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Research article

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Different fresh gas flows in prone position under general anesthesia: comparison of costs and effects on airway and endotracheal cuff pressures

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Abstract

Background/Aim: Many studies have been performed on different fresh gas flows for general anesthesia. In this study, we aimed to compare the costs, airway, and endotracheal cuff pressures of different fresh flows (low, medium, high) of patients receiving general anesthesia in the prone position.

Methods: A total of 150 ASA I-II patients over the age of 18 years who underwent lumbar vertebral surgery in prone position were included in this retrospective cohort study. Patients were divided into three groups: Low-flow (n=50, fresh gas flow: 1 l/min), medium-flow (n=50, fresh gas flow: 2 l/min) and high-flow (n=50, fresh gas flow: 4 l/min). In addition to the preoperative heart rates, peripheral oxygen saturation, mean arterial pressures, endotracheal cuff pressures, airway peak and plateau pressures in the first 60 minutes (as 0th, 15th, 30th, 45th, 60th minutes) were noted, and the amount of inhaled gases (sevoflurane, oxygen, nitrogen protoxide) based on the data of the device were recorded to evaluate cost.

Results: The two groups were similar in terms of hemodynamics, airway, and endotracheal cuff pressures. Regarding cost, there was a significant difference in the low-flow anesthesia group in terms of inhaled anesthetic agents, oxygen, and nitrogen protoxide.

Conclusion: With modern anesthesia machines, it is unnecessary to avoid low-flow anesthesia applications. However, we recommend that the fresh gas flow be more than 2 l/min for anesthetists lacking experience or those who do not prefer low-flow anesthesia.

Keywords: Low-flow anesthesia, Prone position, General anesthesia, Sevoflurane

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Ethics Committee Approval
The study was approved by the Research Ethics Committee, Faculty of Medicine, Tekirdağ Namık Kemal University on 04.02.2020 with protocol number 2019.236.12.11.
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Introduction

The fresh gas used in the anesthesia machine is classified according to the amount of flow. According to this classification, low flow is defined as 0.5-1 liter (l)/minute (min), medium flow, as 1-2 l/min and high flow, as 2-4 l/min. Low-flow anesthesia can be used in rebreathing systems in which 50% of the CO2 can return to the lungs after absorption [1]. In modern anesthesia machines, there are various types of equipment that provide varied fresh gas flow and regulate oxygen concentration [2]. Despite the high standards of modern anesthesia machines, 85-90% of anesthetists prefer high fresh gas flows [3]. Although low-flow anesthesia, which is widely used today, helps reduce cost, prevent environmental pollution, and preserve respiratory physiology [4], there are also publications warning about the risk of intraoperative hypoxia [5]. In low-flow anesthesia, fractional inspiratory oxygen amount (FiO_2) should not be less than 30% [6, 7]. It is considered not reasonable to avoid using low-flow anesthesia with modern anesthesia machines [8]. A study of general anesthetic agents advocated switching from desflurane to sevoflurane, based on the high cost, weak potency, and greater greenhouse effect of desflurane [9].

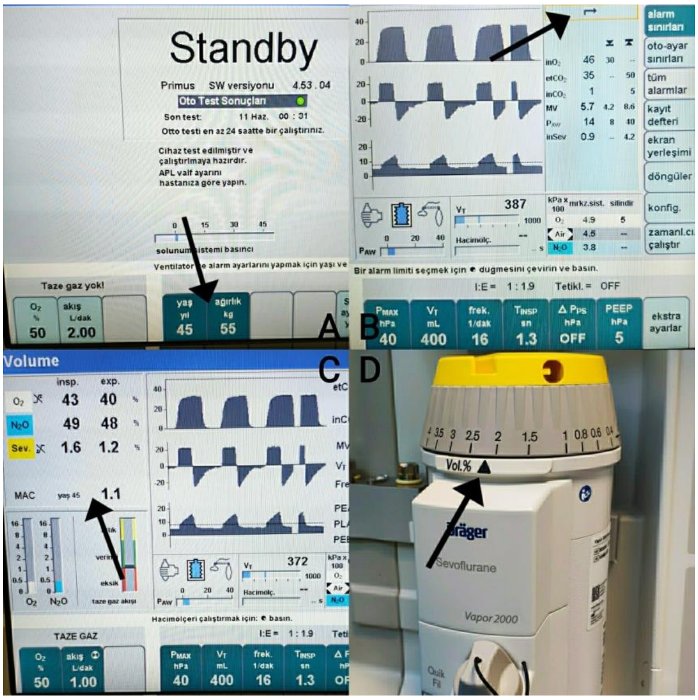
Our study aimed to compare airway peak (Ppeak) and plateau (Pplato) pressures, endotracheal tube cuff pressures, and costs with different fresh gas flow in patients who received general anesthesia with sevoflurane in the prone position while undergoing lumbar vertebral surgery.

Materials and methods

This study was carried out in Tekirdağ Namık Kemal University, Medical Faculty, Department of Anesthesiology and Reanimation after approval was obtained from the Faculty Hospital Ethics Committee (dated 04.02.2020, protocol number: 2019.236.12.11). As a result of the power analysis conducted, the required number of patients at 95% power and 95% confidence interval was 126. A total of 150 ASA I-II patients aged 18 years and over, planned to undergo elective lumbar disc surgery were included in the study. Patients were divided into three groups according to fresh gas flow: Low flow (group L) (1 l/min) (50 individuals), medium flow (group M) (2 l/min) (50 individuals) and high flow (group H) (4 l/min) (50 individuals). Patients excluded in the study were those with ASA scores other than ASA I-II, body mass index (BMI) >40 kg/m^2 and pregnant or breast-feeding women.

Leak checks and calibration of anesthesia machines were performed before each operation. Soda-lime (Drägersorb 800 plus) (Dräger Medical, Lübeck, Germany) was used as CO_2 absorbent, and Dräger Primus (Dräger Medical, Lübeck, Germany) was used as the anesthesia machine. All patients received standard premedication. The patients were monitored preoperatively on ECG, and heart rate (HR), noninvasive blood pressure (NIBP), and peripheral oxygen saturation (SpO_2) were noted. The patient's age and ideal weight (actual weight should not be preferred) were entered to adjust the appropriate MAC (minimum alveolar concentration) and tidal volume on the anesthesia machine before induction. The monitoring alarm limits were set (Alarm for FiO_2 should be set at 30% minimum). All patients were pre-oxygenated for 3 minutes before induction at 4 l/min with 100% oxygen. Following intubation, the patient was turned to prone position. Fresh gas flow was provided at low and medium flows of 4 l/min for 10 minutes and a high flow of 4 l/min throughout the entire case. After intubation, the sevoflurane vaporizer was adjusted so that the MAC value was 1.1-1.3, according to the age of the patient (Figure 1).

Figure 1: Switch to low-flow anesthesia. (Arrow A is the preoperative entry of patient's age and ideal weight into the machine, Arrow B is the setting of the alarm limits, Arrow C is the attempt to maintain the MAC value appropriate to the age between 1.1-1.3 (if the patient's hemodynamics allow), Arrow D is the vaporizer adjustment required for the MAC value that is provided)



During the administration of anesthesia, a mixture of 2 l/min oxygen and 2 l/min N2O were provided to Group H (1:1). After giving prone position, Group M and Group L were maintained with the same ratio (1:1). After 10 minutes, the fresh gas flows were reduced to 2 l/min and 1 l/min. End-tidal carbon dioxide ($EtCO_2$) was maintained between 30-35 mmHg. Sevoflurane was turned off in all three groups 5 minutes before the end of the operation, and the fresh gas flows of the medium and low groups were increased to 4 l/min and oxygen to 100% with the start of the surgical dressing. Patients with sufficient spontaneous breathing after decurarization with neostigmine 0.03 mg/kg and atropine 0.01 mg/kg were extubated and transported to the recovery unit.

In both groups, mean arterial pressure (MAP), SpO_2, heart rate (HR), endotracheal tube cuff pressure (ECP), Ppeak (PEAK) and Pplateau (PLAT) pressures (by decreasing this value if PEEP is given) in the first 60 minutes (as 0th, 15th, 30th, 45th, and 60th minutes) were recorded. The duration of the operation and the amounts of oxygen, N_2O (nitrogen oxide) and total sevoflurane consumed (inhaled and used for the whole case) at the end of the operation were also noted.

Statistical analysis

Statistical analyses were performed using SPSS version 26.0 software. Mean, standard deviation, median, lowest, highest, frequency, and ratio values were used in the descriptive statistics of the data. The Kolmogorov–Smirnov test was used to measure the distribution of variables. Kruskal-Wallis and Mann-Whitney U tests were used for quantitative independent data analysis. A Chi-square test was used to analyze independent qualitative data. Pearson's and Spearman's rank correlation were used for correlation analysis. *P*-values of less than 0.05 indicated significance.

Results

The data of 150 patients were analyzed. The demographic and operational data of the patients are presented in Table 1. There was no statistically difference between the age and gender distribution of the patients in the low, medium and high-flow groups (*P*=0.450 and *P*=0.682 respectively). Demographic data of all groups were similar (height, weight, BMI: *P*=0.346, *P*=0.336 and *P*=0.878 respectively).

There was no significant difference between ASA values, or durations of operation in the low, medium, and high-flow groups (*P*>0.05 for all) (Table 2). In the low-flow group, the amount of oxygen, N_2O and sevoflurane used were significantly lower (*P*<0.05) than the medium flow and high-flow groups. In the medium-flow group, the amount of oxygen, N_2O and sevoflurane used were significantly lower (*P*<0.05) than the high-flow group. The amounts of sevoflurane inhaled in the low, medium, and high-flow groups did not differ significantly (*P*>0.05) (Table 2).

Table 1: Demographic and operational data of the patients

		Min-Max			Median	Mean (SD) / n-%	
Age		20.0	-	77.0	56.5	54.3	(12.4)
Gender	Male					52	34.7%
	Female					98	65.3%
Height		1.5	-	1.8	1.7	1.7	(0.1)
Weight		57.0	-	110.0	80.0	81.7	(11.6)
BMI		20.8	-	41.9	29.4	29.8	(4.4)
ASA	I					31	20.7%
	II					119	79.3%
Duration of the operation (min)		38.0	-	264.0	97.0	109.1	(47.5)
Oxygen (lt)		23.0	-	582.0	166.0	189.6	(88.3)
N_2O (lt)		31.0	-	544.0	94.5	119.4	(83.9)
Sevoflurane (ml)		7.0	-	129.0	21.0	26.6	(19.3)
Inhaled Sevoflurane (ml)		1.0	-	29.0	7.0	7.3	(4.1)
MAP		77.0	-	169	110.5	111.5	(17.1)
SpO_2		92.0	-	100.0	98.0	97.8	(2.1)
HR		51.0	-	116.0	80.0	81.4	(14.3)

Min-Max: Minimum-Maximum, Mean (SD) / n-%: Mean, standard deviation, number, percentage, BMI: Body mass index, ASA: American Society of Anesthesiologists, min: minute, lt: liter, ml: milliliter, MAP: Mean arterial pressure, SpO2: Peripheral oxygen saturation, HR: Heart rate.

In low, medium, and high-flow groups, 0th, 15th, 30th, 45th, 60th minute MAP, SpO_2, HR, ECP, PEAK, PLAT values were similar (*P*>0.05 for all) (Table 3).

Table 2: Data of the study groups

		Group L			Group M			Group H			*P*-value	
		Mean (SD) / n-%		Med	Mean (SD) / n-%		Med	Mean (SD) / n-%		Med		
Age		54.8	(12.5)	56.0	52.9	(12.8)	54.0	55.3	(12.1)	58.0	0.450	K
Gender	M	18	36.0%		15	30.0%		19	38.0%		0.682	X^2
	F	32	64.0%		35	70.0%		31	62.0%			
Height		1.7	(0.1)	1.7	1.6	(0.1)	1.7	1.7	(0.1)	1.7	0.346	K
Weight		83.2	(11.6)	80.0	79.3	(9.9)	80.0	82.7	(13.1)	80.0	0.336	K
BMI		29.9	(4.0)	29.4	29.5	(4.7)	29.4	29.9	(4.6)	29.2	0.878	K
ASA	I	14	28.0%		11	22.0%		6	12.0%		0.072	X^2
	II	36	72.0%		39	78.0%		44	88.0%			
Time (min.)		112.1	(52.2)	103.5	104.2	(43.8)	84.0	110.9	(46.8)	106.0	0.718	K
Oxygen (lt)		140.5	(35.0)	136.5	161.2	(47.7)	151.0	267.1	(104.1)	258.0	*0.000*	K
N_2O (lt)		63.9	(26.7)	56.0	104.9	(45.6)	86.5	189.5	(101.3)	168.0	*0.000*	K
Sev (ml)		15.8	(5.5)	15.0	22.3	(10.6)	20.0	41.7	(24.9)	35.5	*0.000*	K
Inh Sev (ml)		7.0	(3.2)	6.5	7.0	(3.9)	6.0	8.0	(4.9)	7.0	0.497	K

K: Kruskal-Wallis (Mann-Whitney U test) / X^2 Chi-square test, Med: Median, M: Male, F: Female, Sev: Sevoflurane consumed, Inh Sev: Inhaled sevoflurane, Mean (SD) / n-%: Mean, standard deviation, number, percentage, M: male, F: female, BMI: Body mass index, ASA: American Society of Anesthesiologists, min: minute, lt: liter, ml: milliliter

Table 3: MAP, SpO2, HR, ECP, PEAK, PLAT values

Minute	Group L			Group M			Group H			*P*-value	
	Mean (SD)		Median	Mean (SD)		Median	Mean (SD)		Median		
MAP											
0	107.4	(13.5)	109.0	109.0	(14.6)	107.5	117.9	(20.6)	115.5	*0.013*	K
15th	83.5	(14.8)	81.0	83.7	(13.1)	84.0	83.7	(14.1)	80.0	0.977	K
30th	85.4	(13.2)	84.5	90.8	(17.6)	88.0	82.7	(10.5)	82.0	0.054	K
45th	81.0	(11.1)	81.5	83.3	(13.1)	82.5	78.3	(14.3)	79.0	0.220	K
60th	88.4	(13.6)	88.0	89.2	(18.4)	86.0	82.7	(14.6)	83.5	0.182	K
SpO_2											
0	98.0	(2.0)	99.0	97.9	(1.9)	98.0	97.4	(2.4)	98.0	0.516	K
15th	99.4	(0.7)	99.0	99.4	(0.9)	100.0	99.0	(0.8)	99.0	0.052	K
30th	99.3	(0.9)	100.0	99.2	(1.0)	99.5	98.9	(0.9)	99.0	0.056	K
45th	99.3	(0.8)	99.5	99.2	(1.0)	100.0	99.0	(0.8)	99.0	0.092	K
60th	99.4	(0.8)	100.0	98.3	(6.2)	100.0	99.2	(0.8)	99.0	0.418	K
HR											
0	78.5	(11.8)	76.0	83.8	(15.2)	82.0	81.8	(15.3)	78.5	0.233	K
15th	77.7	(12.9)	74.0	76.2	(14.0)	73.5	70.8	(12.5)	71.5	0.054	K
30th	67.5	(10.0)	65.5	69.3	(11.2)	67.0	66.3	(11.4)	63.0	0.303	K
45th	67.9	(10.8)	66.0	67.2	(11.7)	63.5	65.1	(12.8)	61.0	0.252	K
60th	64.4	(8.1)	62.5	67.1	(12.6)	63.0	66.4	(10.9)	65.0	0.831	K
ECP											
15th	36.5	(3.9)	36.0	38.8	(4.4)	40.0	38.9	(4.9)	38.0	0.062	K
30th	44.3	(6.1)	44.0	46.8	(6.6)	47.5	45.8	(7.5)	45.5	0.071	K
45th	48.8	(7,3)	49.0	52.3	(7.8)	50.0	49.4	(9.6)	50.0	0.077	K
60th	56.7	(9.7)	55.5	61.7	(11.8)	60.0	56.8	(10.9)	57.0	0.127	K
PEAK											
15th	16.3	(3.4)	16.0	16.1	(3.6)	15.0	15.7	(3.4)	15.0	0.595	K
30th	17.5	(3.6)	17.0	17.5	(3.8)	17.0	16.4	(3.4)	17.0	0.280	K
45th	18.5	(5.8)	18.0	17.7	(3.6)	18.0	16.9	(3.4)	17.0	0.276	K
60th	18.0	(4.1)	18.0	17.6	(3.7)	17.0	16.6	(3.8)	17.0	0.281	K
PLAT											
15th	13.9	(3.3)	13.0	14.4	(4.0)	14.0	13.7	(3.1)	14.0	0.785	K
30th	15.3	(3.6)	15.5	15.4	(3.5)	15.0	14.5	(3.5)	15.0	0.395	K
45th	15.6	(4.0)	16.0	16.0	(3.8)	16.0	15.1	(3.2)	15.0	0.644	K
60th	15.8	(3.9)	16.0	15.9	(3.5)	16.0	15.1	(3.7)	15.5	0.564	K

K: Kruskal-Wallis (Mann-Whitney U test), Mean (SD): Mean, standard deviation, MAP: Mean arterial pressure, SpO2: Peripheral oxygen saturation, HR: Heart rate, ECP: Endotracheal tube cuff pressure, PEAK: Airway peak pressure, PLAT: Airway plateau pressure.

Discussion

Baker et al. [1] discussed the classification of the amount of fresh gas flow used in the anesthesia machine. According to this classification, metabolic flow is defined as 250 ml (milliliter) / min, minimal flow, as 250-500 ml/min, low flow, as 0.5-1 l/min, medium flow, as 1-2 l/min, high flow, as 2-4 l/min and very high flow, as >4 l/min. Low-flow anesthesia can be used in rebreathing systems in which 50% of the CO2 can return to the lungs after absorption. Our study was conducted in patients who received general anesthesia with low, medium, and high fresh gas flow in prone position. They were monitored on the Dräger Primus anesthesia machine. We used sevoflurane as an inhaled anesthetic agent. In their study, McGain et al. [9] and Chatrath et al. [10] suggested switching from desflurane to sevoflurane to minimize the cost and environmental impact of inhalation anesthesia, based on the high cost, low potency, and greater greenhouse gas effect of desflurane.

In our study, there was no significant difference between hemodynamic, endotracheal cuff, and airway pressures in low, medium, and high-flow groups. Hemodynamically, our results are similar to other studies [11-13]. With this result, we found that the use of low-flow anesthesia (even in prone position) has no drawbacks in terms of hemodynamics.

The patient's age and ideal weight (actual weight should not be preferred) were entered, and the device alarm limits were set to adjust the appropriate MAC and tidal volume on the anesthesia machine before the induction [6]. As the amount of fresh gas flow decreases in low-flow anesthesia, the difference between the oxygen concentration in the inspired gas increases. One of the essential concerns in low-flow anesthesia is that the patient breathes the hypoxic gas mixture through the rebreathing system. Therefore, FiO_2 must be continuously monitored [6, 14, 15]. However, thanks to the alarm limits in modern machines, these data and $InspCO_2$ can be monitored easily, and high flow may be switched to until the end of the case by increasing oxygen/air (or N_2O) mixing rates in favor of oxygen if necessary, or if there is an increase in $inspCO_2$. In our study, FiO_2 value did not fall below 40% in any of the cases. Since necessary changes were performed for soda-lime reaction, no other changes were required. During the operation, considering the hemodynamics in all groups, the sevoflurane vaporizer was adjusted according to the age-based algorithm of the anesthesia machine after intubation, so that the MAC value reached and stabilized at 1.1-1.3. Similar studies reported remaining within the recommended MAC limits (1-1.5) [16, 17].

It has been shown that low-flow anesthesia ensures the preservation of heat and moisture in the respiratory system, less air pollution, and lower costs [11, 18, 19]. In our study, we compared the amounts of sevoflurane and other gases consumed according to the different fresh gas flow in patients undergoing general anesthesia in the prone position in terms of cost. Accordingly, our groups were statistically similar with regards to operation duration, the amount of sevoflurane inhaled, and other data. The amount of sevoflurane consumed even in our low-flow (1lt/min) group (15.8 (5.5) ml) was twice the mean sevoflurane amount used by patients (7.0 (3.2) ml). While this ratio can increase to 5 times the amount of sevoflurane consumed in other groups, these results were similar to previous studies [20]. In terms of the amount of sevoflurane consumed, our low-flow group saved 62% on average compared to the high-flow group and 30% on average compared to the medium-flow group. In terms of nitrogen protoxide use, they saved 66% compared to high flow and 39% compared to medium flow. These rates remained at 47% and 13% for oxygen. Inhaler anesthetics rank second after muscle relaxants by constituting 20% of the cost. Inhaled anesthetic agents are more costly than other anesthetic drugs. It is known that the most important control mechanism of anesthetic gases in terms of cost is the amount of fresh gas flow [21]. Fresh gas flow control will prevent unnecessary costs to increase.

Although in terms of cost, the lack of evaluation of CO_2 absorbent (soda-lime) can be considered as a shortcoming of our study, it has been reported in other studies that the decrease in the cost with sevoflurane at low flow will be higher than with CO_2 absorbent [22]. However, for those with limited experience in the use of sevoflurane with low/minimal-flow anesthesia, fresh gas flow under 2 l/min is not recommended in circle-system anesthesia machines [23].

Recent studies concluded that, with modern anesthesia machines (the anesthesia machine we used was Dräger Primus), there is no reason why anesthetists managed fresh gas flow (even in prone position) to avoid low-flow anesthesia. The monitoring capabilities and alarms of modern anesthesia machines are sufficient to convince users that low-flow anesthesia will not put the patient under risk. However, for anesthetists who do not prefer low-flow anesthesia or have limited experience, our study recommended that the fresh gas flow should not exceed 2 lt/min.

Conclusion

By practice on low-flow anesthesia, and allowing better monitoring of patients (with monitor and machine settings), significant savings with be achieved. This training should be provided not only to physicians but also to anesthesia technicians who will follow up patients under general anesthesia. For those who do not prefer low-flow anesthesia, we do not recommend the use of a fresh gas flow of more than 2 l/min, which is considered the end of mid-flow anesthesia, and the starting point of high-flow.

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