Minimal and medium flow anaesthesia with isoflurane and desflurane: Effects on inspired and expired oxygen and anaesthetic gas concentrations

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Citation

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Abstract

Background: In this study we aimed to compare haemodynamics, body temperature, inspired and expired oxygen and anaesthetic gas concentrations in minimal and medium flow anaesthesia with isoflurane and desflurane.
Methods: We studied 60 ASA 1-2 patients undergoing elective surgical procedures Patients were randomly divided to two equal main groups to receive isoflurane and desflurane. Then these main groups were randomly divided to 3 equal sub-groups such as to receive isoflurane or desflurane in 500, 1000 and 2000 ml.min^{-1} fresh gas flow (FGF) respectively. FGF was applied 4 L min^{-1} in initial phase (10 min) after standard anaesthetic induction, then isoflurane and desflurane concentrations were adjusted as 1.5 % and 6 % respectively and FGF was adjusted according to groups. HR, MAP, SpO^2 oesophageal temperature, vaporizer settings, inspired and expired anaesthetic gas concentrations were recorded at regular intervals throughout the study.
Results: Inspired and expired anaesthetic concentrations were decreased significantly in minimal flow groups compared to medium and high flow groups. FiO2 values were decreased parallel to duration of anaesthesia. Low FiO^2 occurred in 2 cases in minimal flow isoflurane group and 8 cases in minimal flow desflurane group.
Conclusion: Isoflurane and desflurane could be used safely with minimal and medium FGF, but we decided that isoflurane was superior to desflurane regarding oxygenation. We thought that there was hypoxia risk in cases which desflurane was used as inhalant agent in minimal flow with 50 % N^2O in O^2. However, we concluded that the increasing FiO^2 % ratio can prevent hypoxia.

INTRODUCTION

There is increasing interest in the subject of inhalation anaesthesia using low rates of fresh gas flow. The reasons for this interest are not hard to discover. The lower the fresh gas flow, the less do anaesthetic agents pollute the environment. Very considerable reductions in the cost of expensive agents can be made ([1]).The major risks which have been identified if low-flow anaesthesia is used inappropriately are accidental hypoxia, over- or under dosage of volatile anaesthetics, hypercapnia, and accumulation of potentially toxic trace gases ([2]).

In low-flow anaesthesia, there is a marked difference between the fresh gas concentration of the anaesthetic and its concentration within the breathing system, and this difference increases with the decreasing fresh gas flow, but decreases with decreasing solubility of the anaesthetic agent such as desflurane. If the concentration of the volatile anaesthetic shall be changed, the vaporizer has to be adjusted to a concentration considerably exceeding the aspired nominal value ([3]).

Isoflurane is considered to be the most suitable of the group of older anaesthetic agents to be used in low flow systems ([4]). It was reported that desflurane is suitable for low flow techniques with maximum output vaporizer. In addition, due to low blood/gas solubility of desflurane, it may be superior to isoflurane when used in low flow anaesthesia ([5]).

In this study, we aimed to compare haemodynamics, body temperature, inspired and expired oxygen and anaesthetic gas concentrations in minimal and medium flow anaesthesia with isoflurane and desflurane.

METHODS

With institutional ethics committee approval and written,

informed consent from the subjects, we studied sixty ASA 1-2 patients undergoing elective surgical procedures. Patients with acute or chronic pulmonary, cardiac or metabolic disease, hepatic or renal dysfunction, anaemia, weight over ideal body weight of 30% or under 50 kg, history of current or past smoking or alcohol addiction, and younger than 18 years old were excluded from the study.

Patients were randomly divided to two equal main groups to receive isoflurane (group I, n: 30) and desflurane (group D, n: 30). Then these main groups were randomly divided to three equal sub-groups such as to receive isoflurane or desflurane in 500 ml.min $^{-1}$ fresh gas flow (group I1, groupD1, n: 10), 1000 ml.min $^{-1}$ fresh gas flow (group I2, group D2, n: 10), 2000 ml.min $^{-1}$ fresh gas flow (group I3, group D3, n: 10) respectively. We used Cato workstation (Drager Cato Edition Luebeck, Germany) with isoflurane and desflurane vaporizer. Oxygen, nitrous oxide, isoflurane and desflurane concentrations were measured with (200 mL.min $^{-1}$ sampling speed) side stream gas analyser by galvanic cell principal and under red light absorption spectrophotometer. Anaesthetic machine and all analysers were calibrated before use, according to the instructions of the manufacturers. Fresh soda-lime, disposable circle system and bacterial filter were used in each patient. Operating room temperature was set at 21 $^{\circ}$ C.

Eight, and 2 hours before inducing anaesthesia, all patients were premedicated with diazepam 5 mg orally. Heart rate, oxygen saturation (SpO_2, %), non invasive arterial blood pressure were monitored in operating room. Heart rate (HR, beat.min $^{-1}$), mean arterial pressure (MAP, mmHg), and SpO_2 were recorded preoperatively. Patients received lactated ringer solution 5 ml. kg $^{-1}$ .h $^{-1}$ intravenously (i.v.) during surgery.

Anaesthesia was induced in both groups with lidocaine 1.0 mg.kg $^{-1}$, fentanyl 1 µg.kg $^{-1}$ and thiopental 5 mg.kg $^{-1}$ i.v. after one min pre-oxygenation with oxygen 100 % in fresh gas flow of 10 L.min $^{-1}$. A single dose of vecuronium 0.1 mg.kg $^{-1}$ was given to facilitate orotracheal intubation. After tracheal intubation, controlled ventilation was adjusted to maintain the end-tidal carbon dioxide at ($EtCO_2$) 30-35 mmHg, and SpO_2 97-100 % (fixed respiratory rate of 12 per min, tidal volume variable).

All cases were monitored by oesophageal temperature probe, spirometer, and gas analyser.

During the initial phase, lasting 10 min, the fresh gas flow was set to 4 L.min $^{-1}$ (O_2 2 L.min $^{-1}$, N_2O 2 L.min $^{-1}$). Then isoflurane and desflurane concentration were set 1.5 % and 6 % respectively and after initial phase the fresh gas flow was reduced to 500, 1000 or 2000 L.min $^{-1}$ according to group design. Oxygen and nitrous oxide fresh gas concentrations were set to 50 % nitrous oxide in oxygen.

If the inspired oxygen concentration (FiO_2) decreased to less than 30 % during maintenance of anaesthesia, oxygen flow was increased 0.5 L.min $^{-1}$ and simultaneously nitrous oxide flow decreased 0.5 L.min $^{-1}$. Fresh gas flow decreased again, once FiO_2 increased to 40 % by this setting.

Control of depth of anaesthesia depended primarily on MAP in relation to a reference preoperative value. Therefore, first, MAP was measured three times, at intervals, during the preoperative visit and twice in the anaesthesia room. The mean of the two lowest of these three measurements was taken as the baseline MAP. Thereafter, signs of light anaesthesia (increase in MAP or HR >20 % above baseline, patient movement, and sweating) were treated with, increasing concentrations of isoflurane or desflurane. Additional bolus doses of fentanyl (0.5 µg.kg $^{-1}$ i.v.) were also allowed to control acute haemodynamic changes that did not respond to an increase in the inspired concentration of isoflurane or desflurane. If hypotension was occurred (the MAP decreased by more than 20 %), a single dose of ephedrine (5 mg i.v.) was allowed.

HR, MAP, SpO_2 were recorded after induction of anaesthesia. In addition, oesophagus temperature (°C), vaporizer gas concentration, inspired anaesthetic gas concentration (FiAN), end-tidal anaesthetic gas concentration (FetAN), FiO_2, %, expired oxygen concentration ($FetO_2$, %), inspired nitrous oxide concentration (FiN_2O, %), expired nitrous oxide concentration ($FetN_2O$, %) at 1 st , 5 th , 10 th , 15 th min, and then in 15 min intervals to 150 th min were recorded after intubation.

At the end of surgery, in both groups administration of inhaled gases was terminated and the lungs were ventilated with oxygen 100 % in a fresh gas flow of 4 L.min $^{-1}$. After obtaining spontaneous breathing, residual neuromuscular block was reversed with atropine 0.02 mg.kg $^{-1}$ and neostigmine 0.05 mg. kg $^{-1}$. When breathing was adequate, the trachea was extubated. After extubation HR, SAP, DAP, and MAP were recorded. The patient was observed in the

recovery room for one hour. The patient was then returned to the ward.

Statistical analyses of the study were performed using SPSS for Windows, version 10.0 (SPSS Inc., Chicago, IL, USA). Numerical variables in the two groups were compared by the paired t-test when data were normally distributed; otherwise the Wilcoxon signed rank test was used. The Mann–Whitney U test was used to compare demographic data, as appropriate. P values < 0.05 were considered statistically significant. The data were presented as mean ± SD, median (range) or as a percentage as appropriate.

RESULTS

The groups were similar with respect to sex, age, height, weight, body surface area, duration of anaesthesia, and duration of surgery (table 1).

Figure 1

Table 1: Patient characteristics and data concerning the duration of anaesthesia and surgery of the groups. (Values are means ± SD)

	Group I (n:30)	Group D (n:30)
Sex (F/M)	15/15	11/19
Age (year)	26,53±7,14	25,60±10,15
Weight (kg)	66,33±12,31	61,26±7,12
Height (cm)	169,86±8,60	168,16±7,01
BSA (kg/m^2)	1,75±0,19	1,68±0,12
Duration of anaesthesia (min)	154,53±38,20	156,43±47,79
Duration of surgery (min)	129,30±37,48	134,50±46,64

There was no significant difference between the HR and MAP values of groups preoperatively and during anaesthesia. Haemodynamic changes, which occurred in patients, were within ranges of ± 20 % (table 2).

Figure 2

Table 2: Haemodynamic data of the groups (Values are means ± SD)

	HR (beat.min^{-1})	HR (beat.min^{-1})	MAP (mmHg)	MAP (mmHg)
Time (min)	Group I (n:30)	Group D (n:30)	Group I (n:30)	Group D (n:30)
Baseline	85,9±18,3	86,3±15,5	90,2±7,9	90,0±7,7
0	98,2±10,6	106,1±13,7	110,2±13,1	112,3±11,5
1	93,8±14,3	97,9±15,4	102,8±14,7	102,7±11,8
5	83,8±16,2	85,1±16,1	86,8±10,3	90,5±13,3
10	84,1±16,1	83,1±14,2	80,6±11,1	81,3±12,9
15	81,6±16,3	78,0±15,1	77,5±8,2	78,8±10,7
30	77,8±12,5	75,2±14,3	76,1±10,6	75,0±8,7
45	75,8±12,2	73,0±12,7	74,8±11,0	76,4±11,3
60	76,2±11,7	74,9±11,6	79,2±11,4	77,9±8,1
75	78,0±11,6	76,6±12,0	80,1±10,2	77,5±7,1
90	80,6±11,1	78,3±11,4	78,4±10,1	78,4±9,4
105	81,4±11,7	78,4±11,8	74,1±9,3	79,5±10,6
1120	84 ,4±11,9	80,4±11,7	76,1±7,8	77,6±7,8
135	87,5±11,1	76,7±8,3	77,7±10,1	75,6±5,2
150	88,5±10,5	77,8±9,1	72,0± 8,5	76,6±5,5

There was no significant difference between the HR and MAP values of groups preoperatively and during anaesthesia.

No arrhythmia was occurred during anaesthesia. Any patients required ephedrine to treat hypotension.

Vaporizer concentrations were significantly higher in group D than group I during anaesthesia (p<0.05) (table 3).

Figure 3

Table 3: Vaporizer concentration settings (%)

Time(min)	GroupI1 (n:10)	GroupI2 (n:10)	Group I3 (n:10)	Group D1* (n:10)	Group D2* (n:10)	Group D3* (n:10)
1	1,5± 0,0	1,5±0,0	1,5±0,0	6,0±0,0	6,0±0,0	6,0±0,0
5	1,5±0,0	1,5±0,0	1,5±0,0	6,0±0,0	6,0±0,0	6,0±0,0
10	1,5±0,0	1,5±0,0	1,5±0,0	6,0±0,0	6,0±0,0	6,1±0,3
15	1,9±0,1	1,9±0,1	1,6±0,6	6,6±0,6	6,3±2,2	7,1±1,1
30	1,6±0,3	1,7±0,3	1,8±0,3	6,2±1,4	6,7±1,8	7,2±1,6
45	1,4±0,6	1,4±0,5	1,6±0,3	5,0±2,7	6,5±2,4	6,6±2,0
60	1,5±0,5	1,4±0,6	1,4±0,4	5,9±1,9	6,3±2,6	6,6±1,8
75	1,7±0,4	1,4±0,5	1,5±0,5	7,2±1,8	7,2±3,3	6,6±2,5
90	1,7±0,4	1,5±0,7	1,4±0,6	7,0±2,2	6,8±2,2	7,2±2,3
105	1,6±0,3	1,7±0,4	1,4±0,5	7,3±2,2	6,6±3,3	7,2±1,9
120	1,6±0,5	1,5±0,4	1,4±0,5	6,2±2,2	6,7±1,9	7,1±1,6
135	1,6±0,4	1,8±0,4	1,6±0,4	7,4±1,3	5,2±2,4	7,3±1,6
150	1,5±0,0	1,8±0,2	1,5±0,5	6,6±1,3	4,6±3,7	6,4±1,1

*Vaporizer concentrations were significantly higher in desflurane groups than isoflurane groups during anaesthesia ($p<0.05$).

FiAN was significantly higher in group I1 than group I2 at 10 th min after intubation, and than group I3 between 15 th and 90 th min. FiAN was significantly lower in group D1 than group D2 and D3 between 15 th -30 th min. FetAN was significantly lower in group I1 than group I2 and I3 between 30 th -105 th min. In group D1 FetAN was significantly lower than group D2 and D3 at 30 th min (table 4).

Figure 4

Table 4: Inspired and expired anaesthetic agent concentrations of groups (%). (n:10).

Time (min)	GroupI1 FiAN*	GroupI1 FetAN*	GroupI2 FiAN	GroupI2 FetAN	GroupI3 FiAN	GroupI3 FetAN	GroupD1 FiAN*	GroupD1 FetAN*	GroupD2 FiAN	GroupD2 FetAN	GroupD3 FiAN	GroupD3 FetAN
1	0,8±0,2	0,4±0,1	1,0±0,1	0,4±0,1	1,1±0,1	0,5±0,1	3,4±0,5	2,3±0,6	3,4±0,3	2,0±0,3	3,2±0,3	1,9±0,4
5	1,3±0,1	0,8±0,1	1,4±0,1	0,9±0,1	1,4±0,2	0,9±0,1	5,2±0,2	4,4±0,2	5,4±0,2	4,4±0,2	5,2±0,2	4,4±0,2
10	1,4±0,2	1,0±0,1	1,5±0,2	1,0±0,1	1,4±0,1	1,0±0,1	5,5±0,3	5,0±0,3	5,6±0,3	5,0±0,2	5,6±0,3	5,0±0,3
15	1,1±0,1	0,9±0,1	1,4±0,1	1,0±0,1	1,3±0,3	0,9±0,2	5,1±0,5	4,8±0,5	5,5±0,6	5,1±0,4	5,9±0,7	5,3±0,6
30	0,9±0,1	0,7±0,1	1,4±0,2	1,0±0,1	1,3±0,2	1,1±0,1	4,9±0,4	4,6±0,3	5,7±1,7	5,4±1,5	6,3±1,3	5,9±1,2
45	0,8±0,1	0,6±0,1	1,2±0,3	1,0±0,2	1,5±0,2	1,1±0,2	4,8±0,7	4,6±0,6	5,9±1,9	5,6±1,8	6,2±1,8	5,9±1,6
60	0,8±0,1	0,7±0,1	1,2±0,4	1,0±0,3	1,4±0,3	1,1±0,2	4,9±1,1	4,7±1,0	6,2±1,9	5,9±1,9	6,0±1,8	5,8±1,7
75	0,9±0,2	0,7±0,1	1,3±0,3	1,1±0,3	1,4±0,4	1,2±0,3	5,7±1,2	5,4±1,1	6,7±2,6	6,5±2,4	6,3±2,2	6,1±2,0
90	1,1±0,4	0,9±0,3	1,4±0,4	1,1±0,3	1,4±0,4	1,2±0,3	6,1±1,5	5,9±1,3	6,8±2,2	6,6±2,0	6,7±2,3	6,4±2,1
105	1,0±0,2	0,9±0,2	1,5±0,3	1,2±0,2	1,4±0,4	1,2±0,3	6,5±1,7	6,3±1,6	6,3±2,5	6,1±2,4	6,4±1,7	6,2±1,7
120	1,0±0,2	0,8±02	1,4±0,3	1,2±0,3	1,4±0,4	1,2±0,3	6,4±1,5	6,2±1,5	6,2±2,1	6,1±2,1	6,4±1,8	6,1±1,7
135	1,0±0,2	0,9±0,2	1,6±0,3	1,4±0,2	1,5±0,3	1,3±0,3	6,7±1,7	6,4±1,6	5,2±2,0	5,0±2,0	6,8±1,5	6,5±1,3
150	1,1±0,2	1,0±0,2	1,6±0,2	1,4±0,1	1,5±0,4	1,4±0,4	6,8±1,5	6,6±1,6	5,2±2,3	5,2±2,2	6,2±1,3	6,0±1,2

* Inspired and expired anaesthetic concentrations decreased significantly in minimal flow groups (group I1 and group D1) during anaesthesia.

$FiCO_2$ was never increased above zero in groups. Only in one case from group I1, SpO_2 and $EtCO_2$ were decreased to 97% and 30 mmHg respectively at 90 th min after intubation. At the same time FiO_2 was higher than 30%, therefore, fresh gas flow was increased to 6 L.min $^{-1}$ for 5 min. Two cases in group I1 and 8 cases in group D1, FiO_2 was decreased less than 30% (table 5).

Figure 5

Table 5: Patients who fresh gas flow changed, time of decreasing FiO30 %↓ (min) and changed gas flows.

	Fresh gas flow (L)		$FiO_2$30 %↓time(min)	Changed gas flow (L)	
	O_2	N_2O		O_2	N_2O
Group I1	0,31	0,31	105	0,36	0,26
Group I1*	0,35	0,35	61	0,40	0,30
Group D1*	0,25	0,25	105	0,30	0,20
Group D1	0,36	0,36	101	0,41	0,31
Group D1	0,32	0,32	70	0,37	0,27
Group D1	0,30	0,30	75	0,35	0,25
Group D1	0,29	0,29	113	0,34	0,24
Group D1	0,25	0,25	60	0,30	0,20
Group D1	0,29	0,29	60	0,34	0,24
Group D1*	0,35	0,35	45	0,40	0,30

*Cases who fresh gas flow changed two times.

FiO_2 decreased less than 30% in 2 patients in minimal flow isoflurane group (group I1) and 8 patients in minimal flow desflurane group (group D1).

The lowest FiO_2 was 42% in group I2 and I3, 38% in group D2 and 41% in group D3. In table 6 demographic characteristics, duration of surgery and anaesthesia were detailed of the cases which fresh gas flow was changed.

Figure 6

Table 6: Demographic characteristics, duration of surgery and anaesthesia of the cases which fresh gas flow was changed. (Values are means ± SD).

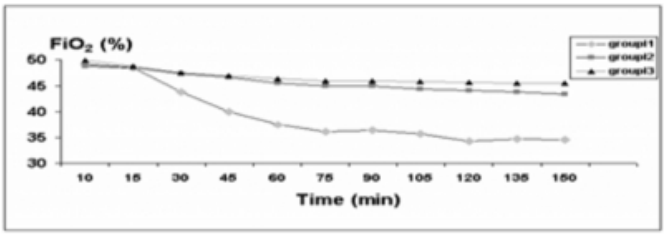
	FGF not changed	FGF changed
Sex (F/M)	24/26	2/8
Age (year)	26,92±8,84	23,58±7,94
Weight (kg)	64,26±10,70	61,16±8,05
Height (cm)	168,44±7,92	170,41±8,17
BSA (kg/m^2)	1,72±0,16	1,69±0,13
Duration of anaesthesia	153,54±44,10	154,25±40,44
Duration of surgery	130,08±43,29	133,45±37,66

FGF: Fresh gas flow

FiO_2 was significantly lower in group I1 than group I2 and I3, in group D1 than group D2 and D3 at 30 th min. FiO_2 was significantly lower in group D1 than group I1 at 10 th min. FiO_2 was significantly lower in group I1 than group D2 and D3, in group D1, D2, D3 than group I2, in group D2 and D3 than group I3 at 10 th min after intubation (figure 1, figure 2).

Figure 7

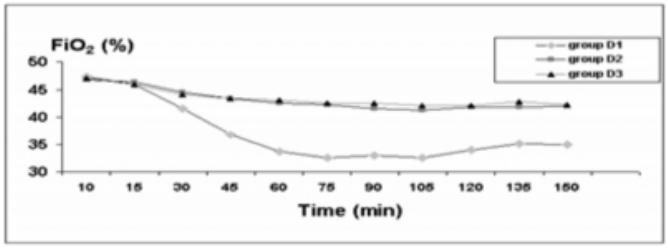
Figure 1: Inspired oxygen concentrations in isoflurane group.



FiO_2 concentration decreased significantly in minimal flow isoflurane group (group I1) than medium and high flow groups.

Figure 8

Figure 2: Inspired oxygen concentrations in desflurane group.



FiO_2 concentration decreased significantly in minimal flow desflurane group (group D1) than medium and high flow groups.

$FetO_2$ was significantly lower in group I1 than group I2 and I3, in group D1 than group D2 and D3 at 30 th min. $FetO_2$ was significantly lower in group I1 than group D1 at 5 th , 10 th , 15 th , 75 th , 90 th and 105 th min after intubation. $FetO_2$ was significantly lower in group I1 than group D2 and D3 at 10 th min. $FetO_2$ was significantly lower in group D1 than group I2 at 10 th min. In group D2 and D3, $FetO_2$ was significantly lower at 10 th , 15 th , 30 th , 45 th , 60 th , 75 th , 90 th and 105 th min than group I2. In group D1, D2 and D3, $FetO_2$ was significantly lower than group I3 at 10 th min after intubation. FiN_2O concentration was significantly higher in group D1 than group D2 and D3 between 45 th and 105 th min and than group I3 between 60 th and 105 th min. In group I2, FiN_2O was lower at 5 th min and higher at 90 th min than group D1. In group D1, $FetN_2O$ was significantly higher between 60 th and 105 th min than group D2. In group D1 $FetN_2O$ was significantly higher between 45 th and 120 th min than group D3. In group I3, $FetN_2O$ was significantly higher between 60 th and 105 th min than group D1 (table 7).

Figure 9

Table 7: Expired oxygen concentration during anaesthesia (%). (n:10)

Time (min)	Group I1	Group I2	Group I3	Group D1	Group D2	Group D3
1	67,3±6,6	64,3±5,2	63,5±6,8	66,8±5,6	69,3±3,8	67,3±3,1
5	50,7±1,8	49,8±2,6	49,0±2,5	48,4±2,5	48,8±2,0	49,2±1,8
10	46,8±1,0	46,5±2,1	47,0±2,8	44,5±1,1	44,2±0,9	44,4±1,1
15	45,7±1,3	45,1±2,8	45,8±2,2	42,9±2,6	43,1±1,5	42,6±1,1
30	39,9±2,1*	43,3±1,3	43,7±1,5	37,8±2,6*	40,6±1,2	42,5±1,3
45	35,5±2,7	42,1±1,1	42,5±1,6	32,7±3,8	39,1±1,5	39,3±1,5
60	32,8±3,7	40,7±1,7	41,7±1,8	29,2±4,1	38,3±2,1	38,7±1,2
75	31,1±2,3	39,8±1,3	41,1±1,7	27,8±3,1	37,3±1,7	38,2±1,3
90	31,5±5,5	49,6±1,5	40,7±2,0	27,4±2,0	36,8±1,7	37,7±0,7
105	31,1±4,0	38,7±1,3	40,4±1,7	27,6±2,1	36,7±2,1	37,3±0,9
120	29,8±2,6	38,6±1,8	40,4±1,7	29,0±1,9	36,7±1,6	37,1±1,0
135	29,0±2,0	38,1±1,7	40,3±1,9	30,5±2,8	37,4±1,3	37,0±1,4
150	29,0±0,0	37,6±1,3	40,7±2,2	29,8±3,2	37,2±1,3	37,0±1,0

Expired oxygen concentrations increased parallel to duration of anaesthesia in all groups.

* Expired oxygen concentration decreased significantly in minimal flow groups (group I1 and groupD1) after 30. min of intubation than other groups ($p<0.05$).

There were no significant differences between groups regarding body temperature during anaesthesia (table 8).

Figure 10

Table 8: Inspired and expired nitrous oxide concentration (%). (n:10)

Time (min)	GroupI1 FiN_2O	GroupI1 $FetN_2O$	GroupI2 FiN_2O	GroupI2 $FetN_2O$	GroupI3 FiN_2O	GroupI3 $FetN_2O$	GroupD1 FiN_2O	GroupD1 $FetN_2O$	GroupD2 FiN_2O	GroupD2 $FetN_2O$	GroupD3 FiN_2O	GroupD3 $FetN_2O$
1	32,6±4,7	22,9±5,3	35,3±6,6	25,8±6,6	35,6±7,3	27,9±7,0	31,8±5,6	22,6±6,4	31,1±4,0	21,2±3,9	30,9±2,4	21,7±2,9
5	42,9±3,7	39,4±4,1	45,4±4,3	41,5±3,6	44,1±4,5	40,3±4,9	41,4±3,0	37,9±2,9	42,7±2,8	38,0±5,5	42,1±3,0	38,6±3,9
10	44,8±3,7	42,4±3,8	46,8±4,1	44,6±4,0	44,7±3,9	42,3±4,6	43,8±2,6	41,5±2,7	44,7±2,0	42,7±1,9	43,6±3,0	41,7±2,9
15	43,9±3,1	42,1±5,2	46,2±3,5	44,5±3,8	44,8±4,4	42,6±4,7	43,9±2,9	42,1±3,1	44,7±2,6	42,8±3,1	43,5±2,5	42,1±2,8
30	46,3±6,3	45,0±6,4	47,2±2,7	46,4±3,3	46,4±4,1	42,2±4,2	46,9±2,6	45,0±2,9	45,9±3,0	45,1±3,1	45,1±2,8	43,7±3,3
45	49,1±6,6	48,1±7,1	49,0±2,6	48,2±3,4	47,3±3,9	46,7±3,7	50,4±3,5	44,8±3,8	47,6±3,3	46,9±3,5	46,6±2,7	46,2±3,0
60	51,6±7,1	50,9±7,3	49,4±3,2	49,4±3,6	47,8±3,8	47,5±3,8	53,1±4,6	52,8±4,8	48,0±3,3	47,6±3,5	46,9±3,2	47,0±3,1
75	52,8±6,6	52,8±7,0	49,7±3,2	49,7±, 7,7	47,8±3,8	48,1±4,1	53,9±3,9	54,2±3,6	47,6±2,7	47,3±2,7	47,3±3,5	47,3±3,4
90	51,7±8,4	52,1±8,4	49,1±3,2	49,6±3,6	48,2±3,8	48,4±3,8	53,8±4,8	54,4±4,9	48,1±2,4	47,8±2,3	46,8±3,1	46,6±3,0
105	52,6±8,2	53,0±8,1	50,1±3,6	50,6±3,5	48,1±3,6	48,4±3,6	54,1±5,9	54,3±5,5	48,1±3,6	48,7±2,9	47,0±3,3	47,3±2,9
120	54,4±7,4	54,4±7,4	50,3±3,0	51,1±3,6	48,3±3,5	48,7±3,8	53,1±5,6	53,5±5,1	48,0±2,9	48,0±2,6	47,0±3,4	47,4±3,5
135	51,0±5,3	51,7±5,6	49,8±3,4	50,3±3,8	48,0±4,0	48,3±4,0	52,1±4,9	52,5±5,1	48,4±3,0	48,6±3,0	46,3±2,3	46,6±2,4
150	53,5±7,7	54,5±7,7	51,0±1,8	51,6±2,3	48,2±4,9	48,7±5,3	51,6±5,3	51,8±5,8	49,2±3,1	48,6±3,0	47,2±3,0	47,6±2,9

Inspired and expired nitrous oxide concentrations increased parallel to duration of anaesthesia in all groups.

DISCUSSION

When low flow anaesthesia was used with inhalant agents, it was known that uptake of the anaesthetics was almost constant after equilibrium with initial phase and during inhalation anaesthesia, it was reported that uptake of volatile anaesthetics changed insignificantly ([6]). In low flow inhalation anaesthesia; high re-breathing ratio has great effect on exhaled gas configuration and concentration within breathing system ([7]). Due to its specific pharmacokinetic properties, only the fresh gas desflurane concentration can be maintained unchanged. Desflurane concentration can be reached to 85% in fresh gas flow after ten minutes of administration. However, due to its low anaesthetic potency, MAC value changes between 4-8% depending on age, so it was required high alveolar concentration ([5]).

According to guidelines of low flow anaesthesia, during the initial phase lasting 10 to 15 minutes, a high fresh gas flow has to be used. This phase guarantees inspired oxygen of at least 30% in most of patients. If the flow would be reduced too early to low values, inevitably gas volume deficiency would result compromising adequate ventilation ([8]). The following settings of the vaporizers are used routinely during the initial phase: isoflurane 1-1.5 %, and desflurane 4.0 to 6.0%. If these settings are used over the first 10 to 15 minutes, an expired concentration of about 0.7 to 0.8 times the MAC of the respective volatile agent will be gained ([3]).

In our study, during initial phase, isoflurane and desflurane concentrations were arranged as 1.5%, 6% respectively. After initial phase, isoflurane and desflurane concentration were increased to 2%, 8% respectively. Sufficient end tidal anaesthetic values were gained with these vaporizer settings. The difference of vaporizer settings between groups was a result of different MAC values of these agents ([3]). In our study, inspired and expired concentration of anaesthetics was decreased in a short time in desflurane group compared to isoflurane group when minimal flow used. This can be explained with lower blood /gas partition coefficient of desflurane, because it is saturated and eliminated from tissues quickly ([9]).

Smith ([10]) reported that there was no relation between concentration of oxygen, nitrous oxide and anaesthetic gas in fresh gas flow, when fresh gas flow was lower than 0.9 $L.min^{-1}$. However, if a gas mixture was inhaled during low flow anaesthesia, there might be a significant difference between FiO_2 and oxygen concentration in fresh gas flow.

Flow reduction will lead to a significant increase of re-breathing. The inspired gas, thus, contains a markedly increased proportion of the exhaled gas which already had passed the patient's lung and contains less oxygen. The resulting decrease of oxygen content in the gas mixture has to be compensated by increasing the fresh gas oxygen content, which must be the higher; the lower is the flow ([7]). During the course of anaesthesia, the consumption of oxygen is constant in haemodynamic stability and oxygen is taken up constantly by the patient in the range of the basal metabolic needs ([11]). In addition N_2O absorption is determined by alveolar- arterial pressure difference, because it is not metabolized. Absorption is high at the beginning but it decreases as tissue N_2O concentration level increases. In normal weighing adults N_2O concentration is 60-65% provides maximum analgesia and amnesia. At that time this ratio is concordant with recommended 30% oxygen concentration ([12]).

In our study, after the initial period by decreasing the fresh gas flow rate FiN_2O level increased as FiO_2 level decreased concordant with the known effects of low flow anaesthesia on inspired gas concentrations ([2], [13]). However FiO_2 level decreased less than 30% especially in minimal flow groups. So O_2 and N_2O flows were set reversely as 50 mL.min $^{-1}$ units and FiO_2 /FiN_2O ratio preserved 50-50 %. Only in one case oxygen saturation decreased below 97% and system was needed to be washed with high flow. In principle, the accumulation of nitrogen in the breathing system can lead to a reduction in the concentration of oxygen as well as nitrous oxide. A reduction of nitrous oxide gas concentration is not a problem, though it may lead to a weakening of the effect of nitrous oxide. In our groups FiO_2–FiN_2O sum was at least 85 % and this showed that there was no significant nitrogen accumulation.

Okada et al. ([14]) used isoflurane with 600 mL.min $^{-1}$ fresh gas flow in their study and reported that oxygen consumption could be more than oxygen requirement and hypoxia could be occurred because of N_2O saturation. They suggested that with 600 mL.min $^{-1}$ fresh gas flow in high weighted cases, consumption could not be supported. In our study, low FiO_2 occurred in more cases in minimal flow anaesthesia with desflurane. This can be explained by desflurane reaction with soda-lime. It is known that reaction of inhaled agents and carbon dioxide absorbents increased in low flow anaesthesia. Carbon monoxide which has high solubility and tissue affinity is mostly formed with desflurane soda-lime reaction ([15]). But in low flow systems when the absorbent humidity is conserved, carbon monoxide production is very low without clinical importance ([16], [17]). For decrease this risk and to avoid hypercapnia it is recommended that soda-lime canisters should be changed frequently ([13]). In this study carbon dioxide absorbent was refreshed for every case.

If we criticise our study according to disadvantages of low flow anaesthesia practices, we can say that this technique is safe clinically due to no decrease of SpO_2 below 97%, except one case, no arrhythmia development and no increase of $FiCO_2$ above zero. However our cases were from ASA 1 physical status and duration of anaesthesia was not exceeded above 200 min. So this technique should be studied in cases with proceeding diseases and with long duration of anaesthesias.

Although heat humidity exchanger was not used in our cases, heat conservation effect was seen after 30 th min of low flow anaesthesia. This effect can be explained with heat conservation effect of inspired gases. ([18]).

As a result we concluded that isoflurane and desflurane in minimal and low flow anaesthesia were not affecting on haemodynamics. They could be used safely with 500-1000 mL.min $^{-1}$ fresh gas flows, but we decided that isoflurane was superior to desflurane regarding oxygenation in minimal flow. We thought that there was hypoxia risk in cases which desflurane was used as inhalant agent in 500 mL.min $^{-1}$ fresh gas flow with 50% N_2O in O_2. However, we concluded that the increasing FiO_2 % ratio can prevent hypoxia. We thought that there was no difference between 1000-2000 mL.min $^{-1}$ fresh gas flows with 50% N_2O in oxygen regarding oxygenation.

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