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

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Research Article

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Abstract

Background: Low flow anesthesia reduces the fresh gas flow (FGF) entering the anesthesia circuit and saves on the volatile agent used. In this study, the effect of low-flow anesthesia with sevoflurane on core temperature and the incidence of perioperative hypothermia were investigated.

Methods: Records of patients who underwent general anesthesia with sevoflurane were analyzed retrospectively. According to the fresh gas flow applied, the patients were divided into three groups: Low flow anesthesia (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) temperatures during the operation were compared.

Results: A total of 160 patients were included in the study. There was no significant difference in T1 temperature values between the groups. 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 (T2<36 degrees) 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: Low flow anesthesia using sevoflurane was not sufficient alone to reduce the incidence of hypothermia. However, the LFA technique preserved the patient's core temperature better than the MFA and HFA techniques. Therefore, in addition to low-flow anesthesia being a cost-oriented technique, we have demonstrated that it may also have a beneficial effect on reducing perioperative temperature loss.

Trial Registration: Researchregistary.com/6840

Ethics committee: Yozgat Bozok University 2017-KAEK-25122019.1

1. Introduction

Low flow anesthesia reduces the fresh gas flow (FGF) entering the anesthesia circuit and saves on volatile agent used, which saves on inhaler gas and prevents unnecessary waste gas emissions into the atmosphere. Ventilation applied with fresh gas addition less than alveolar ventilation can be called low flow anesthesia[1]. Repeated use of unused volatile anesthetic in expiratory gas saves on use without changing the level of anesthesia in patients[2]. This technique saves up to 75% in terms of the amount of inhalation anesthetic used[3]. It allows the gas mixture given to the patient to be adjusted to the desired oxygen and inhaler 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. Besides, the amount of inspired oxygen may also be lower than the set value, resulting in an increased risk of hypoxia. In this respect, patients undergoing low flow anesthesia need careful monitoring of carbon dioxide and oxygen inspired and expired[4]. 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[5]. 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[6]. According to one study, 30% of patients experience hypothermia in operations under one hour when heating methods are not applied[7]. For this reason, core temperature monitoring, diagnosis, and treatment of hypothermia are important concerns for anesthesiologists.

Nowadays, sevoflurane is widely used in LFA[8]. 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],[4],[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.

2. Materials And Methods

After obtaining approval for our study from the local ethics committee (2017-KAEK-251219), the hospital archives and patient records were examined retrospectively between January 2020 and December 2020, and data were collected. Informed consent was obtained from all our patients, allowing the operation and the use of the data in academic research. For this retrospective study, all methods were carried out in accordance with relevant guidelines and regulations

2.1. 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 two hours were included. Septoplasty, rhinoplasty, and other nose and ear surgeries performed in the otolaryngology (ENT) operating room were included.

Operations lasting less than two hours, cases in which fresh gas flow 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 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 (ECG), pulse oximetry, non-invasive blood pressure monitoring were performed on the patients after they were taken to the operating table. Anesthesia was induced with 2 mg / kg propofol, 2mcg / 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 fresh gas flow of 4 lt / min with 80% O_2 mixed with air was applied until 0.9-1 MAC value was reached. Later, the free fresh gas flow of some of the patients was reduced and surgery was continued under low flow and medium flow anesthesia. Mechanical ventilation settings on volume-controlled mode; tidal volume 8–10 ml/kg, frequency; 12–14/min, end-tidal carbon dioxide value 30–40 mmHg, PEEP (positive end-expiratory pressure) 5 cmH2O and a patient-inspired oxygen rate > 40% (oxygen-air mixture) were set and ventilation provided (GE Datex-Ohmeda Avance, 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 minutes before the end of the surgery, the sevoflurane vaporizer was turned off and the fresh gas flow was increased to 4 lt / 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 post-anesthesia care unit (PACU).

2.2. Groups according to the different fresh gas flows applied;

In our study, patients were classified as the low flow anesthesia (LFA) group (1 l/min), medium flow anesthesia (MFA) group (2 l/min) or high flow anesthesia (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 minutes of the procedure before the flow was increased was recorded as the final temperature value (T2). 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 degrees[6][10]. Preoperative hypothermic patients were excluded. Patients with a T2 temperature of < 36°C were considered hypothermic. Mild hypothermia refers to core temperatures between 34 and 36°C [10][11].

2.3. Statistical analysis

Data were statistically analyzed using the Statistical Package for the Social Sciences software package (SPSS version 18.0, IBM). 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 (SD), and categorical variables were expressed as frequencies and percentages. One-way analysis of variance (ANOVA) was used for parametric variables with a normal distribution and the chi-squared test was used for categorical variables. Post-hoc analysis was done for variables with a homogenous distribution. In the comparison of temperature variations between groups, a repeated-measures ANOVA was used. $P < 0.05$ was considered statistically significant.

3. 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 of these patients were in the 1 l/min low flow group, 50 were in the 2 l/min medium flow, and 44 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.

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

	LFA group (n = 66)	**MFA group (n = 50)**	**HFA group (n = 44)**	**p**
Age (years)	35.75 ± 15.16	38.46 ± 14.63	40.47 ± 15.75	0.268
Gender (F/M)*	38/28	28/22	19/25	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)	1162.12 ± 593.49	1380.00 ± 605.75	1288.75 ± 628.36	0.102
Preoperative Hb (mg/dl)	12.55 ± 2.59	12.76 ± 1.74	12.78 ± 2.26	0.482
Surgery(Sp,Ms,Rh)*	19/29/18	19/16/15	17/13/14	0.543

Statistical analysis: one-way analysis of variance (ANOVA) and *chi-squared test. $p < 0.05$ significant.

LFA, MFA, HFA: low, medium, high flow anesthesia, F/M: female/male. Sp: Septoplasty, Ms: Mastoidectomies, Rh: Rhinoplasty

There was no significant difference in T1 temperature values between the groups. When the T2 temperature 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 ($F = 21.630$, $p < 0.001$, partial eta squared = 0.216) (Fig. 1).
It was observed that there was a significant difference between the mean temperatures measured at two different times ($F = 301.064$, $p < 0.001$, partial eta squared = 0.657). Among all patients included in the study, 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 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).

Table 2

Comparison of temperature measurements between groups.

	LFA group (n = 66)	**MFA group (n = 50)**	**HFA group (n = 44)**	**p**
T1	36.57 ± 0.41	36.58 ± 0.49	36.76 ± 0.36	0.061
T2	36.25 ± 0.47[b]	36.17 ± 0.58	35.99 ± 0.42	0.028
Td**	0.32 ± 0.31[a]	0.40 ± 0.36[a]	0.88 ± 0.43	< 0.001
Hypothermia* incidence	19 (28.8%)	17(34%)	16 (36.4%)	0.682
Analysis of variance in repetitive measurements (repeated measures ANOVA)				
**; ANOVA *; chi-squared test. p < 0.05 significant.				
a; Significantly lower than HFA group. b; Significantly higher than HFA group				
Td: T1-T2. LFA, MFA, HFA: low, medium, high flow anesthesia.				

4. 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 [5][11]. In a previous study, the risk of hypothermia at the end of the operation was calculated as 77% in patients without perioperative heating. 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. There are limited numbers of studies in the literature examining the effect of mechanical ventilation settings on core temperature [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]. It is critical to reaching the isothermal saturation limit to avoid damage to the mucosa and the ciliary epithelium [20][21]. The excessive flow of fresh gas into the anesthesia circuit in high-flow anesthesia requires the air supplied to the patient to be reheated and humidified each time [22][23]. This causes temperature loss in the patient through the airway. 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.

The use of sevoflurane in low flow anesthesia started late compared to desflurane due to manufacturers' recommendations and renal side effect concerns. Nowadays, sevoflurane is a frequently preferred gas in low flow anesthesia [25][26]. However, there are still some risks of low flow anesthesia. Some problems should be taken into consideration, such as increased risk of hypercarbia, early depletion of carbon dioxide absorption, 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; As long as careful monitoring and control of concentrations and appropriate technology are performed, Low-flow anesthesia 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 minutes, and our incidence of hypothermia was 32.5%. In a study conducted by Aksu et al, which included pediatric and geriatric patients, the incidence of postoperative hypothermia was found to be 45% [28]. In another study conducted on geriatric patients, the incidence of hypothermia increased even in operations under 1 hour [7]. The benefit of LFA application on reducing temperature loss may be more pronounced in procedures that take longer than one hour, and in hypothermia-sensitive groups such as pediatric and geriatric patients.

There are also studies showing that patients wake up faster after low flow anesthesia [29][30]. Heiler et al. showed that plasma anesthetic concentrations were higher in hypothermic patients during recovery [31][30]. Recovery times were not examined in our study. However, we determined that different flow rates affect the core temperature and we think that the reduction of temperature loss in low flow anesthesia may have an effective role on rapid recovery. An additional warming method was not applied to the patients in our study group. 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. Many factors increase perioperative core temperature loss [32]. Considering all these in the same study and the correlations of these factors with temperature loss may be the subject of a different study. Although low-flow anesthesia 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 fresh gas flow 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 low flow anesthesia can contribute to the maintenance of core temperature as well as to reduce costs.

5. Conclusion

Our study results show that low flow anesthesia 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 low flow anesthesia being a cost-oriented technique, its use can have a beneficial effect in terms of reducing perioperative temperature loss.

Declarations

Ethics approval and consent to participate

This study was approved by the Yozgat Bozok University clinical research ethics committee with the ethics committee decision dated 25.12.2019 and numbered 2017-KAEK-25122019.1. All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all our patients, allowing the operation and the use of the data in academic research.

Consent for publication

In this retrospective study, permission to use and publish hospital archives was obtained from Yozgat Bozok University Training and Research Hospital chief physician.

Availability of data and materials:

Dataset can be given on request as SPSS statistics program file.

Competing interests:

None

Funding:

None

Authors' contributions:

Dr. Ahmet Yuksek; Designing the research, collecting data and writing the article. Dr. Gamze Talih; Data collection and analysis, review of the article

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None

Conflict of interest:

None

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Figures

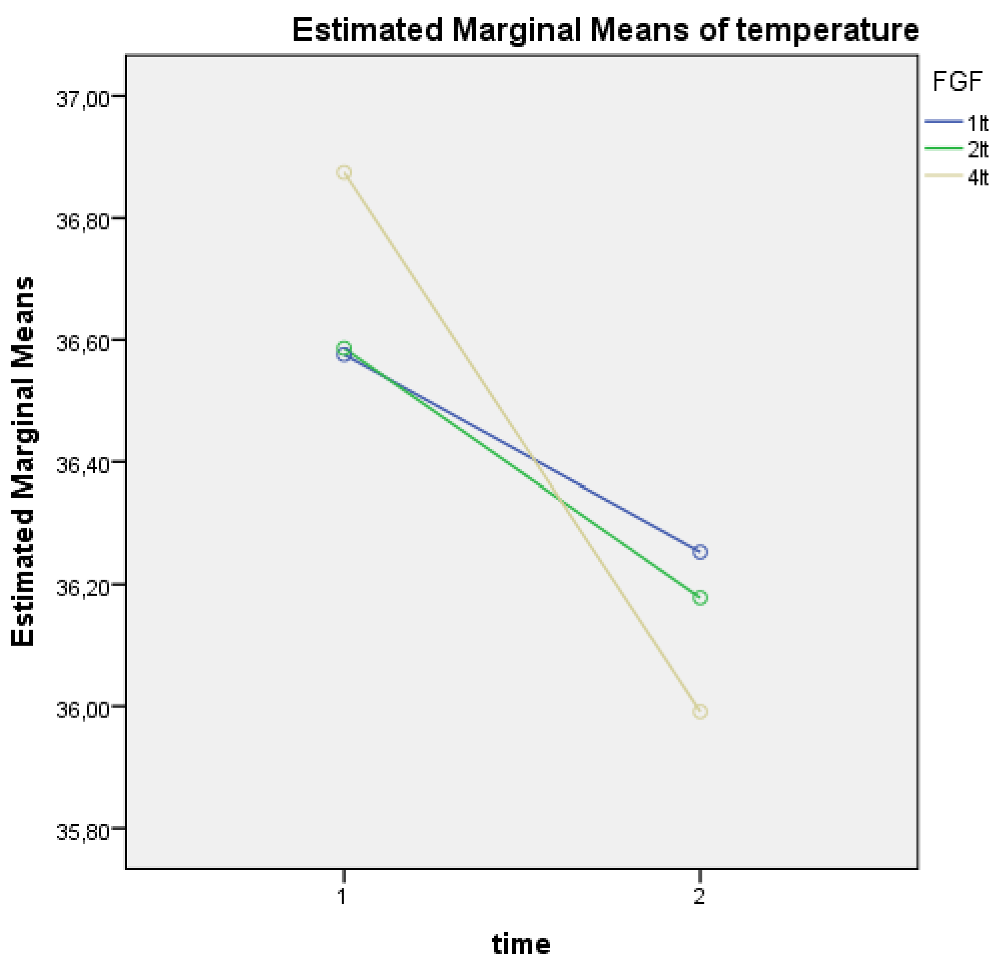

Figure 1

Change graph of average temperature according to flows

Supplementary Files

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- suplementarydata.docx