



Original Article

Guarding The Brain While Saving the Gas: Cerebral Oximetry as A Window to Brain Oxygenation, A Prospective Observational Study

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ABSTRACT

Background: Low flow anaesthesia (LFA) is increasingly used due to its economic and environmental benefits. However, concerns remain regarding adequate oxygen delivery, particularly cerebral oxygenation.

AIM: To evaluate the safety and efficacy of low flow anaesthesia with respect to regional cerebral oxygenation (rSO₂).

Methods: This prospective observational study included 32 ASA I-II patients posted for major surgeries under general anaesthesia. After induction, fresh gas flow was reduced to 1 L/min after equilibration (F_e/F_i = 0.8) was achieved. Cerebral oxygenation (rSO₂), minimum alveolar concentration (MAC), bispectral index (BIS), and hemodynamic parameters were monitored at predefined intervals.

Results: Baseline rSO₂ values were 71.2±2.1 (right) and 70.8±2.1 (left). A mild reduction was observed after induction and intubation, however, rSO₂ values remained stable intraoperatively (68-69) without significant cerebral desaturation. MAC was maintained between 1.0-1.2 during surgery and reduced gradually toward emergence. BIS values remained within 40-60. Pulse rate and systolic blood pressure showed significant fall initially but stable intraoperatively (p < 0.0001)

Conclusion: Low flow anaesthesia is safe and effective technique without any untoward effects on cerebral oxygenation and hemodynamic parameters.

Clinical Significance: Continuous cerebral oximetry during low-flow anaesthesia demonstrates that cerebral oxygenation remains stable despite reduced fresh gas flow, supporting the safe application of low-flow anaesthesia in major surgical procedures while providing economic and environmental benefits.

Keywords: Low flow anaesthesia , cerebral oxygenation , rSO₂ , BIS , MAC , general anaesthesia.

INTRODUCTION

Advances in anaesthesia techniques have increasingly focused on enhancing patient safety while promoting environmental and economic sustainability. One such innovation is low flow anaesthesia, characterized by use of reduced fresh gas flows during maintenance of anaesthesia. By minimising consumption of anaesthetic agents and preserving heat and humidity within breathing circuit, low flow anaesthesia offers several clinical advantages. This approach needs a very specific monitoring throughout the procedure to look cautiously for adequate delivery of oxygen especially the brain and anaesthetic gases because as the low flow rates of oxygen may predispose patients to hypoxia and impaired tissue perfusion hypercapnia, insufficient depth of anaesthesia, and accumulation of potential toxic gases. There should be close monitoring of all parameter including cerebral oxygenation.

The brain is being highly sensitive to fluctuations in oxygen supply and therefore represents a critical organ at risk during the period of anaesthesia. Traditional monitoring methods such as pulse oximetry and systemic blood pressure measurement, may not provide sufficient early warning of compromised cerebral oxygenation.

In this context cerebral oximetry, using near infra-red spectroscopy (NIRS), has emerged as a valuable noninvasive tool for real-time monitoring of regional cerebral oxygen saturation (rSO₂). Integrating cerebral oximetry to measure regional cerebral oxygenation in practice of low flow anaesthesia offers the potential to detect early signs of cerebral desaturation before systemic parameters become deranged.

A study by Casati et al. (2005) demonstrated stable rSO₂ values during low flow anaesthesia in elderly patients undergoing abdominal surgery showing no significant cerebral desaturation. Similarly Yoshitani et al. (2007) noted moderate reductions in mean arterial pressure during anaesthesia which were not necessarily associated with decreased cerebral oxygen saturation, highlighting the preservation of autoregulatory capacity. In contrast Fassoulaki et al. (2010) observed that significant hypotension under anaesthesia may lead to transient rSO₂ dips, though typically within non-critical limits. These studies form some background for our study.

MATERIALS AND METHODS :

This prospective observational study was conducted in Department of Anaesthesiology, a tertiary care hospital in Maharashtra, after approval from the hospital ethics committee.

Sample size was 32 and is calculated by taking the mean with standard deviation of equilibration time of sevoflurane from previous study (6) and by taking absolute error of 5% with 95% confidence interval and 80% power.

Statistical comparison was performed using independent two-sample t-tests with a sample size of 32.

Inclusion Criteria

Adult patients of age 18-65 years, ASA grade 1 or 2 and patients posted for various surgical procedures under general anaesthesia.

Exclusion Criteria

Patients unwilling, ASA Grade 3 and 4, those with mental incapacity, BMI over 35, active cancer, coagulation disorders, severe cardiac and respiratory diseases.

Along with all ASA standard monitors, leads of cerebral oximeter were also attached to record the right and left cerebral oxygen saturation levels.



Patients were pre-medicated with Intravenous (IV) Glycopyrrolate 0.2mg, Midazolam 0.03mg/kg, and Fentanyl 2mcg/kg. Patients were preoxygenated with 100% oxygen using dual limb closed circuit till end-tidal oxygen concentration reaches 90%. Anaesthesia induction by administering intravenous (IV) Propofol 2 mg/kg, and Rocuronium 0.9 mg/kg. Patients were hand ventilated using a facemask with an FGF of oxygen 6-8L/min for 60 seconds. Trachea was then intubated using appropriate size Endotracheal tube. sevoflurane was set at 2% on vaporizer dial. Once the ratio of expired (Fe) to inspired (Fi) sevoflurane concentration became 0.8, high FGF was reduced to the Low FGF mixture, i.e., 1 L/min of oxygen this event was defined as the “equilibration point” of the inhalational anaesthetic agent. The time required to achieve Equilibration point from start of sevoflurane administration was noted.

During maintenance phase of anaesthesia, the vaporizer dial setting was changed, if needed, after flow reduction to maintain Bispectrality index between 40 – 60 or as required depending on the type of surgery but keeping the FGF constant. Top-up doses of atracurium 0.1 mg/kg IV were given as needed. Paracetamol 20 mg/kg IV was given to all patients as a part of the multimodal approach to analgesia.

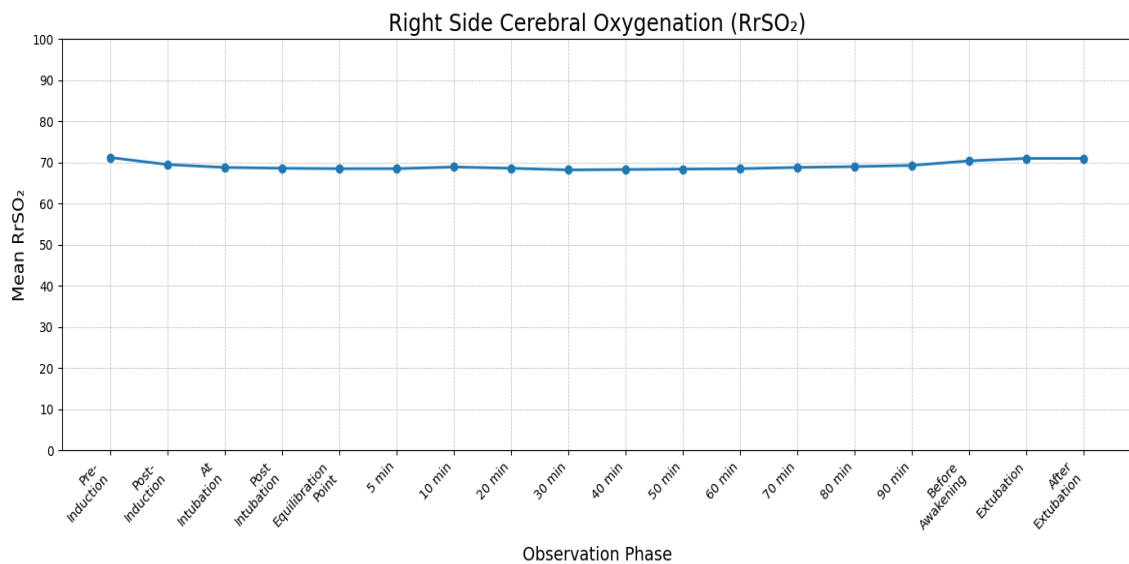
At the end of surgery, after last suture/removal of port, the vaporizer dial of sevoflurane was turned off and oxygen flow was increased to 6L/min. Residual neuromuscular block was antagonized with 0.05 mg/kg Neostigmine and 0.01 mg/kg

Inj. Glycopyrrolate were used, and patients were extubated after return of all reflexes. The time required for resumption of spontaneous respiration and meeting extubation criteria and for gaining orientation i.e., stating name etc. and modified Aldrete score >8 was used to assess the recovery characteristics. Recovery time was defined as the time required to achieve an Aldrete score of >8 after discontinuing sevoflurane, and the Aldrete score at extubation was also recorded. Finally, total consumption of sevoflurane was recorded from the anaesthesia machine (Mindray WATO EX 55 Pro) software. The patient was post operatively transferred to recovery unit and monitored

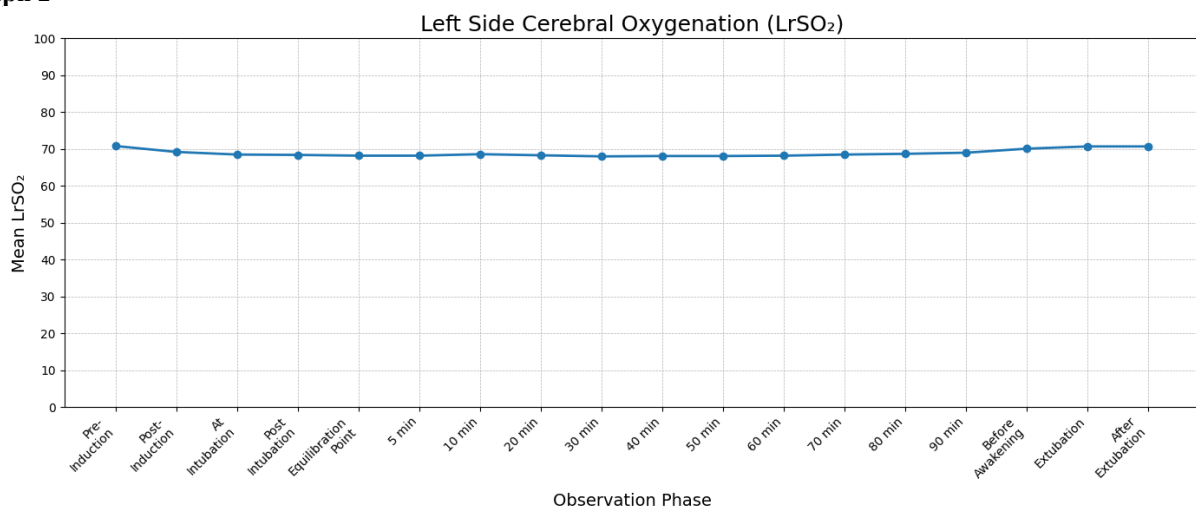
Demographic variables

Variable	category	Frequency	Percentage (%)
Age group (years)	18-30	5	15.6
	31-40	11	34.4
	41-50	8	25.0
	51-60	8	25.0
Gender	Male	15	46.9
	Female	17	53.1
Weight (kg)	41-50	22	68.8
	51-60	10	31.3
	BMI (Kg/m2)	<18.5	10
	18.5-24.9	19	59.4
	25-25.9	3	9.4

Graph 1



Graph 2



Right Cerebral oxygenation (RSO2)

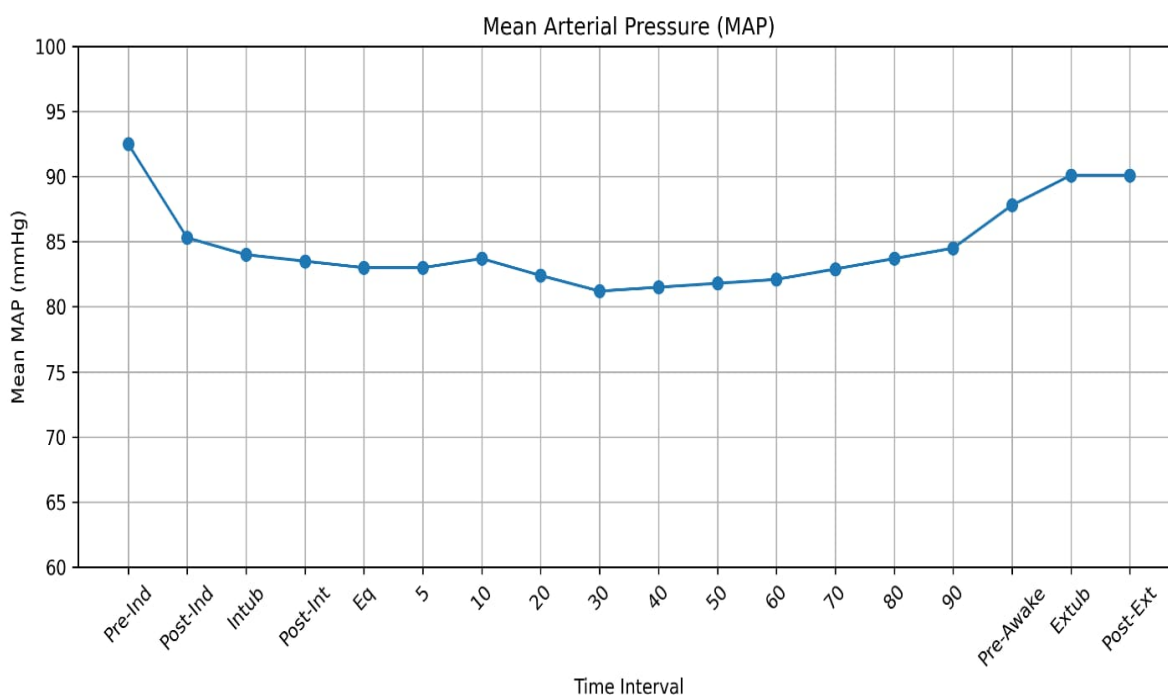
Pre-Induction it was 71.2 ± 2.1 , Post-Induction Slight decline to 69.5 ± 2.0 , At and Post Intubation decrease rSO₂ to 68.8 ± 2.0 and 68.6 ± 2.0 respectively. Despite this decline, values remained within a clinically acceptable range (>60%), and rapid recovery in subsequent readings suggests intact cerebral autoregulation and effective anaesthetic management. From Equilibration until the end of surgery values remained stable between 68.5 to 68.3 and Before Awakening to After Extubation Gradual increase (Before Awakening: 69.3; Extubation: 70.3; After Extubation: 71.2 showing restored cerebral perfusion

Left cerebral oxygenation (Lso2)

Pre-Induction rSO₂ was 70.8 ± 2.1 , Post-Induction there is Slight decline to 69.2 ± 2.0 , At and Post Intubation further decline in Left rSO₂ to 68.5 ± 2.0 at intubation and 68.4 ± 2.0 post-intubation. However, the values remained above critical thresholds, suggesting effective autoregulation and preserved cerebral perfusion during this phase of low-flow anaesthesia. Equilibration to till end of surgery Values stabilized around 68.2 to 68.0. Before awakening to after Extubation there is gradual return to near-baseline levels (Before Awakening: 69.0; Extubation: 70.0; After Extubation: 70.8).

Mean arterial pressure (MAP)

Graph 3



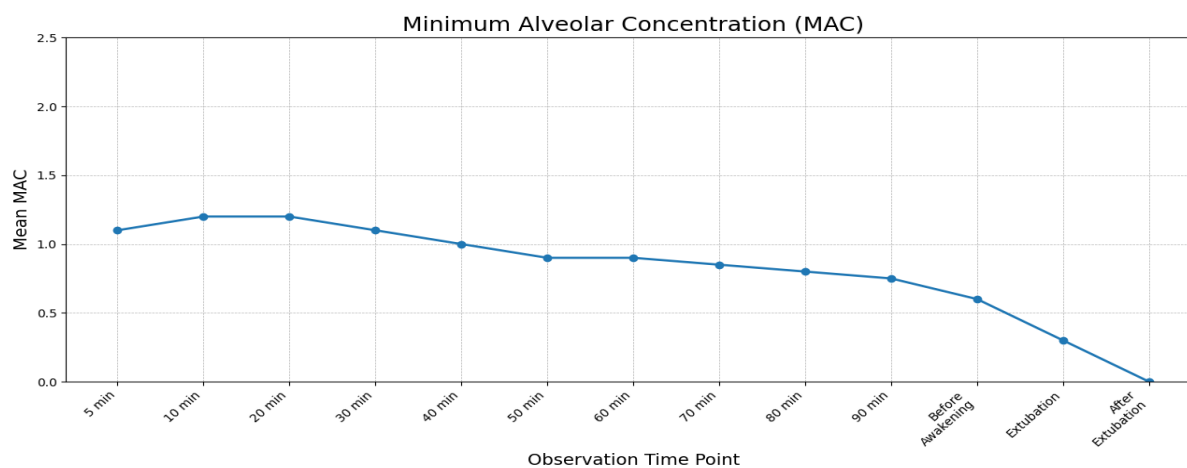
Pre-Induction MAP: 92.5 ± 7.2 mmHg at 30 Minutes: 81.2 ± 6.4 mmHg ($p < 0.0001$) 40 Minutes: 81.5 ± 6.5 mmHg ($p < 0.0001$) and 50 Minutes: 81.8 ± 6.5 mmHg ($p < 0.0001$)

MAP showed a statistically significant reduction from baseline following induction and intubation, with stabilization around 81–83 mmHg during the mid-surgical phase. These values remained well above the lower physiological threshold for cerebral perfusion, indicating that low-flow anaesthesia maintained adequate systemic pressure and gradual increase in MAP near extubation marks autonomic recovery, which aligns with smooth emergence from anaesthesia.

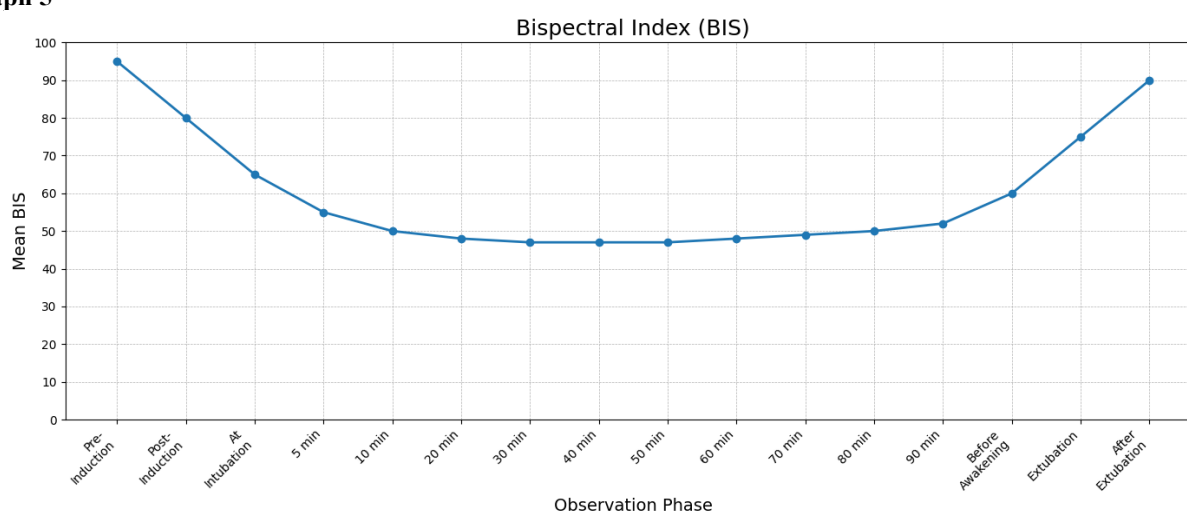
Hemodynamics

Importantly, SBP, pulse rate values remained within safe clinical limits, indicating that low-flow anaesthesia can be used reliably for maintaining cardiovascular stability throughout major surgical procedures.

Graph 4



Graph 5



MAC and BISS

Indicators of depth of anaesthesia were monitored through out the surgery and BISS was maintained between 40-60 and MAC accordingly and no significant variability is observed with low flow anaesthesia .

DISCUSSION

This study explored the relationship between low flow anaesthesia and cerebral oxygenation with the discussion of physiological and clinical considerations that reflects safe and effective anaesthetic practice. And it has been observed that when adequate depth of anaesthesia has been achieved , inspite of decrease in MAP there is no alteration in cerebral perfusion pressure henceforth cerebral oxygen saturation is maintained. This may be attributed to modern anaesthesia work stations, efficient CO₂ absorbers, and advanced monitoring modalities such as cerebral oximetry and BIS.

The use of low-flow anaesthesia also offers economic and environmental advantages by decreasing volatile anaesthetic consumption and reducing operating room pollution. Preservation of heat and humidity within the breathing circuit may additionally contribute to improved perioperative patient comfort and recovery.

One of the principal concerns associated with low flow anaesthesia is the potential risk of hypoxia and impaired cerebral oxygenation.

This prospective observational study evaluated the effects of low-flow anaesthesia (LFA) on regional cerebral oxygen saturation (rSO₂), anaesthetic depth, and haemodynamic stability in 32 adult patients undergoing major surgical procedures under general anaesthesia.

Baseline right and left rSO₂ values were within normal physiological limits and showed only a mild decline following induction and intubation. The transient reduction observed during airway manipulation may be attributed to sympathetic stimulation and short-term alterations in cerebral perfusion. This modest also likely reflects a transient increase in

intracranial pressure (ICP) due to airway manipulation, laryngoscopy, and sympathetic stimulation. The elevated ICP may momentarily reduce cerebral perfusion pressure, leading to reduced cerebral oxygen saturation. However, rSO₂ values remained much high above critical desaturation thresholds throughout the procedure, suggesting preserved cerebral autoregulation and adequate oxygen delivery inspite of low-flow anaesthesia. Gradual return of rSO₂ values toward baseline during emergence and extubation further supports maintenance of cerebral perfusion.

Our findings are consistent with studies by Akbas and Ozkan and Kupisiak et al., who reported stable cerebral oxygenation during low-flow anaesthesia without clinically significant desaturation episodes. Similarly, Casati et al. demonstrated that continuous cerebral oximetry is detecting perioperative cerebral hypoxia, particularly in elderly patients undergoing major surgery.

MAC values remained within the desired surgical plane of anaesthesia during the maintenance phase, indicating effective delivery of inhalational anaesthesia despite reduced fresh gas flow. BIS values were maintained between 40 and 60 intraoperatively, confirming adequate depth of anaesthesia and minimizing the risk of intraoperative awareness. The gradual rise in BIS values during recovery reflected smooth emergence from anaesthesia.

Hemodynamic parameters including pulse rate and systolic blood pressure remained stable throughout surgery.

Although there was a statistically significant reduction in pulse rate and blood pressure after induction, values remained within acceptable physiological limits and no major hemodynamic instability was observed. rSO₂ remained in acceptable range in this condition also. These findings correlate with previous studies showing that low-flow techniques provide adequate autonomic stability while reducing anaesthetic agent consumption.

Overall, the present study supports that low-flow anaesthesia with sevoflurane is a safe and effective technique for major surgical procedures when combined with continuous monitoring of cerebral oxygenation, anaesthetic depth, and hemodynamic parameters. Cerebral oximetry serves as a valuable adjunct for early detection of cerebral hypoperfusion and may improve perioperative neurological safety.

CONCLUSION

The present observational study demonstrates that low flow general anaesthesia is safe and effective in respect of cerebral perfusion inspite of minor hemodynamic changes owing to effect of inhalational agents. This has been proved by cerebral oximetry.

It is also devoid of any period of light plane of anesthesia as ensured with monitoring by MAC and BISS. Thus low flow anaesthesia technique can be practically useful in day-to-day anaesthesia practice when appropriate monitoring is available.

REFERENCES:

1. Baum JA. Low-flow anaesthesia. *Anaesthesia*. 1993;48(7):637-40.
2. Toal P, Chiplonkar S, Panchal P. A randomised prospective comparison of equilibration point and changing gas composition during low-flow anaesthesia with sevoflurane vs desflurane. *Indian J Anaesth*. 2019;63(10):814-9.
3. Casati A, Fanelli G, Pietropaoli P, Proietti R, Tufano R, Danelli G, et al. Continuous monitoring of cerebral oxygen saturation in elderly patients undergoing major abdominal surgery minimizes brain exposure to potential hypoxia. *Anesth Analg*. 2005;101(3):740-7.
4. Fassoulaki A, Petropoulos G, Nikolaou C, Karabinis G. Cerebral oximetry during sevoflurane or desflurane anesthesia under controlled ventilation. *J Anesth*. 2010;24(3):354-60.
5. Akbas S, Ozkan AS. Comparison of effects of low-flow and normal-flow anesthesia on cerebral oxygenation and bispectral index in morbidly obese patients undergoing laparoscopic bariatric surgery: A prospective randomized clinical trial. *J Clin Monit Comput*. 2019;33(5):873-82.
6. Shelgaonkar VC, Choudhary A. Low flow anaesthesia: economic, eco friendly and effective. *Indian J Clin Anaesth*. 2017;4(3):382-7.
7. Doger C, Kahveci K, Ornek D, But A, Aksoy M, Gokcinar D, et al. Effects of low-flow sevoflurane anesthesia on pulmonary functions in patients undergoing laparoscopic abdominal surgery. *Biomed Res Int*. 2016;2016:3068467.
8. Duymaz G, Yagar S, Ozgok A. Comparison of effects of low-flow sevoflurane and low-flow desflurane anaesthesia on renal functions using cystatin C. *Turk J Anaesthesiol Reanim*. 2017;45(2):73-8.
9. Kutlusoy S, Duger C, Karadas O, Karabulut I, Solmaz I. Reliability of low-flow anesthesia procedures in patients undergoing laparoscopic cholecystectomy: Their effects on our costs and ecological balance. *Niger J Clin Pract*. 2022;25(10):1672-8.
10. Venkatachalapathy R, Cherian A, Balachander H, Ramamoorthy G. Changes in gas composition during low flow anaesthesia without nitrous oxide. *J Clin Diagn Res*. 2017;11(7):UC29-UC32.