

The effect of low flow anesthesia on hemodynamic and peripheral oxygenation parameters in obesity surgery

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ABSTRACT

الأهداف: تزايد استخدام التدفق المنخفض في التخدير العام في السنوات الأخيرة بسبب التطورات التكنولوجية ومزاياها العديدة. ومع ذلك، لا تزال الدراسات حول التخدير منخفض التدفق لدى الأفراد الذين يعانون من السمنة غير متوفرة. في هذه الدراسة، هدفنا إلى التحقيق في آثار التخدير منخفض التدفق على معايير الدورة الدموية والتعافي من التخدير لدى الأفراد الذين يعانون من السمنة المفرطة والذين يخضعون لعملية جراحية بالمنظار.

المنهجية: شملت هذه الدراسة العشوائية المرتقبة 44 مريضاً يعانون من السمنة المفرطة خضعوا لعملية جراحية مناسبة. تم تقسيم المرضى بشكل عشوائي إلى مجموعتين: التخدير منخفض التدفق وعالي التدفق. تمت مقارنة المجموعات أيضاً من حيث المعلمات الديناميكية الدموية، وأوقات التعافي من التخدير، وأوقات العمليات، ومعلومات غاز الدم الشرياني.

النتائج: كانت المجموعات متشابهة فيما يتعلق بالبيانات الديموغرافية: معدل ضربات القلب، تشبع الأكسجين المحيطي، قياسات ضغط الدم الشرياني (الضغط الانقباضي، الانبساطي، الضغط الشرياني المتوسط)، قياسات نهاية المد و ثاني أكسيد الكربون كانت متشابهة في كلا المجموعتين خلال الإجراء بأكمله. عندما تم فحص معلومات غاز الدم الشرياني وفترات استعادة التخدير، لم يتم العثور على فرق معتد به إحصائياً.

الخلاصة: يبدو أن التخدير منخفض التدفق في جراحة السمنة بالمنظار آمن من حيث كفاية نضح الأنسجة وعمق التخدير والتعافي بعد الجراحة، مقارنة بالتخدير عالي التدفق.

Objectives: To investigate the effects of low-flow anesthesia on hemodynamic parameters and recovery from anesthesia in obese individuals undergoing laparoscopic surgery.

Methods: This randomized-controlled and prospective study included 44 obese patients who underwent laparoscopic sleeve gastrectomy operation. The patients were randomly allocated into 2 groups as low-flow and high-flow anesthesia. Further, the groups compared in terms of hemodynamic parameters, anesthesia recovery times, operation times, and arterial blood gas parameters.

Results: The groups were similar with respect to demographic data. Heart rate, peripheral oxygen saturation, arterial blood pressure measurements, end-tidal, and CO₂, lactate levels measurements were similar

in both groups during the entire procedure. There was also no statistically significant difference in terms of arterial blood gas parameters or anesthesia recovery periods.

Conclusion: Low-flow anesthesia in laparoscopic obesity surgery seems to be safer compared to high-flow anesthesia in terms of the adequacy of tissue perfusion, depth of anesthesia, and postoperative recovery.

Keywords: low-flow anesthesia, morbid obesity, bariatric/metabolic surgery

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Low-flow anesthesia is a technique in which at least 50% of the exhaled gas is returned into the system by rebreathing. Although not preferred much in the past, this method has become widespread with the introduction of new generation anesthesia devices and monitors and volatile agents. Despite its prominent advantages such as reduction of environmental pollution, minimal loss of heat and moisture, and low cost due to the use of less anesthetic drugs, low-flow anesthesia needs a more advanced technical infrastructure due to the necessity to follow the patients more closely.¹⁻³ Obesity surgery may lead to many complications, such as difficult intubation,

increased risk of atelectasis, obesity hypoventilation syndrome, and so forth.⁴⁻⁶ In these patients, respiratory capacity, which is already constrained due to obesity, is further limited due to the presence of carbon dioxide (CO₂) insufflation and the lithotomy position during laparoscopic surgery. These factors increase the risk of developing hypoxia. Therefore, the use of low current was limited in these patients. However, considering the publications on tissue oxygenation for obese individuals with normal heart pumping functions and sufficient blood volume and hemoglobin levels, it can be predicted that oxygen will be sufficient at the tissue level in low-flow anesthesia.⁷ Also, there are studies where low-flow anesthesia in laparoscopic surgery resulted in successful outcomes in addition to balanced oxygen delivery consumption.^{8,9} Although limited, there are studies reporting use of low-flow anesthesia in bariatric surgery.⁹⁻¹¹

This paper aims to examine the effects of low-flow anesthesia on arterial blood gas, hemodynamic parameters, and anesthesia recovery in patients with morbid obesity who underwent laparoscopic sleeve gastrectomy.

Methods. Concern for hypoxia plays an important role in avoiding the use of low flow in morbidly obese individuals. For this reason, studies on this subject remain limited. Therefore, we think that this original clinical study could be a reference to studies of low flow use in morbidly obese patients. The study proceeded with the permission from the Ethics Committee of the Clinical Research, Kafkas University, Kafkas, Turkey (26.06.2016/132). The ethical standards of the Declaration of Helsinki were adhered to. For the sample size of the study, a similar study previously conducted was referenced. The minimum sample size calculated by taking 0.05 alpha error and 0.20 beta error was found as 15 patients in both groups. This prospective randomized controlled clinical trial, which is also an equivalent clinical trial was performed with 44 adult patients with American Society of Anesthesiologists scores of I-II, aged 18-75 years, and with a body mass index (BMI) of >35 kg/m². Informed consent was obtained from all participants. Patients with cardiovascular disease, liver disease, pulmonary disease or cerebrovascular disease and those refusing to give an informed consent were

excluded. The references for the research were created using PubMed and Google academic indexes.

Upon receiving their informed consent, patients were randomly allocated to 2 groups as a study and a control group. This randomized study was performed by the blind anesthesiologist, who did not participate in the study, using the coin flip method. The patients were examined preoperatively and were taken to the operating room without premedication after the appropriate fasting period.

The leak test of the anesthesia device was performed for each patient before anesthesia. The soda lime used as the CO₂ absorbent was changed when the color changed. Standard monitoring procedures were used for electrocardiogram, and peripheral oxygen saturation (SpO₂). Besides, a 20G cannula was inserted into the radial artery, and intraarterial pressure was continuously monitored. The patients underwent 5 minutes of preoxygenation (100% 4 L/min O₂) followed by propofol 2 mg kg⁻¹ (Propofol 1%, Fresenius® Fresenius Kabi Medicine, Istanbul, Turkey), fentanyl 1 mcg kg⁻¹ (Fentanyl 0.05 mg/ml, Johnson and Johnson Medicine, Istanbul, Turkey) and rocuronium bromide 0.6 mg kg⁻¹ (Curon® 50 mg/5 ml Mustafa Nevzat, Istanbul, Turkey) administered intravenously during the induction of anesthesia.

Following intubation with an appropriate endotracheal tube, patients were connected to the anesthesia device. End-tidal carbon dioxide (EtCO₂), amount of sevoflurane, nitrous oxide, and oxygen flow were continuously monitored after intubation.

In order to provide faster depth of anesthesia at the beginning of anesthesia in the low-flow (study) group, the combination of 2 L min⁻¹ nitrous oxide (N₂O), 2 L min⁻¹ oxygen (O₂), and 2-3% sevoflurane (Sevorane®, Liquid 100%, Queenborough, UK) was administered with a minimum alveolar concentration (MAC) of 1 for 5 minutes. Later, 50% O₂ + 50% N₂O and 2-3% sevoflurane was given by setting the fresh gas flow to 1 L min⁻¹. In the high-flow (control) group, a combination of 2 L min⁻¹ N₂O, 2 L min⁻¹ O₂, and 2-3% sevoflurane was given at the same concentration throughout the procedure. At the end of the operation, fresh gas flow was removed at 6-8 L min⁻¹ and inhalation of the anesthetic agent was closed for all patients. Ventilation was continued manually with 100% O₂. For the reversal of the neuromuscular block, neostigmine 0.04 mg/kg⁻¹ (Neostigmine, Adeka Samsun, Turkey) and atropine 0.02 mg/kg⁻¹ (Atropine Sulphate, Galen Medical, Istanbul, Turkey, 0.02 mg kg⁻¹ intravenously) were administered. For the treatment of postoperative pain, tramadol (1 mg/kg⁻¹) and dexketoprofen (50 mg) were administered.

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Patients' demographic data, vital signs at 30 min intervals (heart rate [HR], peripheral oxygen saturation [SpO₂], and arterial pressure), and preoperative, intraoperative (30, 60, 90 and 120 min), and postoperative arterial blood gas values, operation times, and postoperative complications were recorded. In this clinical trial, we do not analyze the variability of the vital signs according to the time in their own. We analyzed all vital signs between groups for each minutes as aforementioned.

Statistical analysis were performed using the Statistical Package for Social Sciences (IBM Corp., Armonk, NY, USA) version 22. Continuous and categorical variables are expressed as mean ± standard deviation and percentages. Differences in subject characteristics between low-flow and high-flow anesthesia were analyzed using the t-test and the Mann-Whitney U test for continuous variables and the Chi-squared test/Fisher's exact test for categorical variables. The dependent t-test and repeated measurement analysis of variance (ANOVA) and the Friedman test were used to compare laboratory parameters between the beginning and the end of the study period.

Results. The study population consisted of 44 patients (mean age 36±9 years; 31.8% male) who underwent sleeve gastrectomy operation. The low-flow

anesthesia technique was performed in 27 (61.4%) patients and the high-flow anesthesia technique was performed in 17 (38.6%).

The 2 groups were statistically similar in terms of demographic data. Patients' demographic, clinical, and operation feature are listed in **Table 1**. Ten-minute HR values were statistically higher in the high-flow anesthesia group ($p=0.035$). Heart rate values at other times were similar in both groups ($p>0.05$). Systolic, diastolic, mean arterial pressures, end tidal CO₂ levels, and O₂ saturation were similar in both groups ($p>0.05$ for all) (**Table 2**). Arterial blood gas values

Table 1 - Demographic data.

Demographic data	High-flow n=17	Low-flow n=27	P-value
Age	38±11	35±8	0.484
Gender (M/F)	8/9	6/21	0.089
Height	166±8	164±9	0.438
Weight	134±19	126±20	0.154
Body mass index	47±6	46±5	0.856
Operation time	122±45	144±51	0.100
Extubation time	6.2±3.2	5.5±2.8	0.352
Recovery time	10.8±3.5	8.4±3.2	0.076
Hemoglobin (g/dl)	16.8±1.7	16.6±1.4	0.745

Table 2 - Analysis of vital signs.

Vital signs	Beginning	10 th min	30 th min	60 th min	Extubation	Postoperative
HR (beat/min)						
High-flow	94 ± 13	96 ± 11	89 ± 13	84 ± 12	78 ± 19	84 ± 15
Low-flow	91 ± 17	86 ± 15	80 ± 15	84 ± 15	82 ± 14	79 ± 13
P-value	0.366	0.035	0.074	0.772	0.499	0.188
SAP (mm Hg)						
High-flow	156 ± 21	136 ± 51	117 ± 17	124 ± 25	141 ± 36	139 ± 26
Low-flow	142 ± 21	125 ± 30	114 ± 23	119 ± 20	129 ± 21	130 ± 19
P-value	0.089	0.419	0.772	0.426	0.242	0.098
DAP (mm Hg)						
High-flow	94 ± 18	73 ± 17	68 ± 15	80 ± 23	81 ± 21	81 ± 20
Low-flow	85 ± 17	74 ± 21	68 ± 18	74 ± 14	78 ± 17	76 ± 17
P-value	0.151	0.781	0.894	0.267	0.587	0.267
MAP (mm Hg)						
High-flow	117 ± 19	92 ± 18	86 ± 13	93 ± 17	99 ± 24	102 ± 20
Low-flow	110 ± 16	92 ± 3	85 ± 20	92 ± 16	98 ± 18	98 ± 16
P-value	0.252		0.990	0.655	0.952	0.347
SPO₂ (%)						
High-flow	95 ± 3	97 ± 3	98 ± 2	96 ± 4	94 ± 3	96 ± 5
Low-flow	95 ± 4	97 ± 4	98 ± 2	98 ± 2	95 ± 3	97 ± 3
P-value	0.496	0.835	0.639	0.669	0.133	0.370
EtCO₂ (mm Hg)						
High-flow	36 ± 7	34 ± 4	34 ± 3	38 ± 4	36 ± 4	36 ± 5
Low-flow	35 ± 7	34 ± 4	37 ± 5	38 ± 5	35 ± 2	37 ± 5
P-value	0.838	0.904	0.173	0.913	0.405	0.673

SpO₂: peripheral oxygen saturation, HR: heart rate, SAP: full meaning, MAP: full meaning, EtCO₂: end-tidal carbon dioxide

were evaluated throughout the operation. Patients with low-flow and high-flow anesthesia had similar pressure of oxygen (pO_2), partial pressure of carbon dioxide (pCO_2), arterial oxygen saturation (SaO_2), bicarbonate (HCO_3), base excess (BE), and lactate levels ($p>0.05$ for all) (Table 3). During the entire procedure, including the onset, the 30th, 60th, and 90th minutes, and the extubation period, the patients with low-flow anesthesia showed similar values to those with high-flow anesthesia ($p>0.05$ for all). Although, the duration of exubation and recovery was shorter in the low-flow anesthesia, albeit not statistically significant.

Discussion. Low-flow anesthesia is becoming increasingly common with the provision of technical infrastructure and the development of continuous and detailed monitoring systems. However, low-flow anesthesia has not been preferred in morbid obese

individuals because of the expectation of hypoxia and tissue hypoxia due to the weight of morbidly obese patients. Basic elements of tissue hypoxia include the amount of oxygen presented (fiO_2), which is the amount of blood volume together with cardiac output, and the hemoglobin level.⁷ When tissue oxygenation is calculated in low-flow anesthesia, tissue hypoxia is not expected in healthy obese individuals whose surgical bleeding is replaced. Lactate level is an important indicator that reacts later than SaO_2 and PO_2 to tissue hypoxia. Here, we found no statistically significant difference in terms of lactate levels. These findings show that adequate tissue oxygenation can be provided at low-flow in obese individuals. However, close monitoring of oxygenation is still required. Low-flow anesthesia has been used in many different patient groups and has been found to be similar to or better than high-flow anesthesia in many ways.^{12,13}

Table 3 - Arterial blood gas analysis.

Arterial blood gas analysis	Beginning	10 th min	30 th min	60 th min	Extubation
<i>PO₂ (mm Hg)</i>					
High-flow	98 ± 18	100 ± 20	103 ± 13	110 ± 9	104 ± 34
Low-flow	94 ± 25	101 ± 20	102 ± 19	112 ± 14	101 ± 25
<i>P</i> -value	0.440	0.914	0.563	0.942	0.933
<i>PCO₂ (mm Hg)</i>					
High-flow	35 ± 4	39 ± 4	40 ± 4	41 ± 3	43 ± 6
Low-flow	36 ± 5	36 ± 5	39 ± 5	41 ± 3	40 ± 5
<i>P</i> -value	0.716	0.039	0.252	0.923	0.064
<i>SaO₂ (%)</i>					
High-flow	98 ± 3	96 ± 3	96 ± 4	97 ± 1	96 ± 4
Low-flow	97 ± 3	95 ± 4	96 ± 3	97 ± 2	96 ± 2
<i>P</i> -value	0.344	0.715	0.875	0.725	0.961
<i>HCO₃ (mmol/L)</i>					
High-flow	23.7 ± 1.2	20.7 ± 1.5	20.4 ± 1.9	20.1 ± 1.0	20.1 ± 1.1
Low-flow	20.7 ± 1.6	20.5 ± 2.7	20.3 ± 1.9	20.3 ± 1.6	21.0 ± 1.8
<i>P</i> -value	0.328	0.962	0.971	0.718	0.106
<i>BE (mmol/l) (base excess)</i>					
High-flow	2.3 ± 1.4	3.9 ± 1.7	5.1 ± 1.3	5.0 ± 1.2	4.9 ± 1.5
Low-flow	2.2 ± 1.6	3.9 ± 2.1	4.6 ± 2.0	4.7 ± 1.7	4.3 ± 2.1
<i>P</i> -value	0.563	0.923	0.455	0.214	0.341
<i>PH</i>					
High-flow	7.39 ± 0.05	7.36 ± 0.06	7.34 ± 0.06	7.32 ± 0.05	4.9 ± 1.5
Low-flow	7.39 ± 0.06	7.36 ± 0.07	7.36 ± 0.06	7.31 ± 0.06	4.3 ± 2.1
<i>P</i> -value	0.990	0.971	0.524	0.731	0.138
<i>Lactate (mmol/L)</i>					
High-flow	0.7 ± 0.3	0.9 ± 0.4	1.1 ± 0.6	1.3 ± 0.8	1.0 ± 0.3
Low-flow	0.7 ± 0.3	0.9 ± 0.4	1.3 ± 0.6	1.4 ± 0.8	1.0 ± 0.3
<i>P</i> -value	0.971	0.990	0.317	0.857	0.971

PO₂: oxygen saturation, PCO₂: pressure of carbon dioxide, SaO₂: oxygen saturation, HCO₃: Bicarbonate, BE: fbase excess, PH: arterial hydrogen ion concentration

Obesity surgery has the potential to increase the risks of hypoperfusion, bleeding, hypovolemia, and prolonged surgical procedures. Moreover, pulmonary function is limited in morbid obesity.^{14,15} In laparoscopic surgery, a perioperative significant increase of intra-abdominal pressure with CO₂ infusion is associated with further decrease of lung volumes and decreased diaphragm movements, which is clinically reflected in terms of hypoxia and increased EtCO₂ levels.¹⁶⁻¹⁸ These patients benefit from intraoperative positive end-expiratory pressure (PEEP) and postoperative breathing exercises.^{18,19} We applied 10 cmH₂O PEEP to prevent atelectasis during the operation. Also, all patients had respiratory exercises during the postoperative period. In the current study, PCO₂, EtCO₂, and SatO₂ parameters were not different between obese patients receiving high-flow and low-flow anesthesia. We found that the risk for low-flow peripheral perfusion impairment was similar between groups. However, it should be kept in mind that close follow-up is required.

The depth of anesthesia is one of the main concerns of the anesthesiologist during operations. To evaluate the depth of anesthesia, many hemodynamic parameters, such as electroencephalography (EEG), pupil diameter, hemodynamic parameters have been used. Electroencephalography could not be performed because there was no EEG device in our hospital. Also, it was excluded from the evaluation as the pupil diameter may vary due to the narcotics used. Another factor affecting the depth of anesthesia is the use of different agents.²⁰⁻²² In our study, the use of sevoflurane, rocuronium, and fentanyl in all patients neutralized this effect. Also, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and HR were evaluated to assess the depth of anesthesia. These hemodynamic parameters did not differ between the low-flow and high-flow anesthesia groups.

As an important postoperative parameter, recovery time may depend on many variables, including the pharmacodynamics and pharmacokinetics of the anesthetic agent used, the anesthesia technique, operation time, and operation type.^{23,24} Many studies have shown that low-flow anesthesia is similar to or better than high-flow anesthesia in terms of recovery times.^{10,25} In the present study, rescue times were similar in both groups, consistent with the findings of other studies.

Study limitations. Kars is one of the smaller cities in Turkey with a population of approximately 250,000 people. Therefore, the number of patients included

in the sample could not be increased during the research process due to such small population and the sociocultural structure; most of our patients came from other cities. Also, since there is no EEG or bispectral index device in our hospital, evaluation of depth of anesthesia was limited.

In conclusion, effects of low-flow anesthesia on arterial blood gas, hemodynamic parameters, and anesthesia recovery times were similar to high-flow anesthesia in laparoscopic obesity surgery. The use of low-flow anesthesia in laparoscopic obesity surgery seems to be safer than high-flow anesthesia in terms of the adequacy of tissue perfusion, depth of anesthesia, and postoperative recovery. We think that with careful monitoring, low-flow anesthesia can be used in obese individuals. However, further research on the matter is still needed.

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