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Does the Laminar Airflow System Affect the Development of Perioperative Hypothermia? A Randomized Clinical Trial

Recai Dagli, MD[1], Fatma Çelik, MD[1], Hüseyin Özden, MD[2], and Serdar Şahin, MD[2]

Abstract

Objectives: We aimed to compare tympanic membrane temperature changes and the incidence of inadvertent perioperative hypothermia (IPH) in patients undergoing laparoscopic cholecystectomy under general anesthesia in laminar airflow systems (LAS-OR) and conventional turbulent airflow systems (CAS-OR). **Background:** Different heating, ventilation, and air-conditioning (HVAC) systems are used in the operating room (OR), such as LAS and CAS. Laminar airflow is directed directly to the patient in LAS-OR. Does laminar airflow in ORs cause faster heat loss by convection? **Methods:** This is a prospective, randomized study. We divided 200 patients with simple randomization (1:1), as group LAS and group CAS, and took the patients into the LAS-OR or CAS-OR for the operation. Clinical trial number: IRCT20180324039145N3. The tympanic membrane temperatures of patients were measured (°C) before anesthesia induction (T_0) and then every 15 min during surgery (T_n). Changes (Δ_n) between T_0 and T_n were measured. **Results:** In the first 30 min, there was a temperature decrease of approximately 0.8 °C (1.44 °F) in both groups. Temperature decreases at 45 min were higher in group LAS than in group CAS but not statistically significant, Δ_{45}, respectively, 0.89 (95% confidence interval [CI] [0.77, 1.02]) versus 0.77 (95% CI [0.69, 0.84]; $p = .09$). IPH occurred in a total of 60.9% (112 of 184) of patients in the entire surgical evaluation period in group LAS and group CAS (58.9% vs. 62.8%, $p = .59$). **Conclusions:** IPH is seen frequently in both HVAC systems. Clinically, the advantage of HVAC systems relative to each other has not been demonstrated during laparoscopic cholecystectomy.

Keywords

general anesthesia, laminar airflow, laparoscopic cholecystectomy, operating room, perioperative hypothermia, indoor air, patient safety

[1] Department of Anaesthesiology and Reanimation, Faculty of Medicine, Kirsehir Ahi Evran University, Turkey
[2] Department of Surgery, Faculty of Medicine, Kirsehir Ahi Evran University, Turkey

Corresponding Author:
Recai Dagli, Department of Anaesthesiology and Reanimation, Faculty of Medicine, Kirsehir Ahi Evran University, Kirsehir, Turkey.
Email: recai.dagli@ahievran.edu.tr; drresel@gmail.com

Inadvertent perioperative hypothermia (IPH), defined as perioperative core temperature <36 °C (96.8 °F), frequently occurs (up to 70%) during surgery under anesthesia (Torossian, 2008). The frequency of IPH in patients under general anesthesia is affected due to many different factors such as patient age, body mass index (BMI), surgical duration, and type of surgery and anesthesia (Giuliano & Hendricks, 2017).

Another factor that affects the heat loss from the body and the rate of IPH is the ambient temperature of the operating room (OR; Knaepel, 2012). Different heating, ventilation, and air-conditioning (HVAC) systems are used in the OR in order to ensure stable temperature and humidity, to provide thermal comfort of the surgical team and patient, and to provide a clean microenvironment in the surgical site (Alsved et al., 2018; Van Gaever et al., 2014). In the last decades, laminar airflow systems (LAS) and conventional airflow systems (CAS) have been widely used for the air conditioning of ORs. In ORs with laminar airflow systems (LAS-OR), called ultraclean rooms, laminar airflow is routed vertically (ceiling mounted with a downward flow over the operating table) or horizontally (wall mounted with the horizontal flow) to the operating table. In ORs with conventional airflow (CAS-OR), turbulent airflow (nonlaminar flow) is routed from a ceiling- or wall-mounted inlets to ORs (Weiser & Moucha, 2018).

In order to provide optimal conditions for thermal safety and thermal comfort of patients and employees, new hospital buildings, ORs, and HVAC systems are being designed. Nowadays, there are different standards for the air conditioning of ORs, and in many countries, different HVAC systems are used simultaneously (Uścinowicz et al., 2015; Weiser & Moucha, 2018). In research with mannequins, according to the type of airflow, different temperatures and humidity rates were shown at different points in the ORs (Cao et al., 2018; Liu et al., 2015). Is this difference in airflow significant to the core temperature of patients in the clinic? Laminar airflow is directed directly to the patient in LAS-OR. Does laminar airflow in ORs cause faster heat loss by convection? There are insufficient studies in the literature on this subject. Randomized trials are needed to answer these questions. Therefore, we planned this randomized clinical trial to compare the effects of conditioning systems on IPH during surgeries with general anesthesia. In our research, we aimed to evaluate whether the temperature changes of patients undergoing laparoscopic cholecystectomy under general anesthesia were different in LAS-OR and CAS-OR.

Is this difference in airflow significant to the core temperature of patients in the clinic? Laminar airflow is directed directly to the patient in LAS-OR. Does laminar airflow in ORs cause faster heat loss by convection?

Method

Ethical Considerations

The Kirsehir Ahi Evran University Ethics Committee for Clinical Investigations approved this Clinical trial (27.3.2018 No: 2018-06/57), and we registered to the IRCT (IRCT2018032403 9145N3). We planned our survey according to the Helsinki guidelines. Patients included in the study, according to inclusion criteria, were informed about the research and each signed an informed consent form.

Study Design

The study was a prospective, parallel-group, randomized trial.

Specifications of ORs

There are a total of 10 ORs in Kirsehir Training and Research Hospital. Four ORs are LAS-OR, vertical single large diffuser systems, and six ORs are CAS-OR, vertical multi-inlet systems; the inlets are mounted, not over the operating table. Validation tests of air conditioning systems of the ORs are conducted regularly (ISO 14644 and DIN 1946 standard). All OR classifications are ISO CLASS 7.

For this study, we used two ORs, a LAS-OR (Figure 1) and a CAS-OR (Figure 2), with similar

Figure 1. The operating room with laminar airflow systems (LAS-OR).

Figure 2. The operating room with conventional airflow systems (CAS-OR).

validation results, respectively, OR volumes 117.7–120.7 m^3 (4,146.54–4,262.48 ft^3), air supply fresh air 1,860–1,877 m^3/h (65,685.3–66,285.65 ft^3/h), air changes per hour 16–16, humidity 34%–31.3%, and temperature 22.2 °C–22.8 °C (71.96 °F–73.04 °F).

We performed all operations in these two ORs, according to randomization.

Patients, Inclusion and Exclusion Criteria

We investigated patients who underwent laparoscopic cholecystectomy under general anesthesia in Kirsehir Training and Research Hospital between December 2018 and November 2019. We included patients whose American Society of Anesthesiologists (ASA) score was I–II, who were aged 18–65 years, with BMI between 18.5 and 35.0, and who signed the research volunteer form. We excluded patients who have hypertension, cardiac arrhythmia, hypothyroid, hyperthyroid, and corticoadrenal insufficiency.

Groups and Randomization

Two groups were defined:

1. Group LAS: patients underwent surgery in ORs with a LAS.
2. Group CAS: patients underwent surgery in ORs with a CAS.

The volunteers were divided using simple randomization by the closed envelope method, respectively, as group LAS and group CAS (1:1) preoperatively. We determined the actual sample size by a preliminary study on 20 patients from each group. According to the preliminary study, the majority of operations took less than 60 min. For this reason, the sample size was made based on the data in 45th min. We used the G*Power Version 3.1.9.2 statistical program for power analysis ($\alpha = .05$, $1 - \beta = .9$ effect size .5) and detected that there should be 70 patients in each group. According to the results of the preliminary study, we calculated the frequency of IPH approximately 30% during this period, and patient losses during follow-up. Therefore, we included a total of 200 volunteers in the study, group LAS ($n = 100$) and group CAS ($n = 100$).

Practice

Patients were taken into the LAS-OR or CAS-OR according to the randomization. The patient's age, sex, BMI, operation room temperature (°C) and humidity (%), the amount of intravenous fluid (ml) used, and the amount of carbon dioxide (CO_2; L) insufflated at the end of surgery were recorded.

The tympanic membrane temperature of patients was measured using a Braun IRT6520 (Braun, Germany) device before anesthesia induction (T_0) and then every 15 min during surgery (T_n). All measurements were made by an anesthesia technician who was not part of the research group.

During general anesthesia, 10 ml/kg/hr 0.9% NaCl was administered intravenously at room temperature infusion using a Braun Infusomat® Space (Braun, Germany). Patients were monitored with noninvasive blood pressure, pulse oximetry saturation (SpO_2), and electrocardiography.

The induction of general anaesthesia was provided with 2–3 mg/kg (3.2–4.8 oz/lbs) propofol and 0.6 mg/kg (0.96 oz/lbs) rocuronium bromide intravenously. Patients were intubated. General anesthesia was provided with 4 L O_2, air (50%–50%), and 1 the minimum alveolar concentration (MAC) sevoflurane.

After anesthesia induction, surgical field sterilization was performed and then the patient was covered with standard surgical cotton drapes. If an intraoperative tympanic membrane temperature was detected lower than 36 °C (96.8 °F), active warming therapy was given with a Thermacare TC3249 convective warming system (Gaymar, USA).

For creating pneumoperitoneum during laparoscopy, CO_2, the intraabdominal pressure max. 12 cmH_2O, was used. CO_2, at room temperature and without humidification, was insufflated using a BL-Med15 insufflator (Med15, Turkey).

Statistical Analysis

The primary outcome of the study was to detect the change between the preanesthesia induction temperature (T_0) and temperatures measured at 15 min (T_n) intervals during the surgical procedure (Δ_T), Δ_T (°C) $= T_0$ (°C) $- T_n$ (°C). The secondary outcomes were rates of IPH (%).

Additionally, we compared basic characteristic data such as the patient's age, sex, BMI, operation room temperature and humidity, the amount of intravenous fluid used, and the amount of CO_2 used. Patients whose temperature went lower than 36 °C (96.8 °F) during surgery were accepted as having IPH, and Δ_T was not calculated in subsequent measurements due to the use of the warming therapy.

We did not follow patients who were insufflated more than 100 L (21.9 gal) of CO_2 to provide intraabdominal pressure (trocar entry leakage). Patients whose procedures started laparoscopically but then switched to open cholecystectomy due to reasons such as bleeding or adhesions were not followed up. Patients who were given blood, medication due to hypertension, hypotension, and bradycardia during surgery were not included in the statistical analysis.

Data were analyzed using the IBM SPSS Version 23.0 (IBM SPSS Inc., Chicago, IL) package program. Descriptive statistical methods (frequency, percentage, mean, standard deviation, median, interquartile (Q_1–Q_3) and 95% confidence intervals (CIs), min–max, were used to analyze the collected data. The normality of data distribution was analyzed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. In the study, the independent samples t test was used for evaluating quantitative data with normal distribution, and the Mann–Whitney U test was used to evaluate data with the abnormal distribution. The χ^2 test was used for categorical variables ($p < .05$ was accepted as significant).

Results

During the study, we evaluated 265 patients and excluded 65 patients because they did not meet the inclusion criteria. We included 200 volunteers who agreed to participate in the study; one patient in the group LAS and five patients in group CAS underwent open surgery due to intraabdominal adhesions. Due to technical problems, three patients in both groups (CO_2 outflow from trocar entry points)

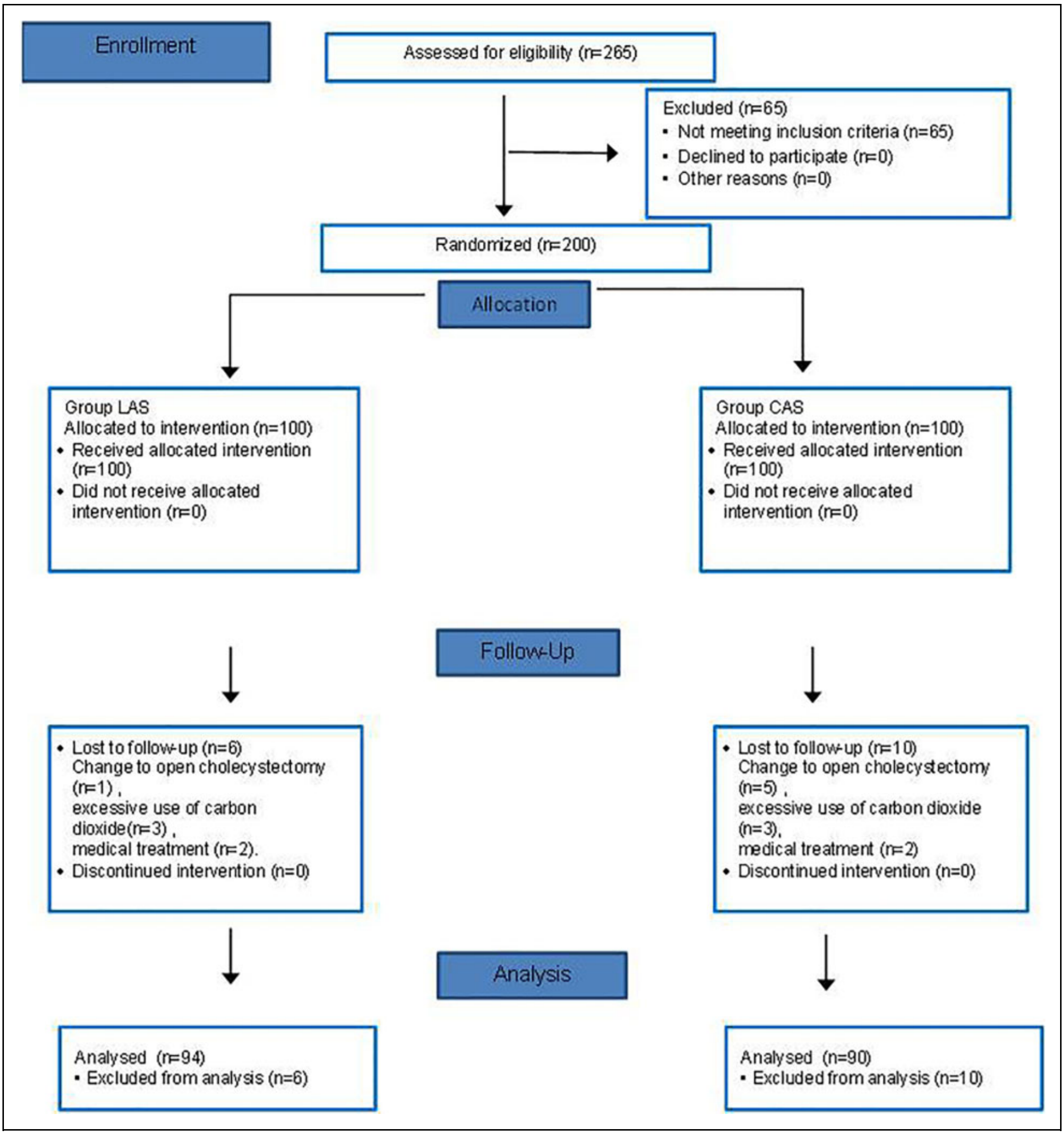

Figure 3. The Consolidated Standards for Reporting of Trials (CONSORT) flow diagram.

were insufflated for pneumoperitoneum with high volume CO_2 (>100 L). In both the groups, two patients were treated for hypertension, hypotension, or bradycardia. These patients were not followed up, and the data of the patients were not included in the statistical examination (Figure 3).

There was no statistical difference between the groups in terms of sex, ASA status, age, BMI, surgical duration, operation room temperature and humidity, the amount of intravenous fluid volume used, and the CO_2 volume used (Table 1).

We detected the mean surgical duration as 56.30 $\pm$ 19.25 min. No statistically significant difference was detected between T_0 of group LAS 36.92 $\pm$ 0.42 (95% CI [36.84, 37.01]) and T_0 of group CAS 36.89 $\pm$ 0.31 (95% CI [36.80, 36.93];

Table 1. Baseline characteristics.

Baseline characteristics		Group LAS ($n = 94$)	Group CAS ($n = 90$)	p
Sex, n (%)	Female	63 (67.0%)	63 (70.0%)	.66*
	Male	31 (33.0%)	27 (30.0%)	
ASA, n (%)	I	39 (41.5%)	40 (44.4%)	.68*
	II	55 (58.5%)	50 (55.6%)	
Age (year)		44.62 ± 11.68	44.22 ± 12.84	.83**
		45 [35–55]	25 [35–54]	
BMI (weight/height^2)		28.78 ± 3.06	28.89 ± 4.15	.83**
		29.00 [27.00–31.00]	29.50 [26.00–32.00]	
Operation times (min)		55.80 ± 21.23	56.83 ± 17.05	.27**
		45 [45–60]	60 [45–60]	
Operation room temperature (°C)		21.43 ± 1.04	21.62 ± 0.76	.11**
		21 [21–22]	22 [21–22]	
Operation room temperature (°F)		70.57 ± 1.87	70.91 ± 1.36	
		69.8 [69.8–71.6]	71.6 [69.8–71.6]	
Operation room humidity (%)		36.36 ± 13.25	34.73 ± 11.46	.53**
		37.50 [24.00–45.00]	35.00 [26.00–44.00]	
Intravenous fluid volume (ml)		802.13 ± 252.51	813.89 ± 248.37	.94**
		800.00 [600.00–1,000.00]	800.00 [600.00–1,000.00]	
Intravenous fluid volume (fl oz)		27.12 ± 8.53	27.520 ± 8.39	
		27.05 [20.28–33.81]	27.05 [20.28–33.81]	
Insufflated CO_2 volume (L)		35.12 ± 26.63	35.22 ± 18.81	.19**
		21.50 [15.00–52.00]	35.00 [22.00–45.00]	
Insufflated CO_2 volume (gal)		9.27 ± 7.03	9.30 ± 4.97	
		5.68 [3.96–13.73]	9.24 [5.81–11.88]	

Note. The data are presented as n (%), mean ± SD, and median [Q1–Q3]. LAS = laminar airflow system; CAS = conventional airflow system; ASA = American Society of Anesthesiologists score; BMI = body mass index; CO_2 = carbon dioxide.
*χ^2 test. **Mann–Whitney U Test.

$p = .21$). Tympanic temperature measurements are presented in Figure 4.

The comparison of temperature changes according to minutes (Δ_T) of group LAS and group CAS is presented in Table 2. In the first 15 min, a decrease in temperature of approximately 0.4 °C (0.72 °F) was detected in both groups. The Δ_{15}, Δ_{45} between group LAS and group CAS were not statistically significantly different ($p = .19$, $p = .09$). At the end of the 60th min (Δ_{60}), compared with baseline, an approximately 1 °C (1.8 °F) decrease in temperature occurred in both group LAS and group CAS ($p = .29$).

The comparison of the incidence of IPH during laparoscopic cholecystectomy in group LAS and group CAS is presented in Table 3. IPH occurred in 112 of 184 patients (60.9%). IPH has been detected in group LAS in 59 of 94 patients (58.9%) and 53 of 90 patients (62.8%) in group CAS ($p = .59$). When evaluated according to the intervals and total time, there was no statistically significant difference between the groups in terms of IPH incidence.

Discussion

In this study, we detected that the effects of heat loss and IPH incidence of operation rooms with LAS and CAS were similar in patients undergoing laparoscopic cholecystectomy under general anesthesia. Heat loss from the body develops with radiation, convection, conduction, and evaporation. A significant part of the heat loss in the clinic is through radiation and convection, and these are dependent on skin–air temperature difference and airflow (English, 2001).

Heat loss from the body develops with radiation, convection, conduction, and evaporation. A significant part of the heat loss in the clinic is through radiation and convection, and these are dependent on skin–air temperature difference and airflow.

Different HVAC systems are used to provide ambient temperature and clean airflow in the ORs. In these systems, airflow is provided at different points in the ORs. As a result, different temperatures and humidity can be seen in different areas in ORs. Especially with laminar airflow, the purpose is to ensure a clean microenvironment in operation rooms and reduce surgical site infection (SSI) rates (Alsved et al., 2018; Van Gaever et al., 2014; Weiser & Moucha, 2018). In LAS-OR, laminar airflow is directed toward the patient, but does laminar airflow cause faster heat loss and higher IPH rates?

Different HVAC systems are used to provide ambient temperature and clean airflow in the ORs. In these systems, airflow is provided at different points in the ORs. As a result, different temperatures and humidity can be seen in different areas in ORs.

The main question of our study originates from the study of Yang et al. In this study, it was reported that LAS-OR was a risk factor for IPH (Yang et al., 2015). In today's literature, there are insufficient data to support their findings; however, Yang et al. evaluated 1,840 patients who underwent surgery under general anesthesia in their prospective, cohort, multicenter study and detected the prevalence of hypothermia under general anesthesia as 25.7%. Besides, advanced age and general surgeries were high-risk factors for IPH, according to that study. Nevertheless, the type of surgery, age, and ASA score of the patient operated in the LAS-OR were not known.

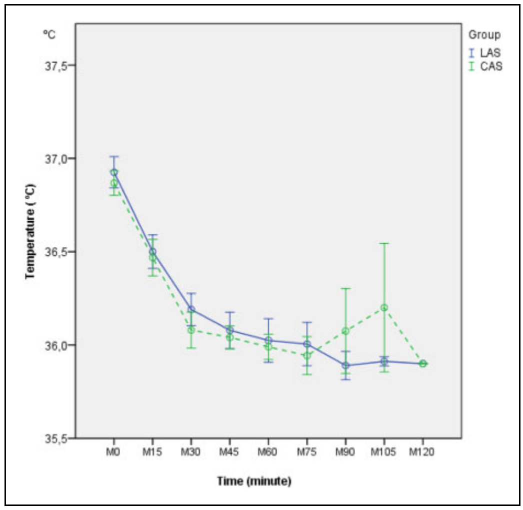

Figure 4. Tympanic temperature measurements.
Note. The data (°C) are presented as mean ± 95% confidence interval. LAS = laminar airflow system; CAS = conventional airflow system; M_0 = time (before anesthesia induction); M_n = time (n minute after anesthesia induction).

Long-term and high-risk operations are usually performed in LAS-ORs. We compared patients undergoing a single type of surgery under general anesthesia in LAS-ORs and CAS-ORs. We included patients with similar characteristics such as age, ASA risk status, and BMI.

After reviewing the study of Yang et al., we searched the literature and found no prospective randomized studies comparing the effects of different HVAC systems on IPH and heat loss; therefore, we planned this prospective randomized study. It is known that the ASA risk group, age, and BMI of the patient, surgical duration, type of surgery, and anesthesia affect the incidence of IPH and heat loss from the body (Giuliano & Hendricks, 2017; Knaepel, 2012; Sessler, 2008). Therefore, we included patients with similar ASA risk groups, BMI, and age range for standardization in the study. We performed general anesthesia with standard anesthesia induction on all patients. For our study, we decided upon laparoscopic cholecystectomy as the standard type of surgery. The same surgical team performed standard laparoscopic cholecystectomy on all patients. In addition, we did

Table 2. Compare of Temperature Change According to Minutes (Δ_T) of Group LAS and Group CAS.

Change According to Minutes	Total Patient (*n*)/ Group LAS (*n*)/Group CAS(*n*) (184/94/90)	Group LAS	Group CAS	*p*
Δ_{15} (°C)	184/94/90	0.43 ± 0.36 0.40 [0.20–0.60]	0.40 ± 0.46 0.40 [0.20–0.50]	.19*
Δ_{30} (°C)	165/83/82	0.76 ± 0.41 0.70 [0.40–1.10]	0.78 ± 0.51 0.70 [0.40–1.10]	.67*
Δ_{45} (°C)	117/60/57	0.90 ± 0.49 0.90 [0.60–1.25]	0.77 ± 0.28 0.80 [0.60–1.00]	.09**
Δ_{60} (°C)	48/22/26	1.01 ± 0.50 1.00 [0.70–1.20]	0.87 ± 0.37 0.95 [0.70–1.20]	.30**
Δ_{75} (°C)	14/6/8	0.95 ± 0.16 0.95 [0.90–1.00]	1.20 ± 0.32 1.30 [1.00–1.40]	.07**
Δ_{90} (°C)	5/3/2	1.23 ± 0.21 1.30 [1.00–1.40]	1.00 ± 0.00 1.00 [1.00–1.00]	.23**
Δ_{105} (°C)	3/1/2	1.10 1.10	1.10 ± 0.00 1.10 [1.100–1.10]	
Δ_{120} (°C)	0			

Δ_T (°C)= T_0 (°C) − T_n (°C)
Δ_T (°F)= [T_0 (°C) − T_n (°C)] × 1.8

Note. T_0, °C (before anesthesia induction); T_n, °C (*n* minute after anesthesia induction). The data are presented as *n* (%), mean ± *SD*, and median [Q1–Q3]. LAS = laminar airflow system; CAS = conventional airflow system.
*Mann–Whitney *U* Test. **Student's *t* test.

statistically analyze patients who were converted from laparoscopy to open surgery.

It is known that the ASA risk group, age, and BMI of the patient, surgical duration, type of surgery, and anesthesia affect the incidence of IPH and heat loss from the body.

Laparoscopic cholecystectomy has been used since the 1980s (Keus et al., 2006). CO_2 is often used to provide pneumoperitoneum during laparoscopic cholecystectomy (Perrin & Fletcher, 2004). Numerous complications such as visceral and vascular damage, acute kidney injury, cardio cerebral vascular insufficiency, pulmonary atelectasis, and venous gas embolism may occur due to increased intraabdominal pressure, the patient position, and absorption of CO_2 during laparoscopic surgery (Hayden & Cowman, 2011; Junghans et al., 1997; Odeberg et al., 1994).

Heat loss and hypothermia in laparoscopic surgeries have been investigated in numerous studies since the 1980s (Berber et al., 2001; Birch et al., 2016; Dean et al., 2017; Makinen, 1997; Ott, 1991). According to these studies, there are factors specific to laparoscopic surgery associated with heat loss and hypothermia, such as the amount of CO_2 used, and whether heated and humidified CO_2 is used.

In the study of Berber et al. (2001), which compared laparoscopic and open surgeries, approximately 1 °C (1.8 °F) heat loss was detected during laparoscopic cholecystectomy. It was stated that the majority of heat loss was related to general anesthesia. Besides, in this study, it is seen that the surgical procedure lasted longer than 2 hr, approximately 400 L of CO_2 was used, and the measurements of hypothermic patients were included (Berber et al., 2001). In our study, we found that heat loss occurred in patients at similar rates to this study. However, the average surgical duration in our study was less than 1 hr. Also, the amount of CO_2 used was much less. In our study, unlike this study, we provided active heating therapy to patients who developed IPH and did not statistically evaluate

Table 3. Comparison of the Incidence of Inadvertent Perioperative Hypothermia During Laparoscopic Cholecystectomy in Group LAS and Group CAS.

Time	Total IPH IPH (*n*)/Total (*n*) (%)	Group LAS IPH–LAS (*n*)/LAS (*n*) (%)	Group CAS IPH–CAS (*n*)/CAS (*n*) (%)	*p*
M_0	0/184	0/94	0/90	
M_{15}	18/184(9.8%)	10/94(10.6%)	8/90(8.9%)	.88*
M_{30}	58/183(31.7%)	27/93(29.0%)	31/90(34.4%)	.43**
M_{45}	83/165(50.3%)	43/81(53.1%)	40/84(47.6%)	.48**
M_{60}	59/95(62.1%)	30/45(66.7%)	29/50(58.0%)	.51*
M_{75}	26/35(74.3%)	16/21(76.2%)	10/14(74.3%)	1.00***
M_{90}	15/18(83.3%)	9/10(90.0%)	6/8(75.0%)	.56***
M_{105}	9/12(75.0%)	7/8(87.5%)	2/4(50.0%)	.24***
M_{120}	4/4(100.0%)	2/2(100.0%)	2/2(100.0%)	
Total	112/184(60.9%)	59/94(62.8%)	53/90(58.9%)	.59**

Note. The data are presented as *n* (%). IPH = inadvertent perioperative hypothermia; LAS = laminar airflow system; CAS = conventional airflow system; M_0 = time (before anesthesia induction); M_n = time (*n* minute after anesthesia induction). *Continuity correction. **Pearson χ^2. ***Fisher's exact test.

other temperature measurements of these patients during the surgical procedure.

In another study that compared heat loss in laparoscopic and open cholecystectomies, it was shown that there was 0.7 °C heat loss in 1 hr in both groups (Makinen, 1997). Heat loss in open surgery and laparoscopic surgery using unheated CO_2 is similar in terms of heat loss during the surgical procedure, according to this study. The core temperature drops 0.3 °C, with every 50 L of CO_2 used in pneumoperitoneum in laparoscopic surgeries (Ott, 1991). In our study, the amounts of CO_2 used in both groups were similar. To reduce the effect of CO_2-related heat loss, we did not statistically evaluate the data of patients who received more than 100 L (21.99 gal) of CO_2.

We have known that the risk and rate of development of IPH are different according to different anesthesia methods. In particular, general anesthesia has a significant effect on thermal hemostasis at the beginning of the perioperative period (Sessler, 2008). The core temperature decrease in the rapid reduction phase after the general anesthesia induction, in the first 30–45 min, was reported as 1 °C–1.5 °C (Kirkbride & Buggy, 2003). In our study, we found a heat loss of approximately 0.8 °C (1.44 °F) in the first 30 min.

In addition to the effects of surgical method and general anesthesia on heat loss and IPH incidence, some factors should be discussed, such as the temperature of intravenous fluids and patient insulation. According to the review of Campbell et al. (2015), warmed intravenous fluid keeps the core temperature about half a degree warmer than room temperature intravenous fluids and reduces the risk of shivering. In our study, all patients were given intravenous infusion at room temperature at the standard rate.

Nowadays, much passive thermal insulation and active heating systems are used to prevent IPH during surgery. In the literature, it is emphasized that active systems are more successful than passive systems in preventing the development of IPH (Carroll & Davis, 2013; Kurnat-Thoma et al., 2016; Maglinger et al., 2005). In our study, all patients were covered with a cotton drape during the preoperative period. Patients were actively warmed when the tympanic membrane temperature of the patient was <36 °C (96.8 °F) during surgery.

The meta-analysis of Dean et al. (2017) indicated that warmed, humidified CO_2 used in laparoscopic surgery provided benefits in intraoperative core temperature. On the other hand, it was stated in the review of Cheong et al. (2018) that "while evidence supporting the benefits of using humidified and warmed CO_2 can be found in the literature, large human randomized controlled trials are required to validate these findings." In our study, we used a similar amount of unheated and nonhumidified CO_2 in both groups.

Limitations

In some studies, it is stated that laminar flow does not give the desired effect in terms of lower SSI rates, which is due to the position of the surgical lamps and surgical team and the opening and closing of the operation room door during surgery (Erichsen Andersson et al., 2014; Weiser & Moucha, 2018). During our research, we removed the surgical lamps from the processing area in order not to obstruct the laminar airflow. Nevertheless, we could not wholly prevent the opening and closing of the room door.

Depending on the redistribution after the general anesthesia induction, the temperature in different areas of the body develops in different degrees (Makinen, 1997). In studies investigating heat loss in laparoscopic surgeries, temperature measurements were frequently performed nasopharyngeal and rectally, and naturally, the amount of heat loss recorded during surgery was determined differently (Berber et al., 2001; Makinen, 1997). Tympanic temperature measurement by an infrared thermometer has its limitations (Sessler, 2008). In our study, we measured the tympanic temperature and calculated the temperature differences according to these values. Unlike these studies, we gave active warming treatment from the moment the patient was detected as being hypothermic, accepted the patient as having IPH, and calculated not Δ_T for statistical evaluation from this point. The amount of heat loss detected in our study is different from those found in these studies. We attribute this difference to factors such as measuring tympanic temperature, and actively warming hypothermic patients, thereby preventing further increases in heat loss.

In our study, in the first 30 min, all patients had significant heat loss, about 0.8 °C (1.44 °F), due to unheated CO_2 insufflation and induction of general anesthesia. The effects of general anesthesia and the effects of unheated CO_2 insufflation could mask heat loss due to airflow in the room during the first 30 min. At 45 and 60 min, the heat loss in the LAS-OR was more pronounced but was not statistically significant. Most of the operations in our study lasted less than 60 min.

We presented only the number of patients calculated with Δ_T in Table 2. On the other hand, in Table 3, the total number of patients ongoing surgery and the number of patients with IPH were presented. These differences in the number of patients between the two tables are because, while the operation ongoing, Δ_T was not calculated from the moment the patient was hypothermic.

Initially, we planned the IPH frequency as 30% while calculating the sample size. However, the frequency of IPH in the 45th min is about 50%. Therefore, the initially calculated power could not be realized.

For these reasons, the results of this study should be supported with more prolonged surgical procedures where hypothermia develops more slowly, with the exclusion of factors that cause hypothermia, such as rapid insufflation of unheated CO_2. In addition, as stated in the review, interdisciplinary research is needed to evaluate the effects of HVAC systems on perioperative patients' safety during surgery (Shajahan et al., 2019).

Conclusion

As a result, IPH is seen frequently in both HVAC systems. The temperature should be strictly monitored to ensure the safety of the patient during the operation in both HVAC systems. In terms of IPH development, the advantage of LAS and CAS relative to each other has not been demonstrated in patients undergoing laparoscopic cholecystectomy under general anesthesia.

Interdisciplinary researches, more prolonged surgical procedures where hypothermia develops slowly during surgery, are needed to evaluate the relationship between HVAC systems and IPH. A large number of interdisciplinary clinical studies on humans should be conducted to guide the design of new optimal ORs and HVAC systems.

Implications for Practice

- IPH frequently occurs during surgery under anesthesia.
- The temperature should be strictly monitored to ensure the safety of the patient during the surgery.
- The frequency of IPH is affected surgical duration, type of surgery and anesthesia, and the ambient temperature of the operating room.
- Laminar airflow systems (LAS-OR) and conventional turbulent airflow systems (CAS-OR) are used in the operating room.
- Laminar airflow is directed toward the patient in LAS-OR.
- Is laminar airflow cause the faster heat loss and higher IPH rates?
- IPH incidence is similar in operation rooms with laminar and conventional airflow systems.

Authors' Note

The data are deidentified participant data (Microsoft Excel file (.xlsx)). Data are available by email from the corresponding author. The authors presented this preliminary study at 53th TARD National Congress (2019, Antalya, Turkey) as an oral presentation.

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ORCID iD

Recai Dagli https://orcid.org/0000-0002-6364-0545

Supplemental Material

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