Comparison Of The Efficacy Of Two Low Fresh Gas Flow Techniques In Low Flow Anaesthesia

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Abstract

In Queen Elizabeth Hospital, Kota Kinabalu, Sabah, Malaysia, most of the cases are performed under high gas flow even with the available high tech machine and gas monitoring. Unfamiliarity with low flow anaesthesia and fear of life-threatening sequalae to patients are the causes for reluctance to use low gas flow.

To review the advantages and claimed disadvantages in low flow anaesthesia, we conducted this study under the quality assurance program. This prospective randomized study uses two different low flow fresh gas flow techniques 1.5 and 1.0 lit / min. Fifty-four patients (ASA 1 & 2) undergoing elective surgical procedures were randomly allocated into two groups A & B of 27 patients each.

Group A received 1.5 lit / min (oxygen 0.5 lit and nitrous oxide 1.0 lit) while group B received 1.0 lit / min (oxygen 0.5 lit and nitrous oxide 0.5 lit). Gas and volatile variables were analyzed via the gas analyzer and arterial blood gases. There was no significant difference in gas analyzer monitoring and arterial blood gases in both groups.

Thus our study concluded and suggested the use of 1 liter (0.5 lit oxygen / 0.5 lit nitrous oxide) low flow technique in operations of intermediate and long duration with the availability of high tech anaesthetic machines and gas analyzers rather than 1.5 lit / minute thereby further reducing the cost expended on gases and volatile agents as well as minimizing operating room pollution and its consequent health hazard.

(This study is conducted for the Quality Assurance Program)

INTRODUCTION

Rebreathing means breathing some or all of previously exhaled gas. CO_2 is removed by soda lime. Remaining expired gas goes to fresh gas flow (FGF) and is rebreathed in. Recycling of gases reduces the fresh gas flow requirement. In low flow anaesthesia, inspired gas contains fresh gas flow and recycled exhaled gas.

According to Simmonescu's suggestion, low flow means

- Low flow - 500 – 1000 ml / min
- Medium flow - 1 lit – 2 lit / min
- High flow - 2 – 4 lit / min

Low flow has been variously defined as FGF less than alveolar minute volume. For the performance of safe low flow anaesthesia, a modern anaesthesic machine and gas monitoring is needed. Education to increase awareness of staff regarding the advantages of low flow anesthesia such as the reduction in the consumption of gases and vapor (expensive volatiles-sevoflurane, isoflurane and desflurane) and therefore cost, as well as reduction in patient's heat loss (latent heat of vaporization) and preservation of mucociliary clearance at respiratory tract. Reduction in operation theatre pollution (believed to be related to an increase in the rate of spontaneous abortion, liver disease, headache and tiredness) and reduction in environmental pollution (destruction of ozone layer and green house effect) in the long term are other advantages of using low flow anaesthesia.

The most quoted reason for the reluctance to use this technique is unfamiliarity. Risk of hypoxia and hypercarbia, over or under usage of volatiles, accumulation of potentially toxic gases (CO, methane acetone etc.) are the possible disadvantages.

The disadvantages can be overcomed by proper training, regular usage, understanding the uptake kinetics of anaesthetic gases, suitable monitoring devices and efficient means of carbon dioxide absorption, all of which will make the low flow technique a safe technique.

Objective: To compare the efficacy of two fresh gas low flow techniques in the daily use of controlled general anaesthesia and thereby reduce the usage of medical gases and

volatile agents in order to reduce the cost and theatre pollution.

STANDARDIZATION

Low flow anaesthesia was used in intermediate to long duration operations. High flow was given for 10minutes at induction and during reversal to allow the rapid uptake and removal of anesthetic gases respectively. The anesthetic equipment should have a flow meter with small graduations (100 ml), circle system- CO2 absorber, vaporizer outside the circuit (VOC), calibrated flow compensated vaporizers and bag in the bellows ventilator.

The entire breathing system should be leak proof. The leak test for anaesthetic machine and for the breathing circuit was performed before starting as follows:-

Leak test for anaesthesia machine- a rubber suction bulb(this may be modified from the bulb used in sphygmomanometer) was completely deflated and then attached to the common gas outlet. The bulb was observed for 10 seconds. It should not reinflate as reinflation indicated that entrainment of air from the atmosphere through a leak in the anaesthetic machine had occurred.

Leak test for breathing circuit- the pressure in the breathing system was increased to 50 cm of water by completely closing the expiratory valve and occluding the patient end. The fresh gas flow required to maintain this pressure was checked and for low flow techniques to be used correctly, FGF should be 100 ml per minute.

High flow removed nitrogen from the patient and circuit. Denitrogenation speeded up the rate of uptake of volatile anaesthetic. High flow was maintained for 10 minutes before switching to low flow according to the group in the study.

VOC delivered less than the dial setting of volatile agent when low flow was used while the uptake of nitrous oxide reduced with time as the body got saturated.

Minimum oxygen concentration used in low flow is 33- 35 %.

MONITORING

The ventilator were equipped with low pressure or disconnection alarms, airway pressure gauge and had an oxygen sensor to measure oxygen concentration.

A multigas analyzer was used to continuously measure the inspired / expired end tidal concentration of oxygen, carbon dioxide, nitrous oxide and volatile concentration as well as mean alveolar concentration or MAC. An oxygen analyzer was considered mandatory to avoid hypoxic mixtures being delivered to the patients. Gas extracted through the multigas analyzer was returned to the circuit.

Standard monitoring was carried out including pulse oximetry, non-invasive blood pressure, ECG and end tidal CO_2.

METHODS AND MATERIALS

Informed consent from each patient and approval from the ethics committee were obtained. ASA grade 1 & 2 patients were accepted for this study. Before starting the case, routine check of machine including leak proof test and the monitors were performed. All the cases were premedicated with oral midazolam, and were administered controlled general anaesthesia using propofol/thiopentone, narcotics, esmeron, isoflurane and reversal agent.

In this prospective randomized study, we divided the patients into two groups

Figure 1

Group A	Group B
27 cases	27 cases
Low flow 1.5 lit / min	Low flow 1.0 lit/ min
Oxygen 0.5 lit / min	Oxygen 0.5 lit / min
Nitrous oxide 1 lit / min	Nitrous oxide 0.5 lit /min

Isoflurane is the volatile agent, 1 MAC is maintained.

Age, sex and duration of surgery.

Figure 2

	Group A	Group B
Age	1-74 years	13- 71 years
Sex	Female 20, Male 7	Female 21, Male 6
Duration of surgery	1 hr- 4hr 15 min	1 hr - 4 hr 30 min

Types of surgery			
Orthopedic	General surgery	O & G	Others
Spine Shoulder Knee Replacment Hip OR&IF	Mastectomy Thyroid Cholecystectomy Laparatomy Splenectomy	TAHBSO	Rhinoplasty Nephrectomy FESS

TECHNIQUE

Patients were started with high flow induction for 10 minutes, followed by low flow settings according to the group. Monitoring carried out included pulse oximetry, $ETCO_2$, ECG, noninvasive blood pressure, and gas analyzer which monitored the inspired / expired values of oxygen, volatiles and MAC. All the findings were documented in the form prepared for the study and also in the anaesthesia record form.

Arterial blood gases were sampled for analysis at 10 minutes before the end of surgery.

The results were analyzed.

Figure 3

Gas analysis report		
	Group A (FGF- 1.5 lit / mt)	Group B (FGF- 1.0 lit / mt)
Oxygen Inspired / Expired difference	2 - 5 %	2 - 5 %
Nitrous oxide Inspired / Expired difference	1- 3 %	1- 3 %
Nitrous oxide uptake reduction time	15- 30 min	15- 45 min

1 MAC isoflurane was maintained throughout the operation and was switched off 10 -15 min before the end of operation.

Figure 4

Hemodynamic parameters		
	Group A	Group B
HR / BP	Stable	Stable
SpO_2	97- 100%	99- 100%
$ETCO_2$	2.9- 5.1 kPa	3.1- 5.3 kPa

Arterial blood gas analysis		
	Group A	Group B
pH	7.358- 7.444	7.39 – 7.5
pCO_2	26.6- 41.8	26.1- 42
pO_2	123.0- 341.6	143 - 323.4
BE	-2.6 to -6.7 (negative base excess)	0.8 to -5.0 (negative base excess)
SpO_2	97- 99.9	98- 99.5

Ventilator settings- Tidal volume 10ml / kg, RR- 12/ min, I: E ratio 1:2

Modern anaesthesia machines and monitoring were used in this study.

Figure 5

Datex Ohmeda
- anesthesia machine excel 210 sel
- 7900 ventilator
- cardiocap 5 monitor with gas analyzer was used for all cases.

RESULTS

ASA grade 1 & 2 patients selected for the study, randomized into 2 groups A & B , 27 patients each, were given controlled general anaesthesia using isoflurane.

Group A received 1.5 lit / min- oxygen 0.5 lit and N_2O 1 lit

Group B received 1.0 lit / min – oxygen0.5 lit, N_2O 0.5 lit

All cases were maintained with 1 MAC isoflurane, narcotics and relaxants. The total duration of operation ranged from 1-4h 30 min.

The gas analyzer monitoring report shows inspired/ expired oxygen difference is 2-5 % and for nitrous oxide is 1-3 % in both groups. Nitrous oxide uptake was reduced after 15-30 minutes in group A and 15-45 minutes in group B. Oxygen 2-5% was continuously taken up by the patients in both groups while nitrous oxide uptake reduced in both groups with time.

Hemodynamic parameters i.e. saturation, blood pressure heart rate and ETCO2 were stable in both groups.

Arterial Blood Gas (ABG) analysis shows arterial oxygen (pO_2) and saturation were maintained in both groups. Base excess was negative, carbon dioxide (pCO_2) was between lower to normal levels and pH was maintained in both groups. ABG results showed compensated pH with respiratory alkalosis and compensatory metabolic acidosis.

DISCUSSION

Carbon dioxide absorption was used as early as 1850 by John Snow. Partial rebreathing anaesthetic technique was first described by Foldes and colleagues in 1952 involving fresh gas flow 1 lit / min or less. In 1924 , Waters used a canister with sodalime.

John Snow, Waters and Brain were the protagonists for CO_2 absorption.

Low flow anaesthesia can be defined as a technique which, using a rebreathing system, results in at least 50% of exhaled air being returned to the lungs after CO_2 absorption.

86% expired air is rebreathed in when FGF 1 lit / min is used in low flow. Whitcher in 1986 showed an over 60% reduction in potent anaesthetic use with low flow, thus saving 120,000 dollars / year for a hospital of moderate size.

Forrester reported a 25% reduction in isoflurane use when 75- 80 % of cases were done under low flow anaesthesia. Benefits of rebreathing, cost savings, humidification, heat conservation and reduction in pollution can be achieved by using low flow technique.

Pollution is not reduced to zero because of leaks through the circuit and losses during high flow periods at induction and emergence from anaesthesia.

Although many anaesthetic machines are equipped with circle breathing system, controlled GA using high fresh gas flow remains frequently performed. Modern anaesthetic machines and gas analyzers are needed for the safe use of low flow technique.

Monitoring inhaled and exhaled gas concentrations will likely become an obligatory safe standard in many countries. For vaporizer outside circuit, in high flow, inspired concentration is equal to vaporizer concentration setting but in low flow, inspired concentration is less than the setting due to a long time constant for achieving desired inspired concentration. Therefore, a higher vaporizer concentration must be set.

In long term low flow anaesthesia using sevoflurane, compound A, the degradation product, had been shown to cause histological renal tubular damage in rats, but awaits clarification in humans.

Monitor sample circuit removes gases at rates 50- 250 ml / min but that is insignificant

In our study, two low flow techniques were used with modern anaesthesic machines and multigas analyzer setup. The difference in inspired / expired oxygen in the gas analyzer monitor shows constant uptake of oxygen throughout anaesthesia, uptake of nitrous oxide reduced within 15-30 minutes in group A and 30 – 45 minutes in group B. Vital signs were stable in both groups and ABG at the end of surgery showed compensated pH, respiratory alkalosis and metabolic acidosis in both groups. This may be due to hyperventilation in controlled general anaesthesia. Thus, there was no significant difference in inspired / expired oxygen and nitrous oxide, hemodynamic parameters and arterial blood gas analysis in both groups.

This study suggests that both low flow techniques are safe with new high tech anaesthesia machines using soda lime and gas analyzers thereby reducing the usage of gases and volatiles, cost and pollution.

Figure 6

	High flow	Low flow	Minimal flow closed circuit
% Rebreathing	0%	86 %	97- 100%

Estimate of annual anaesthetic gas consumption & cost reduction in Germany and UK

Figure 7

	Consumption / year (FGF 4.5 lit/ min)	Consumption / year (FGF 1.0 lit /min)	Cost savings USD
Oxygen	700,000,000	3 50,000,000	510,000
N_2O	1, 500,000,000	500,000,000	12,200,000
Isoflurane (volumes of liquid)	61, 650	28,500	31,800,000
Soda lime			
Double jumbo canister 2 x1.5 lit = absorb continuously for 24 hours 1 Column = 1.5 kg 2 Column = 3.0kg 1 can soda lime contains 4.5 kg 1 can costs about RM. 61.36 1 USD = RM 3.82			

Halothane costs- RM.128.50
Isoflurane costs- RM. 382.00
Sevoflurane costs- RM.473.00

Oxygen 7300 lit = RM.14.31, 1 litre costs RM 0.19 Nitrous oxide 1400 lit = RM.49.00 , 1 litre costs RM 3.58

A Comparison of 1 and 2 hour anaesthetic costs and potential savings over the range of fresh gas flows (Prys-Roberts and Brown, 1996)

Figure 8

Agent	1 hour case High	1 hour case Low	2 hour case High	2 hour case Low
Oxygen				
Usage	145 L	70 L	265 L	86.5 L
Cost	$ 0.29	$ 0.14	$ 0.52	$ 0.17
N_2O				
Usage	180 L	55 L	360 L	85 L
Cost	$ 0.43	$ 0.13	$ 0.86	$ 0.20
CO_2 absorber				
Usage	0.0 L	8.4 L	0.0 L	18.0 L
Cost	0.00	$ 0.16	0.00	$ 0.35
Isoflurane				
Usage	16.1 ml	7.6 ml	30.1 ml	11.5 ml
Cost	$ 13.85	$ 6.54	$ 25.89	$ 9.72
Total costs	$ 14.57	$ 6.97	$ 27.27	$ 10.47
Total savings	0%	52%	0%	62%

Datex Ohmeda Anaesthesia machine and monitor:

Figure 9

Changing of Sodalime:

Figure 10

Cardiocap and 7900 Ventilator

Figure 11

CONCLUSION

In Queen Elizabeth Hospital, Kota Kinabalu, Sabah, Malaysia, most of the cases are performed under high gas flow techniques despite the operation theatre being well equipped with modern anaesthetic machines with circle breathing systems and monitors.

Hypoxia, hypercarbia, under or overdosage of volatiles are the prejudice points against low flow, to be kept in mind before using low flow technique. This technique needs high tech anaesthesia machines and multigas analyzers to ensure safety of patient.

Low flow anaesthesia reduces the cost spent on gases, environmental pollution and reduces the heat loss in patients by latent heat of vaporization as well as preserving the mucociliary clearance of patients' respiratory tract.

In the study, high flow was used during induction, reversal, maintenance for 5 minutes every hour and for any disconnection in the breathing circuit / ventilator during maintenance to ensure adequate depth of anaesthesia was maintained. There were no complaints of awareness from the patients however.

Though our QAP study shows no significant difference in both low flow techniques, it is preferable and suggested to use 1 lit low flow (oxygen 0.5 l and 0.5 l nitrous oxide) technique in intermediate and long duration surgical procedures as 1 litre low flow will further reduce the cost and pollution compared to 1.5 lit.

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