Original Article

Reliability of Low-Flow Anesthesia Procedures in Patients Undergoing Laparoscopic Cholecystectomy: Their Effects on Our Costs and Ecological Balance

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Abstract

Background and Aim: The many advantages of low-flow anesthesia are now recognized. Apart from its positive effects on the patient, it is clear that it is a method that all anesthetists should prefer with its positive effects on the ecological balance. **Patients and Methods:** This prospective, observational, cross-sectional study included 80 patients aged 18-65 years with an American Society of Anesthesiologists score of 1-2 (ASA I-II) who were scheduled for laparoscopic cholecystectomy. **Results:** Although the operation time and anesthesia duration were higher in the low anesthesia group group, sevoflurane consumption was lower. Considering the operation times, up to 60% savings were achieved. **Conclusion:** In our study, we safely applied low-flow anesthesia to our patients with advanced monitoring. We believe that low-flow anesthesia is advantageous in terms of both patients' health, ecological balance, and cost.

Keywords: *Anesthesia, cholecystectomy, costs, ecological balance, low-flow anesthesia, patient*

Introduction

Low-flow anesthesia is an inhalation anesthetic technique in which at least 50% of the gases are returned to the lungs after capturing carbon dioxide (CO_2) from exhaled gases using high-standard rebreathing anesthesia devices.[1] Low-flow anesthesia is administered at gas flow rates of 1 lt/min or less with modern anesthesia devices that allow continuous and detailed monitoring of the anesthetic gas mixture.[2] The use of low fresh gas flow (FGF) (0.35-1 L/min) during inhalation anesthesia increases humidity levels of inhaled anesthetic gases and minimizes heat loss, which not only improves the gas dynamics for the lungs but also provides physiological benefits such as improved mucociliary function and maintenance of body temperature.[3,4] Although low-flow anesthesia (LFA) is associated with risks such as hypoxia, hypercapnia, insufficient depth of anesthesia, and accumulation of potential toxic gases, adequate anesthesia safety has been achieved thanks to high-standard anesthesia devices, new CO_2 absorbers, and advanced monitoring techniques.[5]

According to the classification of flow rates of gases into anesthetic circuits proposed by Baker and Simionescu, very high flow is defined as >4 L/min, high flow as 2-4 L/min, medium flow as 1-2 L/min, low flow as 0.5-1.0 L/min, minimal flow as 0.25-0.5 L/min, metabolic flow as <0.25 L/min (Baker and Simionescu).[6]

The use of LFA decreases the consumption of inhaler agents and provides savings of up to 75%,[3] resulting in a reduction in waste anesthetic gas and the health risks of the operating room personnel, while maintaining

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the balance in the ecosystems.[3] In laparoscopic abdominal surgeries, CO_2 insufflation and concerns about hypoxemia and hypercapnia due to lithotomy position limited low FGF practices; however, there are many studies showing its successful use.[7,8] This study aimed to investigate the effects of sevoflurane anesthesia with low-flow and high-flow FGF on hemodynamics, oxygenation, gas consumption, and recovery in laparoscopic cholecystectomy cases and to draw attention to the cost and ecological effects related to the reduction in sevoflurane consumption.

Subjects and Methods

Following obtaining the ethical approval (No 2021/122) from Malatya Turgut Özal University Clinical Research Ethics Committee, this prospective, observational, cross-sectional study included 80 patients aged 18-65 years with an American Society of Anesthesiologists score of 1-2 (ASA I-II) who were scheduled for laparoscopic cholecystectomy. The study adhered to the ethical principles of the Declaration of Helsinki. Patients who did not want to participate in the study, emergency cases and those with ASA III or higher scores were excluded from the study. After obtaining informed consent, the patients were randomly divided into two groups. No premedication was administered. Age, gender, and ASA scores were recorded. After transferring the patients to the operating room, electrocardiography, heart rate/minute (HR/min), systolic arterial pressure (SAP-mmHg), diastolic arterial pressure (DAP-mmHg), mean arterial pressure (MAP-mmHg), peripheral oxygen saturation (SpO_2%) were monitored. Total oxygen content (SpOC), perfusion index (PI), oxygen reserve index (ORI) (Root – Masimo, Irvine, CA, USA), and Bispectral Index (BIS) were used for monitoring the depth of anesthesia, and baseline values were recorded. Before the induction of anesthesia, a leak test was performed on the anesthesia device in each patient. Soda lime used as a CO_2 absorber was replaced when its color changed. After preoxygenation of the patients, intravenous anesthesia was administered with lidocaine 1 mg/kg, propofol 2 mg kg, fentanyl 1 mcg/kg, rocuronium 0.6 mg/kg, and after induction, adequate anesthesia depth was achieved and patients were connected to the anesthesia device after intubation with an endotracheal tube of appropriate size. End-tidal carbon dioxide ($EtCO_2$), sevoflurane amount, and oxygen flow were continuously monitored after intubation. A combination of 4 L min 100% oxygen (O_2) and 3% sevoflurane (Sevorane®, Liquid 100%, Queenborough, UK) was administered to Group 1 (T1 group) for 10 min. The fresh gas flow was then set at 1 L/min, and 60% O_2+40% air and 2-3% sevoflurane were administered. A combination of 4 L/min 100% oxygen (O_2) and 3% sevoflurane (Sevorane®, Liquid 100%, Queenborough, UK) was administered to Group 2 (T2 group) for 10 min. The fresh gas flow was then set at 2.5 L/min, and 60% O_2+40% air and 2-3% sevoflurane were administered. Tramadol (1 mg/kg) was administered to both groups for postoperative pain relief. We used 5 cm H_2O PEEP to prevent intraoperative atelectasis and we managed to maintain the BIS value around 40-50 for the depth of anesthesia during the operation.

HR, MAP, SpO_2, PI, ORi, and SPOC values of the patients were recorded throughout the surgery at baseline, after anesthesia induction, after intubation, and before and after extubation. At the end of the operation, the inhaled anesthetic agent was discontinued in all patients. Ventilation was continued manually with 100% O_2. Neostigmine 0.04 mg/kg-1 (Neostigmine, Adeka Samsun, Turkey) and atropine 0.01-0.02 mg/kg (Atropine Sulfate, Galen Medikal, Istanbul, Turkey, 0.02 mg/kg) was intravenously administered for reversal of neuromuscular block and the patients were extubated. Total operative time, anesthesia time, amount of fluid administered, and amount of anesthetic gas consumed were recorded separately for each patient (through the anesthesia device). The patients were postoperatively transferred to the recovery unit. In the recovery room, HR, MAP, and SpO_2 were recorded at 1, 5, and 10 min.

Statistical analysis

The analysis of the study data was carried out using the Statistical Package for the Social Sciences (SPSS) version 26 software. The Shapiro–Wilk test was used to check if the data included in the study follow a normal distribution. The level of significance for comparison tests was set at $P < 0.05$. Since the variables were non-normally distributed ($p > 0.05$), the analysis was continued with non-parametric test methods. The Mann–Whitney U test was used to compare differences between two independent groups since the assumption of normality was not met. In

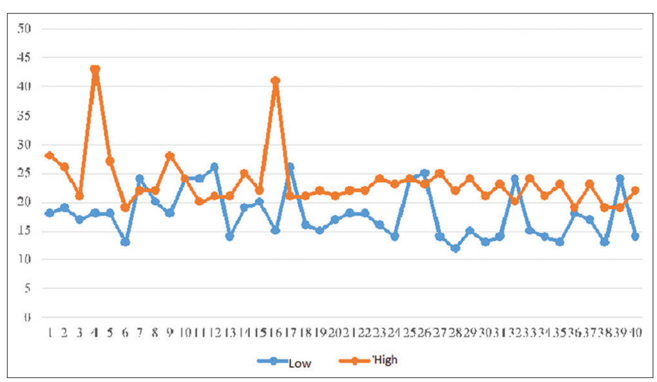

Figure 1: Sevoflurane consumption among groups

Table: 1. Demographic Data

Variable	Group	*n*/%	group		Total	Test Value	*P*
			T1 group	T2 group			
Gender	Female	*n*	30	32	62	0.072	0.789
		%	75.0%	80.0%	77.5%		
	Male	*n*	10	8	18		
		%	25.0%	20.0%	22.5%		
ASA	1	*n*	13_a	15_a	28	0.220	0.639
		%	32.5%	37.5%	35.0%		
	2	*n*	27_a	25_a	52		
		%	67.5%	62.5%	65.0%		
DM	No	*n*	33	38	71	2.003	0.157
		%	82.5%	95.0%	88.8%		
	yes	*n*	7	2	9		
		%	17.5%	5.0%	11.3%		
HT	no	*n*	29	34	63	1.195	0.274
		%	72.5%	85.0%	78.8%		
	yes	*n*	11	6	17		
		%	27.5%	15.0%	21.3%		
COPD	no	*n*	38	39	77	0.353	0.553
		%	95.0%	97.5%	96.3%		
	yes	*n*	2	1	3		
		%	5.0%	2.5%	3.8%		
CAD	no	*n*	38	40	78	0.513	0.474
		%	95.0%	100.0%	97.5%		
	yes	*n*	2	0	2		
		%	5.0%	0.0%	2.5%		

n; number of samples, %; percent, Chi-square Test value (x^2) . There was no statistically significant difference between T1 and T2 flow groups according to the variables of gender, ASA, DM, HT, COPD, CAD in the participants $P > 0.05$ [Table 1].

Table 2. Comparison of age, duration of anesthesia and sevoflurane consumption variables according to flows

Variable	Group	Mean±SD	Median	Min-Max	*P*
Age	T1group	48.88±13.7	48.5	22-73	0.538
	T2 Group	47.33±16.48	47.0	18-90	
Liquid Supplied	T1group	1330±1412.98	1100.0	900-10000	0.020*
	T2 Group	1041.45±170.38	1010.0	775-1600	
Duration of Anesthesia	T1group	76.25±17.47	74.0	50-110	0.001*
	T2 Group	63.4±13.99	62.0	48-115	
Duration of Surgery	T1group	68.8±17.59	67.0	43-103	<0.001*
	T2 Group	55.7±13.77	52.0	41-107	
Sevoflurane Consumption	T1group	17.9±4.18	17.5	12-26	<0.001*
	T2 Group	23.5±4.87	22	19-43	

Cover; mean, SD; standard deviation, min; minimum value, max; maximum value, Mann Whitney *U* Test, $P < 0.05$; The mean age was 48.5 in the T1 group and 47 in the T2 group. There was no significant age difference between the groups $P > 0.05$ [Table 2].

the analysis of categorical data, Chi-square ($\chi 2$) analysis was performed by creating crosstabs.

Results

During the study, data of 80 cases, 40 cases from each group, were collected. Demographic data were similar between groups. There was no statistically significant difference between T1 and T2 flow groups according to the variables of gender, ASA, DM, HT, COPD, CAD in the participants $P > 0.05$ [Table 1].

The mean age was 48.5 in the T1 group and 47 in the T2 group. There was no significant age difference between the groups $P > 0.05$ [Table 2]. The operation time was 67 min in the T1 group and 52 min in the T2 group, $P < 0.001$. Anesthesia duration was 74 min in the T1 group and 62 min in the T2 group p: 0.001. The fluid administered was 1100 ml in the T1 group and 1010 ml in the T2 group p: 0.020. There was a statistically significant difference between the two groups in terms of operation time, anesthesia duration, and fluid administered [Table 2].

Table: 3. Comparison of baseline MAP, ORI, HR, PI and SPOC values between groups

Variable	Group	Mean±SD	Median	Min-Max	*P*
MAP mmHg	T1group	101.65±10.97	101.0	80-123	0.040*
	T2 group	109.95±16.91	111.5	83-148	<0.001*
ORI	T1group	0±0	0.0	0-0	No change
	T2 group	0±0	0.0	0-0	
HR/min	T1group	79.03±12.01	77.0	54-110	0.814
	T2 group	79.75±15.34	80.0	55-111	
PI	T1group	1.71±1.1	1.3	0.39-5	0.954
	T2 group	1.55±0.83	1.4	0.41-4.5	
SPOC	T1group	15.65±2.36	15.5	12-20	0.536
	T2 group	15.28±1.5	15.0	13-18	

Cover; mean, SD; standard deviation, min; minimum value, max; maximum value, Mann Whitney *U*-Test Between groups, baseline MAP was slightly different from 101.0 mmHg in the T1 group to 111.5 mmHg in the T2 group [Table 3].

Table: 4. Comparison of MAP, ORI, HR, PI, SpO_2 and SPOC values between groups after intubation

Variable	Group	Mean±SD	Median	Min-Max	*P*
MAP	T1group	101.78±14.71	100.0	75-128	0.038*
	T2 group	108.2±31.13	112.0	1-158	
ORI	T1group	0.28±0.2	0.2	0.03-1.15	0.001*
	T2 group	0.42±0.26	0.4	0-0.99	
Spo_2	T1group	99.5±0.75	100.0	98-100	0.009*
	T2 group	98.98±1.05	99.0	95-100	
HR/min	T1group	85.15±9.84	85.0	60-110	0.011*
	T2 group	92.88±13.92	93.5	60-114	
PI	T1group	2.64±1.27	2.3	0.9-6	0.840
	T2 group	2.77±1.76	2.5	0.47-7.9	
SPOC	T1group	17.28±2.6	17.0	12-22	0.007*
	T2 group	15.85±1.93	16.0	12-19	

Cover; mean. SD; standard deviation. min; minimum value. max; maximum value. Mann Whitney *U*-Test. Among the groups. MAP. HR were more stable. SpO_2 and SPOC were higher in T1 group after intubation. ORI was higher in T2 group. PI values were normal in both groups [Table 4].

Between the groups, the median value of sevoflurane consumption was 17.5 in the T1 group and 22-P < 0.001 in the T2 group, which was significantly lower. Considering the consumption cost of sevoflurane, it was 2,8 dollar in the T1 group and 3,7 dollars in the T2 group [Figure 1].

Although the operation time and anesthesia duration were higher in the T1 group, sevoflurane consumption was lower. Considering the operation times, up to 60% savings were achieved [Table 2]. Between groups, baseline MAP was slightly different from 101.0 mmHg in the T1 group to 111.5 mmHg in the T2 group [Table 3]. Baseline ORI, HR, PI, and SPOC were similar in the T1 and T2 groups [Table 3]. Among the groups, MAP, HR were more stable, SpO_2 and SPOC were higher in T1 group after intubation, ORI was higher in T2 group. PI values were normal in both groups [Table 4] [Figure 2]. Pre-extubation MAP, ORI, HR, PI were similar. SPOC and SpO_2 were higher in the T1 group [Table 5].

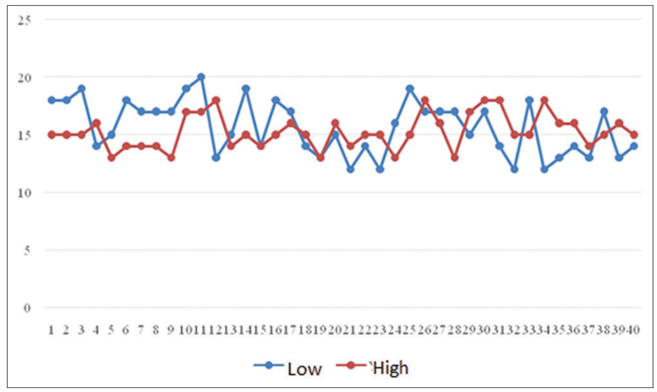

Figure 2: SPOC values between groups

Post-extubation MAP, SpO_2, and PI were similar in the participants included in the study. Although HR and SPOC were high in the T1 group, no statistically significant difference was found $P > 0.05$ [Table 6]. When the data of the participants included in the study in the recovery room in the 1st, 5th and 10th min were compared, 1 min-HR, 5 min-SpO_2, 5 min-MAP were more stable in the T1 group, 10 min-MAP, 10 min-SpO_2, and 10 min-HR were more stable in the T1 group than in the T2 group $P < 0.05$ [Table 7].

Discussion

Oxygenation and depth of anesthesia are of main concern in low-flow anesthesia procedures. In our study, the adequate depth of anesthesia was maintained with BIS monitoring throughout the operation, the oxygenation parameters (SpO_2, ORI, SPOC, and PI) were observed to be within the safety limits, and no statistically significant difference was found between the two groups. The high SPOC value in the T1 group was attributed to the changes in hemoglobin levels [Table 1].

Oterkus *et al.*[7] used 1 L/min FGF in laparoscopic bariatric surgery and found it to be similar to high

Table: 5. Comparison of MAP, ORI, HR, PI and SPOC values between groups before extubation

Variable	Group	Mean±SD	Median	Min-Max	Test Value	*P*
MAP	T1group	90.78±12.33	90.5	70-120	667.500	0.202
	T2 group	95.43±16.85	91.5	62-127		
ORI	T1group	0.3±0.23	0.2	0.11-1	771.500	0.784
	T2 group	0.42±0.78	0.3	0-5		
Spo_2	T1group	99.73±0.51	100.0	98-100	186.000	<0.001*
	T2 group	97.98±1.37	98.0	94-100		
HR/min	T1group	74.6±10.34	75.0	53-99	790.000	0.923
	T2 group	75.48±13.46	73.5	55-106		
PI	T1group	2.31±1.15	2.0	0.74-5.8	598.500	0.052
	T2 group	1.98±1.48	1.7	0.32-8.5		
Spoc	T1group	18.33±2.06	19.0	12-22	384.000	<0.001*
	T2 group	16.43±1.96	16.5	12-21		

Cover; mean. SD; standard deviation. min; minimum value. max; maximum value. Mann Whitney *U* Test. Pre-extubation MAP, ORI, HR, PI were similar. SPOC and SpO_2 were higher in the T1 group [Table 5].

Table: 6. Comparison of MAP, ORI, HR, PI and SPOC values between groups after extubation

Variable	Group	Mean±SD	Median	Min-Max	*P*
MAP	T1group	100.38±12.27	100.0	70-125	0.126
	T2 group	95.88±16.16	94.0	63-130	
ORI	T1group	0	0	0	0
	T2 group	0	0	0	
Spo2	T1group	98.33±1.16	98.0	95-100	0.770
	T2 group	98.2±1.51	98.0	94-100	
HR/min	T1group	81.3±9.99	80.0	62-98	0.038*
	T2 group	75.98±13.18	75.0	53-104	
PI	T1group	2.62±3.4	2.0	0.45-19	0.878
	T2 group	2.24±1.73	1.6	0.32-8.6	
SPOC	T1group	17.8±3.35	18.0	2-23	0.006*
	T2 group	16.65±2.03	17.0	12-22	

Cover; mean. SD; standard deviation. min; minimum value. max; maximum value. MannWhitney *U* Test. HR and SPOC were high in the T1 group, no statistically significant difference was found *P* >0.05 [Table 6].

flow in terms of adequacy of tissue perfusion, depth of anesthesia, and postoperative recovery. Similar to procedures reported in the literature, it was paid attention not to exceed the safety limits of oxygenation parameters (SpO_2, ORI, SPOC) in our study.

Akbas *et al.*[8] investigated the effects of 0.75 L/min FGF and normal-flow anesthesia on the depth of anesthesia in morbidly obese patients during laparoscopic bariatric surgery, and their results did not show a significant clinical difference between the two groups. Hemodynamic parameters of all the patients included in the study were stable intraoperatively. In terms of hemodynamic indicators recorded in the recovery room, rec1 min-HR, rec5 min-SpO_2, rec5 min-MAP were more stable in the T1 group, rec10 min-MAP, rec10 min-SpO_2, and rec10 min-HR were also more stable in the T1 group compared to the T2 group, which was attributed to the physiological benefits of LFA. Thus, the duration of PACU was observed to be shorter in the LFA group.

In order to prevent overdose of inhaled anesthetic agents and hypercapnia in low-flow anesthesia and to provide adequate depth of anesthesia.[9,10] The use of high-flow 100% O_2 ventilation for 10-20 min at the beginning of low-flow anesthesia allows for the elimination of nitrogen in the blood, easier distribution of anesthetic gases into the system and easier adjustment of gas concentrations.[11,12] Similarly, in our study, 100% O_2 ventilation was administered for 10 min, N_2O was not used, and end-tidal CO_2 could be maintained around 30-35 thanks to modern CO_2 absorbers.[13]

The study of Colak *et al.*[14] calculating the amount of FGF by body weight as 10 ml/kg and 20 ml/kg reported a 43% decrease in sevoflurane consumption. Since our anesthesia device was not suitable, FGF could not be calculated according to body weight; however, the mean body weight of our patients in both groups was similar and was around 60-70 kg. The results of our study similarly using 1 L/min and 2.5 L/min FGF showed a reduction of up to 50% in sevoflurane consumption, considering the operative times of the groups. Thus, a significant reduction was achieved in cost.[15] Since the main determinant of the amount of gas entering the waste gas system is the amount of FGF, the health risks of the operating room personnel also decreased. A study comparing pediatric anesthetists with other anesthetists found higher spontaneous abortion rates in pediatric anesthetists as they were exposed to waste anesthetic gases more.[16]

Another important issue that prevails in terms of ecological balance related to inhaled agents is the effects of atmospheric greenhouse gases caused by all

Table: 7. In the recovery room 1.5. and 10. minutes, measured MAP, HR, SpO_2 values.

Variable	Group	Mean±SD	Median	Min-Max	Test Value	*P*
MAP (1)	T1group	98.88±10.56	100.0	74-120	442.000	0.001
	T2 group	109.95±14.27	110.0	80-141		
SpO2 (1)	T1group	98.23±1.49	98.0	90-100	640.000	0.112
	T2 group	97.75±1.81	98.0	93-100		
HT/min (1)	T1group	79.03±11.7	78.0	58-120	531.000	0.010*
	T2 group	85.28±11.08	86.0	66-105		
MAP mmHg (5)	T1group	92±11.94	90.0	70-118	334.000	<0.001*
	T2 group	104.5±9.11	103.5	83-120		
SPO2 (5)	T1group	98.68±1.69	99.0	90-100	349.000	<0.001*
	T2 group	97.7±1.2	98.0	95-99		
HR/min (5)	T1group	79.03±7.24	79.0	60-100	495.500	0.003*
	T2 group	86.6±15.41	86.0	52-117		
MAP mmHg (10)	T1group	89.73±10.12	90.0	68-110	415.500	<0.001*
	T2 group	97.98±7.62	98.0	79-120		
SpO2 (10)	T1group	99.43±0.9	100.0	95-100	199.500	<0.001*
	T2 group	98.08±1	98.0	96-99		
HR/min (10)	T1group	75.58±5.65	76.5	64-90	409.500	<0.001*
	T2 group	84.93±14.44	84.5	49-110		

Cover; mean. SD; standard deviation. min; minimum value. max; maximum value.MannWhitney *U* Test. When the data of the participants included in the study in the recovery room in the 1st. 5th and 10th minutes were compared. 1 min-HR. 5 min-SpO_2. 5 min-MAP were more stable in the T1 group. 10 min-MAP. 10 min-SpO_2 and 10 min- HR were more stable in the T1 group than in the T2 group $P<0.05$ [Table 7].

volatile agents, especially desflurane.[17,18] Therefore, anesthetists avoid high FGF nowadays and tend toward low-flow anesthesia procedures.[18,19] The gases accumulated in the waste gas system are sent from the operating room to the atmosphere and the main determinant of the amount of gas accumulated in the waste gas system is the amount of fresh gas flow. For this reason, measures to reduce the amount of waste and environmental effects of anesthetic gases focus on the amount of fresh gas flow.[19] We can emphasize that LFA is safer in terms of both cost and environmental contamination in today's world where patients receive the same level of anesthesia in LFA procedures, and in fact, modern anesthesia devices are safer with their advanced warning and sensor systems.[20] It is the ethical obligation of all anesthesiologists to minimize the harmful effect of anesthesia practice on environmental sustainability.[21]

Our study had some limitations. The sensor and warning systems of our anesthesia device did not allow us to adjust the FGF amount below 1 L/min and by body weight, and circuit leaks were inevitable. However, we were able to minimize the amount of leak gas with the advanced sensors and warning systems of modern anesthesia devices.

Conclusion

The use of low-flow anesthesia in appropriate cases with our advanced technology anesthesia devices and monitors with superior safety equipment, which we have today, is a logical option for our environment, nature, future, and costs. In our study, we administered 1 L/min FGF to patients undergoing laparoscopic cholecystectomy without deviation from safety limits and observed about 50% lower sevoflurane consumption compared to 2.5 L/min FGF. Therefore, we concluded that low-flow anesthesia can be used safely in patients undergoing laparoscopic cholecystectomy. Nevertheless, there is a need for further studies on this subject in different cases.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Baum JA, Aitkenhead AR. Low-flowanaesthesia. Anaesthesia 1995;50:37-44.

2. Kutlusoy S. Düşük Akımlı Anestezi. In: Ayvat P, editor. Anestezide İnovatif Teknolojiler içinde. Ankara: Akademisyen Kitabevi; 2022. p. 321-30.
3. Hönemann C, Hagemann O, Doll D. Inhalational anaesthesia with low fresh gas flow. Indian J Anesth 2013;57:345-50.
4. Bilgi M, Goksu S, Mizrak A, Cevik C, Gul R, Koruk S, *et al.* Comparison of theeffects of low-flowandhigh-flow inhalational anaesthesia with nitrousoxide and desflurane on mucociliaryactivity and pulmonary function tests. Eur J Anaesthesiol 2011;28:279-83.
5. Doger C, Kahveci K, Ornek D, But A, Aksoy M, Gokcinar D, *et al.* Effects of low-flow sevoflurane anesthesia on pulmonary functions in patients undergoing laparoscopic abdominal surgery. Biomed Res Int 2016;2016:3068467.
6. Baker AB. Low flow and closed circuits. Anaesth Intensive Care 1994;22:341-42.
7. Oterkus M, Dönmez İ, Nadir AH, Rencüzoğulları İ, Karabağ Y, Binnetoğlu K. The effect of low flow anesthesia on hemodynamic and peripheral oxygenation parameters in obesity surgery. Saudi Med J 2021;42:264-9.
8. Akbas S, Ozkan AS. Comparison of effects of low-flowand normal-flow anesthesia on cerebral oxygenation and bispectralindex in morbidly obese patients undergoing laparoscopic sleeve gastrectomy: A prospective, randomized clinical trial. Wideochir Inne Tech Maloinwazyjne 2019;14:19-26.
9. Baraka A, Jabbour S, Hammoud R, Aouad M, Najjar F, Khoury G, *et al.* End-tidal carbondioxide tension during laparoscopic cholecystectomy—correlation with the base line value prior to carbondioxide insufflation. Anaesthesia 1994;49:304-6.
10. Sajedi P, Naghibi K, Soltani H, Amoshahi A. A randomized, prospective comparison of end-tidal CO_2 pressure during laparoscopic cholecystectomy in low and high flow anesthetic system. Acta Anaesthesiol Sin 2003;41:3-5.
11. Upadya M, Saneesh PJ. Low-flow anaesthesia – under used mode towards "sustainable anaesthesia". Indian J Anaesth 2018;62:166-72.
12. Chatrath V, Khetarpal R, Bansal D, Kaur H. Sevoflurane in low-flow anesthesia using "equilibration point". Anesth Essays Res 2016;10:284-90.
13. Frink EJ, Malan TP, Morgan SE, Brown EA, Malcomson M, Brown BR Jr. Quantification of the degradation products of sevoflurane in two CO_2 absorbants during low-flow anesthesia in surgical patients. Anesthesiology 1992;77:1064-9.
14. Colak YZ, Toprak Hİ. Feasibility, safety, and economic consequences of using low flow anesthesia according to body weight. J Anesth 2020;34:537-42.
15. Suttner S, Boldt J. Low-flow anaesthesia does it have potential pharmaco economic consequences? Pharmacoeconomics 2000;17:585-90.
16. Gauger VT, Voepel-Lewis T, Rubin P, Kostrzewa A, Tait AR. A survey of obstetric complications and pregnancy outcomes. Paediatr Anaesth 2003;13:490-5.
17. Charlesworth M, Swinton F. Anaesthetic gases, climate change, and sustainable practice. Lancet Planet Health 2017;1:216-7.
18. Sherman J, Cathy Le MD, Lamers V, Eckelman M. Life cycle greenhouse gas emissions of anesthetic drugs. Anesthesia-Analgesia 2012;114:1086-90.
19. Feldman JM. Managing fresh gas flow to reduce environmental contamination. Anesth Analg 2012;114:1093-101.
20. Kalmar AF, Vekens NVD, Rydt FD, Allaert S, Van De Velde M, Mulier J. Minimizing sevoflurane wastage by sensible use of automated gas control technology in theflow-i workstation: An economic and ecological assessment. J Clin Monit Comput 2022;36:1239.
21. Van Norman GA, Jackson S. The anesthesiologist and global climate change: An ethical obligation to act. Curr Opin Anaesthesiol 2020;33:577-83.