The Effect of Sevoflurane Low-Flow Anesthesia on Preserving Patient Core Temperature

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Low-flow anesthesia · Perioperative hypothermia · Sevoflurane

Abstract

Introduction: Low-flow anesthesia (LFA) reduces the fresh gas flow (FGF) entering the anesthesia circuit and saves on volatile agent used. In this study, the effect of LFA with sevoflurane on core temperature and the incidence of perioperative hypothermia were investigated. Methods: According to the FGF applied, patients were classified into three groups: LFA (1 L/min), medium-flow anesthesia (MFA = 2 L/min), and high-flow anesthesia (HFA = 4 L/min). Patients’ demographic data and the initial (T1) and final (T2) core temperatures during the operation were compared. Results: A total of 160 patients were included in the study. The T2 value of the HFA group was significantly lower than the LFA group ($p = 0.028$). Different flow values were found to have a significant effect on temperature change ($F = 21.630$, $p < 0.001$, partial eta squared = 0.216). There was a significant difference between the mean temperatures measured at two different times ($F = 301.064$, $p < 0.001$, partial eta squared = 0.657). The overall incidence of hypothermia was 32.5%, with 52 patients. Hypothermia ($T^\circ < 36^\circ C$) incidences were not different between the LFA group and the MFA and HFA groups ($p = 0.682$). However, perioperative core temperature loss was significantly lower in the LFA group ($p = 0.001$).

Conclusions: LFA using sevoflurane was not sufficient alone to significantly reduce the incidence of hypothermia. However, we have demonstrated that it may also have a beneficial effect on reducing perioperative temperature loss.

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haler concentration and used again after passing through a carbon dioxide absorbent. However, with this technique, carbon dioxide absorbent quickly consumes its usage capacity and patients have an increased risk of hypercarbia. It provides significant savings for hospitals as the extra spent absorbent is cheaper than the amount of wasted inhaler gas. Perioperative hypothermia is associated with increased complications in patients [4]. Delay in recovery from anesthesia, increased cardiac complications, delay in wound healing, disruption of coagulation, and increased hospital stay are some undesirable consequences of hypothermia [5]. According to one study, 30% of patients experience hypothermia in operations under 1 h when heating methods are not applied [6]. For this reason, core temperature monitoring, diagnosis, and treatment of hypothermia are important concerns for anesthesiologists. Nowadays, sevoflurane is widely used in LFA [7]. This technique, which is primarily cost-oriented, has been subject of studies on the depth of anesthesia, recovery time, anesthetic gas consumption, costs, and effects on global warming [2, 8, 9]. However, the effect of the LFA technique using sevoflurane on the preservation of patient core temperature has not been adequately investigated yet. Our study aimed to test the effectiveness of low-flow sevoflurane anesthesia in maintaining patient core temperature by comparing it with high-flow anesthesia (HFA).

**Materials and Methods**

After obtaining approval for our study from the Local Ethics Committee (2017-KAEK-251219.1), the hospital archives and patient records were examined retrospectively between January 2018 and June 2020, and data were collected.

**Data Studied**

Inclusion criteria: American Society of Anesthesia (ASA) class 1–3 patients aged 18–65 years were included. Patients with anesthesia follow-up available forms, surgical procedures performed under general anesthesia, patients who had preoperative and postoperative temperature measurements, and patients operated on with sevoflurane anesthesia at different flow rates were included in our study. Among these patients, those whose operation lasted over 2 h were included. Septoplasty, rhinoplasty, and other nose and ear surgeries performed in the otolaryngology (ENT) operating room were included.

Operations lasting less than 2 h, cases in which FGF rates were not specified, and blood, fluid, heating methods, or mechanical ventilator modes not specified were not included. In addition, those with known autonomic neuropathy, diabetic neuropathy, chronic obstructive lung diseases, peripheral vascular diseases, and patients whose body mass index (BMI) was >40 were excluded. The operating room temperature is kept in a constant range in all ENT rooms.

General anesthesia and flow protocol was applied as follows in our clinic; electrocardiography, pulse oximetry, noninvasive blood pressure monitoring were performed on the patients after they were taken to the operating table. Anesthesia was induced with 2 mg/kg propofol, 2 μg/kg fentanyl, and 0.6 mg/kg rocuronium. After induction, a thermocouple temperature probe was placed in the patients’ pharynx for temperature measurement. Sevoflurane was used for anesthesia maintenance. A FGF of 4 L/min with 80% O₂ mixed with air was applied until 0.9–1 MAC value was reached. Later, the free FGF of some of the patients was reduced and surgery was continued under LFA and medium-flow anesthesia (MFA). Mechanical ventilation settings on volume-controlled mode; tidal volume 8–10 mL/kg; respiration rate 12–14 r/min; end-tidal carbon dioxide value 30–40 mm Hg; PEEP (positive end-expiratory pressure) 5 cm H₂O; and a patient-inspired oxygen rate >40% (oxygen-air mixture) were set and ventilation provided (GE Datex-Ohmeda Avance, Irvin, CA, USA). Intravenous remifentanil infusion of 0.05–0.2 μg/kg/min was applied to all patients for intraoperative analgesia. 1 mg/kg tramadol for postoperative analgesia and ondansetron hydrochloride (0.15 mg/kg) for postoperative nausea and vomiting were administered intravenously 20 min before the end of the operation. Mechanical heat and moisture exchangers were used as a standard in all cases. 10 min before the end of the surgery, the sevoflurane vaporizer was turned off and the FGF was increased to 4 L/min. One last measurement was made and the temperature probe was removed. 2 mg/kg sugammadex was administered to reverse muscle relaxants. After the extubated patients responded to verbal stimulus, they were transferred to the postanesthesia care unit.

**Groups according to the Different FGFs Applied**

In our study, patients were classified as the LFA group (1 L/min), MFA group (2 L/min), or HFA group (4 L/min) according to the flow rates used in inhalation anesthesia. Between the groups, demographic data including age, gender, BMI, and intraoperative data including applied fluids, blood or blood products, and temperature changes were compared.

Core temperature measurements were made with a temperature probe placed in the pharynx (reusable temperature probe 2107176-031, GE Bluepoint Medical, Germany). The first measurement made with the temperature probe placed after endotracheal intubation was recorded as the initial core temperature (T1). The measurement made in the last 10 min of the procedure before the flow was increased was recorded as the final temperature (T2) value. Perioperative temperature losses of the patients were calculated with the formula T1–T2 and recorded as Td. Hypothermia was defined as core temperature below 36°C [5, 10]. Preoperative hypothermic patients were excluded. Patients with a T2 of <36°C were considered hypothermic. Mild hypothermia refers to core temperatures between 34 and 36°C [10, 11].

**Statistical Analysis**

Data were statistically analyzed using the Statistical Package for the Social Sciences software (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc.). The suitability of variables to normal distribution was examined with histogram graphics and the Kolmogorov-Smirnov test. All continuous variables were expressed as the mean ± standard deviation, and categorical variables were expressed as frequencies and percentages. One-way ANOVA was used for parametric variables with a
normal distribution and the $\chi^2$ test was used for categorical variables. Tukey test was used for post hoc analysis. To define the effect size, the partial eta square value was calculated using the SPSS program. According to this analysis, a value of 0.01 is considered minor impact, 0.06 is considered medium impact, and 0.14 is considered large clinical impact.

## Results

Anesthesia follow-up records of operations performed under general anesthesia in our ENT operating rooms between January 2018 and January 2020 were retrospectively examined. A total of 160 patients who met the study criteria were identified; 66 (41.25%) of these patients were in the 1 L/min low flow group, 50 (31.25%) were in the 2 L/min medium flow, and 44 (27.5%) were in the 4 L/min high flow group. Age, gender, BMI, amount of applied fluid, hemoglobin levels, operation times, surgery type, and intraoperative temperature data recorded in files and anesthesia follow-up forms were examined and analyzed.

When the age, gender, BMI, and type of surgery were compared, the groups were not statistically different ($p > 0.05$; Table 1). There was no significant difference between the groups in terms of operation time, intraoperative fluid treatments and pre-procedure hemoglobin values of the patients ($p > 0.05$; Table 1). There were no patients using blood products and therefore excluded from the study.

There was no significant difference in T1 temperature values between the groups. When the T2 values were compared, it was observed that the temperature value of the HFA group was significantly lower than the LFA group ($p = 0.028)$ (Table 2). Different flow values were found to have a significant effect on temperature change ($F = 21.630, p < 0.001, \text{partial eta squared} = 0.216$). This relationship is shown in Figure 1. It was observed that there was a significant difference between the mean temperatures measured at two different times ($F = 301.064, p < 0.001, \text{partial eta squared} = 0.657$). It was found that the effect of both perioperative temperature changes and flow changes significantly affected the clinical outcomes of the patients. Among all patients included in the study, the

### Table 1. Comparison of demographic data, operation times, and intraoperative fluid amounts given by the groups

|                      | LFA group | MFA group | HFA group | $p$ value |
|----------------------|-----------|-----------|-----------|-----------|
| n (%)                | 66 (41.5) | 50 (31.25)| 44 (27.5) |           |
| Age, years           | 35.75±15.16 | 38.46±14.63 | 40.47±15.75 | 0.268     |
| Gender, female/male  | 38 (57.6)/28 (42.4) | 28 (56)/22 (44) | 19 (43.2)/25 (56.8) | 0.296 |
| BMI                  | 27.33±4.51 | 29.06±5.42 | 28.15±5.04 | 0.189     |
| Surgery duration, min | 179.75±55.59 | 185.36±61.34 | 190.25±61.18 | 0.653     |
| Fluids applied, mL   | 1,162.12±593.49 | 1,380.00±605.75 | 1,288.75±628.36 | 0.102     |
| Preoperative Hb, mmol/L | 7.79±1.61 | 7.92±1.08 | 7.93±1.4 | 0.482     |
| Surgery, (Sp, Ms, Rh), n | 19/29/18 | 19/16/15 | 17/13/14 | 0.543     |
| Surgery, %           | 28.8/43.9/27.3 | 32/32/30 | 38.6/29.5/31.8 |           |

The results are expressed as mean and SD. LFA, low-flow anesthesia; MFA, medium-flow anesthesia; HFA, high-flow anesthesia; SD, standard deviation.

### Table 2. Comparison of temperature measurements between groups

|                      | LFA group | MFA group | HFA group | $p$ value |
|----------------------|-----------|-----------|-----------|-----------|
| T1                   | 36.57±0.41 | 36.58±0.49 | 36.76±0.36 | 0.061     |
| T2                   | 36.25±0.47 | 36.17±0.58 | 35.99±0.42 | 0.028     |
| Td                   | 0.32±0.31 | 0.40±0.36 | 0.88±0.43 | <0.001    |
| Hypothermia incidence, n (%) | 19 (28.8) | 17 (34) | 16 (36.4) | 0.682     |

The results are expressed as mean and SD. T1, initial temperature in Celsius; T2, final temperature; Td, difference between T1 and T2; LFA, low-flow anesthesia; MFA, medium-flow anesthesia; HFA, high-flow anesthesia; SD, standard deviation.
The incidence of postoperative hypothermia was found to be 32.5%. According to the groups, this ratio was calculated as 28.8% in the LFA group, 34% in the MFA group, and 36.4% in the HFA group. There was no statistically significant difference in the incidence of postoperative hypothermia between the groups ($p = 0.682$; Table 2). However, when the temperature changes between the groups were compared, the first and last temperature difference (Td) in the group HFA was significantly higher than the other two groups ($p < 0.001$; Table 2).

**Discussion**

Hypothermia, defined as a core body temperature less than 36°C (96.8°F), is a relatively common occurrence in the unwarmed surgical patient [12]. Hypothermia is associated with increased perioperative bleeding, a delay in wound healing, prolonged anesthesia extubation time, increased cardiac complications, and even increased mortality [13]. Even in mild hypothermia, a significant increase in cardiac complications is observed [4, 11]. Many national and international guidelines have been published to reduce the risks of hypothermia [12, 14, 15]. However, the application of guidelines and the measures taken to prevent hypothermia seems to be insufficient. In a study, it was observed that anesthesiologists do not sufficiently follow hypothermia guides [16]. Eventually, despite the precautions taken, it was seen that a significant proportion of patients were sent to the recovery room hypothermic after the operation. Complications from hypothermia result in prolonged hospitalization, mortality, morbidity, which justifies the importance of this issue on the agenda.

Apart from applying active heating methods in patients, the effectiveness of anesthesia in preventing hypothermia is a research topic [17, 18]. In a study comparing lung-protective ventilation and conventional high tidal volume ventilation, lung-protective ventilation did not have an advantage in maintaining the patient’s core temperature [19]. The excessive flow of fresh gas into the anesthesia circuit in HFA requires the air supplied to the patient to be reheated and humidified each time [20, 21]. This causes temperature loss in the patient through the airway [22, 23]. Also, better protection of mucociliary activity in LFA provides a benefit in maintaining temperature [24]. In our results, it was seen that patients who underwent HFA had more temperature loss. Low fresh gas application is more effective in maintaining the patient’s core temperature. Theoretically, this method may also reduce the costs associated with hypothermia complications and may be another cost effect of LFA.

Nowadays, sevoflurane is a frequently preferred gas in LFA [25, 26]. However, there are still some risks of LFA. Some problems should be taken into consideration, such as increased risk of hypercarbia, early depletion of carbon dioxide absorption, and the possibility of failing to achieve target oxygenation even with 100% oxygen delivered to the circuit in overweight patients [27]. The need to calibrate flow meters for low flow will always be a must [25]. Considering the results of our study, with all its benefits and limitations, LFA appears to be profitable for the hospital and advantageous for the patient in maintaining core temperature, with the potential to reduce complications and costs from hypothermia.

In our study, the mean duration of surgery was 185.6 ± 59.7 min, and our incidence of hypothermia was 32.5%. In a study conducted by Aksu et al. [28], which included pediatric and geriatric patients, the incidence of postoperative hypothermia was found to be 45%. In another study conducted on geriatric patients, the incidence of hypothermia increased even in operations under 1 h [6]. The benefit of LFA application on reducing temperature loss may be more pronounced in procedures that take longer than 1 h and in hypothermia-sensitive groups such as infants and children. Additionally, LFA can be used as an effective method to reduce postoperative hypothermia, especially in procedures that take longer than 1 h. However, the effectiveness of LFA in reducing hypothermia may be limited in procedures that take longer than 1 h, such as those performed with other anesthetic techniques. In conclusion, LFA appears to be advantageous for hospital and patient in maintaining core temperature and reducing complications from hypothermia.
as pediatric and geriatric patients. In addition, although the decrease in the incidence of hypothermia is not statistically significant, this situation may change with increasing sample size.

There are also studies showing that patients wake up faster after LFA [29, 30]. Heiler et al. [31] showed that plasma anesthetic concentrations were higher in hypothermic patients during recovery [30]. However, we determined that different flow rates affect the core temperature and we think that the reduction of temperature loss in LFA may have an effective role on rapid recovery. Operating room temperatures were in a constant range in each room. In our study, the operations were maintained in all three groups with fixed-range analgesic dose and neuromuscular blockers, and the depth of anesthesia was not followed during the operation [32]. Considering all these in the same study, the correlations of these factors with temperature loss may be the subject of a different study. Although LFA reduced core temperature loss, it was certainly not sufficient alone to reduce the incidence of hypothermia. Besides, in cases where the anesthesia method cannot be changed, changing the method of applying anesthetic gas (HFA or LFA) may be a method to reduce core temperature loss.

Limitations: the most important limitation of our study is that it is a retrospective study. In addition, the low number of study patients can be considered as another important limitation. Undoubtedly, more operations were performed in the ENT room during the specified periods. However, the selection criteria for inclusion in our study and the exclusion of patients with incomplete information in their files caused a significant decrease in the number of patients. In practice, many factors can affect the patient’s temperature. It may be necessary to work with a larger number of patients to understand the total effect of these factors. Since our study was conducted with retrospective data, we tried to keep other factors constant in order to focus only on the effect of FGF on core temperature. We believe that a larger patient cohort should be used in a prospective study. This study may also contribute to future studies as it shows that LFA can contribute to the maintenance of core temperature as well as to reduce costs.

**Conclusion**

Our study results show that LFA is superior for maintaining patient core temperature compared to medium and high flows. However, it is not sufficient to decrease the incidence of perioperative hypothermia. In addition to LFA being a cost-oriented technique, its use can have a beneficial effect in terms of reducing perioperative temperature loss.

**Statement of Ethics**

In order to carry out the research, necessary institutional permissions were obtained from the relevant units, and local and international ethics committee permission was obtained from the Ethics Committee. De-identification of patients’ data used in this research was carried retrospectively, and the need to obtain a written consent, rather than the general patient’s consent to treat and use their data for research, was waived by the Bozok University Ethical Committee. Trial Registration: researchregistry.com/6480, January 20, 2021. University Ethical Committee: Yozgat Bozok University (2017-KAEK-251219.1) date: December 25, 2019.

**Conflict of Interest Statement**

The authors have no conflicts of interest to declare.

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**Author Contributions**

Dr. Ahmet Yuksek is responsible for designing the study, collecting data, and writing the article. Dr. Gamze Talih is responsible for collecting and analyzing data. The final version of the article was reviewed and approved by both the authors.

**Data Availability Statement**

The data that support the findings of this study are not publicly available as the data contain the identity information of the participants, but are available without participant names from the corresponding author (A.Y.) or Data Sharing Committee (Bozok University Clinical Research Ethics Committee, kliniketikkurul@bozok.edu.tr) upon reasonable request.

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