



Effects of Minimal Flow Sevoflurane or Desflurane Anaesthesia on Hemodynamic Parameters, Body Temperature and Anaesthetic Consumption

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Abstract

Objective: We aimed to compare minimal flow sevoflurane and desflurane anaesthesia in terms of hemodynamic parameters, body temperature, anaesthetic gas consumption and cost.

Methods: 120 patients with ASA I-II (>18yo) who underwent elective surgery for longer than 60 min after general anaesthesia were randomized into two groups. The Dräger Perseus® A500 workstation was used. Pre-oxygenation was performed for 3 min with 6 L min⁻¹ to 100% oxygen. Fractional inspirium oxygen concentration (FiO₂) was reduced to 40%, fresh gas flow was 4 L min⁻¹ after intubation. Sevoflurane or desflurane was started at 1.5 minimal alveolar concentration (MAC). When the MAC value reached 0.9, fresh gas flow was reduced to 0.5 L min⁻¹, FiO₂ was increased to 68%. At the end of the surgery, the vaporizer was switched off, the fresh gas flow was increased (4 L min⁻¹, FiO₂ 100%). When the train-of-four (TOF) ratio was 100%, extubation was carried out.

Results: There were no differences in patient characteristics and initial hemodynamic parameters of the groups. There were statistically significant differences between the times to reach 0.9 MAC, extubation and eye opening; anaesthetic, O₂ and air consumption in both groups.

Conclusion: With minimal flow, the time to reach target MAC, time to extubation and eye opening were significantly faster for desflurane and anaesthetic, oxygen and air consumption in desflurane anaesthesia were less than sevoflurane. Thus, we can say that desflurane has faster anaesthetic induction and recovery time with lower anaesthetic consumption than sevoflurane.

Keywords: Consumption, desflurane, minimal flow anaesthesia, sevoflurane

Introduction

Low-flow anaesthesia is described as a technique that results in a return of at least 50% of the exhaled gas mixture to the lungs following the absorption of carbon dioxide (CO₂) by using a rebreathing system (1). This anaesthesia technique in which the fresh gas flow was reduced to 1 L min⁻¹ was administered by Foldes for the first time in 1952 (2). In 1974, Virtue stated that use of a fresh gas flow of 0.5 L min⁻¹ that was a type of low flow was economical and safe (3). Minimal flow anaesthesia could be considered as a subtype of low-flow anaesthesia with the lowest possible gas volume and full re-breathing. It can be safely applied with the modern devices of anaesthesia.

Following routine induction of anaesthesia, intubation, and attachment to the respiratory system, high fresh gas flow anaesthesia is applied for 15 min at the beginning. Early reduction of fresh gas flow increases the risk of gas volume deficiency since a low gas volume of 0.5 L min⁻¹ cannot fulfill the initial high uptake and losses due to the leaks. The lack of gas volume also causes inadequate respiration. After the onset period, the flow of the fresh gas is reduced to 0.5 L min⁻¹ and the gas composition is adjusted as 0.3 L min⁻¹ oxygen (O₂) and 0.2 L min⁻¹ air or nitrous oxide (N₂O). Since the rebreathing rate is increased with minimal flow compared to low-flow anaesthesia, O₂ content of fresh gas should also be increased to at least 50% or even 60% in order to prevent hypoxic gas mixture (4). Furthermore, the concentration of the anaesthetic agent should be increased to enable target minimal alveolar anaesthetic concentration (MAC) (1-2%).

Sevoflurane and desflurane have low blood/gas solubility and are preferred as ideal and safe inhalation anaesthetics for low and minimal flow anaesthesia. With technical advantages of modern anaesthesia devices, these agents are widely used in general anaesthesia practice and in our clinics (5). There is a limited number of studies comparing these two inhalation anaesthetics with minimal flow. In this study, we compared groups of 120 patients randomized either to sevoflurane or desflurane who were switched to minimal flow with 0.5 L min^{-1} in maintenance phase by using 4 L min^{-1} flow for anaesthesia induction. The aim of our study is to compare the groups in terms of hemodynamic parameters, anaesthetic consumption and cost, as well as body temperatures since conserving the temperature is an important advantage attributed to this technique.

Methods

After obtaining the approval of Başkent University, Clinical Research and Ethics Committee (number KA17/222), 120 patients with American Society of Anaesthesiologists (ASA) I-II physical status aged 18 years and older scheduled to undergo a minimum of 60 min of surgeries between September 2017 and March 2018 were examined prospectively in order to evaluate the minimal flow anaesthesia using the Dräger Perseus® A500 anaesthesia workstation at Baskent University Faculty of Medicine Ankara Hospital.

Patients having co-morbidities such as chronic obstructive pulmonary disease, coronary artery disease, congestive heart failure, marked anemia, unregulated diabetes mellitus, local or general circulatory failure, having more than 30% of their ideal body weight, using microsomal enzyme induction drugs and being heavy smokers, chronic alcoholics and whose liv-

er and kidney function tests were significantly impaired, and who received general anaesthesia in the last two weeks were excluded from the study.

For the study, an anaesthesia workstation (Dräger Perseus® A500, Lubeck, Germany) providing minimal flow was used.

After the preoperative evaluations in outpatient anaesthesia clinic or at the bedside, the patients were taken to the operation room following an appropriate period of fasting. Demographic data such as age, gender, body weight, height, and body surface area were recorded. Before induction, the standard monitorization of electrocardiography, non-invasive blood pressure, pulse oximetry; and after induction nasopharyngeal temperature and end-tidal carbon dioxide pressure (EtCO_2) were performed. The neuromuscular transmission monitor (TOF-Guard) was used for the evaluation of muscle relaxant effect. In all cases, the operating room temperature was kept stable at 21°C and the patients were heated with the help of the blankets. All cases were pre-oxygenated with 6 L min^{-1} 100% O_2 for 3 min by means of face masks.

The standard induction of 40 mg of prilocaine, 2.5 mg kg^{-1} of propofol, and $1 \mu\text{g kg}^{-1}$ of fentanyl, followed by 0.6 mg kg^{-1} of rocuronium bromide for muscle relaxation was carried out, and endotracheal intubation was performed. After endotracheal intubation, sevoflurane or desflurane was initiated according to the groups. Medical air was utilized as the carrier gas. Patients were ventilated in a volume-controlled mode with a tidal volume of $6\text{--}8 \text{ mL kg}^{-1}$, respiratory frequency 12 min^{-1} , and positive end expiratory pressure (PEEP) of $5 \text{ cmH}_2\text{O}$. The target EtCO_2 value was set as $30\text{--}40 \text{ mmHg}$. Patients were randomly divided into two groups, and randomization was performed using an internet-based software program (Research Randomizer, <http://www.randomizer.org/>). Minimal flow anaesthesia was administered to all patients. MAC value was set as 1.5; Group S: $1 \text{ L min}^{-1} \text{ O}_2$, 3 L min^{-1} air (total fresh gas flow 4 L min^{-1} , FiO_2 40%) sevoflurane at a concentration of 2.7%, Group D: $1 \text{ L min}^{-1} \text{ O}_2$, 3 L min^{-1} air (total fresh gas flow 4 L min^{-1} , FiO_2 40%) desflurane at a concentration of 9.9% were used. When the target inhalation agent MAC value reached 0.9 in all groups, the fresh gas flow was reduced to 0.5 L min^{-1} ($0.3 \text{ L min}^{-1} \text{ O}_2 + 0.2 \text{ L min}^{-1}$ air, FiO_2 68%). Inhalation agent concentrations were also adjusted to ensure the continuity with 0.9 MAC (6). The anaesthesia depth required for the surgery in the period of anaesthesia maintenance was provided by remifentanyl infusion ($0.05\text{--}0.1 \mu\text{g kg}^{-1} \text{ min}^{-1}$).

Basal measurements of heart rate (pulse/min), systolic arterial pressure (SAP, mmHg), diastolic arterial pressure (DAP,

Main Points:

- Minimal flow anaesthesia is an anaesthesia method that should be encouraged due to its cost-reducing effect and reducing intraoperative hypothermia.
- Minimal flow anaesthesia with both sevoflurane and desflurane were hemodynamically safe with modern technical equipment and did not make any difference in body temperature. They did not differ in body temperature during minimal flow.
- Both anaesthetic agents can be used safely in terms of hemodynamically providing and maintaining oxygenation.
- Desflurane was found to achieve a faster target MAK value compared to sevoflurane. Extubation and eye opening times were shorter with desflurane. It was seen that there was less expenditure with desflurane than sevoflurane, and the consumption of O_2 and air was lower in desflurane group compared to sevoflurane.
- Minimal flow desflurane anaesthesia has more positive results on anaesthetic consumption than sevoflurane anaesthesia.

mmHg), mean arterial pressure (MAP, mmHg), and peripheral oxygen saturation (SpO_2 , %) were recorded when the patient entered the operating room. Then the processes of all these measurements were repeated after every 5 min. After induction, the measurements recorded at 1st, 5th, 10th, 15th, 30th min and every 30 min were considered for statistical evaluation. Nasopharyngeal temperature (°C), inspiratory (F_{iagent}) and expiratory anaesthetic concentration (F_{eagent}), inspiratory oxygen and carbon dioxide concentration (FiO_2 , $FiCO_2$, %), MAC values, expiratory minute volume (MV_e , L min^{-1}), and $EtCO_2$ (mmHg) values were recorded every 5 min after intubation. After induction, the measurements recorded at 1st, 5th, 10th, 15th, 30th min, and every 30 min were compared for statistical evaluation.

When the surgical procedure was completed, the vaporizer was turned off, and fresh gas flow (4 L min^{-1} , FiO_2 100%) was increased. 0.05 mg kg^{-1} of neostigmine and 0.02 mg kg^{-1} of atropine were given to the patient for the reversal of muscle relaxant. At the 3rd and 6th min after the vaporizer was shut down and later every minute, patients were instructed to open their eyes. Extubation was performed when the TOF ratio was 100%. The time from vaporizer closure to extubation and to opening the eyes were recorded.

Inhalation anaesthetics, O_2 and medical air consumption were determined and recorded for each case with the data obtained from the anaesthesia workstation (7). These values were multiplied by the average current unit prices and cost analysis was performed. Total durations of surgery and anaesthesia were recorded. During the anaesthesia period, the onset period after induction, the maintenance period, and the recovery period following complete discontinuation of inhalation anaesthesia were further specified. According to the formula defined by Biro (8), as shown below, the amount of liquid volatile agent was calculated separately for the initial period and maintenance period and then the whole amount was determined.

Liquid volatile agent = (fresh gas flow ($mL min^{-1}$) x volatile agent concentration (% volume) x anaesthesia time (min) / (gas volume saturation ($mL mL^{-1}$) x 100)

The volume of saturated gas (it was 1 mL volatile anaesthesia evaporation volume when room temperature was accepted as 22°C and vaporization temperature was accepted as 20°C) was 184 mL mL^{-1} for sevoflurane and 210 mL mL^{-1} for desflurane (8).

Statistical analysis

IBM Statistical Package for the Social Sciences (IBM SPSS Corp.; Armonk, NY, USA) version 20.0 program was used to analyze the data. The Mann-Whitney U test was used for comparison between the groups. Paired samples Wilcoxon tests were used for intra-group comparisons, and chi-squared and Fisher's exact chi-squared tests were used for the analysis of other data. Results were presented as mean \pm standard deviation. A value of $p < 0.05$ was considered statistically significant.

Results

A total of 120 patients with ASA I-II physical status aged 18 years and older who received minimal flow sevoflurane and desflurane anaesthesia for elective surgeries lasting more than 60 minutes were examined prospectively. The sevoflurane group was named as group S and the desflurane group as group D. Demographic data of the patients are shown in Table 1. Age, body weight, height, and body surface area average, gender and ASA score distributions were found to be similar in both groups ($p > 0.05$).

When the intraoperative heart rate, systolic, diastolic, and mean arterial pressures values of the patients were examined, no significant difference was found between the two groups in any period of anaesthesia ($p > 0.05$).

Intraoperative SpO_2 values are given in Table 2. No statistically significant difference was found between the two groups in any period of anaesthesia ($p > 0.05$). In intra-group comparison, basal SpO_2 value and SpO_2 values in the 1st, 5th, 60th, and 90th min of anaesthesia were statistically different in group S ($p < 0.05$). It was found that SpO_2 values in the 1st, 5th, 60th, and 120th min of anaesthesia and basal SpO_2 value were statistically different in group D ($p < 0.05$).

Table 1. Demographic data of the patients (mean \pm standard deviation, number)

	Group S (n=60)	Group D (n=60)	p
Age (year)	35.6 \pm 13.7	36.3 \pm 14.1	0.787
Weight (kg)	71.3 \pm 16.4	72.6 \pm 14.0	0.525
Height (cm)	168.7 \pm 10.9	170.4 \pm 9.1	0.249
Body surface area (m ²)	1.8 \pm 0.3	1.8 \pm 0.2	0.407
Gender (F/M)	32/28	31/29	-
ASA score (I/II)	39/21	42/18	-

Table 2. Intraoperative SpO₂ values (mean ± standard deviation)

SpO ₂ (%)	Group S (n=60)	Group D (n=60)	p value (intergroup)	p value for intragroup S	p value for intragroup D
Basal	98.3±1.5	98.2±1.4	0.869	-	-
1 st	98.8±1.5	98.8±1.2	0.407	0.004*	0.002*
5 th	99.0±1.1	98.6±1.4	0.188	0.000*	0.045*
10 th	98.3±1.3	98.3±1.2	0.959	0.953	0.958
15 th	98.1±1.3	98.4±1.2	0.423	0.454	0.573
30 th	98.0±1.3	97.9±1.3	0.776	0.144	0.190
60 th	97.9±1.5	97.7±1.4	0.351	0.044*	0.014*
90 th	97.5±1.9	97.8±1.5	0.626	0.012*	0.053
120 th	97.5±1.6	97.8±1.4	0.681	0.181	0.024*
150 th	97.7±1.5	98.5±1.2	0.221	0.772	0.465
180 th	98.2±1.0	98.2±1.3	1.000	0.108	0.357

*Statistically significant difference in intragroup evaluation (p<0.05).

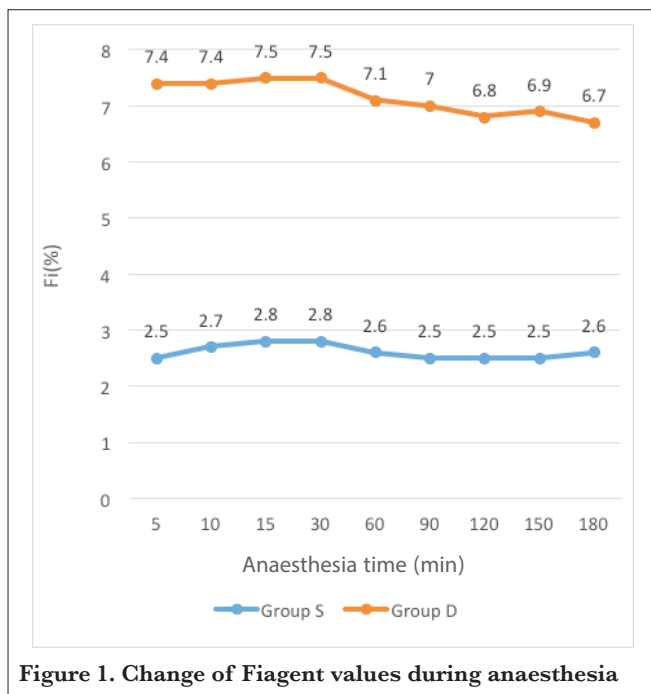


Figure 1. Change of Fiagent values during anaesthesia

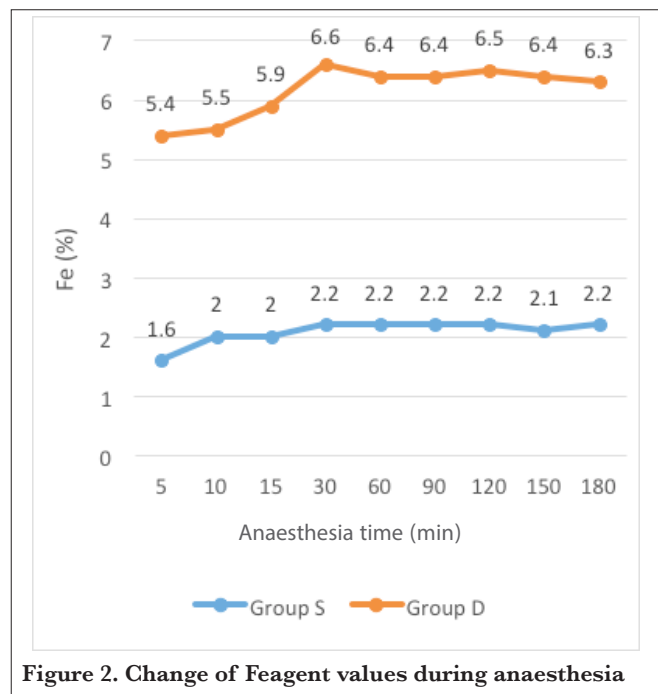


Figure 2. Change of Feagent values during anaesthesia

Intraoperative body temperatures were similar in all periods of anaesthesia for group S and group D (p>0.05).

Fiagent values were found as statistically different in group S and group D. In the intra-group comparisons of Fiagent considering the change during anaesthesia with minimal flow, it was found that Fiagent values at the 5th min of anaesthesia was significantly different than at the 10th, 15th, 30th, and 60th min of anaesthesia in group S whereas Fiagent values at the 5th min of anaesthesia was found significantly different compared to the 60th, 90th, 120th, and 180th minutes of anaesthesia in group D (p<0.05). Figure 1 shows the change of Fiagent values during anaesthesia.

Feagent values were also found to be different in group S and group D (p<0.05). In the intra-group comparisons performed to see the change during anaesthesia, a significant difference was found in Feagent values at the 5th min of anaesthesia and in all other periods for group S (p<0.05). For group D, except for the 10th min, a difference was observed in all other periods (p<0.05). Figure 2 shows the change of Feagent values during anaesthesia.

When FiO₂ values were examined during anaesthesia, FiO₂ percentages were found different between the 5th, 10th, 15th, 60th, 90th, and 180th min of anaesthesia in the two groups (p<0.05). For intra-group comparison, it was found that FiO₂ value at the 5th min and FiO₂ values at the 10th, 15th, and 120th

min in group S were different. In Group D, FiO_2 value in the 5th min and FiO_2 values in 60th, 90th and 120th min were found different ($p<0.05$). The change of FiO_2 values during anaesthesia is shown in Figure 3.

When the durations between the two groups were compared (Table 3), it was concluded that differences between the duration of onset period, extubation, and eye-opening times

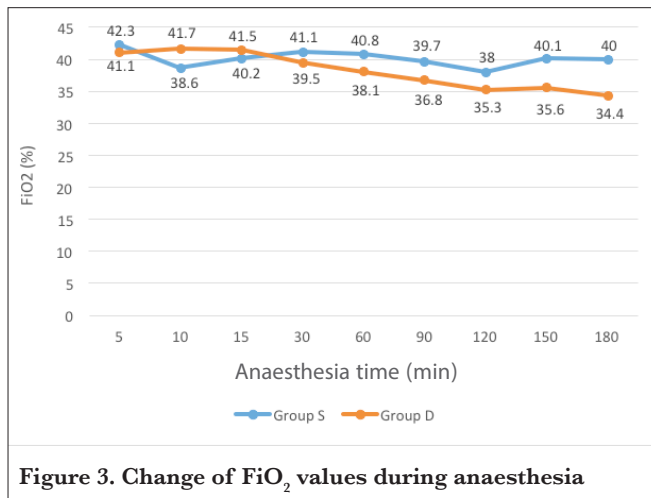


Figure 3. Change of FiO_2 values during anaesthesia

were found statistically significant. These three periods were found to be shorter in group D compared to group S.

Anaesthetic, O_2 , and air consumption averages are given in Table 4. The mean sevoflurane consumption calculated by the anaesthetic workstation was 23.6 ± 10.9 mL, and mean desflurane consumption was 31.6 ± 12.0 mL. When the oxygen and air consumption were compared, there was a difference between the two groups with the consumption being lower in desflurane group ($p<0.05$).

According to Biro's formula (8), the mean sevoflurane consumption was 11.5 ± 3.8 mL and the mean desflurane consumption was 21.6 ± 8.1 mL. Although, these values were lower than the consumption values obtained from the Dräger Perseus® A500 anaesthesia workstation, the difference was found statistically significant ($p<0.05$). Table 5 shows the comparison of anaesthetic agent consumption.

Oxygen and air consumption were found to be lower in the desflurane group when the two groups were compared. The unit prices of desflurane and sevoflurane were 0.8085₺/mL and 1.2458 ₺/mL respectively. When we performed the cost analysis, the cost of sevoflurane per case was 29.4₺ and the desflurane cost was 25.6₺.

Table 3. Time periods compared between two groups (mean \pm standard deviation)

Durations (min)	Group S (n=60)	Group D (n=60)	p
Surgery	119.8 \pm 58.3	102.6 \pm 46.1	0.099
Anaesthesia	135.5 \pm 59.7	117.6 \pm 49.3	0.061
Onset ¹	7.3 \pm 3.2	4.2 \pm 1.5	0.000*
Maintenance ²	124.9 \pm 59.4	110.3 \pm 49.3	0.147
Extubation ³	7.1 \pm 2.5	6.1 \pm 1.8	0.009*
Eye-opening ⁴	10.7 \pm 2.7	7.9 \pm 2.2	0.000*
Recovery	39.1 \pm 17.9	43.8 \pm 16.0	0.094

*Statistically significant difference in intergroup evaluation ($p<0.05$). ¹Time from intubation to MAC reached 0.9. ²Time from MAC reached 0.9 to vaporizer closure. ³Time from vaporizer closure to extubation. ⁴Time from vaporizer closure to eye-opening.

Table 4. Anaesthetic, O_2 , and air consumption (mean \pm standard deviation)

Consumption	Group S (n=60)	Group D (n=60)	p
Sevoflurane (mL)	23.6 \pm 10.9	-	-
Desflurane (mL)	-	31.6 \pm 12.0	-
Oxygen (L)	115.2 \pm 34.0	95.7 \pm 19.6	0.000*
Air (L)	49.8 \pm 19.5	32.5 \pm 11.8	0.000*

*Statistically significant difference in intergroup evaluation ($p<0.05$).

Table 5. Comparison of anaesthetic agent consumption (mean \pm standard deviation)

Consumption	Dräger algorithm (mL)	Biro's formula (mL)	p
Group S (n=60)	23.6 \pm 10.9	11.5 \pm 3.8	0.000*
Group D (n=60)	31.6 \pm 12.0	21.6 \pm 8.1	0.000*

*Statistically significant difference in intergroup evaluation ($p<0.05$).

Discussion

Technological advancements in terms of anaesthesia devices, increased environmental sensitivity, new inhalation agents being more expensive, and the limited economical resources in the healthcare sector across the globe have led to a tendency toward utilization of low-flow anaesthesia techniques (9). Within the scope of the Common European Standard (EN740) in terms of safe application of low flow anaesthesia, airway pressure, expired gas volume, FiO_2 , volatile anaesthetic concentration, CO_2 concentration, and SpO_2 values are required to be monitored continuously (10).

In a study conducted by Isik et al. (11), it was shown that sevoflurane and desflurane anaesthesia with a flow rate of 1 L min^{-1} did not adversely affect hemodynamic parameters. In the study of Ceylan et al. (12), no hemodynamically significant difference was found in desflurane and sevoflurane anaesthesia with a flow rate of 1 L min^{-1} . When hemodynamic data were evaluated, it was concluded that minimal flow anaesthesia technique was a hemodynamically safe and stable method. In the study of Elmacioglu et al. (13), it was noted that perioperative hemodynamics were stable when desflurane anaesthesia was used at three different fresh flow rates (0.5, 1 and 2 L min^{-1}). Minimal flow had no negative effect on recovery. Therefore, it was concluded that minimal flow desflurane anaesthesia may be an alternative to mid-flow desflurane anaesthesia in patients with ASA I-II score. These results have shown that minimal flow anaesthesia could be applicable.

High flow was required for a certain period of time before minimal flow was applied for removal of the nitrogen. In our study, high flow was applied until the MAC reached 0.9 before the fresh gas flow was reduced. In order to maintain the depth of safe anaesthesia, the end-expiratory anaesthetic agent concentration was suggested to be in the range of 0.7–1.3 MAC (5, 14). Horwitz (5) adjusted the vaporizer to 0.8 MAC during surgery in his study. After our pilot studies, the target MAC value was determined as 0.9 in this study.

Inspiratory oxygen concentration should be at least 40% in low-flow techniques to prevent hypoxia and provide adequate oxygen support (1). When the flow becomes lower, the oxygen content in the fresh gas should be increased in order to ensure adequate oxygen concentration in the inspired gas (15). As the re-ventilation rate is increased, when low-flow anaesthesia compared to low flow, O_2 concentration of fresh gas should be increased minimum 50% or even 60% to prevent hypoxic gas mixture (4). In our study, O_2 concentration of the inspired gas was adjusted at 68% in the period passing to the minimal flow.

According to the expiratory minute volume ratios of Gedik (16), it was noted that the SpO_2 value did not fall below 97% in any group, and the technique was found to be safe in the low-flow anaesthesia method where the sevoflurane – $\text{O}_2/\text{N}_2\text{O}$ mixture was applied and the fresh gas flow was not below 1 L min^{-1} . In our study, fresh gas flow was reduced to 0.5 L min^{-1} and the lowest SpO_2 value was observed as 93% in group S. No intervention was required for the increase. For group D, the lowest SpO_2 value was observed as 92%. Meanwhile, it was seen that the patient's FiO_2 was 21% due to the fact that 3.33 min passed in order to reach a MAC value of 0.9 and keeping the high flow period short. Then the system was rinsed with high flow, and the routine values were obtained.

Another concern in low-flow administration, other than hypoxia, was the lightening of anaesthesia (17). It was suggested to keep vaporizer settings higher in adults in low flow techniques compared to the high ones (18). Minimal and low-flow desflurane anaesthetics were compared. Minimal increase in desflurane concentration of 1–2% was required, while a low flow vaporizer setting was not changed (19). In our study, initial vaporizer settings were set at 2.7% for sevoflurane and 9.9% for desflurane, equivalent to 1.5 MAC value. During the transition period to minimum flow, our vaporizer settings were increased in such a way that the MAC remained constant at 0.9.

It is known that the interactions of volatile anaesthetics with absorbers increase due to the increase in CO_2 load re-inhalation in low flow anaesthesia techniques (20). When the fresh gas flow is reduced to 0.5 L min^{-1} , the absorber usage increases four times. Therefore, EtCO_2 and F_iCO_2 monitorization should be performed in low flow anaesthesia applications (21). In our study, continuous EtCO_2 monitoring was performed during anaesthesia and the target values (30–40 mmHg) were maintained in all groups during anaesthesia. In order to avoid hypercapnia, regular and frequent replacement of sodalime is recommended (21, 22).

Temperature and humidity values measured during low flow techniques were found to be higher than high flow applications (15). The returning gas is heated and moistened. Therefore, it is given to the patient under more physiological conditions (23). In our study, temperature values were recorded during anaesthesia by placing nasopharyngeal heat probe after intubation in all patients. No significant difference was found in the body temperature between two groups. As warm air was inhaled by re-inhalation, no decrease in body temperature was observed. Minimal flow helped to maintain body temperatures. It was also due to our use of routine blankets to warm our patients.

The durations of surgery, anaesthesia, maintenance, and recovery were found to be similar for both groups. The onset time showing the time to reach MAC value of 0.9 from anaesthesia induction was found significantly shorter in the desflurane group. Moreover, times to extubation and eye-opening were shorter in the desflurane group than the sevoflurane group. Our results support the study results (5) where minimal and low flow desflurane and sevoflurane anaesthetics were compared. In the study, the time required for desflurane to reach 1 and 1.5 MAC values and the duration of extubation and eye-opening were significantly shorter than the time required for sevoflurane. Desflurane is known to provide rapid induction and recovery in high-flow anaesthesia due to low blood/gas partition coefficient (5). Due to this characteristic, filling and emptying the system with the agent is short, therefore induction and recovery are fast. Agent concentrations can be adjusted more quickly and easily.

One of the most important advantages of low flow anaesthesia techniques is the reduction in anaesthetic consumption. Parallel to this decrease, cost efficiency could be counted as one of the positive effects. It is particularly important for expensive inhalers such as sevoflurane and desflurane agents. In order to determine consumption in our study, the data obtained from the Dräger Perseus® A500 anaesthesia workstation and the inhalation anaesthesia, oxygen and medical air consumption were determined and then recorded for each case (7). These values were multiplied by the average flow unit prices, then the cost analysis was performed. According to the formula defined by Biro (8), the calculated amount of liquid volatile agent was calculated separately for the onset and maintenance periods and then the total amount was found.

The cost of minimal-flow anaesthesia with desflurane was found to be lower than the cost of low-flow anaesthesia with sevoflurane and cost of TIVA (24). It was also found that the cost of minimal flow anaesthesia with sevoflurane was slightly lower than the cost of TIVA. In another study (25), fresh gas flow was reduced from 7 L min⁻¹ to 0.5 L min⁻¹ and a gain of 146 mL was achieved for 1 h of isoflurane consumption. In a study of fresh gas flows of 1 L min⁻¹ and 0.3 L min⁻¹, sevoflurane consumption was found to be 0.26 mL min⁻¹ and 0.17 mL min⁻¹, respectively (26).

Anaesthetic agent consumption can be calculated by various methods. In our study comparing cost calculation with the additional software developed by the new anaesthesia workstations and the formula defined by Biro (8), a difference was observed between the amounts of consumption for sevoflurane and desflurane obtained from the Dräger Perseus® A500 anaesthesia workstation and the formula defined by Biro. The amounts obtained with the formula were found to be lower. The main reason for this difference could be considered

as continuous updates to the vaporizer settings to maintain a constant 0.9 MAC value for both agents after the onset phase. Calculation of appropriate MAC value for the ages of patients in the Dräger Perseus® A500 anaesthesia workstation, and the use of the same MAC value for each patient in the Biro's formula could have also caused the difference in the results. Increased reliability of the anaesthesia workstations and less leakages as a result of advanced technological developments have indicated that the results of the anaesthesia workstation are more valuable. In addition, in cases where these workstations are not available and an old type of anaesthesia device is used that cannot perform consumption calculation, Biro's formula can provide a general data.

Conclusion

In our study, it was concluded that sevoflurane and desflurane used with minimal flow were hemodynamically safe with modern technical equipment and did not cause any differences in body temperature. The body temperature could be maintained with the two agents during minimal flow, and a decrease in volatile anaesthetic consumption was enabled. These two anaesthetic agents could also be used safely to provide and sustain oxygenation from an hemodynamic perspective. It was noted that the target MAC value was reached faster with desflurane anaesthesia. Moreover, extubation and eye-opening periods were shorter. In our cost calculation, it was found that desflurane had a lower cost than the sevoflurane, and O₂ and air consumption were less in desflurane. Considering our results, it was concluded that minimal flow desflurane anaesthesia had more positive results on hemodynamic stability and anaesthetic agent consumption compared to sevoflurane anaesthesia.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Başkent University (number KA17/222).

Informed Consent: In our study, informed consent was not obtained because any interventional procedure was not performed on patients and minimal flow anaesthesia was applied to all.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – D.T., E.G., Z.K.; Design – E.G.; Supervision – D.T., E.G., Z.K.; Resources – E.G.; Materials – D.T.; Data Collection and/or Processing – D.T.; Analysis and/or Interpretation – D.T., E.G.; Literature Search – D.T., Z.K.; Writing Manuscript – D.T., E.G., Z.K.; Critical Review – D.T., E.G., Z.K.; Other – D.T., E.G., Z.K.

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