Clinical Trial/Experimental Study

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Clinical effects of warmed humidified carbon dioxide insufflation in infants undergoing major laparoscopic surgery

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Abstract

Purpose: Some studies have reported that warmed humidified carbon dioxide (CO_2) insufflation in adult laparoscopic surgery could reduce pain and improve the core body temperature (CBT). However, similar studies are lacking in infants. Thus, this study aimed to investigate the clinical effects of warmed, humidified CO_2 insufflation in pediatric patients undergoing major laparoscopic surgeries.

Methods: From January 2015 to December 2017, infants who underwent major laparoscopic surgeries in Ningbo Women and Children's Hospital were randomized to Group A (standard CO_2 insufflation) or Group B (warmed humidified CO_2 insufflation, 35°C, 95% relative humidity). Change in CBT at the end of surgery was the primary outcome. Secondary outcomes included surgery time, intraoperative blood loss, oxygen saturation (SO_2), and Face, Legs, Activity, Cry and Consolability (FLACC) scale. These variables were compared between the 2 groups.

Results: Sixty-three infants (38 females, 25 males) were included; 30 patients were in Group A and 33 in Group B. The diseases treated with the laparoscopic approach included congenital megacolon, congenital diaphragmatic hernia, and intestinal malrotation. No deaths were noted. CBT was significantly higher in Group B at the end of surgery ($P=.021$). The occurrence of postoperative shivering ($P=.02$), hypothermia ($P=.032$), bowel movement ($P=.044$), and hospital stay ($P=.038$) was significantly different between the 2 groups; Group B had less shivering and hypothermia occurrence after surgery. Moreover, Group B demonstrated a more rapid postoperative recovery of bowel movement and shortened hospital stay than Group A. There was no statistical difference in operative time ($P=.162$), intraoperative blood loss ($P=.541$), SO_2 ($P=.59$), and FLACC scale ($P=.65$) between the 2 groups.

Conclusion: The use of warmed humidified CO_2 insufflation in infants undergoing major laparoscopic surgery was helpful for maintaining normothermia and was associated with several positive postoperative outcomes, including less shivering and hypothermia, faster recovery of bowel movement, and shortened hospital stay.

Abbreviations: CBT = core body temperature, CO_2 = carbon dioxide. FLACC = face, legs, activity, cry, and consolability.

Keywords: carbon dioxide, hypothermia, infant, laparoscopic surgery

1. Introduction

Since its advent, laparoscopic surgery has been routinely applied in pediatric major surgeries.[1–4] Infants regulate body temperature less efficiently than adults and often have difficulty in maintaining normal body temperatures in environments that are thermally comfortable for adults.[5] With the widespread use of laparoscopic techniques, the problem of hypothermia caused by the insufflation of carbon dioxide (CO_2) gas has drawn the attention of surgeons.[6] Perioperative hypothermia can increase the heart's workload and oxygen consumption, inhibit immune function, and lead to disordered blood coagulation, increased postoperative bleeding, increased rate of incision infection, and myocardial ischemia.[7–11] Because of these adverse events caused by hypothermia, maintaining normothermia is an important focus in surgical practice. Some studies focused on warmed humidified CO_2 insufflation in adult laparoscopic surgeries and obtained positive outcomes.[12–15] However, such studies are lacking regarding the pediatric population.

This study aimed to investigate the intraoperative and postoperative effects of the insufflation of warmed humidified CO_2 into the abdominal cavity during infant major laparoscopic surgeries.

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2. Patients and methods

2.1. Case selection

From January 2015 to December 2017, infants undergoing major laparoscopic surgeries in Ningbo Women and Children's Hospital were randomized to either of 2 groups as follows: Group A (standard CO_2) or Group B (warmed humidified CO_2 insufflation, 35°C, 95% relative humidity). All surgeries were performed by the same team of surgeons. The inclusion criteria were as follows: age ≤1 year, American Society of Anesthesiology class I or II, use of general anesthesia, normal preoperative body temperature on arrival to the operating room, and surgery time of >2 hours. Cases were excluded from this study if they met the following conditions: conversion to open surgery, performance of redo or emergency surgery, and presence of congenital heart or neurological diseases. Written informed consent was obtained from the patients' parents before the study. The study was reviewed and approved by the hospital ethics committee (NO. 107-W-066, November 1, 2014).

2.2. Surgical procedure

In this study, hypothermia was defined as a core body temperature (CBT) less than 36°C.[5] All infants were transported to the operating room with a prewarmed bed and were wrapped in a thermal blanket. The operating room temperature was maintained at 26°C to 27°C and the relative humidity was controlled at 30% to 60%. Prewarmed intravenous fluids (at 37°C) were administered and the preparatory disinfectant was also warmed up to 37°C. During the surgery, a thermal blanket was used to keep the child warm. In Group A, infants received standard CO_2 which was at room temperature. CO_2, warmed and humidified by a photoelectric heating device attached to the insufflation equipment, was applied in infants of Group B. Both groups were treated with combined intravenous and inhalation anesthesia. The anesthetic regime was determined by the anesthesiologist and included atropine, propofol, morphine, and fentanyl, intravenously, and inhaled gases such as sevoflurane and desflurane. CBT was recorded in both groups either by esophageal or rectal probes depending on the type of surgery or the anesthesiologist's preference and access. After surgeries, all infants were transported in a prewarmed bed to the postanesthesia care unit.

2.3. Outcomes

Change in CBT at the end of surgery was the primary outcome of this study. Other intraoperative and postoperative variables were the secondary outcomes.

2.4. Data collection

The multifunction monitor was used to observe and record the CBT at different times. Variables were collected which included operation time, cases of reduction in oxygen saturation (SO_2) <90%, intraoperative blood loss, postoperative pain evaluation, postoperative shivering, postoperative hypothermia, postoperative bowel movement, and hospital stay. Postoperative pain was evaluated by the Face, Legs, Activity, Cry and Consolability (FLACC) scale.[16]

2.5. Statistical analysis

Statistical comparisons between Group A and B were performed for demographic and preoperative, intraoperative, and postoperative data. The *t* test and χ^2 test were used to analyze the data for continuous and categorical variables, respectively. SPSS version 17.0 (SPSS, Inc., Chicago, IL) was used to perform the statistical analysis; $P<.05$ was considered to indicate a statistically significant difference.

Table 1

Demography of infants in the 2 groups.

Clinical data	Group A (n=30)	Group B (n=33)	*P*
Mean age, days	48.12±8.32	51.27±9.35	.685
Sex (female: male)	18/12	20/13	.325
ASA class, n (%)			.083
I	28 (93.33%)	29 (87.88%)	
II	2 (6.67%)	4 (12.12%)	
Type of laparoscopic surgery, n (%)			.131
Congenital megacolon	20 (66.67%)	22 (66.67%)	
Congenital diaphragmatic hernia	4 (13.33%)	3 (9.10%)	
Intestinal malrotation	6 (20.00%)	8 (24.23%)	

ASA = American Society of Anesthesiology.

3. Results

3.1. Demography of patients

Overall, 63 infant patients (Group A, n=30; Group B, n=33) who underwent major laparoscopic surgeries were included in this study. The average age was 48.12±8.32 days in Group A, which comprised 12 male and 18 female infants. The average age was 51.27±9.35 days in Group B, which comprised 13 male and 20 female infants. Diseases treated with abdominal laparoscopic surgery included congenital megacolon, congenital diaphragmatic hernia, and intestinal malrotation. The demographic and clinical characteristics of infants in both groups are described in Table 1. The 2 groups were comparable demographically ($P>.05$).

3.2. CBT comparison

The baseline CBT was similar between the 2 groups at the time of admission to the operating room and at the beginning of surgery ($P=.701$). The difference in CBT between the 2 groups and change in CBT in Group B were statistically significant at the end of the surgeries ($P<.05$). At the end of surgery, the CBT of Group B at the end of surgery was significantly higher than that of Group A (Table 2).

3.3. Comparison of intraoperative and postoperative variables

There were no significant differences in operative time, intraoperative blood loss, cases of SO_2 <90%, and FLACC scale between the 2 groups ($P>.05$). Group B showed less postoperative shivering and hypothermia, more rapid return of bowel movement, and shorter hospital stay than Group A ($P<.05$) (Table 3).

Table 2

CBT compared between the 2 groups ($\bar{x}$ ± s).

	Group A (n=30)	Group B (n=33)	*P*
CBT at the admission to operating room, °C	37.01±0.32	36.82±0.41	.701
CBT at the beginning of surgery, °C	36.61±0.28	36.48±0.30	.067
CBT at the end of surgery, °C	36.04±0.22	36.41±0.31	.021
Decrease in CBT, °C	0.48±0.12	0.11±0.19	.043

CBT=core body temperature.

Table 3

Intraoperative and postoperative variables compared between the 2 groups.

Variable	Group A (n=30)	Group B (n=33)	P
Operative time, min	151.21±31.18	155.16±29.2	.162
Intraoperative blood loss, mL	24.32±9.83	22.42±7.51	.541
SO_2 <90%, n (%)	2 (6.67%)	4 (12.12%)	.59
FLAC scale	3.5±0.45	3.74±0.63	.65
Postoperative shivering, n (%)	4 (13.33%)	1 (3.03%)	.02
Postoperative hypothermia, n (%)	3 (10.00%)	1 (3.03%)	.032
Postoperative bowel movement, h	55.18±5.92	45.30±4.77	.044
Hospital stay, days	13.15±3.76	10.11±2.97	.038

FLACC=Face, Legs, Activity, Cry and Consolability, SO_2=saturation of oxygen.

4. Discussion

The quality of care and safety of children undergoing surgery are ever-present concerns in the perioperative clinical setting. It is generally agreed that hypothermia affects the postoperative course of pediatric patients, especially neonates.[17] Hypothermia occurs when heat loss exceeds metabolic heat production.[18] Although the use of hypothermia in the pediatric population is helpful for treating brain injury and cardiac arrest,[19,20] infants are considered to have a greater risk of developing unplanned hypothermia than adults because of a high body surface area to mass ratio, higher metabolic rate, difference in body size, limited stores of subcutaneous fat, and a less effective regulatory capacity.[5,21–23] Major surgeries can increase the chance of decrease in the infant's CBT.[22] Therefore, infants undergoing lengthy complex laparoscopic surgeries are especially vulnerable to body temperature decrease. The risk of surgery-related hypothermia in infants has been reported to be higher than that in adults.[17,24]

With the development of laparoscopic technology, especially single-port laparoscopy, the difficulty of surgery has increased and the operation time has been prolonged. Moreover, some congenital abdominal diseases are notably complex and require even more time to be operated on using laparoscopy. The longer the surgery time, the more CO_2 is needed to inflate the abdominal cavity to maintain the intra-abdominal operation space. The current approach for most laparoscopic procedures uses CO_2 at a room temperature of 21°C,[12] which is much lower than the normal body temperature. This low-temperature CO_2 goes through the abdominal cavity continuously during laparoscopic surgery and can lead to unavoidable heat loss. Related problems caused by this issue have been noted by surgeons and many studies have attempted to investigate this problem in the adult population.[25–27]

Measures to prevent hypothermia, such as increasing the operating room temperature, using a thermal blanket during surgery, and applying warm irrigation and intravenous fluids have become standard care to warm infants receiving surgery. However, CO_2 gas warming in laparoscopic surgery is usually overlooked. Some studies reported that warmed humidified CO_2 insufflation in adult laparoscopic surgery could reduce pain and improve CBT.[12–15,28] Few studies on this issue in the pediatric population yielded both positive and negative conclusions in relatively minor and nonprolonged laparoscopic surgeries.[29,30]

This study showed that warmed humidified CO_2 insufflation could maintain a higher CBT than standard CO_2 insufflation in infant patients who underwent major laparoscopic surgeries. CO_2 used in pneumoperitoneum during laparoscopic procedures is liquefied before being released, and its storage temperature is low. After entering the abdominal cavity, the surface of the internal organs can be rapidly cooled, affecting the CBT. Using warmed humidified CO_2 insufflated into the abdominal cavity can effectively prevent the marked decrease in CBT and reduce the occurrence of postoperative shivering and hypothermia.

The faster postoperative recovery of bowel movement with warmed humidified CO_2 insufflation noted in this study may be related to less peritoneal alteration caused by the warmed humidified CO_2.[31] Therefore, earlier hospital dismissal is possible with this technique.

An important finding in this study was that although several warming measures and warmed, humidified CO_2 were used in Group B, infants still demonstrated a decrease in CBT postoperatively. This may be associated with the warming efficiency of the device, flow rate of CO_2, long operation time, and low weight of the child, and this requires further research.

This study was limited by its small sample size. Therefore, more randomized studies are needed to assess the impact of warmed humidified CO_2 insufflation in infants undergoing major laparoscopic surgeries.

5. Conclusion

Warmed humidified CO_2 insufflation in infant patients undergoing major laparoscopic surgeries was helpful for maintaining normothermia and resulted in several positive postoperative outcomes including less shivering and hypothermia, faster recovery of bowel movement, and shortened hospital stay. However, prospective studies in larger population are needed to verify our findings.

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