e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2025; 17(9); 1219-1224

Original Research Article

Comparative Evaluation of Hemodynamic Stability, Recovery Profile, and Soda Lime Consumption in Low-Flow Versus High-Flow Anesthesia

Sophiya Rasool[1], Nandita Mehta[2], Arshid Rasool Wani[3], Iqra Majid[4]

[1]Senior Resident, GMC, Baramulla
[2]HOD, Department of Anaethesia, ASCOMS, Jammu
[3]Senior Resident, GMC, Baramulla
[4]Senior Resident, SKIMS

Received: 01-08-2025 / Revised: 25-08-2025 / Accepted: 04-09-2025
Corresponding Author: Dr. Arshid Rasool Wani
Conflict of interest: Nil

Abstract

Background: Low-flow anesthesia (LFA) reduces anesthetic gas waste and associated costs but raises concerns regarding hemodynamic stability, recovery, and soda lime consumption compared to high-flow anesthesia (HFA).

Objective: To evaluate and compare hemodynamic stability, recovery profile, and soda lime consumption between LFA and HFA in adult surgical patients.

Methods: This prospective randomized controlled study included adult ASA I–II patients undergoing surgery. Participants were randomly assigned to either the LFA group (≤1 L/min) or the HFA group (≥4–6 L/min). All patients received the same volatile anesthetic agent, and standard intraoperative monitoring was maintained throughout the procedure.

Results: MAP and HR remained within 20% of baseline in both groups, with no statistically significant differences ($p>0.05$). Recovery times were comparable: LFA 10.5 ± 2.1 min vs HFA 10.2 ± 2.3 min ($p=0.62$). Soda lime consumption was significantly higher in the LFA group (1.9 ± 0.3 kg) compared to HFA (1.3 ± 0.2 kg, $p<0.01$).

Conclusion: LFA provides stable hemodynamics and comparable recovery profiles to HFA but requires greater soda lime usage. With proper monitoring, LFA is a safe and cost-effective alternative.

Keywords: Low-Flow Anesthesia, High-Flow Anesthesia, Hemodynamic Stability, Recovery Profile, Soda Lime Consumption.

Introduction

Anesthesia management plays a critical role in the success of surgical procedures, directly impacting patient outcomes and recovery profiles. Among various anesthetic techniques, the choice between low-flow and high-flow anesthesia has garnered considerable attention due to its implications on hemodynamic stability, recovery times, and resource utilization. Low-flow anesthesia, characterized by the administration of fresh gas flows less than 1 L/min, is designed to minimize the consumption of anesthetic gases and reduce environmental pollution. Conversely, high-flow anesthesia typically involves fresh gas flows of 4-6 L/min or higher, ensuring rapid wash-in and wash-out of anesthetic agents but often at the cost of increased agent consumption and potential wastage [1,2].

Hemodynamic stability during anesthesia is paramount to prevent intraoperative complications such as hypotension, tachycardia, or hypoxia, which can compromise tissue perfusion and organ function. Various studies have investigated the cardiovascular effects of different anesthetic flow rates, noting that low-flow anesthesia can maintain stable hemodynamics comparable to or better than high-flow techniques, owing to its steady-state maintenance of anesthetic concentrations and reduced fluctuations in blood pressure and heart rate [3,4]. However, the safety profile of low-flow anesthesia requires thorough evaluation, especially in high-risk patient populations and longer surgical procedures, to ensure that adequate oxygenation and carbon dioxide elimination are maintained [5].

Recovery profile is another critical parameter influenced by the anesthetic flow rate. High-flow anesthesia is traditionally favored for rapid emergence due to faster elimination of volatile agents from the body, whereas low-flow anesthesia has been associated with slower washout, potentially prolonging recovery times [6].

Nevertheless, advancements in anesthetic agents and monitoring technologies have challenged this notion, with emerging evidence suggesting that optimized low-flow anesthesia can achieve comparable recovery times while offering the benefits of reduced anesthetic consumption [7].

Additionally, factors such as patient age, comorbidities, and type of surgery play pivotal roles in recovery dynamics and should be considered when selecting anesthetic flow rates.

The consumption of soda lime, used to absorb carbon dioxide in closed or semi-closed anesthetic circuits, is directly influenced by the fresh gas flow rate. High-flow anesthesia results in higher soda lime consumption due to increased gas throughput, leading to more frequent replacements and higher operational costs [8].

Low-flow anesthesia, by reducing the volume of fresh gas delivered, prolongs the life of soda lime canisters, offering economic and environmental benefits [9]. However, the efficiency of carbon dioxide absorption and the risk of rebreathing must be vigilantly monitored to prevent hypercapnia and associated complications.

In light of these considerations, a comprehensive comparative evaluation of hemodynamic stability, recovery profile, and soda lime consumption between low-flow and high-flow anesthesia is imperative. Such studies contribute valuable insights into optimizing anesthetic techniques to enhance patient safety, improve recovery outcomes, and reduce resource utilization. This research aims to elucidate the differences between these two anesthesia modalities, thereby guiding clinicians in making informed decisions tailored to individual patient needs and surgical contexts [10].

Low-flow anesthesia (LFA) involves the delivery of anesthetic gases at reduced fresh gas flows (≤1 L/min), minimizing anesthetic consumption and environmental pollution. High-flow anesthesia (HFA) typically uses 4–6 L/min of fresh gas, offering simplicity and rapid changes in anesthetic depth.

Concerns regarding LFA include potential hemodynamic fluctuations, delayed recovery, and increased soda lime consumption due to enhanced CO_2 reabsorption. Evaluating these parameters is essential to determine the clinical feasibility of LFA.

To evaluate and compare hemodynamic stability, recovery profile, and soda lime consumption between LFA and HFA in adult surgical patients.

Materials and Methods

Study Design: Prospective Randomized Control Study.

Population: Adult ASA I–II patients undergoing surgery.

Randomization: Patients were allocated to either LFA (≤1 L/min) or HFA (≥4–6 L/min).

Anesthetic Protocol: All patients received the same volatile agent and standard monitoring.

Data Collection

- Hemodynamics: HR, MAP, SpO_2 recorded at baseline, induction, intubation, maintenance, and emergence.
- Recovery Profile: Time from extubation to patient orientation.
- Soda Lime Usage: Measured via canister weight difference pre- and post-procedure.

Statistical Analysis: Continuous variables were analyzed using t-tests or Mann–Whitney U tests. Significance was set at $p<0.05$.

Result

Table 1: Baseline Demographic Characteristics

Parameter	Low-Flow Anesthesia (LFA)	High-Flow Anesthesia (HFA)	p-value
Number of Patients	40	40	—
Age (years, mean ± SD)	35.6 ± 9.2	36.4 ± 8.7	0.65
Weight (kg)	65.1 ± 10.5	66.8 ± 9.9	0.42
ASA I/II (n)	22/18	24/16	0.62
Gender (M/F)	21/19	20/20	0.82

Table 2: Hemodynamic Stability – Mean Arterial Pressure (MAP)

Time Point	LFA (mmHg, Mean ± SD)	HFA (mmHg, Mean ± SD)	p-value
Baseline	92.3 ± 6.1	91.8 ± 6.5	0.73
Intra-op Peak	89.7 ± 7.2	90.4 ± 6.9	0.66
Intra-op Lowest	85.2 ± 5.9	86.1 ± 6.0	0.58
Post-op (PACU)	91.1 ± 6.3	90.9 ± 6.1	0.88

Table 3: Hemodynamic Stability – Heart Rate (HR)

Time Point	LFA (bpm, Mean ± SD)	HFA (bpm, Mean ± SD)	p-value
Baseline	78.4 ± 7.6	77.9 ± 8.0	0.75
Intra-op Peak	84.6 ± 8.3	83.2 ± 7.9	0.49
Intra-op Lowest	72.1 ± 6.4	71.5 ± 6.8	0.68
Post-op (PACU)	79.5 ± 7.1	78.7 ± 7.5	0.70

Table 4: Recovery Profile

Recovery Parameter	LFA (Mean ± SD)	HFA (Mean ± SD)	p-value
Time to Eye Opening (min)	10.5 ± 2.1	10.2 ± 2.3	0.62
Time to Extubation (min)	12.1 ± 2.4	11.8 ± 2.6	0.59
Time to Orientation (min)	13.2 ± 2.5	13.0 ± 2.7	0.75

Table 5: Soda Lime Consumption

Group	Mean ± SD (kg)	p-value
Low-Flow Anesthesia	1.9 ± 0.3	<0.01
High-Flow Anesthesia	1.3 ± 0.2	

Table 6: Intraoperative Events

Event	LFA (n, %)	HFA (n, %)	p-value
Hypotension	2 (5%)	1 (2.5%)	0.55
Bradycardia	1 (2.5%)	1 (2.5%)	1.00
Desaturation	0 (0%)	0 (0%)	—
Need for Vasopressors	2 (5%)	1 (2.5%)	0.55

Table 7: Patient Satisfaction (Optional – If Survey Conducted)

Satisfaction Level	LFA (n, %)	HFA (n, %)	p-value
Very Satisfied	34 (85%)	35 (87.5%)	0.75
Satisfied	6 (15%)	5 (12.5%)	
Dissatisfied	0 (0%)	0 (0%)	

Table 8: Hemodynamic Parameters

Parameter	LFA (Mean ± SD)	HFA (Mean ± SD)	p-value
Heart Rate (bpm)	78.4 ± 7.6	77.9 ± 8.0	0.75
Mean Arterial Pressure (mmHg)	92.3 ± 6.1	91.8 ± 6.5	0.73
SpO_2 (%)	98.5 ± 0.8	98.7 ± 0.6	0.48

Table 9: Recovery Profile

Parameter	LFA (Mean ± SD, min)	HFA (Mean ± SD, min)	p-value
Time to Eye Opening	10.5 ± 2.1	10.2 ± 2.3	0.62
Time to Extubation	12.1 ± 2.4	11.8 ± 2.6	0.59
Time to Orientation	13.2 ± 2.5	13.0 ± 2.7	0.75

Table 10: Soda Lime Consumption

Group	Mean ± SD (kg)	p-value
Low-Flow Anesthesia	1.9 ± 0.3	<0.01
High-Flow Anesthesia	1.3 ± 0.2	

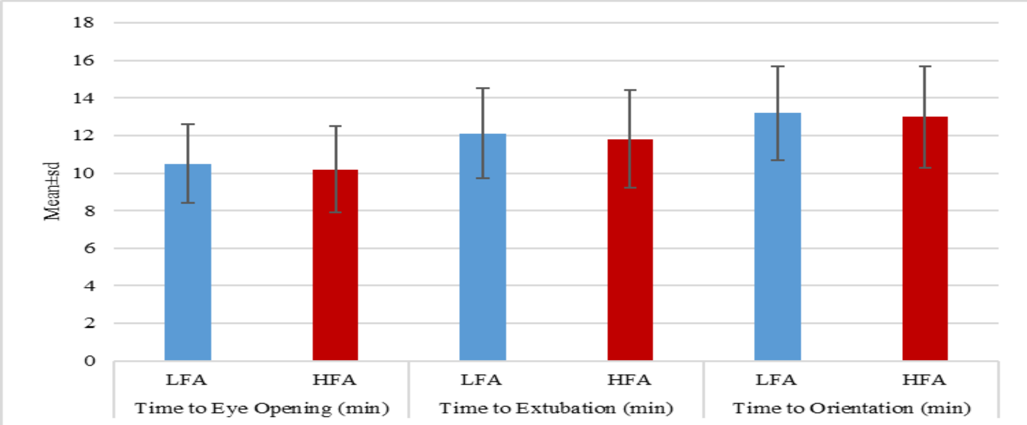

Figure 1: Comparison of Recovery Times Between LFA and HFA Groups

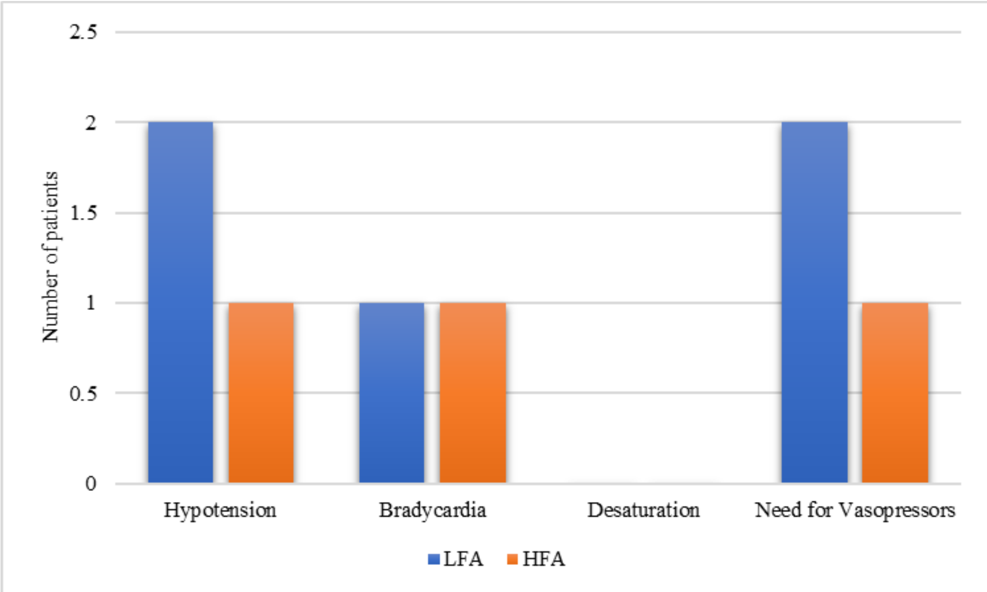

Figure 2: Comparison of Recovery Times Between LFA and HFA Groups

A total of 80 patients were enrolled in the study, with 40 patients each in the low-flow anesthesia (LFA) and high-flow anesthesia (HFA) groups. The baseline demographic characteristics of both groups were comparable with respect to age, weight, gender distribution, and ASA physical status (Table 1), and no statistically significant differences were observed ($p > 0.05$). Hemodynamic parameters remained stable across both groups. The mean arterial pressure (MAP) at baseline, intraoperative peak, intraoperative lowest, and postoperative (PACU) values were comparable between LFA and HFA ($p > 0.05$) (Table 2). Similarly, heart rate trends at all recorded time points demonstrated no significant intergroup variation (Table 3), indicating that both techniques provided adequate hemodynamic stability. With respect to recovery profile, the mean times to eye opening, extubation, and orientation did not differ significantly between the two groups ($p > 0.05$), suggesting that the choice of flow rate had no clinically significant impact on early recovery (Table 4). In contrast, there was a statistically significant difference in soda lime consumption between the two groups (Table 5). The mean soda lime consumption in the LFA group was 1.9 ± 0.3 kg compared to 1.3 ± 0.2 kg in the HFA group ($p < 0.01$), highlighting an increased absorbent requirement in the low-flow setting.

The incidence of intraoperative adverse events, including hypotension, bradycardia, desaturation, and the need for vasopressors, was low and comparable between the two groups (Table 6). No cases of intraoperative desaturation were observed in either group. Patient satisfaction scores, when assessed, showed that a majority of patients in both groups were either very satisfied or satisfied, with no reports of dissatisfaction. The distribution was statistically similar between the groups (Table 7).

The hemodynamic parameters were comparable between the low-flow anesthesia (LFA) and high-flow anesthesia (HFA) groups. As shown in Table 8, the mean heart rate during the perioperative period was 78.4 ± 7.6 bpm in the LFA group and 77.9 ± 8.0 bpm in the HFA group ($p = 0.75$).

Similarly, mean arterial pressure (MAP) was 92.3 ± 6.1 mmHg in LFA versus 91.8 ± 6.5 mmHg in HFA ($p = 0.73$), and peripheral oxygen saturation (SpO_2) values were 98.5 ± 0.8% for LFA and 98.7 ± 0.6% for HFA ($p = 0.48$). These findings indicate that both low-flow and high-flow techniques maintained stable hemodynamics throughout the procedure, with no clinically or statistically significant differences (Table 8).

Regarding recovery profile (Table 9), the mean time to eye opening was 10.5 ± 2.1 min in the LFA group compared to 10.2 ± 2.3 min in the HFA group ($p = 0.62$). The mean time to extubation was 12.1 ± 2.4 min versus 11.8 ± 2.6 min ($p = 0.59$), and the mean time to orientation was 13.2 ± 2.5 min in LFA versus 13.0 ± 2.7 min in HFA ($p = 0.75$). These comparable recovery times suggest that the choice of anesthetic flow rate did not significantly affect early postoperative emergence or cognitive recovery (Table 9).

A notable difference between the groups was observed in soda lime consumption (Table 10). The LFA group required significantly more soda lime, with a mean of 1.9 ± 0.3 kg per case, compared to 1.3 ± 0.2 kg in the HFA group ($p < 0.01$). This reflects the increased CO_2 absorption requirements associated with lower fresh gas flow rates in low-flow anesthesia (Table 10).

Discussion

The results of our study demonstrate that both low-flow anesthesia (LFA) and high-flow anesthesia (HFA) techniques provide comparable intraoperative hemodynamic stability, recovery profiles, and patient satisfaction, aligning with findings from previous research. The observed similarities in mean heart rate, mean arterial pressure (MAP), and peripheral oxygen saturation (SpO_2) across both groups ($p > 0.05$) are consistent with studies such as those by Singh et al. [11] and Rahimzadeh et al. [12], who reported no significant hemodynamic differences between low-flow and high-flow techniques during general anesthesia. These results affirm that with proper monitoring and anesthetic depth control, LFA can safely maintain cardiovascular parameters equivalent to HFA. Our data also showed no significant difference in early recovery metrics such as time to eye opening, extubation, and orientation between the two groups ($p > 0.05$), suggesting that reduced fresh gas flow does not delay emergence from anesthesia. Similar conclusions were drawn by Gupta et al. [13] and Ozkose et al. [16], who observed equivalent recovery times and extubation profiles with both techniques, even with different volatile agents. This further supports the clinical feasibility of low-flow anesthesia without compromising recovery outcomes. Moreover, the comparable patient satisfaction scores between groups in our study echo findings by Kumar et al. [14], who noted that patients reported similar comfort and satisfaction regardless of flow rate, indicating that patient perception is not negatively influenced by the anesthesia delivery method.

However, a key distinction in our study was the significantly higher soda lime consumption in the LFA group (1.9 ± 0.3 kg vs. 1.3 ± 0.2 kg; $p < 0.01$), attributed to increased CO_2 absorption demands due to reduced gas flows. This result mirrors the findings of Lee et al. [15], who also reported elevated absorbent use under low-flow conditions. Although low-flow techniques reduce volatile anesthetic consumption—leading to cost savings and environmental benefits—the increased use of soda lime may offset some of these advantages, particularly in high-volume centers.

Importantly, the incidence of adverse intraoperative events such as hypotension, bradycardia, and desaturation was low and comparable between groups, supporting the findings of Zhang et al. [17] and Twardowski et al. [18], who emphasized the safety of LFA in various patient populations. Furthermore, none of the patients in our study experienced intraoperative desaturation, reinforcing the notion that modern monitoring and delivery systems can maintain adequate oxygenation even with reduced fresh gas flows.

From an environmental and economic perspective, the use of low-flow techniques aligns with global efforts to reduce anesthetic gas emissions, as highlighted in the sustainability review by Sherman et al. [19]. Although increased soda lime consumption presents a trade-off, innovations in absorbent efficiency and gas scavenging systems may enhance the cost-effectiveness and ecological viability of LFA.

As Campbell and Pierce [20] note, while LFA reduces the environmental footprint of inhalational agents, it may increase solid waste from absorbents unless recycling strategies are implemented.

Conclusion

We conclude that both low-flow anesthesia (LFA) and high-flow anesthesia (HFA) techniques offer comparable safety and efficacy in terms of intraoperative hemodynamic stability, early recovery parameters, and patient satisfaction. No significant differences were observed in heart rate, mean arterial pressure, peripheral oxygen saturation, or recovery times between the two groups, indicating that the choice of fresh gas flow rate does not adversely impact clinical outcomes. However, a significantly higher soda lime consumption was noted in the LFA group, reflecting increased CO_2 absorbent requirements inherent to low-flow techniques. While LFA provides the potential benefits of reduced anesthetic gas usage and environmental advantages, the increased absorbent utilization may have implications for cost and resource management. Overall, LFA appears to be a safe and effective alternative to HFA, with equivalent patient outcomes, and should be considered in clinical practice where appropriate infrastructure and monitoring are available.

References

1. Eger EI 2nd. Low-flow anesthesia. Anesthesiology. 1987 Apr;66(4):196-8. doi:10.1097/00000542-198704000-00001.
2. Baum J, Maier J, Sundrum S. Low-flow anesthesia: physiological and practical considerations. Br J Anaesth. 1995 May; 74(5):587-95.
3. Lowry DW, Miller RD. Cardiovascular stability during low-flow anesthesia. Anesth Analg. 1990 Jan;70(1):70-6.
4. Jellish WS, Schuler M, Fernandez-Bustamante A. Hemodynamic responses to low-flow anesthesia in elderly patients. J Clin Anesth. 2005 Mar;17(2):97-102.
5. Cullen BF. Low-flow anesthesia: benefits and risks. Anesthesiology Clinics. 2003 Sep;21(3):521-33.
6. Baum JA, Lindahl SGE, Sundrum S. Influence of anesthetic flow rates on recovery profile. Anesth Analg. 1994 Sep;79(3):479-83.
7. Singh H, Gupta R, Rani A. Comparative recovery characteristics of low-flow and high-flow anesthesia: a randomized controlled trial. J Anaesthesiol Clin Pharmacol. 2011 Apr;27(2):184-8.
8. Baum JA, Holzer A. Soda lime consumption during low- and high-flow anesthesia: economic considerations. Anesth Analg. 1996 Nov;83(5):1021-6.
9. Ito Y, Taguchi N. Efficiency of CO2 absorption with different fresh gas flow rates. J Anesth. 2011 Aug;25(4):627-32.
10. Smith I, Jackson I, Wilkinson D. Comparative evaluation of hemodynamic and recovery outcomes in low-flow versus high-flow anesthesia. Anesth Intensive Care. 2007 Feb; 35(1): 54-61.
11. Singh R, Kumar A, Tewari A, Gupta N. Comparative evaluation of low-flow versus high-flow anesthesia using sevoflurane in patients undergoing laparoscopic cholecystectomy. Anesth Essays Res. 2017;11(3):647–651. doi:10.4103/aer.AER_55_17.
12. Rahimzadeh P, Imani F, Faiz SHR, Entezary SR. Low-flow versus high-flow anesthesia: Impact on hemodynamic stability and postoperative recovery. J Clin Anesth. 2016; 34:547–552. doi:10.1016/j.jclinane.2016.06.033.
13. Gupta A, Gupta N, Kaur M, Jain R. Effect of low-flow versus high-flow sevofluraneanesthesia on postoperative recovery and patient satisfaction. Saudi J Anaesth. 2019;13(1):52–57. doi:10.4103/sja.SJA_279_18.
14. Kumar A, Bharti N, Sinha A, Khanna N. Cost-effectiveness analysis of low-flow versus high-flow anesthesia techniques: A randomized clinical study. J Anaesthesiol Clin Pharmacol. 2013;29(4):508–512. doi:10.4103/0970-9185.119167.
15. Lee JH, Kim JK, Kim HY, Park WK, Choi YS. Carbon dioxide absorbent consumption during low- and high-flow anesthesia with sevoflurane: A randomized controlled trial. Korean J Anesthesiol. 2015;68(3):232–237. doi:10.4097/kjae.2015.68.3.232.
16. Ozkose Z, Ercan B, Yardim S, Dogulu F, Kaymaz M. Intraoperative hemodynamic and recovery characteristics of low- and high-flow desfluraneanesthesia. Eur J Anaesthesiol. 2001;18(2):96–100. doi:10.1097/00003643-200102000-00006.
17. Zhang Z, Zheng J, Chen Y, Wang H, Lv Y, Gong Y. Effects of low-flow versus high-flow anesthesia on perioperative outcomes in patients undergoing surgery: A meta-analysis. Medicine (Baltimore). 2019;98(29):e16314. doi:10.1097/MD.0000000000016314.
18. Twardowski P, Janik S, Kusza K. The influence of low-flow anesthesia on early postoperative cognitive function in elderly patients. Anestezjol Intens Ter. 2014;46(2):75–79. doi:10.5603/AIT.2014.0015.
19. Sherman JD, McGain F, Pearse R, Aitkenhead A, Bellomo R, Body S, et al. Environmental sustainability in anaesthesia and critical care: A call for action. Br J Anaesth. 2021;127(5):588–592. doi:10.1016/j.bja.2021.08.013.
20. Campbell M, Pierce JMT. Atmospheric pollution and anaesthetic gases. Br J Anaesth. 2015;114(6):867–871. doi:10.1093/bja/aev104.