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INHALATION ANESTHESIA WITH LOW FLOW OF FRESH GAS

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Background: The need to reduce environment pollution and treatment costs implies more frequent use of general anaesthesia with low or minimal fresh gas flow rate. Also, the reduction in delivery of fresh gases brings positive effects in patient care, keeping high quality and safety of anaesthesia.

Aim: The aim of this study was to assess the effect of the new protocol of low flow anesthesia on haemodynamic stability.

Material and methods: A total of 100 consecutive patients were included in the study. One group included patients with high flow (HFA) 2 l/min and the second group consisted of patients anesthetized with low-flow anesthesia (LFA) 1 l/min. All patients were scheduled for the surgery of up to 2 hours of duration. In all patients the bispectral index (BIS), heart rate (HR), blood pressure, end-tidal carbon dioxide concentration, haemoglobin oxygen saturation (SaO_2), end-tidal (ET) concentrations of inhalational anesthetic sevoflurane, N_2O and O_2 were monitored.

Results: There is a statistically significant difference in both systolic and dyastolic pressure, hearth rate and SaO^2 between the two groups. The BIS values were similar in both groups and indicated that patients in low-flow anaesthesia group were not exposed to a higher risk of awareness during the procedure. Changes in measured values mean ET anesthetic concentrations at 5, 10, 15, 60 minutes and at the end of surgery were statistically significant between the two groups.

Conclusions: Use of both, low-flow and high-flow rate general anaesthesia provide patients adequate depth of anesthesia and haemodynamic stability.

Key words: low-flow anaesthesia, high-flow anaesthesia, bispectral index.

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INTRODUCTION

Advantages and availability of better techniques and monitoring devices has increased interest in introducing low flow anesthesia in clinical practice. The advantages of low flow anesthesia include cost savings, prevention of environmental pollution, and clinical advantages such as decreased patient loss of heat and moisture. (1) Ever since the era of ether, using open-drop method, through the semi-closed and closed breathing systems, the concept of rebreathing in the exhaled gas was the corner stone of developing anesthesia systems. The modern anaesthesia machines, gas analyser monitors, precision vaporizers and introduction of newer volatile agents enabled easer implementation of low gas flow. Nowadays, the staggering amount of environmental pollution due to anaesthetic gases practice virtually mandates every anaesthesia provider to take extra effort to use the available facilities and implement low-flow anaesthesia (LFA). (2) There is no universally accepted definition for LFA. Any technique that employs an FG flow that is lower than alveolar ventilation can be marked as low-flow anaesthesia. (3) Low-flow anaesthesia is defined to be an inhalation anaesthesia technique where at least 50% of gasses at inspirational part of the system is rebreathed, being a fraction of exhaled gas returned to the patient after CO_2 removal. Using modern anaesthesia machines, this can be achieved when fresh gas flow (FGF) as low as 1 l/min or less. (4) The safety features of anaesthesia machines and the availability of accurate gas monitoring overcome most of the technical shortcomings and offset former resistance to the routine performance of LFA techniques. Widespread availability FiO_2, $ETCO_2$ and inhalational anaesthetic monitoring in modern anaesthesia workstations, aid in the smooth, easy conduct of LFA. (5, 6). The clinical use of LFA is simplified (without the need to resort to difficult mathematical calculations) by the availability of reliable guidelines for the safe performance of these techniques in routine clinical practice. (7) BIS is the most effective method for assessing depth of anesthesia and sedation. It has been shown that BIS monitoring reduces the number of intraoperative awareness episodes. (8) Also, BIS index is quantifiable measure of the sedative and hypnotic effects of anesthetic drugs on the central nervous system (CNS). (9)

The aim of this study was to assess the effect of the new protocol of LFA on haemodynamic stability in patients scheduled for surgery for up to 2 hours of duration.

PATIENTS AND METHODS

This was a prospective observational study which included 100 patients. After approval from the ethics committee and obtaining patient informed consent, study was performed at Anesthesiology and Reanimatology Clinic, Clinical Center of University of Tuzla, Bosnia and Herzegovina. The patients were allocated in two groups: 50 consecutive patients with low flow and 50 of standard flow, who fulfilled the predefined inclusion criteria. Patient were included if classified as I or II ASA (American Society of Anesthesiologist) class, being 18-65 years of age and schedduled for elective surgery for up to 2 hours of duration. Emergency patients, overweight and pregnant patients were not included. Patients included were schedulled for surgery that lasted up to 2 hours: discus hernia (on neurosurgery) or plastic surgery (Dypytreni contracture, tendon surgery, aesthetic operation: augmentation, ginecomastia). In the first group induction and maintaince of anesthesia was performed with high flow 2 l/min, while for second group after induction LFA was used. Induction of low flow anesthesia was identical to conventional methods: after pre-oxygenation, injection of the opioid and hypnotic agent, muscle relaxant, and endotracheal intubation. After connecting the patient to the anesthesia machine, the initial phase of high fresh gas flow (4-6 l / min) was used, until desired level of anesthesia and end tidal concentration of sevoflurane was achieved. The duration of the initial phase was determined by the amount of flow reduction and individual gas injection (4-5 l / min, 6-8 min). After this time, gas mixture was maintained of 30% O_2 and 65% N_2O. Sevoflurane vaporizer was set at 2.5%, until expiratory concentration corresponding to 0.8 minimal alveolar concentration (MAC) of sevoflurane was achieved. After 10 minutes, the total patient gas consumption of the adult patient was about 600 ml / min, so that at this time the flow rate could have be reduced to 1.0 l / min. With the decreased FGF level of 30% inspiratory oxygen concentration could only have been maintained if the oxygen concentration of fresh gas was increased to 50%. Reduction in flow also reduced the amount of Sevoflurane. If the initial selected concentration of anesthetic agents of 0.8 × MAC was maintained, the vaporizer had to be set at 3.0%. In all patients BIS values, HR, blood pressure (BP), SaO_2 and $ETCO_2$ were monitored. The measurements were taken at the following time points: before induction, during mask ventilation, during intubation, after intubation, beginning of surgery (incision), 30 minutes after incision, end of operation, before extubation and when the patient was awake. ET Sevoflurane, N_2O and O_2 concentrations were measured at time intervals of 5, 10, 15, 60 min and at the end of surgery.

Data processing in this research and the application of the statistically mathematical procedures were conducted in the programme package of Microsoft Office Excel 2013 and SPSS 23.0 (SPSS Inc., Chicago, IL, USA). For calculating the chronological age the following formulas from the Microsoft Office Excel 2013 package were used. For significance 5 percent level of ($P < 0.05$) was used. Descriptive statistics (mean and standard deviation) are presented. We used t-test for mean difference between two independent groups.

RESULTS

Table 1. Systolic preassure (mmHg)

Time	Mean ± SD			
	Group 1(LFA)	Group 2(HFA)	df	p
1	129.280 ± 18.443	131.420 ± 13.560	98	.510
2	120.340 ± 22.784	122.960 ± 17.038	98	.516
3	118.380 ± 18.180	124.780 ± 18.888	98	.087
4	123.820 ± 26.501	123.700 ± 19.875	98	.980
5	104.980 ± 12.869	114.340 ± 13.403	98	.001*
6	103.060 ± 11.466	113.220 ± 13.138	98	.000*
7	105.280 ± 13.381	116.500 ± 12.405	98	.000*
8	109.960 ± 14.383	122.380 ± 13.372	98	.000*
9	122.760 ± 12.845	132.980 ± 16.693	98	.001*
10	129.440 ± 15.186	136.300 ± 21.897	98	.072

Abbreviations: M – means; SD – Standard Deviation;
p – T Test Value; * – indicates a significant difference

There is a statistical difference systolic pressure measurements between the first group of HFA and the second group of LFA of 5 (incision) - 9 (during patient awakening) measurements (table 1.)

Table 2. Dyastolic preassure (mmHg)

Time	Mean ± SD			
	Group 1	Group 2	df	p
1	74.980 ± 13.443	76.720± 11.340	98	.486
2	63.160 ± 15.960	72.640 ± 13.156	98	.002*
3	71.200 ± 14.288	76.220 ± 15.679	98	.097
4	72.860 ± 19.990	74.220 ± 16.925	98	.714
5	60.500 ± 12.626	70.500 ± 11.998	98	.000*
6	60.820 ± 10.813	70.740 ± 8.943	98	.000*
7	62.180 ± 8.941	72.480 ± 8.626	98	.000*
8	61.920 ± 11.444	73.880 ± 11.654	98	.000*
9	73.220 ± 12.523	81.740 ± 14.078	98	.000*
10	78.760 ± 11.715	81.880 ± 14.631	98	.002*

Abbreviations: M – means; SD – Standard Deviation;
p – T Test Value; * – indicates a significant difference

There is a statistical difference dyastolic pressure measurements between the first group of HFA and the second group of LFA in the second measurement (during ventilation of the patient with mask) and from 5 (incision) - 10 (awakened patient) measurements (table 2.)

Table 3. SaO_2 (%)

	Mean ± SD			
Time	Group 1	Group 2	df	p
1	77.600 ± 15.080	77.360 ± 11.307	98	.928
2	75.820 ± 14.614	77.960 ± 10.484	98	.402
3	75.080 ± 14.682	77.880 ± 11.483	98	.291
4	72.020 ± 14.680	77.160 ± 12.398	98	.062
5	64.680 ± 12.779	69.800 ± 8.903	98	.022*
6	65.040 ± 12.089	69.140 ± 8.884	98	.056
7	65.660 ± 11.088	69.360 ± 9.066	98	.071
8	67.660 ± 11.220	72.120 ± 8.691	98	.029*
9	73.200 ± 12.534	77.960 ± 11.558	98	.051
10	77.080 ± 14.021	79.780 ± 11.452	98	.294

Abbreviations: M – means; SD – Standard Deviation;
p – T Test Value; * – indicates a significant difference

There is a statistical difference between SaO_2 measurements between the first group of HFA and the second group of LFA in the first measurement (before induction) and from 5-9 measurements (table 3.)

Table 4. Heart rate

Time	Mean ± SD		df	p
	Group 1	Group 2		
1	77.600 ± 15.080	77.360 ± 11.307	98	.928
2	75.820 ± 14.614	77.960 ± 10.484	98	.402
3	75.080 ± 14.682	77.880 ± 11.483	98	.291
4	72.020 ± 14.680	77.160 ± 12.398	98	.062
5	64.680 ± 12.779	69.800 ± 8.903	98	.022*
6	65.040 ± 12.089	69.140 ± 8.884	98	.056
7	65.660 ± 11.088	69.360 ± 9.066	98	.071
8	67.660 ± 11.220	72.120 ± 8.691	98	.029*
9	73.200 ± 12.534	77.960 ± 11.558	98	.051
10	77.080 ± 14.021	79.780 ± 11.452	98	.294

Abbreviations: M – means; SD – Standard Deviation;
p – T Test Value; * – indicates a significant difference

There is a statistical difference in heart rate measurements between the first HFA group and the second LFA group in the fifth and eighth (before extubation) measurements (table 4.)

The BIS values were similar in both groups and indicated that patients who underwent low-flow anaesthesia were not exposed to a higher risk of awareness than the high-flow anaesthesia patients (Figure 1).

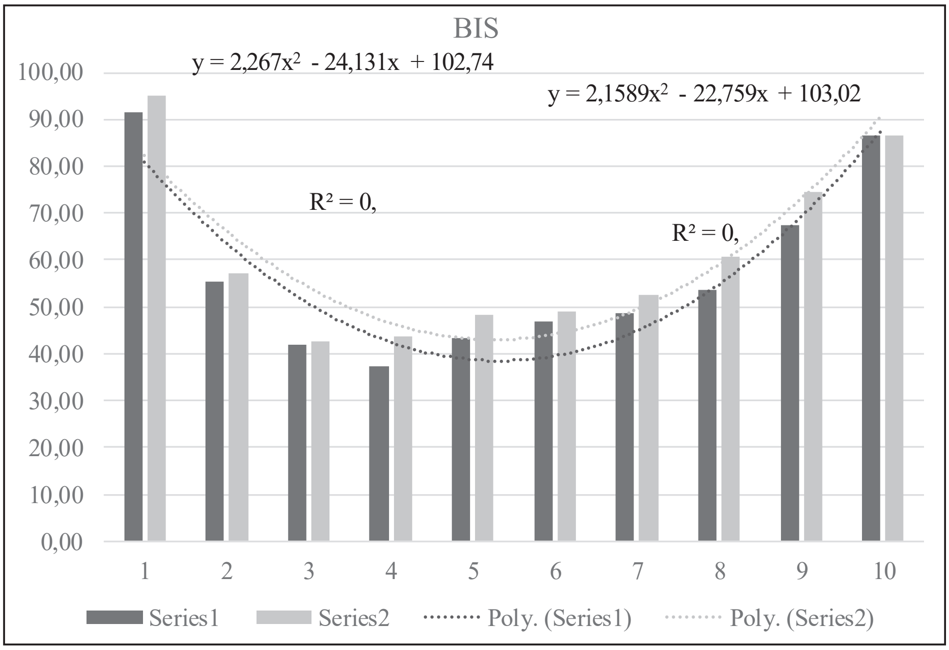

Figure 1. Graphical representation of BIS

Table 5. Observed values

Variables	**Low flow**	**High flow**	**Total**	**p**
Female	32	30	62	0,28
Male	18	20	38	0,17
ASA I	27	18	59	0,26
ASA II	13	18	31	0,14
Hypertension	20	14	34	0,15

(ASA) - international classification of
the American Society of Anesthesiologist

There is no statistically significant difference between the two groups in terms of sex, ASA classification and the presence of the most common comorbidity, hypertension (Table 5). A larger number of patients with previously diagnosed high pressure were in the low-flow group (Table 5).

Table 6. Mean end-tidal sevofluran concentration low flow group and high flow group

Time	Mean ± SD		df	p
	High flow	Low flow	98	.000
5 min	0.638 ± 0.049	1.590 ± 0.073	98	.000
10 min	0.836 ± 0.052	1.670 ± 0.095	98	.000
15 min	0.870 ± 0.046	1.346 ± 0.061	98	.000
60 min	0.884± 0.037	1.048 ± 0.064	98	.000
end of operation	0.534 ± 0.047	0.572 ± 0.045	98	.000

Changes in measured values mean end-tidal volatile anesthetic concentrations at 5, 10, 15, 60, and at the end of operation were statistically significant between the two groups (Figure 2; Table 6.)

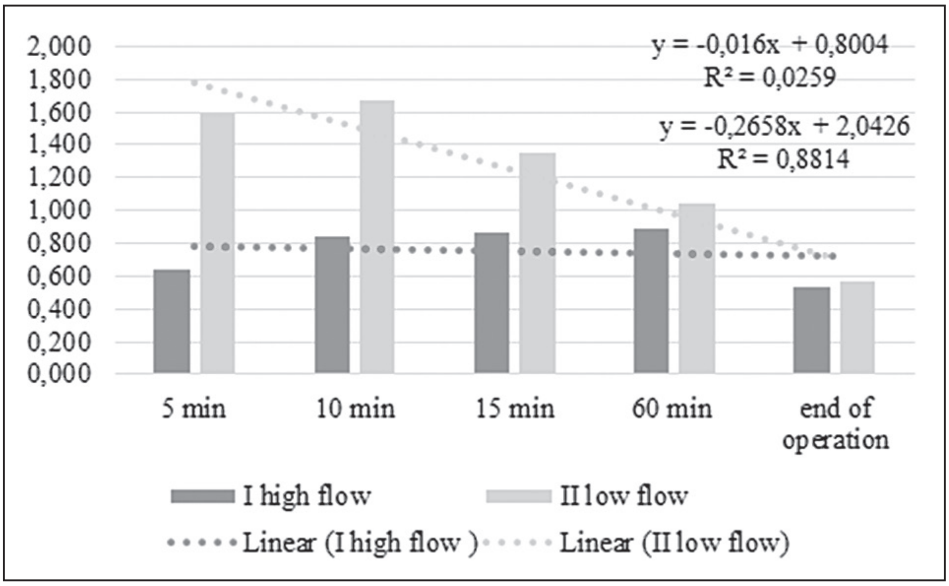

Figure 2. Graphical representation values of variables

In high flow group, end-tidal nitrous oxide concentration was measured from 5 min to the end of operation, it ranged from a minimum of 38% to maximum 59% and in low flow group it ranged from a minimum of 38% to maximum 56%. Concentration of oxygen was measured during the whole of the surgery. The expired oxygen level in both of groups was at minimum of 33% and a maximum of 40%. In both the groups, end-tidal carbon dioxide concentration was maintained between 25 and 35 mm Hg.

DISCUSSION

Our study examined the effects of LFA compering to HFA on hemodynamic stability and depth of anesthesia. When modern rebreathing systems are used, LFA can be performed with FGF of l/min or less. It is difficult to assess depth of anaesthesia based on clinical symptoms alone (10, 11). Without objective measures and monitoring it is just an irrational notion that allows only subjective assessment of too shallow, too deep or adequate anaesthesia. BIS analysis is a non-invasive method of direct measurement of the effect of hypnotic and sedative on the brain as the target organ. Bispectral analysis is based on an EEG analysis of the frontal part of the brain that maintains the level of hypnosis. It uses data obtained by electroencephalography and their analysis. Numerous calculations (integral number in the range of 1-100) calculate the bispectral index (BIS), a numerical value that correlates with the depth of anesthesia and state of consciousness by measuring the hypnotic effect of an intravenous or inhaled drug. This monitoring helps faster recovery from anesthesia, as it is possible to titrate anesthetics more accurately by following its depth (12). Similar observations in relation to different procedures were part of other studies (13, 14). Russell reported that the BIS value is poorly correlated with intraoperative responsiveness (15). In our study, three patients after the introduction to general anesthesia had BIS values between 68 and 72, which were corrected with the addition of an intravenous anesthetic. Before intubation in 6 patients, BIS values were between 20 and 30. Soon after intubation, it improved to expected values. In our study there is a statistical difference systolic pressure measurements between the first group of HFA and the second group of LFA of 5 measurement (incision), 6 (30 minutes after incision), 7 (end of operation, 8 (before extubation) to 9 (during patient awakening) measurement. There is a statistical difference dyastolic pressure measurements between the first group of HFA and the second group of LFA in the second measurement (during ventilation of the patient with mask) and from 5 (incision) - 10 (awakened patient) measurements. There is a statistical difference between SaO_2 measurements between the first group of HFA and the second group of LFA in the first measurement (before induction) and from 5-9 measurements. And also there is a statistical difference in heart rate measurements between the first HFA group and the second LFA group in the fifth and eighth (before extubation) measurements. In a study by Kupisiak et al obtained the results that HR, arterial blood pressure, ETCO2 and SaO_2 were similar for both groups and the differences did not reach statistical significance (7). Although a larger number of patients with previously diagnosed high pressure were in the low-flow group. Patients with diagnosed hypertension, preoperative used their regular antihypertensive therapy. Two patients had an episode of hypotension intraoperative and corrected for additional intravenous infusion. In 2016 Chatrath et al. concluded: Hemodynamic response to surgical stimulus was maintained by regulating the depth of anesthesia (BIS monitoring) or using rescue medications such as propofol. At both the low and high FGF rates, the acute hemodynamic response to surgical stimulus was more efficiently treated by increasing or decreasing end-tidal concentration of sevoflurane concentration. It is because of short time constant of sevoflurane. The time constant is a measure for the time required for changes in the composition of the fresh gas to lead to corresponding changes in the composition of the gas in the anesthetic system (18). Changes in measured values end-tidal volatile anesthetic concentrations (sevoflurane) at 5, 10, 15, 60, and at the end of operation were statistically significant between the two groups. In the low flow group, the values of sevoflurane were higher in I and II measurements due to the higher set concentration and higher flow in the first 10 min. By reducing the flow rate to 1 l / min, they decreased but did not fall below 1%. From results we can see that low flow is a stable system with long time constant. Statistical differences in systolic and dyastolic pressure are not clinically significant, especially since mean pressure is without difference. The heart rate is also the same. Patients are hemodynamically stable and with higher values of ET sevoflurane. In high flow group, end-tidal nitrous oxide concentration was measured from 5 min to the end of operation, it ranged from a minimum of 38% to maximum 59% and in low flow group it ranged from a minimum of 38% to maximum 56%. Concentration of oxygen was measured during the whole of the surgery. The expired oxygen level in both of groups was at minimum of 33% and a maximum of 40%. At no point of time, the concentration did not fall below 30%. The possibility of light anesthesia arising from a decrease in the inspired gas concentration might be prevented by different mixtures of oxygen, air and modern inhaled anesthetics. However, monitoring of anesthesia should not be confused with anesthesia awareness. Objective monitors, BIS and entropy have to be an inseparable part of every anesthetic machine. Also, end tidal concentration of inhalational agent is inseparable part of monitoring in modern anesthesia machines particularly with Low flow anesthesia. There is a need for a larger number of studies for awareness in low flow anesthesia, which will give the answer to the incidence rate and will compare low and high flow anesthesia regarding this setting.

CONCLUSION

we can say that using both, low-flow and high-flow rate, general anaesthesia provide patients haemodynamic stability. Techniques can be easily implemented in surgical patients for up to 2 hours of surgery, but safety issues and attention to intraoperative awareness must also be considered.

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