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The Impact of Fresh Gas Flow Sevoflurane Anesthesia on Perioperative Hypothermia in Adult Patients Undergoing Elective Open or Laparoscopic Digestive Surgery: A Prospective Randomized Controlled Trial

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Abstract

Background: Because body temperature is such an important indicator and a basic requirement for all kinds of life, even tiny variances might induce undesired changes. This study looked at the influence of FGFs sevoflurane anesthesia on heat preservation in patients undergoing open or laparoscopic digestive surgery. **Materials and Methods:** Two hundred and forty adult patients (18 - 75 years) with an ASA of I-II were scheduled for open and laparoscopic digestive surgery: open surgery (Group O, n = 120 patients) and laparoscopic surgery (Group L, n = 120 patients). Each group was separated randomly into four subgroups (n = 30 patients) based on FGFs (0.7, 1, 1.5, or 2 L/min). Each patient's HR, MBP, SpO_2, FiO_2, fluid infusion amount, urine volume, pre/post-Hb, surgery time, and nasopharyngeal temperatures were investigated and recorded every 15 min from 0 to 120 min. **Results:** Between groupings, there were no significant changes in demographic features. In 240 patients, the results of various FGFs (0.7, 1, 1.5, and 2 L/min), no statistically significant differences were found in core body temperature over time within each subgroup, with no statistically significant differences between the two (open and laparoscopic) ($P > 0.05$). **Conclusions:** The study concluded that FGFs (0.7, 1, 1.5, and 2 L/min) could be utilized safely in adult patients undergoing open or laparoscopic digestive surgery. FGFs (0.7, 1, 1.5, and 2 L/min) provide better body heat preservation during sur-

gical operations.

Keywords

Fresh Gas Flow, Perioperative Hypothermia, Core Temperature, Digestive Surgery

1. Introduction

Body temperature is an avital sign for all living organisms, and any minor defect in this leads to severe consequences. During the perioperative period, perioperative hypothermia is defined as (core body temperature < 36˚C) and can be classified into mild (32˚C - 36˚C), moderate (28˚C - 32˚C), and severe (28˚C) groups. Hypothermia is one of the most challenging problems that anesthesiologists face during surgical procedures [1].

Hypothermia is characterized by the severity of its effects on the human body, although even minor changes in core body temperature (dropping) can result in a number of negative consequences for the individual [2] [3] [4], such as postoperative cardiovascular problems after surgery [5] [6], coagulopathy and bleed in the postoperative period [7] [8], drug metabolism is disrupted [9] [10], wound contamination and non-healing after surgery [11] [12] [13] [14], and hypothermia might potentially result in a more extended stay in the PACU or ICU [15]. The balance between generated and lost heat is critical for maintaining body temperature stability; any divergence from this equation has negative consequences [16] [17] [18].

There are a variety of ways to keep patients at a stable temperature during surgery, including blankets, circulating water mattresses, forced air warming, and pre-warmed IV fluids that are widely employed [1] [19]. Preventing perioperative hypothermia during intraoperative time is essential for the well-being of sedative patients. Therefore, many various studies have been conducted on patient core temperature and techniques to preserve perioperative normothermia.

Over the last few years, researchers have focused on the effects of low fresh gas flow on perioperative hypothermia [20]. If the flow rate is 4 L/min or higher, rebreathing increases by 20%; if the flow rate is 2 L/min or lower, rebreathing increases by 50% or more [21]. When anesthetic gases are properly humidified and warmed, they have a considerable impact on respiratory tract function and integrity. When the inspired gas is too dry or too humid, it leads to mucus retention and dry mucus discharges. We hypothesized that using different fresh gas flow techniques (0.7, 1, 1.5, and 2 L/min) might do the same thing in maintaining a perioperative patient's core temperature in normothermia.

The purpose of this study was to determine the impacts of different fresh gas flow techniques (0.7, 1, 1.5, and 2 L/min) on perioperative normothermia maintenance among adults undergoing elective open or laparoscopic digestive surgery and to find clinically valuable values.

2. Methods

This study is prospective, randomized, controlled, single-blind. Qilu Hospital of Shandong University's Ethical Committee gave its approval (approval number: KYLL-202008-080). This randomized controlled trial was registered at clinical-trials.gov, with the number ChiCTR2100046399. This study was conducted from April 1 2021 to September 15 2021.

2.1. Study Population and Exclusion Criteria

A total of 240 patients were randomly allocated to one of two study groups: open digestive surgery (group O, n = 120) or laparoscopic digestive surgery (group L, n = 120), each with four subgroups (n = 30) based on FGFs (0.7, 1, 1.5, and 2 L/min). As the American Society of Anesthesiologists defined, physical state I-II (ages 18 to 75 years) was scheduled for elective open or laparoscopic digestive procedures. Before being included in the trial, all patients signed informed consent.

Adults who underwent open or laparoscopic digestive surgery were included in the study. All patients with a history of cerebrovascular disease, patients with fever due to an infectious agent with a temperature of 38.5˚C or higher, brain injury, or cerebral surgery were excluded from the study, as were those with hypothyroidism/hyperthyroidism, those with morbid obesity (BMI > 35 kg/m^2), patients with dysregulation of the thermoregulatory system (e.g., hyperthermia with malignancy), patients who were below the age of 18 years, those who used a warming device during general anesthesia or had a COPD history. Patients with any of these conditions were also excluded from the study.

2.2. Tools

To avoid any errors during data collection, the same surgical team handled all of the surgeries for each patient, using the same anesthesia equipment and in the same operating room. Leaks in the anesthetic breathing system were examined, the gas sensors were calibrated, the alarm levels were double-checked, a disposable anesthetic cycle, a bacterial strainer was used, and the workplace temperature was kept at 23˚C by the air conditioning system. Every day the soda-lime was replaced.

As soon as the patient was wheeled into the surgery room, we double-checked the patient's identity, the nature of the planned operation, and the side. All of the standard monitoring of various parameters was attached to the patient. Patients were blinded to the group allocation. The patient was anesthetized after all of the procedures were completed satisfactorily.

2.3. Data Collection

Age, gender, BMI, the American Society of Anesthesiologists' definition of physical status as (ASA), duration of surgery, type of operation (open or laparoscopic), mean body temperature during surgery, pre and postoperative hemoglobin, amount of fluid infusion quantity, intraoperative urine volume, the heart rate (HR), and the mean arterial blood pressure (MABP), carbon dioxide concentration at the end of the tide ($EtCO_2$), peripheral oxygen saturation (SpO_2), and perioperative problems were all recorded. The same anesthetist performed intraoperative data collection.

2.4. Anesthesia

Both groups of patients fasted for 8 hours before the operation. Vascular access to the periphery was established with an 18 to 20 gauge cannula, and crystalloid solution (2 mL/kg) per hour was started as a maintenance dose. All patients were premedicated with intravenous midazolam (0.02 - 0.03 mg/kg) 30 minutes before the operation commenced. The patient was pre-oxygenated for a few minutes.

All patients were given thiopental sodium (7 mg/kg), remifentanil (1 μg/kg), and an intravenous infusion of (1 μg/kg/min) to induce anesthesia rocuronium bromide (0.6 mg/kg) for muscular relaxation and analgesia. After 5 minutes of 100% oxygen mask preoxygenation and endotracheal intubation, all patients were ventilated by the Asteiva (Datex Ohmeda) anesthetic machine with a tidal volume of (7 mL/kg) and a respiratory rate of 12 cycles/min. In anesthetic maintenance, sevoflurane with oxygen was employed.

Patients received 4 L/min of high flow fresh gas flow for the first 10 minutes. When sevoflurane was used, it was vaporized at a 2% concentration to regulate the depth of anesthesia. The fresh gas flow was then adjusted to (0.7, 1, 1.5, or 2 L/min) depending on the subgroup.

Following the final surgical procedure, sevoflurane was withdrawn until spontaneous respiration began, and the patient was manually ventilated with 100% O_2. At the onset of spontaneous breathing, the muscle relaxant was reversed with (0.04 mg/kg) neostigmine and (0.01 mg/kg) atropine. Extubation was undertaken when adequate spontaneous breathing occurred, and the BIS value reached 80% or higher.

2.5. Statistical Analysis

Following data collection, statistical analysis was carried out using the SPSS application (version: 26.0). The sample size was determined using the results of a prior study conducted by Lo *et al.* [22]. A power analysis was used to estimate the sample size. A sample size of 30 patients in each of the eight subgroups was needed to detect changes in core body temperature, with a power of 90% and an alpha error of 5%. The results of the one-way analysis of variance (ANOVA) test for regularly distributed data were given as means ± standard deviations (SD). In contrast, the findings of the Kruskal Wallis test for non-normally distributed data were reported as the median with interquartile range (IQR). To examine categorical data given as numbers and percentages, the chi-squared test was applied. A significance level of $P < 0.05$ is regarded as significant.

3. Results

During the five-month study period, data were collected from patients at the same workplace. 15 of the 255 patients enrolled in the trial were eliminated after screening for inclusion and exclusion criteria. Two hundred forty patients underwent elective open or laparoscopic digestive surgeries during the research period. To compare the effects of different fresh gas flow techniques (0.7, 1, 1.5, and 2 L/min) on maintaining perioperative normothermia in adult patients undergoing open and laparoscopic digestive operations, we chose 120 patients who had open digestive operations and were exposed to different fresh gas flow rates (0.7, 1, 1.5, or 2 L/min) for each subgroup (n = 30), as well as 120 patients who had laparoscopic digestive operations. Figure 1 illustrates the study's design.

3.1. Clinical Characteristics

Demographics and the American Society of Anesthesiologists Physical status were similar across groups and subgroups (Table 1). There were no substantial variations in the mean of the core body temperature during the intraoperative time between all subgroups in the open and laparoscopic groups ($P = 0.928$, $P = 0.977$, respectively) (Table 2).

The core body temperature of both open and laparoscopic groups appeared similar (Figure 2(a) and Figure 2(b)).

The findings of the statistical analysis did not demonstrate any differences in all subgroups among different FGFs. However, core temperature did appear to

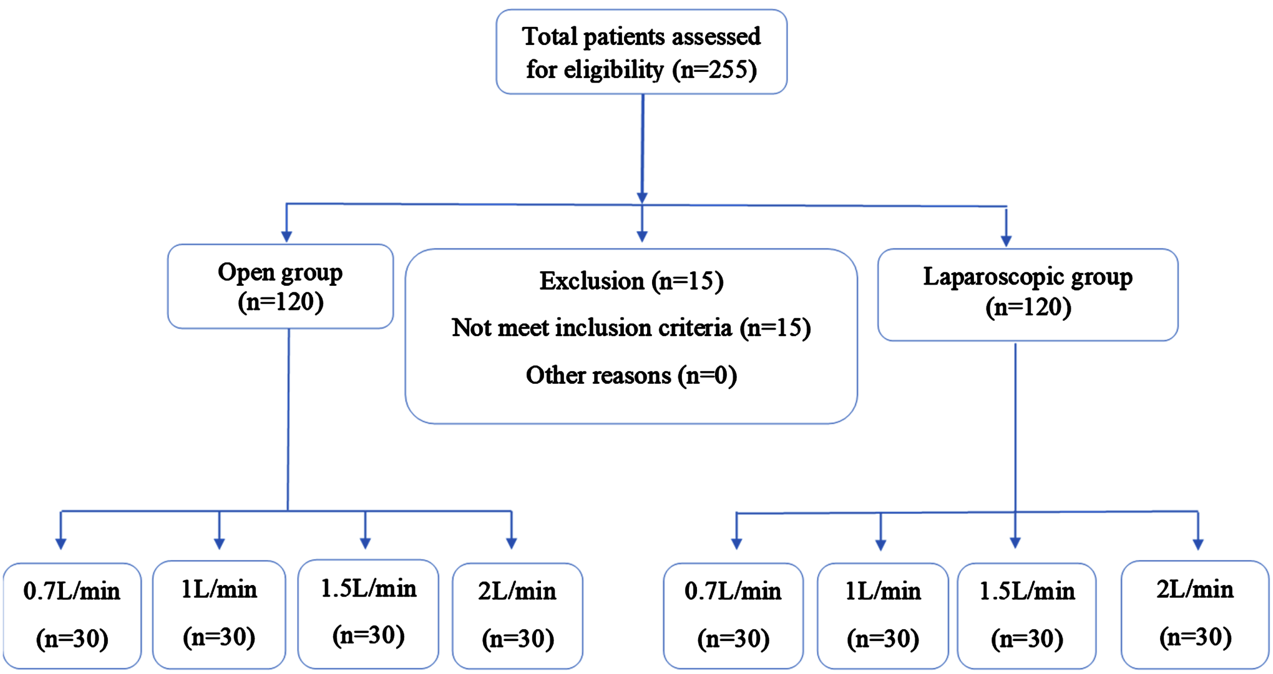


Figure 1. Study design.

Table 1. Demographic characteristics of the patients.

	Surgery type	0.7 L/min (n = 30)	1.0 L/min (n = 30)	1.5 L/min (n = 30)	2.0 L/min (n = 30)	P value
Age (year)	O	56.15 ± 15.24	57.61 ± 10.83	54.43 ± 13.17	59.27 ± 11.85	0.445
	L	51.69 ± 14.36	46.49 ± 12	51.47 ± 16.36	54.21 ± 125	1.421
BMI (kg/m^2)	O	21.73 (19.6, 23.5)	22.56 (21.6, 25)	23.33 (20.5, 24.6)	21.25 (20, 23.7)	0.245
	L	23 (20, 25)	23.16 (21, 26.36)	24 (21.26, 26.13)	23.13 (20, 25.12)	0.566
Sex, n (Male/Female)	O	(17/13)	(5/25)	(2/28)	(1/29)	0.584
	L	(19/11)	(13/17)	(14/16)	(18/12)	0.201
ASA, n (I/II)	O	(3/27)	(5/25)	(2/28)	(1/29)	
	L	(5/25)	(4/26)	(9/21)	(0/30)	

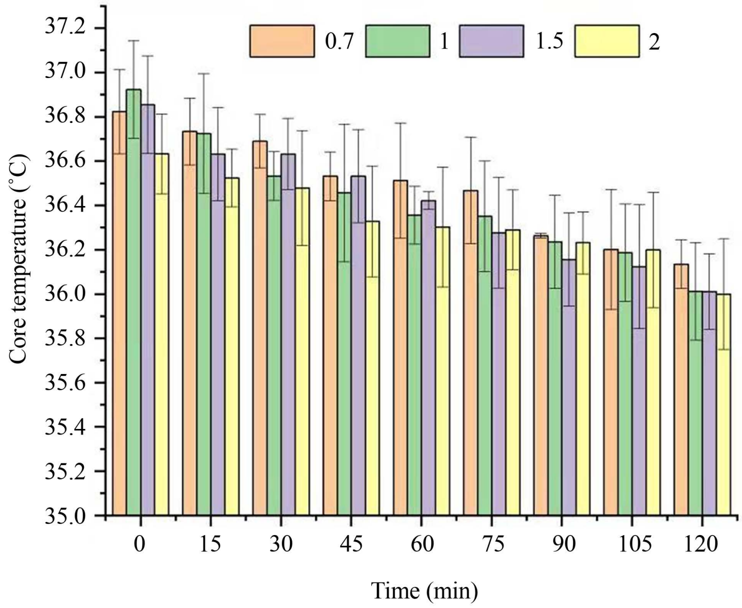
The number of patients with available data, mean ± SD, median value (Q1, Q3) of frequency (%), kg: kilograms, m^2: meter square, BMI: body mass index, ASA: American society of anesthesiologist physical status classification, O: Open surgery, L: Laparoscopic surgery.

Table 2. Comparison of intraoperative parameters between open and laparoscopic operation groups according to fresh gas flow rate (0.7, 1, 1.5, and 2L/min).

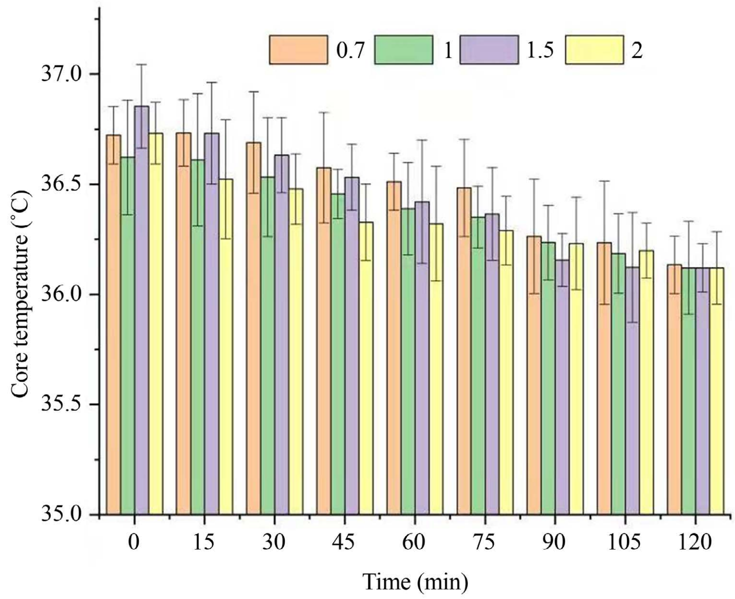
	Surgery type	0.7 L/min (n = 30)	1.0 L/min (n = 30)	1.5 L/min (n = 30)	2.0 L/min (n = 30)	P value
Mean core temperature during surgery	O	36.31 ± 0.24	36.42 ± 0.28	36.33 ± 0.21	36.14 ± 0.29	0.928
	L	36.47 ± 0.22	36.31 ± 0.23	36.43 ± 0.27	36.63 ± 0.22	0.977
Duration of surgery (mins)	O	179.81 ± 72.40	192.25 ± 75.13	204.88 ± 58.46	192.35 ± 69.41	0.593
	L	140.84 ± 77.72	170 ± 84.32	153.41 ± 79.45	149.34 ± 64.71	0.519
Fluid infusion during surgery (L)	O	1.46 ± 0.92	1.52 ± 0.73	1 ± 0.12	1.14 ± 0.86	0.064
	L	1.53 ± 0.78	1.27 ± 0.93	1.91 ± 0.84	1.72 ± 0.83	0.627
Preoperative hemoglobin (g/dl)	O	127.92 ± 15.38	122.27 ± 12.06	121.47 ± 18.82	122.03 ± 9.26	0.286
	L	127.17 ± 14.04	129.34 ± 7.92	128 ± 11.94	125.62 ± 14.63	0.709
Postoperative hemoglobin (g/dl)	O	116 (109, 125)	113.6 (107.81, 119)	105 (102.62, 1903)	118 (112.33, 124.27)	0.092
	L	121.32 (117.23, 125.25)	121 (115.13, 127)	121.17 (117.33, 124.23)	118.6 (114.32, 122.61)	0.757
Urine (ml)	O	550 ± 200	720.45 ± 209.18	637 ± 189.10	699.16 ± 179.46	0.017
	L	667.75 ± 229.54	680 ± 219.91	545 ± 270.22	588.83 ± 210	0.269

The number of patients with available data, mean ± SD, median value (Q1, Q3), O: open surgery; L: laparoscopic surgery; mins: minutes; L: liter; g: gram; dl: deciliter, mL: milliliter.

decline more within 60 minutes after anesthetic induction than for the other 60 minutes during the intraoperative period, as shown in (**Figure 2(a)** and **Figure 2(b)**). During the perioperative period, the average body temperature was frequently higher than 36˚C in all subgroups of both groups.



(a)



(b)

Figure 2. Graph showing the change perioperative core temperature during 0, 15, 30, 45, 60, 75, 90, 105 and 120 min. (a) open operation group, (b) laparoscopic operation group. The groups were subdivided according to the fresh gas flow rate (0.7, 1, 1.5, and 2 L/min).

The fluctuations in core temperature during open and laparoscopic digestive surgery are depicted in (**Figure 3**). There was no statistically significant difference between the groups regarding changes in core body temperature during the perioperative period. The core temperature lowered dramatically after anesthetic induction. Both groups' core temperatures gradually decreased throughout the operation, reaching a similar level two hours after anesthesia induction in the open and laparoscopic groups.

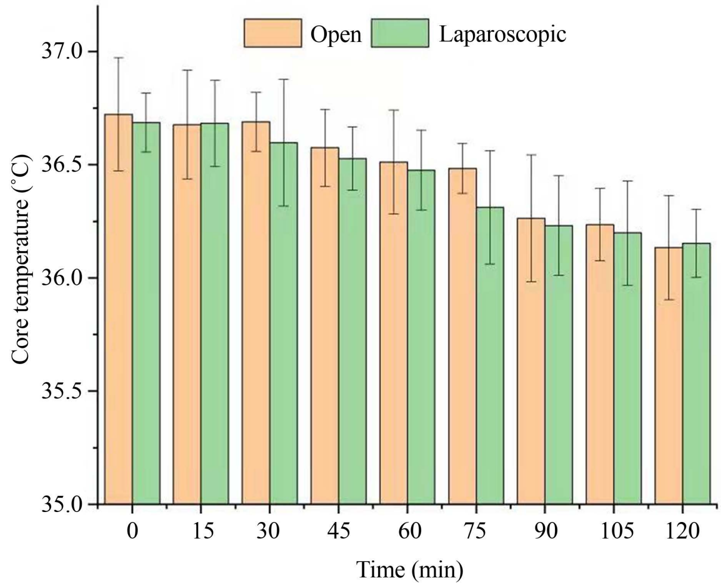


Figure 3. Graph showing a comparison of the change in the perioperative body temperature during 0, 15, 30, 45, 60, 75, 90, 105 and 120 min. Patients' core temperature was measured in open /laparoscopic surgery with the different fresh gas flows (0.7, 1, 1.5, and 2 L/min).

The perioperative period's findings were reported in (**Table 2**). Operation length, pre/post hemoglobin, fluid infusion rate, and urine output rate were all convergent in all subgroups of both the open and laparoscopic groups ($P > 0.05$), except for urine volume in the open group ($P > 0.05$) (**Table 2**). During the perioperative period, no hypothermic states, hypoxic events, respiratory or cardiac issues were observed.

3.2. Hemodynamic Changes

No significant changes in heart rate (HR), main artery pressure (MAP), BIS, end-tidal carbon dioxide concentration ($EtCO_2$), peripheral oxygen saturation (SpO_2), or inspired oxygen concentration (FiO_2) were seen at any time points in either the open or laparoscopic surgery subgroups.

4. Discussion

In a normal physiological condition, human beings can preserve an average core temperature within a restricted range of 37˚C ± 0.2˚C [23]. Heat gain and heat loss are balanced by a central system to control and regulate core body temperature. Internal heat is generated by cellular metabolism and lost through one of the following mechanisms: radiation, conduction, convection, or evaporation [24]. A core body temperature below 36˚C is defined as perioperative hypothermia [25].

Among the benefits of low-flow anesthesia are reduced anaesthetic gas consumption, less ambient pollution with inhaled anaesthetics, preservation of heat and humidity in the respiratory system, and a large reduction in expenses due to the reduction in gas consumption [26] [27]. The physical and chemical properties of inhalational drugs employed in low-flow anesthesia procedures are critical [28]. Volatile anaesthetic substances such as sevoflurane, isoflurane, and desflurane are utilized in low-flow anaesthesia nowadays, as are other volatile anaesthetic agents [29] [30]. Isik *et al.* [31] used desflurane and sevoflurane in low-flow anaesthesia for children. Neither hepatic nor renal function was impaired. Our study found steady hemodynamics in both open and laparoscopic groups.

In recent years, a low fresh gas supply with a closed-circuit rebreathing device to preserve perioperative normothermia has sparked interest in anesthetic approaches [32]. Significant clinical improvement is possible by raising the fraction of rebreathed gas and lowering the quantity of cool, dry, fresh gas inhaled. As we focus on this method in our study, this approach can prevent perioperative hypothermia. Some anesthesiologists prefer it over high-flow anesthesia because low-flow anesthesia preserves heat and humidity while reducing gas consumption [18]. This information is in agreement with what has previously been discovered. Due to this observation, we used varying fresh gas flow rates to keep the core temperature from dropping too much. FGFs may be able to adjust for redistribution-induced temperature gradients between the core and the periphery.

We chose digestive surgeries for this study because they have a higher risk of perioperative hypothermia due to prolonged duration, extensive surgical site exposure, fluid evaporation, significant blood loss, and recurrent lavage with large quantities of room temperature saline [1]. Additionally, massive volumes of cool, dry CO_2 (about 21˚C) are delivered intra-abdominally during laparoscopic surgery [33]; it was the combination of all of the above risk factors, rather than the protective factor, that revealed the study's significance.

Anesthesia care includes knowing how to monitor one's body temperature. Constant monitoring of temperature variations in sedated patients enables the diagnosis of unintentional heat loss or malignant hyperthermia [24]. You can assess your core temperature by inserting small sensors into the esophagus, ear canals, trachea, and nasopharynx [34]. Also, pulmonary artery blood temperature reflects core body temperature [24]. However, we chose the nasopharyngeal probe because other devices were insufficiently accurate, inconvenient, or invasive [34] [35].

As is well known, when air passes through the nose and upper airways during spontaneous breathing, an atypical physiological mechanism moisturizes and warms it to meet the body temperature, preventing any disruption in the body's thermal system [36]. When mechanical ventilation fails, the gases reach the lower airway directly without being warmed, resulting in heat loss through the respiratory tract's airways, Unless proper humidification and heating methods are used [37] [38]. In our research, we use gas rebreathing to solve the problem and create heat and humidity gases.

In our study, operating room temperatures were set to 23˚C from the start, similar to the findings of Morris RH *et al.* [39].

Kleemann *et al.* [40] found that the temperature of inspired gas during low-flow anesthesia was higher at all times when compared to high-flow anesthesia. They also reported that the temperature increased to approximately 28˚C during the first 30 min. Kleemann 15 showed that the mean inspired gas temperature was 31.5˚C after 2 h of anesthesia with a fresh gas flow rate of 0.6 L/min. Bengtson *et al.* [41] used a re-breathing ring system to measure the gas temperature, which was found to be 28.5˚C after 30 min with a fresh gas flow rate of 0.5 L/min; this was approximately 6.8˚C above the room temperature.

Perioperative temperature reductions in our study were lower than those reported by others [42]. A previous study showed that during the first hour of anesthesia, over half of the sedated individuals had core temperatures of less than 36˚C, which steadily rose after that [43]. This demonstrates that the first hour's fall in core temperature is due to heat redistribution, consistent with our data, which shows that the temperature drops faster in the first hour than in the second [44]. According to our data, most operations required more than two hours, and heat redistribution was the primary cause of the temperature drop in this condition [45]. Matsukawaetal *et al.* reported the body's core temperature decrease in the first hour of general anesthesia by 1.6˚C ± 0.3˚C, with a heat redistribution of 81%. Over the second and third hours, the core body temperature continues to fall by 1.1˚C ± 0.3˚C with 43% heat restructuring [45]. This 81% heat redistribution may be caused by general anesthesia-induced fast peripheral vascular dilatation, which causes heat to be transported from the core to the periphery. The core temperature begins a steady decrease in the second and third hours because the loss of body heat exceeds the metabolic generation of heat. As a result, we believe that core-to-peripheral redistribution should be reduced or compensated for to avoid the negative consequences of perioperative hypothermia. In our study, we tried to balance generated and lost heat to maintain body temperature stability.

One-third degree Celsius temperature decline with two-liter infusion of room-temperature crystalloid in normal normothermic adults, according to Barthel *et al.* [46], this is consistent with our findings. We found a correlation between fluid infusion rate and perioperative temperature decrease. Unwarmed fluids should be avoided, according to recent studies.

Previous research has shown that elderly patients may be more susceptible to hypothermia [42] [47]. This data is consistent with ours; most patients (71.6%) in our analysis were under 65 years, and all patients were classified as 1 or 2 by the American Society of Anesthesiologists.

In 2011, Castro demonstrated that a heat and moisture exchanger could be used to increase the heat generated by human breathing gas [48], which is consistent with our study; patients were treated with Aestiva Datex Ohmeda anesthesia workstations, which are more modern and efficient in warming and humidifying rebreathing gas than other aesthetic workstations. With the advent of modern workstations, anesthesia has shifted to be a more friendly and safe approach.

Hypothermia happens during surgery due to various factors, but the rate of occurrence varies according to the factor. We attempted to control the significant risk variables and compensate for lost heat in the current investigation, which explains why the incidence of perioperative hypothermia was not documented.

Individuals undergoing laparoscopic and open operations had similar body temperature fluctuations, according to several studies. Patients undergoing laparoscopic and open cholecystectomy exhibited similar drops in core temperature, according to Makinen *et al.* [49] [50]. We also found similar findings: no significant differences in intraoperative temperature variations between open and laparoscopic digestive operations.

Many prior studies reported that maintaining body temperature under general anesthesia was problematic if the fresh gas flow was greater than 1 L/min. However, our findings show that FGFs of (0.7, 1, 1.5, and 2 L/min) yield similar results. We found no differences in FGF levels (0.7, 1, 1.5, and 2 L/min) after comparing them, indicating that FGFs (0.7, 1, 1.5, and 2 L/min) can be used safely, more pleasantly, and physiologically for patients to alleviate perioperative hypothermia while under general anesthesia.

Limitations

There are some limitations of the current study. The study's sample size can be considered an initial limitation since the number of patients was relatively small. Another limitation of our study was a single-center study, and the results should not be generalized. Additional research is required to evaluate the influence of fresh gas flows on patients' core temperature during the peri/postoperative period with higher precision.

5. Conclusion

In this study, it was concluded that sevoflurane anesthesia is used with the fresh gas flow with one of these values (0.7, 1, 1.5, or 2 L/min) can provide safe anesthetic techniques and a powerful method to use in daily practice without affecting patient care to maintain perioperative normothermia for patients undergoing general anesthesia with open or laparoscopic surgery. When attempts were taken to minimize perioperative hypothermia, our study data also demonstrated that the core peri-operative temperature did not significantly differ between the laparoscopic and open operations.

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Second, I'd want to thank my parents and friends for their assistance in completing this project within the time constraints.

Ethics Approval and Consent to Participate

Qilu Hospital of Shandong University's Ethical Committee approved our study [approval number: KYLL-202008-080]. Written informed consent was obtained from each participant.

Availability of Data and Materials

All data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Registration

This RCT was registered at clinicaltrials.gov and assigned the following identifier: ChiCTR2100046399 submitted on 15\5\2021.

Authors' Contributions

Ahmed Badughaish: drafted and conducted the research. Qiya Hu, Yuanuan Meng, Yu Liu, Lianying Zhao, Shuqin Wang, Amir Muse Mohamud, and Feng Qi revised and supervised this manuscript.

Conflicts of Interest

No conflicts of interest were declared with this article.

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Abbreviations

FGF: Fresh Gas Flow; PLOS: Postoperative hospital Length-Of-Stay; ICU: Intensive Care Unit.