, well-known corresponding strategies have been devised for avoiding these complications, such as using an external warming blanket, warming intravenous fluids, humidifying CO_2 gas, reducing gas leaks to minimize persistent cold gas inflow, increasing the ventilator minute volume and PIP, and increasing the respiratory rates disproportionately during CO_2 insufflation (such as respiratory rate set at 50−60/min in patients with body weight less than 4 kg).[2,4–6] All of the aforementioned strategies had been introduced in this series, although patients in this series with lower body weight had significantly longer operative time and

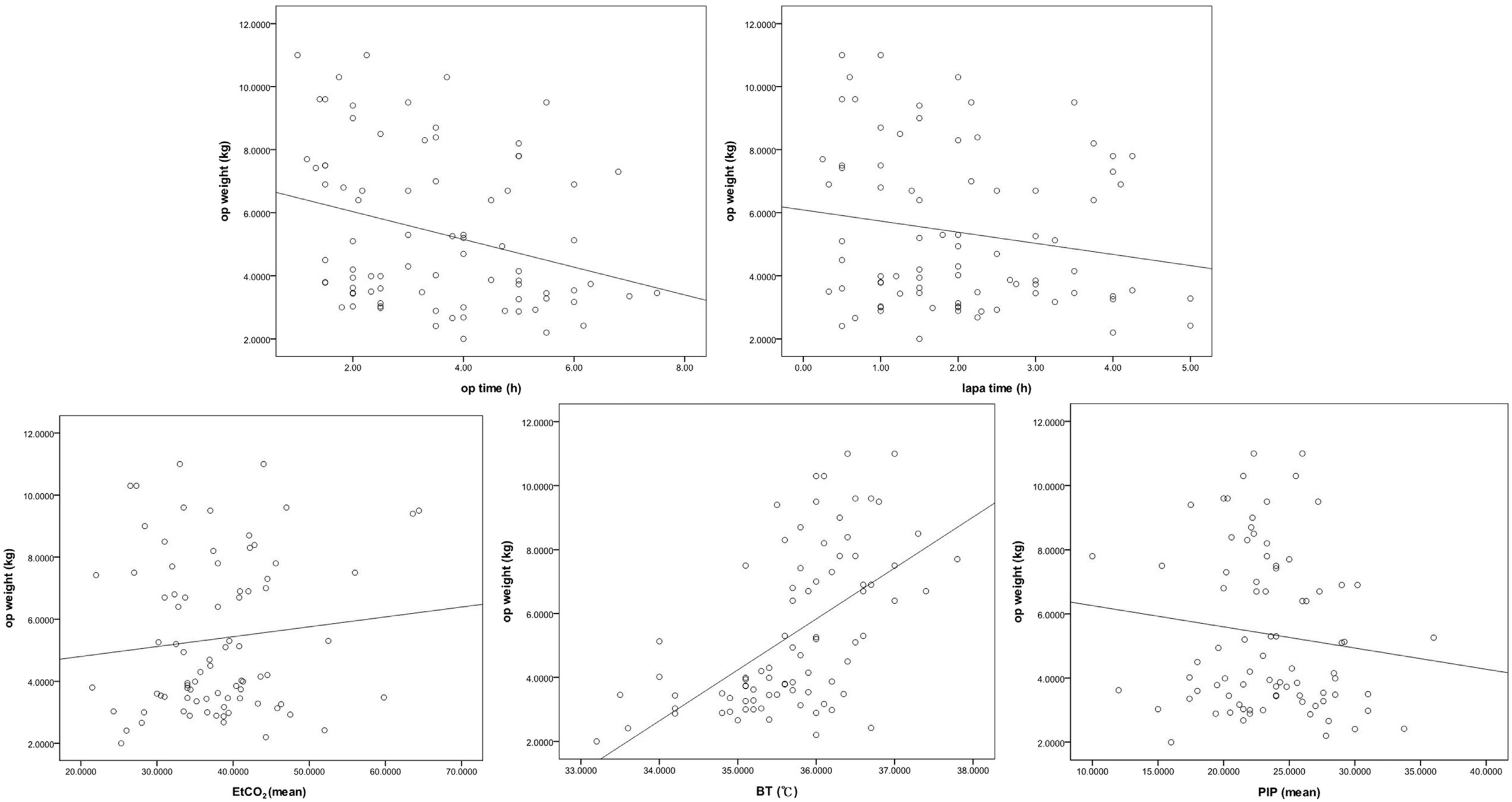

Fig. 1. Scatter graphs of operative weight (op weight) and operative time (op time), CO_2 insufflation time (lapa time), intraoperative end-tidal carbon dioxide ($EtCO_2$) level (mmHg), intraoperative body temperature (BT, °C), and mean peak inspiratory pressure level (PIP, cmH_2O).

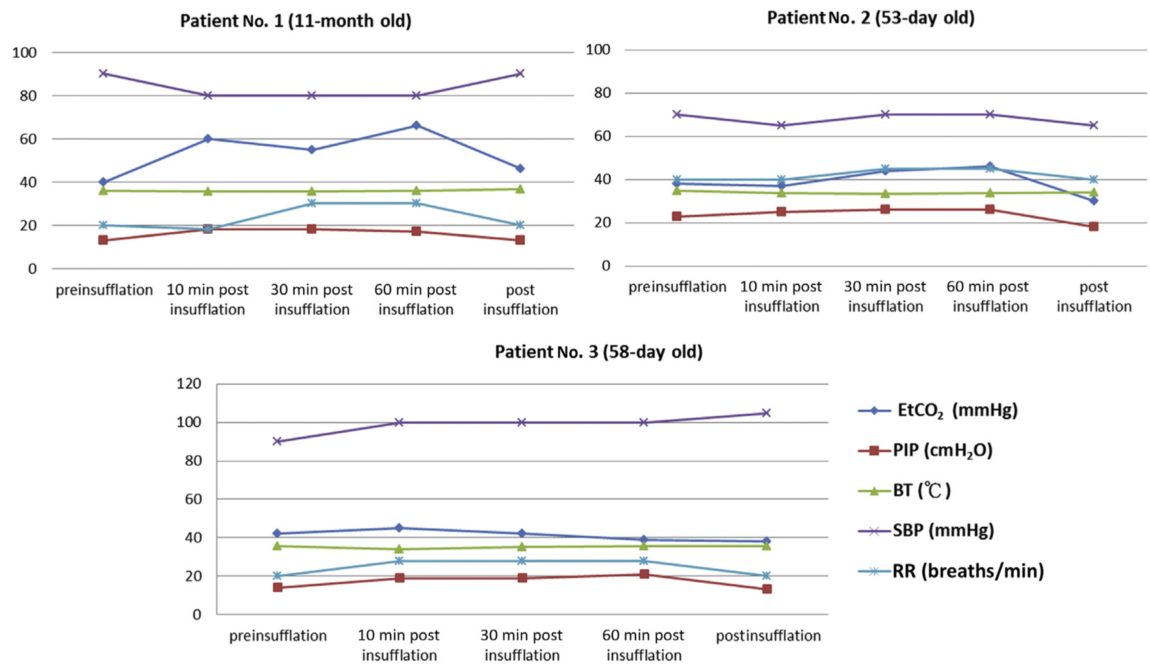

Fig. 2. The line charts of perioperative parameters in three patients with transient hypercarbia, including end-tidal carbon dioxide ($EtCO_2$) level at different time points (preinsufflation, 10/30/60 minutes after insufflation and after insufflation stopped), peak inspiratory pressure level (PIP), body temperature (BT), systolic blood pressure (SBP), and respiratory rate (RR).

CO_2 insufflation time, as well as lower intraoperative BT. Low insufflation pressure below 8 mmHg in neonates undergoing laparoscopic surgery to avoid hemodynamic instability was advised in some papers.[4,14] However, some papers reported that no significant threat was observed even with the CO_2 insufflation pressures up to 15 mmHg in neonates.[9,15,16] The line charts of perioperative parameters ($EtCO_2$ at different time points, PIP, BT, systolic blood pressure, and respiratory rate) in three patients with transient hypercarbia are shown in Fig. 2. In this series, CO_2 insufflation was temporarily stopped or the pressure gradient was lowered by about 2 mmHg (namely 6–8 mmHg in neonates and 8–10 mmHg in infants) when $EtCO_2$ reached above 50–55 mmHg, until hypercarbia resolved. Anesthesiologists, of course, would adjust PIP and respiratory rate to resume $EtCO_2$ level less than 45–50 mmHg. As for hypothermia resulting from persistent cool CO_2 inflow, lowering the gas flow at 3–4 L/min was also introduced in this series to decrease evaporative losses in neonates and infants.

The overall complication rate reported in the literature is approximately 1–4%, with mortality seldomly reported.[7,11] In this series, two patients died of other comorbidities unrelated to laparoscopic surgery. In addition, no patient was converted to open surgery, and the operative complication rate was 6.1% (5/82). The relatively higher complication rate may be attributed to the smaller sample size and steep learning curve. Some papers reported that the incidence of complications in pediatric MIS may be reduced drastically with proper training and increased experience in laparoscopic surgery.[3,7]

In conclusion, laparoscopic surgery in neonates and infants has become more feasible and safe due to the development of technology and instruments, as well as advanced surgical skills and anesthetic reliability. Transient hypercarbia may rapidly ameliorate after CO_2 insufflation is stopped, and can be carefully managed by experienced pediatric surgeons and anesthesiologists.

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