Low flow anaesthesia: economic, eco friendly and effective

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Abstract

Introduction: Low flow anaesthesia, a technique introduced by Foldes in 1952 has resurged in clinical practice due to easy availability of low solubility inhalational agents. Being economical, ecological and clinically advantageous, it has initiated a renaissance in the field of anaesthesia.

This study tested the safety and efficacy of LFA technique using Sevoflurane and its cost effectiveness.

Materials and Method: A prospective observational study including 100 patients (ASA I/II,18-65 years) was conducted with the permission of institutional ethical committee and patient's consent. Selected patients were assigned into two groups by computer generated chit with fresh gas flow 3L and 0.5L in high and low flow group respectively. Chi square test and t test were used for stastical analysis.

Primary objectives were to assess the economic efficacy of low flow technique and to compare the recovery characteristics of patients. Secondary objectives were to compare haemodynamic stability of patients in between two techniques.

Result: Demographic data in both the groups were comparable. Both the techniques were comparable in terms of patient's haemodyanamic stability. Recovery was earlier in low flow group($p<0.05$) with complete return of all reflexes. Consumption of sevoflurane was almost 2.5 times less in LFA group ($p<0.001$) as compared to high flow group.

Conclusion: Low flow technique is a safe, economic & efficient technique of general anaesthesia.

Keywords: Low flow, Laparoscopy, Sevoflurane, Economic

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Introduction

The benefits and application of low-flow anaesthesia have been suggested since a long time. The introduction of newer low solubility agents, like desflurane and sevoflurane has initiated a renaissance in the use of this technique, in order to contain costs by adapting fresh gas flows to patient demand. Low flow anesthesia emerged as the need of time when all modern workstations and monitoring equipments are available, awareness regarding environmental pollution is increasing and when a more economic and daycare services are preffered. Slowly, this technique is gaining popularity among anaesthesiologists due to various advantages, it provide.

T here is no universally accepted definition of low-flow anaesthesia, though it certainly implies a carrier gas flow less than that attainable with a non-absorber breathing system. Baum's suggestion of 'a rebreathing fraction of greater than 50% gives too high a figure, since it is at a rebreathing fraction above 75% that the special characteristics of low-flow anaesthesia become apparent.(1)

Classification of gas flow rates into anaesthetic circuits(2)

Metabolic flow - <250 ml/min
Minimal flow - 250 – 500 ml/min
Low flow - 500 – 1000 ml/min
Medium flow - 1- 2 lit/min
High flow - 2 – 4 lit/min
Very high flow - >4 lit/min

To achieve this, minimum technical requirements are a circle rebreathing system with Carbon dioxide absorption, accurate flow meters calibrated to flows down to 50 ml/min, gas tight breathing system, calibrated vaporizers capable of delivering high concentrations and that are accurate at low fresh gas flow with the breathing system having minimal internal volume and a minimum number of components and connections along with continuous gas monitoring.(3)

The aim of present study was to test the safety and efficacy of low flow anaesthesia technique using sevoflurane and its cost effectiveness. Primary objectives were to assess the economic efficacy of low flow technique and to compare the recovery characteristics of patients.Secondary objectives were to compare haemodynamic stability of patients in between two technique.

Materials and Method

This prospective observational study was conducted in Department of Anaesthesiology, a tertiary hospital in Maharashtra, after approval from the hospital ethics committee. The study was carried out on 100 patients, age in the range of 18 to 60 years undergoing elective laparoscopic or non laparoscopic surgeries under general anaesthesia. Criteria of exclusion were patient under ASA III /IV, patientswith known hepatic, pulmonary, renal, metabolic or neuromuscular disorder, clinically significant laboratory abnormalities, alcohol/drug abuse, diabetes mellitus, unstable angina, history of myocardial infarction <6 months, neuropsychiatric disorder, obesity, smoking, history of adverse reaction from exposure to any anaesthetic drug, pregnancy or breast feeding.

Sample size was calculated according to the recovery characteristics. A pilot study was conducted on 14 cases, it was found that criteria for complete orientation i.e. states name, the mean and standard deviation for high flow anaesthesia and low flow anaesthesia were 11.02 ± 0.80 and 10.35 ± 0.80 respectively. With 95% confidence interval and 95% power, considering the above means, the minimum sample size was found to be 38 in each group. For our convenience, we increased it to 50 in each group.

Detailed pre-anaesthetic evaluation was done to rule out any associated disease followed by well informed, written consent taken from all the patients.

The patients were allocated into two groups of 25 each randomly by computer generated chits about technique low or high flow in either of the group ie lap or non lap as decided by surgeon. Minimum necessary investigations were obtained along with s.creatinine. blood urea and liver function tests i.e. AST, ALT, Alk.Phosphatase, S.protein, S.Albumin, S. Bilirubin (total & direct) repeated at 48 hours postoperatively.

Baseline haemodynamic parameters were recorded after 5 minute stabilization period in the pre operative room. Standard protocol of anaesthesia induction, maintenance and monitoring were followed in all patients. After preoxygenation with fresh gas flow 6 litres/minute, patients were induced and intubated with appropriate size endotracheal tube connected to Dragger primus anaesthesia work station followed by mechanical ventilation with a tidal volume of 8ml/kg at 14 breaths/minute using ventilator and maintained with inhalational agent sevoflurane. Inspiratory/expiratory ratio was set as 1:2. These respiratory parameters were not modified during procedures unless mandatory due to occurrence of hypercapnia if any. All procedures were performed using the similar type of circle breathing system and vaporizer of sevoflurane by same manufacturer under standard operating room conditions. Accuracy of dual cascaded flow meter was verified by passing the fresh gas flow through dry gas meter. Peak airway pressure, tidal volume and minute ventilation were measured using anesthesia ventilator with respiratory mechanics module. Inspiratory and expiratory concentration of oxygen, nitrous oxide, carbon dioxide and sevoflurane along with MAC (minimal alveolar concentration) were recorded using a multigas monitor with fresh gas analyzer.

Similar patient monitoring equipment were used in all cases for electrocardiogram, non invasive blood pressure and pulse oximetry.Variables were measured immediately prior to carbon dioxide insufflation and every 5 minutes thereafter until the end of surgery. Initially, 6 litres of fresh gas flow with dial setting of 2% of sevoflurane in control group (conventional technique) and study group was set. In control group (HFA), fresh gas flow was 3 litres with O_2:N_2O being 1.5 litre : 1.5 litre.In study group(LFA), 500ml of fresh gas flow with O_2:N_2O ratio 1:1 i.e. 250 ml each was kept. In laparoscopic group, during the CO_2 pneumoperitoneum, the intra abdominal pressure was maintained between 12-15 mmHg by calibrated CO_2 insufflators. In all cases sevoflurane concentration was adjusted throughout the anaesthesia to maintain systemic arterial blood pressure and heart rate within +/-30% of base line values.

Light anaesthesia was defined as occurrence of tachycardia (HR +30% of baseline values or HR>100 beats/min), hypertension (MAP+30% of baseline values or MAP>100mmH), hypoxia and hypercapnia are defined as Saturation<90% and end tidal CO_2>50mmHg[4].

At the end of surgery, after last suture/removal of port, the vaporizer dial of sevoflurane was turned off and oxygen flow was increased to 6L/min along with discontinuation of N_2O administration.

The time required for resumption of spontaneous respiration and extubation and for gaining orientation i.e. stating name etc and finally modified aldrete score >8 were used to assess the recovery characteristics. Residual neuromuscular block was antagonized and patients were extubated after return of all reflexes. Finally, total consumption of sevoflurane was recorded from the anaesthesia machine software. There was no loss to follow up.

Data was presented as mean and standard deviation. All data were analyzed by specific statistical methods (Chi Square, t-Test, Z-test, Fisher's exact test and Yates' correction) applicable to the various sets of data.

Table 1: Demographic data

	Laparoscopic procedures			Non Laparoscopic procedures		
	HFA	**LFA**	**p value**	**HFA**	**LFA**	**p value**
Age (years)	33.32±11.36	31.92±14.11	>0.05	36.04±13.38	36.2±11.33	>0.05
Sex (M/F)	8/17	11/14		13/12	12/13	
Weight (kgs)	48.8±9.84	48.04±8.4	>0.05	54.92±8.11	49.47±7.4	<0.05
Height (cms)	157.08±7.27	160±9.22	>0.05	160±8.34	154.48±8	<0.05

Table 2: Variation in blood pressure of patient

SBP	LAP (n=50)			NON LAP (n=50)		
	HFA	LFA	p value	HFA	LFA	p value
Preop	123.64 ± 10.27	125.52 ± 13.01	>0.05	122.08 ± 8.16	123.07 ± 9.89	>0.05
After induction & intubation	130.56 ± 14.83	128.88 ± 14.76	>0.05	132.92 ± 10.19	131.56 ± 12.7	>0.05
5 min	108 ± 10.78	103.28 ± 18.07	>0.05	108.76 ± 12.14	104.08 ± 13.74	>0.05
10 min	105.64 ± 10.84	103.84 ± 14.61	>0.05	107.2 ± 10.14	105.88 ± 12.17	>0.05
20 min	111.8 ± 17.06	109.36 ± 14.04	>0.05	108.32 ± 15.06	110.2 ± 13.92	>0.05
30 min	109.68 ± 14.68	113.24 ± 11.71	>0.05	107.8 ± 13.58	112.04 ± 12	>0.05
60 min	105.2 ± 6.72	108 ± 6.42	>0.05	105.48 ± 7.49	114.66 ± 16.18	>0.05
Post op	133.36 ± 11.7	128.68 ± 14.72	>0.05	130.84 ± 6.33	127.8 ± 11.6	>0.05

Table 3: Variation in pulse rate of patients

Pulse	LAP (n=50)			NON LAP (n=50)		
	HFA	LFA	p value	HFA	LFA	p value
Preop	86.44 ± 13	90.76 ± 15.5	>0.05	87 ± 14.25	90.88 ± 13.98	>0.05
After induction & intubation	104.76 ± 15.57	101.28 ± 16.92	>0.05	101.4 ± 15.57	98.28 ± 10.69	>0.05
5 min	98.44 ± 14.23	94.8 ± 18.09	>0.05	90.52 ± 14.22	85.52 ± 11.7	>0.05
10 min	95.8 ± 16.51	85.36 ± 22.55	>0.05	86.4 ± 13.6	81.92 ± 20.53	>0.05
20 min	92.48 ± 12.81	88.68 ± 15.13	>0.05	85.84 ± 11.29	83.2 ± 13.88	>0.05
30 min	92.2 ± 12.33	87.32 ± 15.39	>0.05	84.72 ± 8.69	84.16 ± 12.89	>0.05
60 min	86 ± 10	89.04 ± 3.44	>0.05	83.84 ± 111.6	81.83 ± 7.70	>0.05
Post op	95.68 ± 11.02	96.68 ± 14.31	>0.05	93.24 ± 12.41	96.6 ± 13.69	>0.05

Table IV: Variation in mean $EtCO_2$, Peak airway pressure, Minute ventilation

		LAP (n=50)		NON LAP (n=50)	
		HFA	LFA	HFA	LFA
$EtCO_2$	5 min	31.6	33.28	31.32	31.88
	10 min	31.84	44.4	31.64	30.88
	20 min	31.76	32.76	31.64	30.68
	30 min	32.76	33.68	31.96	31.2
	60 min	34.2	36.03	31.2	34.66
PAP	5 min	15	15.64	17.32	18.08
	10 min	15.58	16.92	17.88	18.36
	20 min	17.84	18.92	18.5	19.12
	30 min	14.64	19.32	19.76	19.44
	60 min	16.4	17.7	21.04	17.33

MV	5 min	5.86	5.53	6.05	6.03
	10 min	6.05	5.67	5.97	6.09
	20 min	8.3	5.73	5.99	5.86
	30 min	6.21	5.83	8.04	5.97
	60 min	5.44	5.69	5.97	5.8

Table 5: Recovery characteristics

	LAP (n=50)			**NON LAP (n=50)**		
	HFA	**LFA**	**p value**	**HFA**	**HFA**	**p value**
Duration of anaesthesia (mins)	80.4 ± 27.91	71.8 ± 32.68	>0.05	106.8 ± 43.32	96.6 ± 50.05	>0.05
Eye opening (mins)	5.16 ± 0.24	4.88 ± 0.35	0	5.82 ± 0.36	5.32 ± 0.23	0
Extubation (mins)	8.87 ± 0.43	7.57 ± 0.59	0	8.96 ± 0.37	7.83 ± 0.39	0
State name (mins)	10.63 ± 0.61	10.3 ± 0.95	0	11.63 ± 0.69	10.09 ± 0.70	0
Aldrete score >8 (post anesthesia discharge)	22.13 ± 0.92	19.37 ± 1.5	0	23.17 ± 1.01	20.61 ± 1.05	0

Result

There was no significant difference between both groups in terms of demographic data except weight and height in NON LAP group.

Haemodyanamics: Baseline heart rate of patients of LFA group was higher than HFA group, but intraoperative values were less in LFA group. On analysis, it was found that both techniques were comparable as p value was found insignificant at all intervals. Towards the end of surgery, it started increasing and finally postoperative heart rate was higher than the baseline because of the extubation response in all groups studied. Baseline systolic pressure of patients undergoing any kind of procedure or technique was same. Intubation response was present, but it settled by itself in 10-15 mins. After 10 mins, an increase in SBP due to the incision taken/port inserted by the surgeon was present. This increase was more in LAP group, but settled easily within 5 minutes. On comparing the two techniques, no significant difference was noted and p value was found insignificant at all interval of time. There were a few intervals of light anaesthesia in terms definition decided,but BIS reading was within level of surgical depth.

Respiratory mechanics: There was no difference in time to achieve 1.2 MAC. Intraoperatively,inspiratory oxygen concentration decreased with time but never dropped below 44.4% in any group, nitrous oxide was found to be increasing slowly and inspired and expired concentration of sevoflurane was lower in LFA as compared to HFA group. All values were comparable with each other at all intervals of time. EtCO2, peak airway pressure and minute ventilation were within acceptable range in both the groups at all stages of surgery, although EtCO2 was found slightly higher in LFA group in laparoscopic surgeries.

Recovery: There was an early emergence and recovery observed in low flow group group in both laparoscopic and non laparoscopic cases which was significant statistically also in present study.

Consumption: Mean consumption of sevoflurane in LAP LFA and LAP HFA was 17.72 and 43.69 ml which was almost two and half times more consumption in HFA group than LFA group when amount of sevoflurane consumed per minute was compared. In NON LAP LFA and NON LAP HFA group sevoflurane consumed were 15.32 and 61.78 ml,which was almost four times lower in LFA group. p value was found highly significant between the two techniques (<0.0001).

Chart 1: Duration of Anaesthesia & surgery

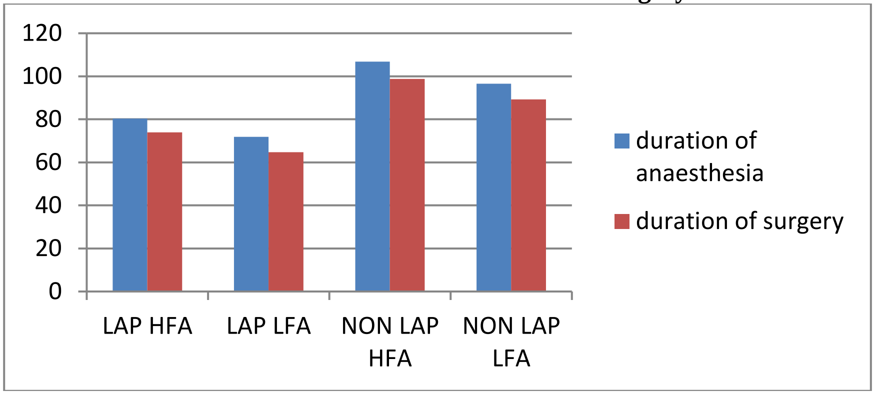
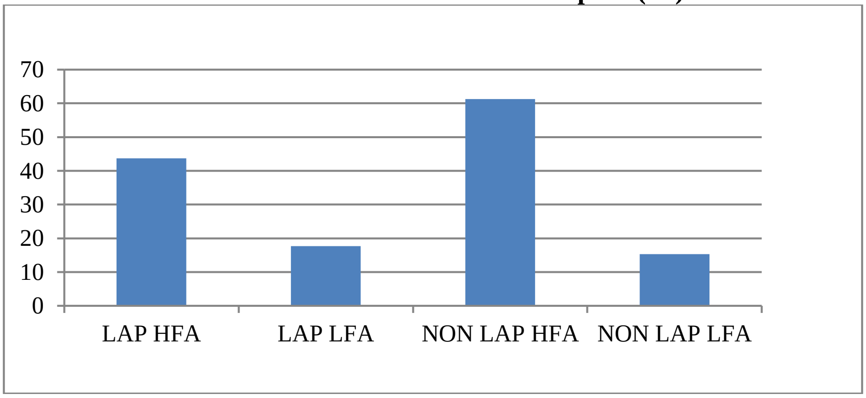


Chart 2: Total sevoflurane consumption(ml)



Discussion

In a time of increased concern over increasing cost and the adverse environmental impact of chlorofluorocarbons, there is a great pressure to use better techniques of general anaesthesia. This study proved that low flow anaesthesia is much safer, economic and eco friendly technique. The use of these costly equipments and drugs is justified only when used along with this technique.

With respect to low flow anaesthesia, properties of inhalation anesthetics which are the most relevant are solubility, metabolism, and anesthetic potency. So, sevoflurane was chosen for our study and supported by various other studies.(4,5,6)

Primary aim at the start of low flow anaesthesia is to achieve an alveolar concentration of the anaesthetic agent that is adequate for producing surgical anaesthesia(7) (approximately 1.2 MAC), so it was achieved by using high flow of gases at initiation. This reduced the time constant, thereby bringing the circuit concentration to the desired concentration rapidly and also compensate for the large uptake seen at the start of the anaesthesia with the added advantage of achieving better denitrogenation, so vital to the conduct of the low flow anaesthesia. The chief disadvantage can be the high flows required which would compromise on the economy of the gas utilization and the need for scavenging systems to prevent theatre pollution.(3) In our study, 1.2 MAC was achieved in all cases within 5 minutes and no significant difference was found between any groups which was in accordance with the results of M. Lindqvist, J. Jakobsson et al where in the dial vaporizer setting was adjusted in order to achieve an end-tidal sevoflurane concentration of 1.2 vol%. Mean time to reach 1.2 MAC increased with the reduction in the fresh gas flow but it was reached within 4 minutes in all patients.(8)

The maintenance of low flow anaesthesia is the most important phase as financial savings result directly from this, since it is stretched over a period. Haemodynamic stability is one of most important parameters of intraoperative safe anaesthesia as it decreases postoperative complications also.(9) In our study, patients of both the group were stable at all intervals which was similar with the findings of Anders Doolke, Ronnie Cannerfelt et al(6) and H. H. Luttropp and A. Johansson et al(10) where no intraoperative complication was noted. So, this technique has no effect over hemodynamic parameters, if monitored carefully.

Speed and quality are important elements of anaesthetic recovery. There was an early emergence and recovery seen in low flow group in both laparoscopic and non laparoscopic cases because there is less consumption of anaesthetic agent but the depth of anaesthesia was ensured by BIS monitoring. At the end of procedure fresh gas flow was increased to wash out inhaled anaesthetic agents to ensure faster recovery.

The appropriate depth of anaesthesia was always maintained which was ensured by BIS monitoring at all intervals of surgery. Still a few events of light anaesthesia, according to haemodyanamic parameters were noted in study, may be because of other causes like painful stimulus, abnormal response of patient to anaesthesia and surgery, CO_2 insufflation etc. Likely postoperative complications were also considered in present study as these factors also affect overall patient's outcome and delay the discharge time. Thus they also contribute to increase the total cost of surgery.A few cases of nausea and agitation were noted after surgery. But they were easily cured by medications (inj ondansetron 8mcg/kg) and counselling. The reasons may be incomplete wash out of CO_2 after surgery particularly in laparoscopic procedures, abnormal drug metabolism, prolonged surgery etc.

The consumption of volatile anaesthetics during general anaesthesia mainly depends on two factors. The set volume percent of the volatile anaesthetic on the vaporiser and the fresh gas flow rate. Regulating the volume percentage of the volatile anaesthetic is impractical and even unethical in terms of cost reduction as depth of anesthesia was maintained by adjusting dial concentration only.[(11)] However, using a lower fresh gas flow rate not only has a direct proportional effect on the consumption of volatile anaesthetics, but it preserves heat and humidity of breathing system and decreases loss of volatile anaesthetic to the environment. Similar results were obtained by Anders Doolke, Ronnie Cannerfelt et al[6] who found that the sevoflurane consumption increased by more than double with each doubling of fresh gas flow rate, and S. M. Cotter and A. J. Petros[(12)] who observed significant differences in consumption between the high and low-flow technique. Even if cost saving may be rather small for an individual patient, the savings should be put into the perspective of number of procedures carried out. Thus,it can be concluded that this technique deserves more importance and wider application.

Study limitations were this was a single centre study, sample size was small as compared to overall patient flow in hospital because total sample size was decided according to the statistical analysis and the acceptance and use of the policy by each anaesthesia caregiver may also be a factor, since the residents of our department rotate through different operation theatre.

Conclusion

LFA is a safe, effective and judicious way of general anaesthesia. Although small, it do contributes to reduction of financial burden. Awareness, enthusiasm and knowledge about the technique can make its implication very easy. The simple reduction of fresh gas flow results in a more than proportional decrease in sevoflurane consumption with a maintained standard of anaesthesia. It provides equivalent hemodynamic stability and earlier recovery of patients with satisfactory outcome. It only requires vigilant monitoring and knowledge about the technique. It offers a valuable opportunity to make use of recent advances economically and safely. Thus, it can be concluded that low flow anaesthesia is a safe, economic, eco friendly and a better technique in various other ways than conventional high flow anaesthesia techniques.

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