Original Article

Physiological Factor Evaluation of the Warm Humidification of Anesthetic Gas Nursing Care

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ABSTRACT

Objective: This study aimed to evaluate the effects of warm humidification of anesthetic gas nursing care on physiological factors in elderly patients during laparoscopic cancer surgery. **Methods:** Sixty elderly laparoscopic surgical patients were recruited from a medical center in Korea. The participants' physiological factors (blood pressure, body temperature, and leukocyte and neutrophil counts) were measured four times. **Results:** After warm humidification of anesthetic gas nursing care, there were significant differences in body temperatures. **Conclusions:** These findings indicate that warm humidification of anesthetic gas nursing care is effective in maintaining body temperature. Thus, this type of nursing care can be effective in elderly cancer patients undergoing laparoscopic surgery.

Key words: Anesthesia, feedback, laparoscopy, physiological

Introduction

General anesthetics administered during surgery lower the body temperature by relaxing peripheral veins and increasing the threshold for vasoconstriction response.[1] Other causes of hypothermia include the administration of 15°C anesthetic gases, disinfectants, and intravenous fluids at room temperature and lower temperature in the operating room.[2] There is a high risk of hypothermia during laparoscopic surgery as the CO_2 gas is pumped into the abdominal cavity due to a procedural inconsistency associated with the surgery.[3]

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The occurrence of hypothermia during surgery increases blood catecholamine levels and causes not only tachycardia, hypertension, and peripheral vasoconstriction but also tissue hypoxia and metabolic acidosis.[4]

Inhalation of anesthetic gases at 15°C damages the human respiratory epithelial cells and reduces cilia function, resulting in the accumulation of secretions and lowered body temperature.[5]

Nursing care is particularly essential during laparoscopic surgery when the patient is in a lithotomy position

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undergoing inhalation of 15°C anesthetic gases[6] and insufflation of 21°C CO_2 gas in the abdominal cavity because the patient is at a high risk of hypothermia.[7] In the heated humidification of anesthetic gas method, gases are warmed and humidified via a warm humidifier.[8] In the previous study, this method specifically involved the warming and humidifying of anesthetic gases by injecting distilled water into the intake circuit of the humidifier, set at 41°C, and connecting it to the endotracheal tube.[8] We aimed not only to analyze the effects of heated humidification of anesthetic gases on physiological factors in elderly patients during laparoscopic cancer surgery but also to observe how this method affects physiological responses to hypothermia, including changes in infection.

Methods

Study design

This study was a randomized controlled trial with the aim of identifying how warm humidification of anesthetic gas nursing care affects physiological factors (blood pressure, body temperature, and leukocyte counts) in elderly patients undergoing laparoscopic cancer surgery.

Research hypotheses

Hypothesis 1

The patients receiving warm humidification of anesthetic gas nursing care (experimental group) will have higher blood pressure than those in the control group.

Hypothesis 2

The patients receiving warm humidification of anesthetic gas nursing care (experimental group) will have higher body temperature than those in the control group.

Hypothesis 3

The patients receiving warm humidification of anesthetic gas nursing care (experimental group) will have lower leukocyte counts than those in the control group.

Setting and samples

This study was conducted at a medical center in South Korea. Sixty patients over 65 years old undergoing laparoscopic cancer surgery under general anesthesia were enrolled. The investigators visited the patients before operation day to explain the purpose and procedure of the study and to obtain written consent.

The inclusion criteria were as follows: (1) patients with American Society of Anesthesiologists (ASA) Physical Status Class I or II,[9] (2) patients who were able to undergo surgery for 3–5 h, and (3) patients who had not received a blood transfusion.

The sample size was calculated using the G Power Program version 3.1.0.[10] To achieve the objective of this study, the number of patients in each group, the experimental group and the control group, was limited to 30, for a total of 60 patients. The aim was to achieve a desired effect size (d) of 0.32, at a significance level (α) of 0.05, and a power of test (1 - β) of 0.80 for the independent t-test, as proposed by Kim and Kang.[11]

Blood pressure and body temperature were measured every 30 min, four times in total, by inserting an esophageal stethoscope (#4-9552-D, DeRoyal, USA) connected to an electrocardiogram monitor at the upper third level of the esophagus.

The percentage of blood leucocytes and neutrophils was measured preoperatively, as well as 1 h, 1 day, and 3 days postoperatively, for a total of four times (measured at 08:00 each instance). This schedule was based on the results of previous studies, suggesting that the duration of immunosuppression can last from 2 h to 1 week postoperatively.[12]

Intervention

Experimental group

In both the experimental group and the control group, warmed intravenous fluids were administrated, and an electric circulating water blanket was applied. In addition, warm humidification of anesthetic gas nursing care was performed by one nurse anesthetist and the authors on patients in the experimental group. For consistency, data collection during each surgery was solely performed by one nurse anesthetist, and pre- and postoperative blood sampling was performed by a general surgery nurse and a nurse from the general surgery ward. An electric circulating water blanket kept at 38°C was applied to patients' back in both the experimental and control groups, and fluid heated to 41°C was infused intravenously. Heated humidified anesthetic gas at 41°C (Heated Humidification Circuit, A10677, Medimed, Korea) was administered to patients in the experimental group.

Data from the experimental and control groups were collected by the investigators the day before surgery. On the day of surgery, 1 mL of arterial blood was drawn for arterial blood gas analysis in the supine position upon patient arrival in the operating room. After induction of anesthesia, the esophageal stethoscope was inserted at the third level of the esophagus, the heated humidification device was turned on, and body temperature was measured. External factors that could affect patient body temperature were taken into account to create identical environments for patients in both the experimental and control groups. These factors included operating room temperature, humidity level,

preoperative medication, skin disinfection, and anesthesia medication. Operating room temperature was maintained between 22°C and 26°C, humidity was maintained between 30% and 40%, and only one operating room was used. Robinul was injected intramuscularly before surgery based on the basic principles of anesthesia induction. Propofol, alfentanil, and desflurane were used for the induction of anesthesia. The muscle relaxant esmeron (1 mg/kg) was injected intravenously. After tracheal intubation, artificial ventilation was performed.

Control group

In both the experimental group and control group, warmed intravenous fluids were administered, and the electric circulating water blanket was applied. In contrast, regular 15°C anesthetic gas was administered to patients in the control group.

Ethical approval

To protect the rights of the participants, this study was conducted after receiving approval from the university institutional review board. The research purpose and method were explained to the subjects. Patients were then asked to sign consent form to agree to participate in the study.

Statistical analysis

Data were collected for 2 years between 2010 and 2011 at the medical center in South Korea. The Statistical Package for the Social Sciences (v. 20.0, IBM Corp., Armonk, NY, USA) was used to analyze the collected data. First, the *t*-test and Chi-square test were utilized to compare differences between patients in the experimental and control groups. Second, an analysis of covariance was used to assess operation time and anesthesia time. Repeated measures analysis of variance (ANOVA) was performed to analyze the differences in blood pressure, body temperature, and leukocyte counts between the experimental and control groups.

Results

Homogeneity of dependent variables of the subjects

There were no statistically significant differences in patient characteristics such as age, sex, diagnosis, type of surgery, amount of intravenous fluid, operating room temperature, humidity, blood pressure, body temperature, and leukocyte count between groups. However, the duration of anesthesia was significantly longer (245.3 ± 45.0 min) in the experimental group than in the control group (226.6 ± 22.2 min) (t = 2.036, P < 0.001). The duration of operation was 210.3 min in the experimental group and 190.5 min in the control group; this difference was statistically significant (t = 2.534, P < 0.001). Therefore, anesthesia time and operation time were considered as covariates and were controlled statistically. Furthermore, there were no statistically significant differences between the two groups in variables such as preoperative blood pressure, body temperature, and leukocyte count [Table 1].

Test of hypotheses

Hypothesis 1

The patients receiving warm humidification of anesthetic gas nursing care (experimental group) will have higher blood pressure than those in the control group.

This was tested by repeated measures ANOVA of the change in blood pressure at four different times: before intervention, after 30 min, after 60 min, and after 90 min. To test Hypothesis 1, anesthesia time and operation time were set as covariables. ANOVA-measured systolic blood pressure after warm humidification of anesthetic gas nursing care was 122.90, which was significantly higher than 120.86, measured in the control group. As for the degree of systolic blood pressure before and after intervention, no statistically significant difference was observed between the two groups in interaction between groups and times (graded exercise test [G X T] effect) (F = 0.54, P = 0.632). Diastolic blood pressure after warm humidification of anesthetic gas nursing care was 68.06, which was significantly higher than 67.16, measured in the control group. As for the degree of diastolic blood pressure before and after intervention, no statistically significant difference was observed between the two groups in interaction between groups and times (G X T effect) (F = 0.22, P = 0.855). Therefore, Hypothesis 1 was rejected [Table 2].

Hypothesis 2

The patients receiving warm humidification of anesthetic gas nursing care (experimental group) will have higher body temperature than those in the control group.

This was tested by repeated measures ANOVA of the change in blood pressure measured at four different times: before intervention, after 30 min, after 60 min, and after 90 min. To test Hypothesis 2, anesthesia time and operation time were set as covariables. ANOVA-measured body temperature after warm humidification of anesthetic gas nursing care was 35.73, which was significantly higher than 35.18, measured in the control group (F = 136.83, P < 0.001). As for the degree of body temperature before and after intervention, a statistically significant difference between the two groups was observed in interaction between groups and times (G X T effect) (F = 11.50, P < 0.001). Therefore, Hypothesis 2 was supported [Table 2].

Table 1: Homogeneity of general characteristics between patients in the anesthetic gas heating group (experimental group) and the anesthetic gas nonheating group (control group) (n=60)

Variables	Experimental group (n=30)	Control group (n=30)	χ^2	t	P
Age (years)	73.7	72.6		0.85	0.399
Sex, n (%)					
Men	17 (54.8)	13 (44.8)	0.601		0.606
Women	14 (45.2)	16 (55.2)			
Diagnosis, n (%)					
Rectal cancer	15 (50.0)	15 (50.0)	0.001		>0.001
Colon cancer	15 (50.0)	15 (50.0)			
Operation, n (%)					
LAR	27 (90.0)	24 (80.0)	1.176		0.472
Colectomy	3 (10.0)	6 (20.0)			
Fluid, mL	1774	1550		1.73	0.088
Operating room temperature (°C)	23.8	23.6		0.47	0640
Humidity, %	26.3	27.6		2.75	0.594
Anesthesia time, min	245.3	226.6		2.03	<0.001
Operation time, min	210.3	190.5		2.534	<0.001
Systolic blood pressure (mmHg)	140.46±20.94	143.06±19.90		−0.49	0.624
Diastolic blood pressure (mmHg)	79.80±11.72	81.26±8.65		−0.55	0.584
Body temperature (°C)	36.1	36.0		1.755	0.085
Leukocyte count (10^3/μL)	6.14±1.66	6.22±2.06		−0.17	0.864

LAR: Lower Anterior resection

Table 2: Differences in physiological factors between the experimental group (heated humidification of anesthetic gases) and control (anesthetic gas nonheating) group (n=60)

Variables	Mean±SD		Source	F	P
	Experimental group (n=30)	Control group (n=30)			
Blood pressure systolic (mmHg)					
Before	140.46±20.94	143.06±19.90	Group	0.58	0.449
After 30 min	124.10±21.17	119.03±19.79	Time	18.37	<0.001
After 60 min	128.13±15.53	124.93±13.71	Group × time	0.54	0.632
After 90 min	122.90±15.15	120.86±14.07			
Diastolic (mmHg)					
Before	79.80±11.27	81.26±8.65	Group	0.10	0.922
After 30 min	70.16±12.73	68.76±14.05	Time	18.21	<0.001
After 60 min	70.83±13.07	71.00±9.58	Group × time	0.22	0.855
After 90 min	68.06±9.94	67.16±8.05			
Body temperature (°C)					
Before	36.22±0.36	36.04±0.44	Group	13.76	<0.001
After 30 min	35.99±0.38	35.63±0.50	Time	136.83	<0.001
After 60 min	35.90±0.40	35.38±0.51	Group × time	11.50	<0.001
After 90 min	35.73±0.43	35.18±0.52			
Leukocyte (10^3/μL)					
Before	6.14±1.66	6.22±2.06	Group	0.54	0.462
After 1 h	10.93±3.60	11.62±2.99	Time	58.37	<0.001
After 1 day	10.40±3.61	10.50±2.63	Group × time	0.40	0.708
After 3 days	8.09±2.00	8.88±4.06			

SD: Standard deviation

Hypothesis 3

The patients receiving warm humidification of anesthetic gas nursing care (experimental group) will have lower leukocyte counts than those in the control group.

This was tested by repeated measures ANOVA of the change in leukocyte count measured at four different times: before intervention, after 1 h, after 1 day, and after 3 days.

To test Hypothesis 3, anesthesia time and operation time were set as covariables. ANOVA-measured leukocyte count after warm humidification of anesthetic gas nursing care was 8.09, which was significantly lower than 8.88, measured

in the control group. As for leukocyte count before and after intervention, no statistically significant difference was observed between the two groups in interaction between groups and times (G X T effect) ($F = 0.40$, $P = 0.708$). Therefore, Hypothesis 3 was rejected [Table 2].

Discussion

The warming care during general anesthesia is a very important nursing intervention for the comfort of elderly patients and the prevention of infection. In the present study, humidification of anesthetic gas is applied to evaluate its effects on patients' blood pressure, body temperature, and leukocyte count.

In the present study, the blood pressure of elderly cancer patients undergoing laparoscopic surgery who received heated humidification of anesthetic gases was higher than of those in the control group postoperatively. There was, however, no significant difference between groups and times. These findings are similar to those of Bae and Hur,[8] in which heated humidification of anesthetic gases was applied to patients under general anesthesia, and blood pressure was not significantly different between the experimental and control groups. There were limits to identify, such as to what extent the humidification of inhalation gases affects immediate as well as sustained effects on blood pressure, as anesthetic drugs for vasoconstriction were not used.

In this study, body temperature of patients increased in the groups in which warmed intravenous fluids were administered and an electric circulating water blanket was applied. In the control group, body temperature decreased to 35.63°C at 30 min postoperatively, 35.38°C at 60 min postoperatively, and 35.18°C at 90 min postoperatively. However, the body temperature of patients in the experimental group, in which heated humidification of anesthetic gases was also applied, was 35.99°C, 35.90°C, and 35.73°C postoperatively, respectively. These measurements indicate that the heated humidification of anesthetic gases administered to elderly colorectal cancer patients during laparoscopic surgery is an effective intervention to prevent body temperature reductions. The body temperature of patients in the experimental group was 0.55°C higher than that in control group patients 90 min postoperatively.

These findings support those from a study by Lee and Kim,[13] in which heated humidification of anesthetic gases was applied to patients under general anesthesia, and their body temperature was maintained at 36.08°C up to 90 min postoperatively, 0.17°C higher than that in control group patients. Our findings also correspond to those reported by Kim and Kang.[11] In their study, heated humidification of anesthetic gases, along with an electric circulating water blanket and warmed intravenous fluids, was applied to patients undergoing gastric resection. At 3 h postoperatively, body temperature was maintained at 36.20°C, 0.70°C higher than that in control group patients. However, body temperature of patients in the present study was 35.60°C at 4 h postoperatively, whereas body temperature was maintained at 36.20°C 3 h postoperatively in the studies by Park *et al*. and Kim and Kang,[11] 0.60°C higher than that in the present study. It is assumed that this difference is due to variations in patient age between studies. The present study included patients over the age of 65 years, while the study by Park *et al*.[14] included adults aged between 20 and 60 years. Furthermore, in the present study, the elderly colorectal cancer patients undergoing laparoscopic surgery who received heated humidification of anesthetic gases could not maintain normal body temperature 3 h postoperatively.

In this study, the body temperature of elderly cancer patients undergoing laparoscopic surgery who received heated humidification of anesthetic gases, an electric circulating water blanket, and administration of intravenous fluids was 35.60°C 3 h postoperatively. However, in the study by Bae and Hur,[8] in which only heated humidification of anesthetic gases was applied, the body temperature was 35.70°C 3 h postoperatively. The reason for these similar results is assumed to be related to the reduction in thermoregulatory ability in elderly patients. Thus, a more careful intervention is required to prevent hypothermia in elderly patients. In this study, it was possible to maintain normal body temperature in the experimental group with the application of humidified heated anesthetic gas despite the longer surgical time as compared with the control group. For these reasons, it is necessary to use an electric circulating water blanket, warmed intravenous fluids, and humidified heated anesthetic gas to prevent hypothermia in patients during laparoscopic surgery.

Body temperatures of patients who received humidified heated anesthetic gas were higher than those of patients who did not receive humidified heated anesthetic gas at 0.5°C, 0.6°C, 0.9°C, and 1.3°C at 1, 2, 3, and 4 h postoperatively, respectively. However, body temperature ranged between 35.6°C and 35.9°C from 1 to 4 h postoperatively; this was below the normal range. Based on these results, it is assumed that the pumping of CO_2 gas at 21°C into the abdominal cavity during laparoscopic surgery is the main cause of hypothermia under application of humidified heated anesthetic gas, an electric circulating water blanket, and warmed intravenous fluid administration, compared with traditional laparotomy. Thus, the method of pumping warmed CO_2 gas into the abdominal cavity should also be considered for the prevention of patient body temperatures falling below 36°C during laparoscopic surgery for colorectal cancer.

Despite the development of hypothermia, the leukocyte counts were maintained at normal levels, and there were significant differences in these parameters between the experimental and control groups in time interaction ($F = 58.37$, $P < 0.001$). This result is similar

to that reported in a study by Matsui *et al.*,[15] in which a low body temperature aggravated infection during surgery. Based on these findings, it is assumed that ordinary 15°C humidification of anesthetic gases and prolonged time cause infection, followed by a reduction in body temperature.

There was, however, no significant difference in leukocyte counts between the experimental group and the control group and in time interaction in this study. Leukocyte level was 6.14 ($\times 10^3/\mu L$) in the experimental group and 6.22 ($10^3/\mu L$) in the control group before surgery; leukocyte level increased to 10.93 ($10^3/\mu L$) and 11.62 ($10^3/\mu L$) in the respective groups at 1 h after surgery though. The leukocyte level gradually dropped at 1 day after surgery and 3 days after surgery. This result is similar to that in the study by Cheon and Yoon,[16] which showed that the erythrocyte sedimentation rate decreased gradually at 1 day after surgery. This indicates that a reduction in body temperature during surgery causes the triggering of immunosuppression,[17] leading to a reduction in leukocyte levels. This finding supports the fact that recovery can be delayed, and infection may occur at the surgical site, depending on the participant's medical condition. Therefore, it is essential to apply the warming method during surgery to promote the recovery of immune function, as well to maintain normal blood pressure and body temperature. In addition to the warming method, it is necessary to consider specific nursing interventions to prevent hypothermia and infection and to accelerate the recovery of patients, not only before surgery but also postoperatively.

Conclusion

We suggest that the application of heated humidification of anesthetic gases during laparoscopic surgery is effective in preventing a reduction in blood pressure and body temperature. Leukocyte counts show significant differences at repeated measurements, by decreasing after surgery in both the experimental group and the control group. Based on the results of this study, heated humidification of anesthetic gases during laparoscopic surgery is effective in preventing decreases in blood pressure and body temperature; however, this method is not able to maintain normal body temperature. Further studies are necessary for an accurate comparison since no other previous studies have been conducted.

Therefore, we suggest that further studies using heated humidification of anesthetic gases before, during, and after surgery should be performed to assess its influence on effective thermoregulation.

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Conflicts of interest

There are no conflicts of interest.

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