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Araştırma/*Research Article*

The Effect of Low- Flow Anesthesia on Hemodynamic Parameters and Gas Consumption in Single Lung Ventilation

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Tek Akciğer Ventilasyonunda Düşük Akımın Hemodinamik Parametrelere ve Gaz Tüketimine Etkisi

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ABSTRACT

Objective: *We aimed to compare the effects of low and medium high- flow anesthesia on hemodynamic parameters, blood gas values and gas consumption in patients undergoing single lung ventilation.*
Methods: *We studied 40 patients over 18 years of age in ASA I-III group who underwent elective thoracic surgery by single lung ventilation. The patients were intubated with double-lumen tube (DLT) following induction of anesthesia. We randomly divided the patients into two groups. In Group 1, 1L/min (80% oxygen+20% air) 4-6% desflurane; in Group 2, 2L/min (80% oxygen+20% air) was applied. Peripheral oxygen saturation, end-tidal carbon dioxide levels, heart rate, invasive blood pressure values, tidal volume, respiration rate, FiO2, fresh gas flow rate values during single lung ventilation in both groups were recorded. Arterial Blood Gas analysis was performed at 1 hour intervals. The amount of desflurane used at the end of single lung ventilation was monitored by anesthesia device.*
Results: *Desflurane consumption was significantly lower in Group 1 (55.3±18.4 vs. 84.9±37.6,p=0.003). EtCO2 was found to be statistically significantly lower in Group 2, especially between 30 and 75 minutes, and systolic, diastolic, and mean arterial pressure between 45 and 120 minutes. There was no significant difference between the groups in terms of NIRS. Only in both left and right NIRS there was a significant elevation in Group 1 at 120 minutes (p=0.08 and p=0.06, respectively).*
Conclusion: *Low flow with desflurane using appropriate equipment and close monitoring can be safely applied without side effects.*

Keywords: *anesthesia, low flow, thoracic surgery, desflurane*

ÖZ

Amaç: *Tek akciğer ventilasyonu uygulanan hastalarda, düşük ve orta yüksek akımlı anestezinin hemodinamik parametreler, arter kan gazı değerleri ve gaz tüketimi üzerine etkilerinin karşılaştırılması amaçlanmıştır.*
Yöntem: *ASA I-III grubunda tek akciğer ventilasyonu ile elektif torasik cerrahi uygulanan 18 yaş üstü 40 hasta incelendi. Hastalar anestezi indüksiyonunu takiben çift lümenli tüp (DLT) ile entübe edildi. Hastaları rastgele iki gruba ayrıldı. Grup 1'de 1L / dak (% 80 oksijen +% 20 hava)% 4-6 desfluran; Grup 2'ye 2L / dk (% 80 oksijen +% 20 hava) uygulandı. Her iki grupta da tek akciğer ventilasyonu sırasında periferik oksijen satürasyonu, End-tidal CO2 seviyeleri, kalp hızı, invazif kan basıncı değerleri, tidal hacim, solunum hızı, FiO2, taze gaz akım hızı değerleri kaydedildi. Arteriyel Kan Gazı analizi 1 saat aralıklarla yapıldı. Tek akciğer ventilasyonu sonunda kullanılan desfluran miktarı anestezi cihazı ile takip edildi.*
Bulgular: *Desfluran tüketimi Grup 1'de anlamlı olarak daha düşüktü (55.3 ± 18.4'e karşı 84.9 ± 37.6, p = 0.003). EtCO2 Grup 2'de özellikle 30 ile 75 dakika arasında, sistolik, diyastolik ve ortalama arter basıncı 45 ile 120 dakika arasında istatistiksel olarak anlamlı derecede düşük bulundu. NIRS konusunda gruplar arasında anlamlı fark yoktu. Sadece hem sol hem de sağ NIRS'de 120. dakikada grup 1'de anlamlı bir yükselme vardı (sırasıyla p = 0,08 ve p = 0,06).*
Sonuç: *Tek akciğer ventilasyonunda uygun ekipman ve yakın izlem ile düşük akım uygulaması, yan etki olmaksızın güvenle uygulanabilir.*

Anahtar kelimeler: *anestezi, düşük akım, torasik cerrahi, desfluran*

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INTRODUCTION

Low-flow anesthesia is a method which is applied by using a re-inhaled anesthesia system during general anesthesia, where the re-inhaled fresh oxygen flow rate is at least 50%, the metabolic requirement is fully met and sufficient volatile agent can be given[1]. The main advantages of low-flow anesthesia include lowering the cost of inhaled agents by reducing the amount of inhaled agent consumed, providing better dynamics, maintaining airway moisture, reducing atmospheric pollution, maintaining ecological balance and lowering heat loss[2]. However, improperly applied low-flow anesthesia may result in hypoxia, hypercapnia, accumulation of potential toxic gases and insufficient accumulation of volatile anesthetic agent [3].

Patients undergoing thoracic surgery are at risk of hypoxemia and hypercarbia caused by their existing disease. In addition, planned surgery-specific features, adverse effects of mechanical ventilation, and ventilation perfusion rates associated with single lung ventilation predispose to perioperative complications[4]. In the perioperative period; there is very limited information in the literature about the need for oxygen concentration titration during surgical manipulations, intermittent separation of the respiratory circuit, the need for alveolar recruitment maneuver and the use of low-flow anesthesia during single lung ventilation.

Studies have shown that increase in heart rate and left ventricular end-diastolic pressure; and the decrease in mean arterial pressure, left ventricular systolic pressure, and stroke volume are observed during desflurane administration at 1 - 1,5 MAC[5]. Gormley WP et al. reported that the use of desflurane in vaporizer settings above 6% caused an increase in heart rate and blood pressure by increasing transient sympathetic activity[6]. Elmacıoğlu et al. examined the effects of desflurane in low-flow anesthesia and reported that hemodynamic stability was maintained in the perioperative period when desflurane anesthesia was administered with different fresh flow rates[7].

We aimed to compare hemodynamic parameters, artery blood gas (ABG) values and gas consumption in patients undergoing low and medium high- flow anesthesia and single lung ventilation.

METHODS

A randomized controlled study was performed with 40 ASA I-III group patients over 18 years of age who underwent elective thoracic surgery and single lung ventilation after the permission of the Ethics Committee (Number: 2019/514/145/4) was obtained.

Patients aged <18 years with ASA physical status greater than III, body mass index >30 kg/m^2 , severe COPD, history of previous thoracic surgery, those who neded postoperative mechanical ventilation treatment, and would undergo emergency surgery, cases that did not consent to participate in the study were excluded.

Anesthesia induction was followed by insertion of double-lumen tube. Difficult intubation during insertion of double-lumen tube (DLT), patients with desaturation observed despite fiberoptic bronchoscopy (SpO_2<95%), those requiring 100% FiO_2 requirement, $ETCO_2$, patients with>45 mmHg and individuals with a single lung ventilation time of less than 1 hour were excluded from the study.

The patients were intubated with DLT following induction, and their records were kept during single lung ventilation. In patients exceeded one hour procedural time limit; in case of requirement for recruitment maneuver due to anesthesia or surgical indications and double lung ventilation, time period and relevant parameters were recorded.

In the preoperative examination, the patients were informed about the study and their written consent was obtained. Anesthesia gas monitor calibration and leakage test was started with automatic tests of anesthesia device (Drager-Perseus A500) in the morning of operation. Alarm limits were set as FiO_2 30% lower limit, desflurane 10% vol upper limit, $etCO_2$ 45mmHg upper limit, Paw 5cm$H_2$0 lower limit, 30 cmH_2O upper limit.

Carbon dioxide scavenger (soda lime: Sorbolime, Berkim) was evaluated in terms of dryness and color and replaced at appropriate intervals. Venous access was made to the patients who were taken to the operation table with a 20 G cannula inserted on the back of the hand and 0.9% sodium chloride perfusion was started at 10 ml/kg/h. Electrocardiogram (ECG), SPO_2, noninvasive blood pressure (NIBP) monitoring (Drager Infinity XL) was performed. NIRS (Near Infrared Spectroscopy) was used for monitorization, starting before anesthesia (basal), after induction and intubation at 15 min intervals. Following induction, 20 gauge catheter was inserted into the radial artery and invasive arterial blood pressure measurements were started. Hourly arterial blood gas monitoring was performed during, and at the end of single lung ventilation.

For anesthesia induction 1µg/kg fentanyl (Fentanil Citrate, Abbott Lab. North Chicago, USA) was used after spontaneous respiration preoxygenation at 100% O_2 and fresh gas flow at a rate of 4L/min with a three minute mask, and 2-3 mg/kg propofol (Fresenius) Istanbul, Turkey) and 0.5 mg/kg rocuronium bromide were administered intravenously. When muscle relaxation was observed, orotracheal intubation was performed and the patient was connected to an anesthesia workstation (Dräger Perseus) and tidal volume (4-6 ml/kg,) the respiratory frequency (16-18/min), and the I:E ratio (1:1,5) were maintained at indicated settings. Selective intubation was performed with fiberoptic bronchoscopy and endotracheal tube was inserted. In the maintenance of anesthesia, patients were divided into two groups using the program on https://www.randomizer.org/. The first group was defined as low-flow (1.00 L/min) desflurane group (Group 1, n=20) and the second group as medium flow (2.00 L/min) desflurane group (Group 2, n=20). Single lung ventilation was initiated in both groups after confirming the location of the tube with fiberoptic bronchoscopy. Within the first 10 min, 4L / min (80% oxygen+20% air mixture) , and 8-10% desflurane (Suprane, Baxter, Puerto Rico, USA) were used. In Group 1, 1L/min (80% oxygen+20% air mixture) 4-6% desflurane (Suprane, Baxter, Puerto Rico, USA), and in Group 2, 2L/min (80% oxygen+20% air mixture) were used. Peripheral oxygen saturation, end-tidal carbon dioxide levels, heart rate, invasive blood pressure values, NIRS (near-infrared spectroscopy), tidal volume, respiration rate, FiO_2, fresh gas flow rate, PEEP (adjusted to 5 cmH_2O) values were monitored during single lung ventilation in both groups at 15 min intervals

Twenty minutes before end of the surgery, flow was increased to 4 L/min. The amount of desflurane used at the end of single lung ventilation was monitored by anesthesia device and recorded. Muscle relaxant antagonism was achieved with 2 mg/kg suggamadex in all patients.

Statistical analysis

The demographic characteristics and collected data of the patients were entered into the IBM SPSS (Statistical Package for Statistics) version 25. Variables were characterized using mean, maximum and minimum values, and percentage values were used for qualitative variables. Normal distributions were reported as mean±SD and Student t-test was used for comparisons between groups. Pearson chi-square test and Fisher exact test were used for the analysis of qualitative variables. Nonparametric continuous variables were recorded as median and intermittent distribution and compared using Mann-Whitney U tests. $p<0.05$ was considered statistically significant.

G * power program (G * Power 3.1.9.2 for Windows 10) was used to calculate the sample size. Within the confidence interval of 95%,, total number of 42 patients were required for the study, when the alpha level (5%), the margin error (5%) and the effect size (0.50) were kept at indicated levels. (Figure 1).

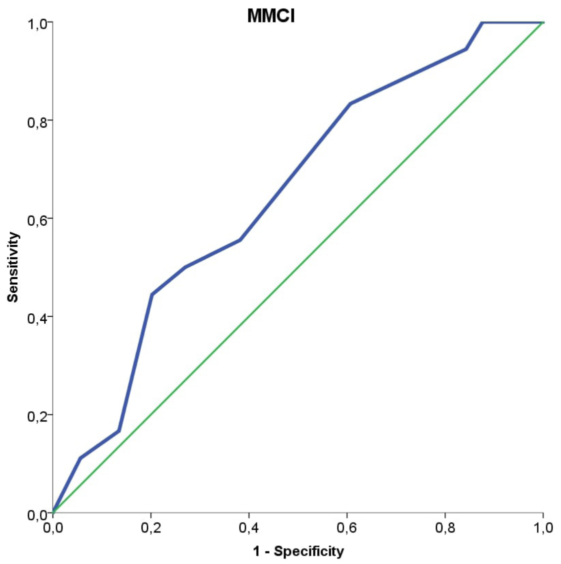

Figure 1: Power analysis of the study.

RESULTS

Each group included 21 patients. However, after randomization, one patient from both groups gave their consent but wanted to leave the study before it ended. Therefore, the results were evaluated on 20 patients for both groups (Figure 2).

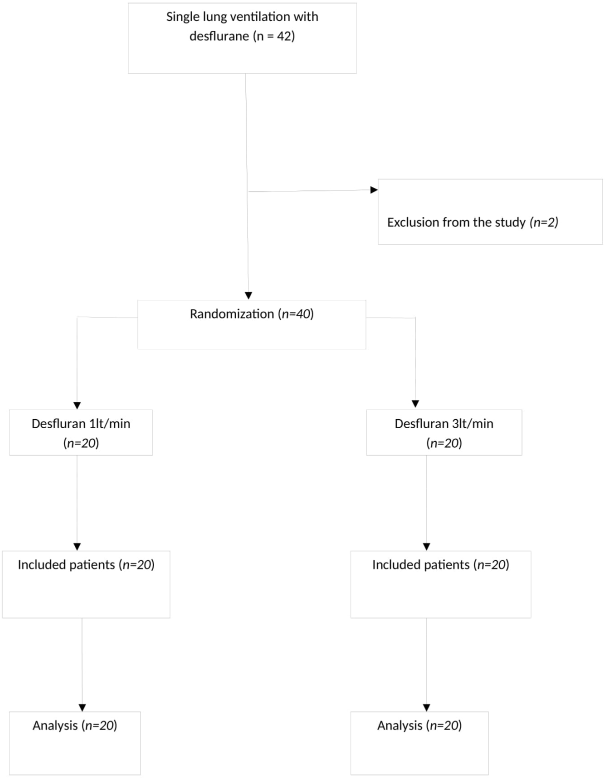

Figure 2: Flow diagram

Of the 40 patients with a mean age of 51.0±16.8 years (range 20-73 years), 33 were male (82.5%) and 7 were female (17.5%). Their mean height was 170.3±8.8 cm and their average weight was 73.3±12.7 kg. When ASA scores were examined, it was seen that the majority were ASA 3 (n=19). Comorbidities were present in 22.5% (n=9) of the cases. While video-assisted thoracic surgery (VATS) (n=22,55.0%) was the most common operation, anatomic lung resection was performed in 11 (27.5%)patients. Thirty-four (85%) patients had left- and 15 patients had right-sided operation. The most commonly used intubation tube length was 39 mm. (n=22.55%). The mean operation time (116.8±53.9 min), anesthesia time (128.8±59.9 min) and the single lung ventilation time (100.8±49.8 min) were as indicated. Mean amount of desflurane used (70.1±32.8 ml) and desflurane intake (23.0±8.6 ml) were also determined (Table 1). There was no statistically significant difference between groups in terms of gender, age, height, weight, ASA score, presence of comorbidity, type of operation, intubation tube size, duration of anesthesia, single lung ventilation, and operation time. Desflurane intake was similar between the groups (p=0.616). Desflurane consumption was significantly lower in Group 1 (55.3±18.4 vs. 84.9±37.6, p=0.003).

There was no statistical difference between groups in terms of SaO_2, heart rate, systolic and diastolic blood pressure, mean arterial pressure, FiO_2, tidal volume, respiration rate, pH, pCO_2, pO_2, HCO_3, end-tidal CO_2 and lactate values. (Table 2). When the perioperative findings were examined, SaO_2, heart rate, FiO_2, tidal volume and respiration rate did not change between the two groups during anesthesia, while $EtCO_2$, systolic artery pressure, diastolic artery pressure and mean arterial pressure significantly differed between the groups (Table 3). Systolic arterial pressures between the groups at 45, 60, 105 and 120 minutes, and diastolic arterial pressures at 90th and 105th min differed between groups. Perioperative blood gas results showed no difference between the groups in terms of pCO_2, pH and HCO_3, whereas pO_2 was higher in Group 2 only in the third hour. Lactate levels were stable in Groups 1 and 2, but increased significantly in Group 1 at the 3rd hour (Table 3).

$EtCO_2$ was found to be statistically significantly lower in Group 2, especially between 30 and 75 minutes, and systolic, diastolic, and mean arterial pressure between 45 and 120 minutes (Figure 3). When left and right NIRSs were examined separately, there was no significant difference between the groups (Figures 4,5,and 6). Only in both left and right NIRSs there was a significant elevation in Group 1 at 120 minutes (p=0.08 and p=0.06). In addition, both right and left NIRSs at 150.minute Group 1 were always at low levels.

DISCUSSION

In our study, we found that desflurane consumption was significantly reduced by using low-flow

Table 1. Demographic characteristics of patients

	Total	Group 1 (n=20)	Group 2 (n=20)	p value
Age (year)	51.0±16.8	52.6±17.8	49.3±15.9	0.542
Gender (M / F)	33 / 7	17 / 3	16 / 4	0.677
Length (cm)	170.3±8.8	172.2±8.9	168.4±8.5	0.183
Weight(kg)	73.3±12.7	76.7±13.1	70.0±11.8	0.09
ASA (1 / 2 / 3)	9 / 12 / 19	5 / 4 / 11	4 / 8 / 8	0.696
Comorbidity rate	9 / 22.5%	4 / 20.0%	5 / 25.0%	0.705
Operation type				
Anatomic lung resection	11 / 27.5%	6 / 30.0%	5 / 25.0%	
VATS	22 / 55.0%	9 / 45.0%	13 / 65.0%	0.638
Other*	7 / 17.5%	5 / 25.0%	2 / 10.0%	
Intubation tube type				
35	8 / 20.0%	2 / 10.0%	6 / 30.0%	
37	10 / 25.0%	5 / 25.0%	5 / 25.0%	0.115
39	22 / 55.0%	13 / 65.0%	9 / 45.0%	
Duration of anesthesia (min)	128.8±59.9	123.0±64.5	134.7±55.9	0.542
Duration of single lung ventilation (min)	100.8±49.8	98.2±53.1	103.5±47.4	0.744
Duration of operation (min)	116.8±53.9	111.6±55.1	122.0±53.5	0.551
Desflurane consumption	70.1±32.8	55.3±18.4	84.9±37.6	**0.003**
Desflurane intake	23.0±8.6	23.7±8.5	22.3±8.9	0.616

** Chest wall resection in 2 patients, pleural decortication in 1 patient, pleectomy in 1 patient, rib stabilization in 1 patient and metastasectomy in 1 patient.*

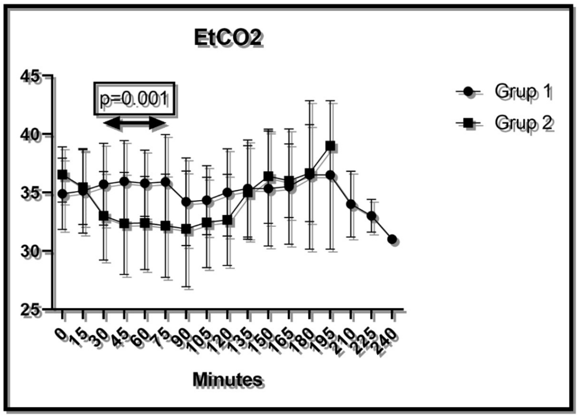

Figure 3. Perioperative change in $EtCO_2$

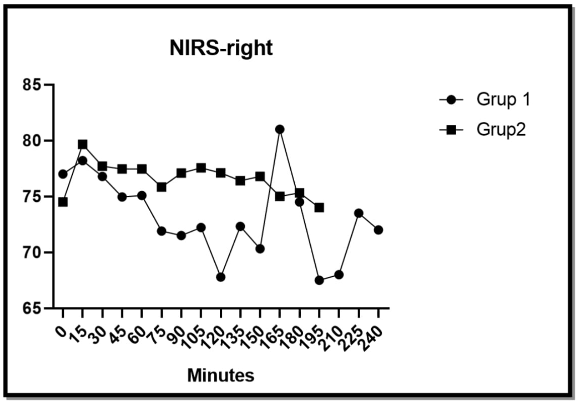

Figure 5. Comparison of right NIRS values between groups

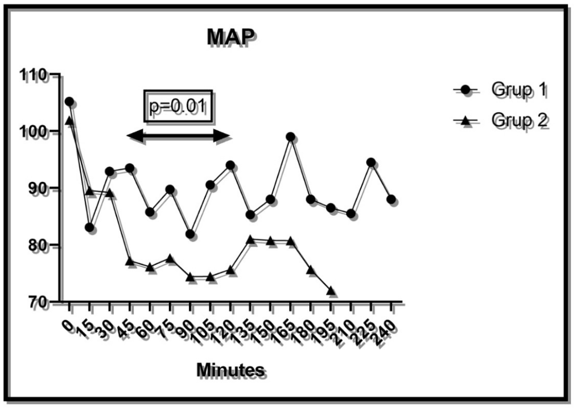

Figure 4. Perioperative change in mean arterial pressure

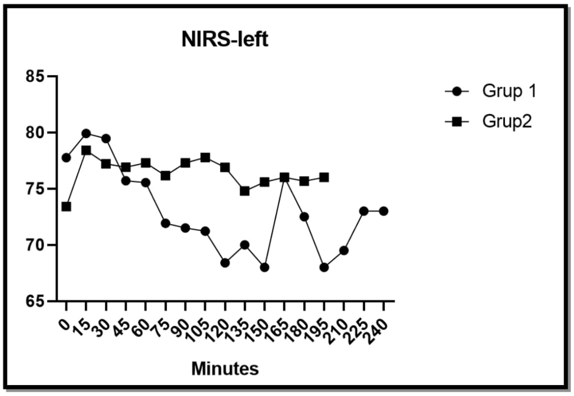

Figure 6. Comparison of left NIRS values between groups

Table 2. Comparison of the groups in terms of zero-minute physiological condition

	Group 1 (n=20)	Group 2 (n=20)	p value
SaO_2 %	98.3±3.0	98.4±1.7	0.851
Heart Rate /Min	82.4±17.0	86.4±14.7	0.438
$ETCO_2$ (mmhg)	34.9±3.0	36.5±2.3	**0.06**
Systolic blood pressure (mmhg)	139.7±21.0	136.8±19.9	0.651
Diastolic blood pressure (mmhg)	78.6±13.0	81.4±12.3	0.491
Mean Arterial Pressure (mmhg)	105.2±15.7	101.9±14.5	0.496
FiO_2 %	100.0±0.0	100.0±0.0	Na
Tidal volume Min/Lt	597.5±47.1	620.0±47.3	0.140
Respiratory rate /Min	12.0±0.0	12.0±0.0	Na
PEEP (cmH_2O)	5.0±0.0	5.0±0.0	Na
pH (mmhg)	7.39±0.02	7.41±0.02	0.112
pCO_2 (mmhg)	42.3±6.2	40.3±4.3	0.253
PaO_2 (mmhg)	179.8±54.0	202.6±60.1	0.215
HCO_3 (mmol/Lt)	24.8±1.2	25.0±1.3	0.678
Lactate (mEq/Lt)	1.09±0.34	1.28±0.33	**0.08**

na; not applicable

Table 3. Peroperative blood gas results *

	Group 1 (n=20)	Group 2 (n=20)	p value
pH			
1.hour	7.39±0.04	7.40±0.04	0.674
2. hour	7.38±0.04	7.40±0.03	0.231
3. hour	7.32±0.09	7.37±0.04	0.428
pCO_2			
1. hour	40.4±4.9	37.9±5.8	0.151
2. hour	40.2±6.4	37.8±4.2	0.360
3. hour	42.0±9.8	41.7±6.8	0.972
PaO_2			
1. hour	133.6±44.7	139.8±44.6	0.663
2. hour	127.3±24.7	139.0±37.6	0.430
3. hour	141.0±49.4	154.2±17.7	**0.01**
HCO_3			
1. hour	24.1±1.4	23.6±1.6	0.389
2. hour	23.9±1.8	23.7±2.1	0.728
3. hour	20.5±2.1	23.4±1.3	0.09
Laktat			
1. hour	1.17±0.44	1.40±0.44	0.668
2. hour	1.18±0.59	1.22±0.35	0.739
3. hour	2.20±0.98	1.42±0.09	**<0.001**

** Fourth hour blood gas was not evaluated because there were only two patients* anesthesia in patients undergoing single lung ventilation, while it did not cause hemodynamic changes during the operation and could be used safely with appropriate anesthesia device and monitorization.

The low- flow anesthesia method, which is widely used nowadays, decreases the cost of anesthetic gas consumption and reduces environmental pollution and leads to positive results[8]. Especially the rapidly increasing healthcare costs and the high costs of modern inhalation anesthetics have brought cost control into consideration.

In particular, the use of new inhalation anesthetics with low flow and low solubility and anesthetic potency is more significant[9]. The use of desflurane reduces the time of filling and discharging of the low-flow system with the agent and confirms the rapid induction and recovery of anesthesia[10]. Desflurane, which has low blood and fat solubility properties and no fresh gas flow limitation in CO_2 absorbers, is best suited for low- flow anesthesia[11]. Therefore; in our study, we used desflurane as inhalation anesthesia at two different flow settings.

The most important factor determining the amount of inhalation agents used in general anesthesia applications is flow rate[12]. In our study; desflurane consumption rate was significantly lower in Group 1 (55.3±18.4 versus 84.9±37.6, p=0.003). Low- flow desflurane use has been reported to reduce the cost per patient and isoflurane increases the cost[13]. In addition, when deslurane was evaluated according to the flow rate (0.5 $Lmin^{-1-1}$ $Lmin^{-1-3}$ L min^{-1}), it was found that there was a proportional decrease in consumption[14]. Similarly, our study showed that the amount of inhalation agent decreased with low flow and thus the cost decreased in patients undergoing single lung ventilation. In the literature, there are limited publications on the use of low flow in patients undergoing single lung ventilation, but the rapid recovery (especially in long-term operations) has been shown to significantly reduce inflammatory mediator expression in patients undergoing thoracic surgery, thereby reducing the risk of inflammatory response[15] Since the desflurane vaporizer can be adjusted over a wide dose range, the fresh gas flow is at a low rate, while the desflurane concentration of the inhaled gases can be changed in a short time. This is important in order to prevent insufficient depth of anesthesia due to shortage of inhalation agents that may be seen in low-flow anesthesia and to allow rapid intervention in the case of deep anesthesia. Also, use of low-flow desflurane, maintaining heat and moisture in the airways; reduces the deterioration of mucociliary activity, preserves the viscosity of secretions and reduces the tendency to atelectasis, especially in patients undergoing thoracic surgery[16].

In our study, initially in both groups; there was no statistically significant intergroup difference as for SaO_2, heart rate, systolic and diastolic blood pressure, mean arterial pressure, FiO_2, tidal volume, respiration rate, pH, pCO_2, pO_2, HCO_3; but $EtCO_2$, systolic arterial pressure, diastolic arterial pressure, mean arterial pressure was significantly different between groups. $EtCO_2$ was found to be significantly lower in Group 2, especially in the 45th and 120th minute measurements of systolic, diastolic and mean arterial pressure between 30 and 75 minutes. We think that this difference does not require intervention and the main reason for this difference is that desflurane causes a more stable response than other procurement agents. However, it has been reported that the use of desflurane at vaporizer settings above 6% increases transient and short-term sympathetic activity, heart rate and blood pressure[17].

Bilgi et al. had shown that oxygen transport parameters were maintained optimally during all anesthesia stages in patients receiving low- flow anesthesia using different inhalation agents[18]. In our patients, no difference was found between the groups in terms of peroperative pH, pCO_2, HCO_3, whereas pO_2 was higher in Group 2 only at the third hour. Hypoxemia developing in thoracic anesthesia during single lung ventilation is still the most important problem. For this purpose, ventilation with high concentration of oxygen and large breath volume is conventionally recommended for the prevention of atelectasis and hypoxia[19].

Fan SZ et al, have indicated that in low- flow techniques, as the fresh gas flow is reduced, the difference between the amount of O_2 content and the inspired O_2 concentration increases. Lower inspiratory O_2 increases the risk of hypoxia. The inspiratory O_2 concentration should be at least 30% in order to prevent hypoxemia with certainty and to ensure consistently adequate O_2 delivery[20]. In our study, there were no decreases in inspired and expired O_2 concentrations in both groups during the operation. We did not find any findings related to hypoxia in arterial blood gas analysis.

There was a statistically significant difference in endtidal CO_2 and lactate. The use of desflurane interacts with soda lime to produce CO but moisture caused by low flow reduces the amount of CO_2 generated.

Increased blood lactate levels have been reported in all volatile anesthetics over 8 hours[22]. In our study; Lactate levels were found to be stable in Groups 1 and 2, but significantly increased in Group 1 at the 3rd hour.

We think that the reason for the increase in lactate after 3 hours in the low-flow group is that the volatile agent increases glycogenolysis and consequently increases the lactate level.

Low -flow applications, and depth of anesthesia should be monitored with NIRS as well as sympathetic and somatic responses to painful stimuli[23]. When the NIRS values of our patients were examined separately as left and right NIRS, no significant difference was found between the groups. Only in both left and right NIRS there was a significant elevation in Group 1 at 120 minutes (p=0.08 and p=0.06, respectively). In addition, it was observed that both right and left NIRSs were always low in Group 1 until 150 min.[24] showed similar results with their study. However, although it was clinically tolerated in patients whose procedures lasted more than two hours, lower oxygenation was observed in the low- flow group. We found that low flow application and NIRS monitoring prevented unnecessary and excessive drug administration to patients.

The most important limitation of our study was the evaluation of the use of a single inhalation agent in low-flow applications. It is known that carbon monoxide is formed in the use of desflurane as a result of interaction with soda lime. It has been stated that the amount of CO produced in low- flow anesthesia methods is clinically insignificant. In our study, the amount of CO accumulated in the system and the amount of carboxyhemoglobin in patients were not measured. However, in order to avoid a possible interaction of soda lime and desflurane and to prevent possible carboxyhemoglobin accumulation and COHb increase, CO_2 absorbance was changed at the end of each day in our study. The comfort of the patients in the recovery room was not evaluated. Since small number of patients were included in the study, further studies with a higher number of patients would be more beneficial

In conclusion, we think that low-flow anesthesia with desflurane delivered with appropriate equipment and close monitoring can be safely applied without causing hemodynamic side effects in single lung ventilation used for thoracic surgery.

REFERENCES

1. Carter LA, Oyewole M, Bates E, et al. Promoting low-flow anaesthesia and volatile anaesthetic agent choice. BMJ Open Qual. 2019;13;8(3):1-4. https://doi.org/10.1136/bmjoq-2018-000479
2. Baum J. Low flow anaesthesia. 2nd edn Butterworths, 2001
3. Nunn G. Low-Flow anaesthesia. Continuing Education in Anaesthesia Critical Care & Pain 2008;8,1-4. https://doi.org/10.1093/bjaceaccp/mkm052
4. Campos JH, Feider A. Hypoxia During One-Lung Ventilation-A Review and Update. J Cardiothorac Vasc Anesth. 2018;32(5):2330-8. https://doi.org/10.1053/j.jvca.2017.12.026
5. Kiliç F, Avci O, Duger C, et al. Evaluation of Low and High Flow Anesthesia Methods Effects on Perioperative Hemodynamics, Depth of Anesthesia and Postoperative Recovery in Patients Undergoing Abdominal Surgery. (2018) J Anesth Surg 5(1):27-33. https://doi.org/10.15436/2377-1364.18.1788
6. Gormley, W.P., Murray, J.M., Trinick, T.R. Intravenous lidocaine does not atenuate the cardiovasculer and catecholamine response to a rapid increase in desflurane concentration. (1996) Anesth Analg 82(2):358-361. PubMed||CrossRef||Others https://doi.org/10.1213/00000539-199602000-00025
7. Elmacıoğlu, M.A., Göksu, S., Koçoğlu, H., et al. Effects of flow rate on hemodynamic parameters and agent consumption in low-flow desflurane anesthesia: An open labels prospective study in 90 patients. (2005) Curr Ther Res Clin Exp 66(1):4-12. https://doi.org/10.1016/j.curtheres.2005.03.001
8. Yasny JS, White J. Environmental implications of anesthetic gases. Anesth Prog. 2012;59:154-8. https://doi.org/10.2344/0003-3006-59.4.154

9. Yoon HK, Lee HJ, Kim WH. Hypnotic potency differs between desflurane and sevoflurane. J Anesth. 2019;33(5):623. https://doi.org/10.1007/s00540-019-02669-7
10. Kim, JK, Kim, DK, Lee, MJ Relationship of bispectral index to minimum alveolar concentration during isoflurane, sevoflurane or desflurane anaesthesia. J Int Med Res 2014;42:130-7. https://doi.org/10.1177/0300060513505525
11. Mallik T, Aneja S, Tope R, et al. A randomized prospective study of desflurane versus isoflurane in minimal flow anesthesia using “equilibration time” as the change-over point to minimal flow. J Anaesthesiol Clin Pharmacol. 2012;28:470-5. https://doi.org/10.4103/0970-9185.101916
12. Chernin EL. Pharmacoeconomics of inhaled anesthetic agents: considerations for the pharmacist. Am J Health Syst Pharm 2004;61 Suppl 4(suppl_4):S18-S22. https://doi.org/10.1093/ajhp/61.suppl_4.S18
13. Baum J, Berghoff M, Stanke HG, et al. Low-flow anesthesia with desflurane. Anaesthesist. 1997;46:287-93. https://doi.org/10.1007/s001010050403
14. Punj J, Pandey R, Darlong VN. Most Hemodynamically Stable Method for Change From High to Low Anesthesia Flow: A Randomized Controlled Trial Comparing State Entropy, High Fresh Gas Flow for 10 Minutes, and 0.8 Ratio of End-Expired Agent Concentration to Inspired Agent Concentration. AANA J. 2019;87(5):390-4.
15. Mineo D, Ambrogi V, Cufari ME, et al. Variations of inflammatory mediators and alpha1-antitrypsin levels after lung volume reduction surgery for emphysema. Am J Respir Crit Care Med. 2010;15;181(8):806-14. https://doi.org/10.1164/rccm.200910-1476OC
16. Biricik E, Karacaer F, Güneş Y, et al. Effect of One-Lung Ventilation on Blood Sevoflurane and Desflurane Concentrations. J Cardiothorac Vasc Anesth. 2019;33(2):442-449. https://doi.org/10.1053/j.jvca.2018.05.032
17. Kapoor MC, Vakamudi MJ. Desflurane-revisited. Anaesthesiol Clin Pharmacol. 2012;28(1):92-100. https://doi.org/10.4103/0970-9185.92455
18. Bilgi M, Goksu S, Mizrak A, et al. Comparison of the effects of low-flow and high-flow inhalational anaesthesia with nitrous oxide and desflurane on mucociliary activity and pulmonary function tests.. Eur J Anaesthesiol. 2011;28(4):279-83. https://doi.org/10.1097/EJA.0b013e3283414cb7
19. Duffy C, Myles PS. Review: thoracic-anesthesia.com. J Cardiothorac Vasc Anesth. 2008;22(4):644. https://doi.org/10.1053/j.jvca.2007.09.005
20. Fan SZ, Lin YW, Chang WS, et al. An evaluation of the contributions by fresh gas flow rate, carbon dioxide concentration and desflurane partial pressure to carbon monoxide concentration during low fresh gas flows to a circle anaesthetic breathing system. Eur J Anaesthesiol. 2008,25(8):620-6. https://doi.org/10.1017/S0265021508003918
21. Garg R. Low flow anesthesia and volatile anesthetic agents-concerns. J Anaesthesiol Clin Pharmacol. 2012;28:475-6.
22. Schricker T, Galeone M, Wykes L, et al. Effect of desflurane/remifentanil anaesthesia on glucose metabolism during surgery: a comparison with desflurane/epidural anaesthesia. Acta Anaesthesiol Scand. 2004;48(2):169-73. https://doi.org/10.1111/j.0001-5172.2004.00297.x
23. Trafidło T, Gaszyński T, Gaszyński W, et al. Intraoperative monitoring of cerebral NIRS oximetry leads to better postoperative cognitive performance: a pilot study.. Int J Surg. 2015;16(Pt A):23-30. https://doi.org/10.1016/j.ijsu.2015.02.009
24. Ajayan N, Thakkar K, Lionel KR, et al. Limitations of near infrared spectroscopy (NIRS) in neurosurgical setting: our case experience. J Clin Monit Comput. 2019;33(4):743-6. https://doi.org/10.1007/s10877-018-0209-1