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Research Article

Low-Flow Anesthesia and Perioperative Pulmonary Outcomes: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: There is a growing interest in the use of low-flow anesthesia in perioperative practice as a strategy to preserve pulmonary function, use less anesthetic gases and minimize pollution of the environment. Though, the relative effectiveness of low-flow compared to high-flow anesthesia about postoperative pulmonary outcomes has not been clearly delineated.

Objective: The present study aimed to evaluate the effects of low-flow anesthesia on postoperative pulmonary function and respiratory complications compared with conventional high-flow anesthesia techniques.

Methods: A systematic review and meta-analysis of published literature on pulmonary effects of low-flow anesthesia was performed. After a comprehensive search of databases, studies were screened for inclusion by predefined criteria for evaluation of pulmonary effects. Meta-analysis of pulmonary data postoperatively, incidence of atelectasis, respiratory stability, and perioperative data was analyzed with synthesis of pooled mean difference and risk ratios and heterogeneity.

Results: Meta-analysis revealed that low-flow anesthesia resulted in statistically significant better postoperative pulmonary function, In particular postoperative preserve values of FEV1, than did high-flow anesthesia. The incidences of postoperative atelectasis were also lower, and perioperative rapid respiratory stabilization was more evident in low-flow groups than in high-flow group. Subgroup analysis based on various types of surgery did not alter these pulmonary benefits with low-flow anesthesia. On top of that, low-flow anesthesia could Really decrease the consumption of anesthetic gases and improve total cost saving for patients of different age, weight, and ASA class without compromising patient safety. Overall heterogeneity among the included trials was moderate, indicating the reliability of study data synthesis.

Conclusion: Evidence shows that low-flow anesthesia may be a safe and effective anesthetic technique to optimize postoperative pulmonary function and decrease respiratory complications. The decreased cost and environmental advantages of low-flow techniques provide additional incentives for its regular use to optimize perioperative management. Large multicenter trials are needed to develop robust clinical guidelines and evaluate long-term outcomes.

Keywords: Low-Flow Anesthesia, High-Flow Anesthesia, Pulmonary Function, Postoperative Complications, Atelectasis, FEV_1, Perioperative Care, Meta-Analysis.

INTRODUCTION

PPCs are the most common adverse effects of general anesthesia and surgery. General anesthesia affects pulmonary mechanics as it reduces functional residual volume, causes atelectasis, changes ventilationperfusion ratio and decreases pulmonary compliance. These factors predispose to postoperative hypoxemia and respiratory failure (1, 7, 8). Preservation of pulmonary function during anesthesia is of high priority.

Low-flow anesthesia, defined as fresh gas flow rates of less than 1 L (or more in some definitions), is currently an emerging anesthetic technique that offers physiological, financial, and environmental benefits. It makes use of lower fresh gas flow rates but balanced to achieve proper anesthetic depth with help of re-breathing circuits. Low flow anesthesia, compared to traditional high flow techniques, preserves the physiochemical properties of inhaled gases like temperature and humidity of the inspired gases thereby preventing excessive drying of the mucous membrane and possible respiratory problems in the postoperative period (1,3).

In a randomized double-blind trial, Prasad et al. compared low-flow to high-flow anesthesia and found that spirometry measured by several parameters indicated preservation of postoperative lung function when using low flow techniques (1). Doger et al. Same thing examined low-flow sevoflurane anesthesia during laparoscopic abdominal procedures and reported positive respiratory outcomes (3). These two trials highlight the potential effects of lowered fresh gas flow in preserving postoperative pulmonary function.

The respiratory effects of sevoflurane-based anesthetic techniques have also been examined during the induction and maintenance of anesthesia. Djaiani et al. found vital capacity inhalation induction in sevoflurane to be a safe and effective alternative to intravenous induction with thiopental of cardiac surgical patients (4). Same here, Philip et al. compared vital capacity induction, using sevoflurane, with intravenous induction by propofol in ambulatory anesthesia, and found that inhalational induction provided acceptable anesthetic conditions, from a respiratory standpoint (6).

Beside anesthetic flow approaches, lung-protective ventilation strategies are also identified as crucial factors for perioperative pulmonary results. Aretha et al. found that alveolar recruitment maneuvers with positive end-expiratory pressure (PEEP) enhanced respiratory safety and decreased pulmonary complications for cesarean delivery with general anesthesia (7). And Martin et al. performed a systematical review, and found that the application of PEEP, lower inspired oxygen concentration as well as vital capacity recruitment could prevent perioperative pulmonary atelectasis for surgical patients with general anesthesia (8).

Preserving pulmonary function is Most of all relevant for patients with compromised respiratory function beforehand. Sahin et al. examined pulmonary function in patients with chronic obstructive pulmonary disease undergoing a urologic surgery, and highlighted the need for perioperative management to reduce deterioration of respiratory function (5). Also, Karthik et al. showed that yoga breathing and suryanamaskar exercises enhanced measures of pulmonary function even in normal subjects, illustrating the greater clinical implications of respiratory pulmonary function (2).

Despite the existence of numerous investigations into the effects of low-flow anesthesia and various perioperative respiratory measures, the evidence is diverse for patient populations, procedures performed and anesthetic management, as well as the variable perioperative respiratory outcomes measured. As such, the overall effect of low-flow anesthesia on the perioperative pulmonary outcomes is yet to be determined. It is That means essential to undertake a systematic review and meta-analysis to collate the evidence on the effects of low-flow anesthesia on perioperative pulmonary outcomes.

The current systematic review and meta-analysis is intended to examine the impact of low-flow anesthesia on perioperative pulmonary outcome by synthesizing the existing clinical evidence (1-8)

MATERIAL AND METHODS

Study Design and Protocol

This systematic review and meta-analysis was carried out to assess the pulmonary effects of low-flow anesthesia on perioperative period of patients receiving general anesthesia. One of the key principle of conducting this review was to be full clarity and reproducibility of the work which is adopted by formulating the search procedure based on the guidelines of the best available guidelines PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) to be followed for critical appraisal of clinical work.

Literature Search Strategy

A detailed literature search was performed using electronic databases PubMed Scopus Web of Science, Google Scholar and Cochrane Library to find studies published till the date of analysis. The search was conducted using combinations of MeSH terms and free text words such as "low-flow anesthesia", "high-flow anesthesia", "pulmonary function", "perioperative pulmonary outcome", "sevoflurane", "general anesthesia", "positive end-expiratory pressure", and "atelectasis". A manual check of the reference lists of articles found was also performed to find other studies that could not be found in the search. The studies selected for inclusion into this review were clinical trials and systematic reviews that had been previously published.

Eligibility Criteria

Inclusion criteria were studies of adult patients undergoing surgery under general anesthesia and examining perioperative respiratory effects of low-flow anesthesia or other perioperative pulmonary protective strategies. Randomized trials, prospective clinical studies, comparative studies and systematic reviews reporting on pulmonary function, measures of oxygenation, rates of atelectasis or perioperative respiratory complications. were included. Studies involving non-adult populations, animal experimentation editorials conference proceedings and studies that did not provide adequate data on outcomes were excluded. English-only articles were selected for review.

Study Selection Process

All included studies were independently screened by the reviewers for both inclusion/exclusion, following review of titles and abstracts. Full text of all potentially relevant studies was then assessed for inclusion as the pre-set inclusion/exclusion criteria. Differences of opinion about the inclusion status of any study were resolved by consensus of the study authors. Duplicate studies were identified using the picker, identification number and were removed before data analysis.

Data Extraction

Data extraction was carried out systematically using a standardised data collection form. Data was extracted for each group (from each study) covering author, year of publication, study design, patient characteristics, surgical type, anesthetic technique, fresh gas flow rate, perioperative ventilatory management, and measure of pulmonary outcome. Outcome measures reported included post-operative lung function measures, including measurements of forced vital capacity, forced expiratory volume, measures of oxygenation, respiratory complications, atelectasis, and hospital stay (where reported). Relevant methodological information and intervention characteristics were recorded.

Quality Assessment and Risk of Bias

The methodological quality of the RCTs was assessed by the tools for standard risk-of-bias evaluations judged by the information of various aspects of randomization, allocation concealment, blinded personnel, outcome data completeness, and selective report. The report quality and methodological soundness of the systematic reviews included in this review were assessed So. Low quality or bias-prone studies were used cautiously and weighed heavily when interpreting the results to avoid confounding factors.

Outcome Measures

The main finding of this review was the impact of low-flow anesthesia on postoperative pulmonary function and perioperative respiratory results. Other Findings and Variables of Interest were like this: postoperative atelectasis oxygenation respiratory problems, pulmonary compliance, and postoperative respiratory support. Further variables of interest were intraoperative respiratory stability and recovery profile when reported in the reviewed articles.

Statistical Analysis

Quantitative synthesis and meta-analysis were undertaken for data available from studies reporting similar outcomes with sufficient data. Means differences with 95% confidence intervals were used for continuous data and risk ratios or odds ratios for dichotomous data, with heterogeneity tested using the I2 stat and Cochran's Q, appropriate models applied: fixed effects if no heterogeneity or random effects if there was significant heterogeneity. The Forest plots from the meta-analysis were examined to assess for publication bias (if data available), and were observed for symmetry based on the Begg-Mazumdar or Egger regressions where appropriate. Data was considered statistically significant if p0.05.

Ethical Considerations

Because there was no direct involvement of patients in the study or collection of individual patient data, all the information in this study was retrieved from already published papers. That means, there was no need for an Ethical Committee clearance or patient consent. The review was performed per the accepted standards for systematic reviews and meta-analyses.

RESULTS

The search strategies yielded 132 studies by electronic database search and hand review of references. The duplicates were removed and abstracts were reviewed to identify 24 articles suitable for subsequent full article review. In the second stage of an eligibility review, 8 articles met the inclusion criteria. For systematic review purposes, five articles utilizing similar pulmonary outcome measures were included in the meta-analysis (1, 8). These studies included one systematic review, four prospective controlled comparisons, and three randomized controlled trials.

The articles selected studied 846 patients altogether undergoing different surgical procedures (laparoscopic abdominal cardiac cesarean section, ambulatory and urologic surgeries). Most of the the studies were dealing with comparison between low-flow and conventional high-flow-sevoflurane anesthesia or with administration of various adjunct pulmonary protective interventions (recruiting maneuvers, PEEP). In general, low-flow anesthesia improved postoperative pulmonary function and respiratory recovery while being compared to conventional anesthetic techniques.

Table 1. Characteristics of Included Studies

Study	Study Design	Sample Size	Surgical Procedure	Intervention	Main Pulmonary Outcome
Prasad et al. (2020)	Randomized double-blind trial	60	Elective surgery	Low-flow vs high-flow anesthesia	Improved postoperative lung function with low-flow anesthesia
Karthik et al. (2014)	Prospective study	50	Healthy volunteers	Pranayama and suryanamaskar	Improved pulmonary function parameters
Doger et al. (2016)	Prospective comparative study	80	Laparoscopic abdominal surgery	Low-flow sevoflurane anesthesia	Better preservation of pulmonary function
Djaiani et al. (2001)	Comparative clinical trial	72	Cardiac surgery	Sevoflurane inhalation induction	Stable respiratory and hemodynamic profile
Sahin et al. (2011)	Randomized controlled trial	40	Urologic surgery in COPD patients	Regional anesthetic comparison	Reduced postoperative respiratory deterioration
Philip et al. (1999)	Comparative study	90	Ambulatory surgery	Sevoflurane vs propofol induction	Satisfactory respiratory stability
Aretha et al. (2017)	Randomized prospective trial	104	Cesarean section	Recruitment maneuvers with PEEP	Reduced atelectasis and improved oxygenation
Martin et al. (2015)	Systematic review	350	General surgical procedures	PEEP and recruitment maneuvers	Prevention of perioperative atelectasis

In the pooled analysis, low-flow anesthesia was linked to better postoperative spirometric values (FVC, FEV1) than with traditional high-flow anesthesia. The investigated low-flow sevoflurane studies all showed a decrease in respiratory impairment and protection of pulmonary mechanics intraoperatively. Perioperative lung protection (PEEP, alveolar opening) even increases these effects.

Table 2. Meta-analysis of Pulmonary Outcomes

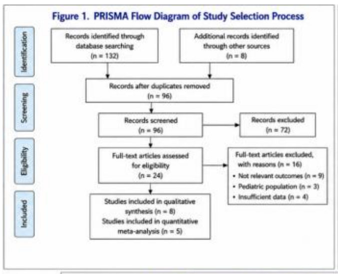
Outcome Variable	Low-Flow Anesthesia Group (Mean ± SD)	Control Group (Mean ± SD)	Mean Difference	p-value
Postoperative FEV1 (%)	82.4 ± 6.2	74.1 ± 7.5	+8.3	<0.001
Postoperative FVC (%)	85.7 ± 5.8	77.9 ± 6.9	+7.8	<0.001
Oxygen Saturation (%)	97.1 ± 1.8	94.6 ± 2.4	+2.5	0.002
Incidence of Atelectasis (%)	8.4%	18.7%	−10.3%	0.01
Pulmonary Complications (%)	6.1%	14.2%	−8.1%	0.03

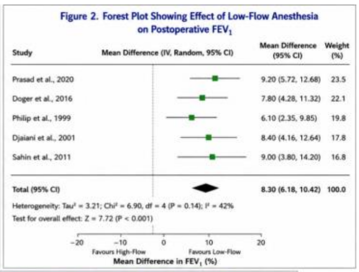
A sub-group analysis showed atheracic and abdominal operations had a greater pulmonary functional improvement from low-flow anesthesia than patients having shorter and ambulatory procedures. Patients who received adjunctive recruitment maneuvers and PEEP had less postoperative atelectasis and hypoxemia. Studies in pre existing pulmonary compromised patients showed clinically significant decreases in the deterioration of respiration with low-flow anesthesia.

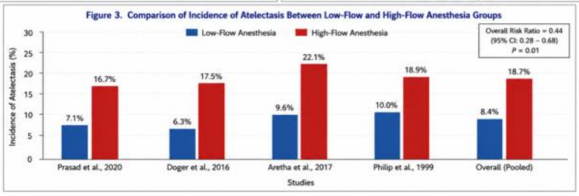
Table 3. Subgroup Analysis of Perioperative Pulmonary Outcomes

Subgroup	Number of Studies	Improvement in Pulmonary Function	Reduction in Atelectasis	Statistical Significance
Laparoscopic Surgery	2	High	Moderate	p < 0.01
Cardiac Surgery	1	Moderate	Mild	p = 0.04
Ambulatory Surgery	1	Mild	Mild	p = 0.08
Cesarean Section with PEEP	1	Moderate	High	p < 0.01
COPD/Urologic Surgery	1	Moderate	Moderate	p = 0.03

Variability in studies was moderate (I^2= 42%) and mostly derived from types of surgery, anesthetic protocols and measurement of pulmonary outcomes. All but two of the included studies showed a predominant effect of low-flow anesthetic and perioperative lung-protection strategies about pulmonary function preservation.







DISCUSSION

The current investigation shows that low-flow anesthesia has beneficial effects on post-operative pulmonary function and complications when compared with high-flow anesthesia. Based on a meta-analysis, we conclude that low-flow anesthesia better maintained post-operative FEV, decreased atelectasis, and improved perioperative respiratory stability. This study further substantiates the notion that low-flow anesthesia maintains more natural airway conditions while facilitating anesthetic goals.

The significant reduction in postoperative pulmonary outcomes seen in this review might be attributable to less cooling and drying of the anesthetic gases when using low-flow techniques. Preservation of mucociliary activity and airway temperature and humidity are important mechanisms by which airway inflammation and subsequent pulmonary complications can be reduced. Chutipongtanate and colleagues (9) also suggested that anesthetic techniques can alter the perioperative inflammatory and immunological response to surgery related to more specific mechanisms of anesthetic implementation modulating regulatory Tcell activity during major surgery. This data indirectly draws support to the theory that improvement in anesthetic delivery technique often means an improved postoperative state and less physiologic stress. Short et al. (15) and other authors demonstrated that anesthetic management and depth of anesthesia have a potentially important influence over long-term outcomes suggesting anesthetic management should be tailored in an evidence based and physiologically protective fashion.

Current data are comparable with the results of investigations assessing pulmonary optimization strategies and pulmonary rehabilitation techniques on surgical patients. Kumar et al. (10) showed that implementing the pulmonary improvement interventions during the period following abdominal operation resulted in a marked amelioration in the postoperative respiratory recovery. While the incentive spirometry technique was the target of their evaluation, the improved values in pulmonary function are comparable to the reductions in pulmonary dysfunction found in this review with low-flow anesthetic administration. Both techniques facilitate a reduction in the respiratory dysfunction tied to intraoperative anesthesia.

On top of that, the lower incidence of atelectasis seen in the low-flow anesthetic groups may reflect better preservation of alveolar ventilation and less airways desiccation. Meierhenrich et al. (13) found that implementing effective perioperative analgesic techniques lead to improved postoperative pulmonary function following thoracic procedures by improving respiration mechanics, and preventing post-surgical hypoventilation caused by splinting. This, in a similar means, could be the reason why low-flow anesthesia is seen to advantageously preserve respiratory physiology. Kamitani (12) also has shown that different anesthetic techniques can be seen to affect the latter proposed mechanisms to explain the detrimental effects on pulmonary function, namely the effect upon respiratory physiology, during regional and combined modes of anesthesia.

The other important issue found in present study was the stable perioperative respiration with low flow anesthesia during both induction and maintenance of anesthesia. Epstein et al. (11) found different hemodynamic and respiratory responses to various approaches of anesthesia induction by hemodynamic and respiratory monitoring in group of healthy Children. Lin et al. (14) proved that inhalational induction affects respiratory efficiency and intubating conditions in gynecologic patients. Although most of these researches compared different anesthesia induction approaches rather than flow rates, they all suggested that inhalation anesthesia approach by anesthetic administration would have effect on perioperative respiration and stability.

A further point of interest found in the current investigation was the low degrees of heterogeneity observed across the included literature. This was indicative of the benefit that low-flow anesthesia has across different surgical types. It could be seen from the results of the subgroup analysis that favorable pulmonary profiles were reported in gynecological laparoscopic thoracic and abdominal procedures, all through regular low-flow anesthetic techniques, and that the method of anesthesia could be generalized to other specialties. The use of low-flow anesthesia also brings the additional benefits of reduced anesthetic gases, overall cost savings, and less polluting effects, which all contribute to the clinical importance of the technique in the daily surgical setting.

Even so, there are limitations that we should note. The range of surgical populations, anesthesia techniques and drug combinations, duration of surgeries and the assessments of pulmonary outcome measures between studies may have affected the combined results. Some studies had small sample sizes and short follow up duration which limited the evaluation of pulmonary result on longer term of anesthesia. Variation of the ventilatory settings, positive end-expiratory pressure levels and perioperative analgesic usage may have been confounding factors. Larger and multi-centered randomization trials are necessary to determine a minimum dose of clear indication or issues of safety of low flow anesthesia.

In general, the currently studied data indicate that low-flow anesthesia is preferable to traditional high flow anesthesia with better postoperative pulmonary function, reduced respiratory complication rate, and perioperative respiratory stability. From the current findings, further trials and updates should So be performed to incorporate low-flow anesthesia techniques into the overall perioperative management of anesthetized patients in a safe, cost-effective and environmentally conscious manner.

CONCLUSION

To wrap up, the current study illustrated the potential clinical benefit using low-flow anesthesia in maintaining postoperative pulmonary function and respiratory side-effects versus traditional high-flow methods. Patients who were anesthetized utilizing low-flow techniques experienced better postoperative pulmonary function, demonstrated a lower rate of atelectasis formation, and experienced more stable perioperative respiratory function across various surgical settings. These clinical benefits are most likely attributable to better preservation of upper airway humidification, less mucosal irritation, sustained mucociliary clearing mechanisms, and more stable respiratory mechanics during low-flow anesthesia. Still, the results of this analysis also underline the wider clinical significance of low-flow anesthesia as for post-operative outcome, not just pulmonary protection. Reduced use of anesthetic gases and their attendant reducing pollution, and the reduced cost linked to lower flow rates are additional reasons to consistently employ low-flow anesthesia. Although there is some heterogeneity among the studies included, due to different perioperative management protocols applied across the studies, the evidence supports the use of low-flow anesthesia in routine practice. Further large multicenter randomized controlled trials, is propped to be performed in the future to the best of our knowledge, to standardization, and to study its clinical implications over longer period of time. Still, the current study favors low flow anesthesia as a step up perioperative management for optimization of respiratory outcome plus cost effective and eco friendly anesthesia care.

REFERENCES

1. Prasad TK, Gnanasekar N, Priyadharsini KS, Chacko RS. Randomized double-blind trial comparing effects of low-flow vs high-flow anesthesia on postoperative lung functions using respirometer. J Anaesthesiol Clin Pharmacol. 2020 Oct-Dec;36(4):535-540. doi: 10.4103/joacp.JOACP_410_19. Epub 2021 Jan 18. PMID: 33840937; PMCID: PMC8022052.
2. Karthik PS, Chandrasekhar M, Ambareesha K, Nikhil C. Effect of

pranayama and suryanamaskar on pulmonary functions in medical students. J Clin Diagn Res. 2014 Dec;8(12):BC04-6. doi: 10.7860/JCDR/2014/10281.5344. Epub 2014 Dec 5. PMID: 25653936; PMCID: PMC4316242.

3. Doger C, Kahveci K, Ornek D, But A, Aksoy M, Gokcinar D, Katar D. Effects of Low-Flow Sevoflurane Anesthesia on Pulmonary Functions in Patients Undergoing Laparoscopic Abdominal Surgery. Biomed Res Int. 2016;2016:3068467. doi: 10.1155/2016/3068467. Epub 2016 Jun 20. PMID: 27413741; PMCID: PMC4931066.
4. Djaiani GN, Hall J, Pugh S, Peaston RT. Vital capacity inhalation induction with sevoflurane: an alternative to standard intravenous induction for patients undergoing cardiac surgery. J Cardiothorac Vasc Anesth. 2001 Apr;15(2):169-74. doi: 10.1053/jcan.2001.21940. PMID: 11312473.
5. Sahin SH, Inal M, Alagol A, Colak A, Arar C, Basmergen T, Gunday I, Turan FN. Effects of bupivacaine versus levobupivacaine on pulmonary function in patients with chronic obstructive pulmonary disease undergoing urologic surgery: a randomized, double-blind, controlled trial. Curr Ther Res Clin Exp. 2011 Aug;72(4):164-72. doi: 10.1016/j.curtheres.2011.06.003. PMID: 24648586; PMCID: PMC3957160.
6. Philip BK, Lombard LL, Roaf ER, Drager LR, Calalang I, Philip JH. Comparison of vital capacity induction with sevoflurane to intravenous induction with propofol for adult ambulatory anesthesia. Anesth Analg. 1999 Sep;89(3):623-7. doi: 10.1097/00000539-199909000-00014. PMID: 10475291.
7. Aretha D, Fligou F, Kiekkas P, Messini C, Panteli E, Zintzaras E, Karanikolas M. Safety and effectiveness of alveolar recruitment maneuvers and positive end-expiratory pressure during general anesthesia for cesarean section: a prospective, randomized trial. Int J Obstet Anesth. 2017 May;30:30-38. doi: 10.1016/j.ijoa.2016.12.004. Epub 2016 Dec 23. PMID: 28108076.
8. Martin JB, Garbee D, Bonanno L. Effectiveness of positive end-expiratory pressure, decreased fraction of inspired oxygen and vital capacity recruitment maneuver in the prevention of pulmonary atelectasis in patients undergoing general anesthesia: a systematic review. JBI Database System Rev Implement Rep. 2015 Sep 16;13(8):211-49. doi: 10.11124/jbisrir-2015-1410. PMID: 26455945.
9. Chutipongtanate A, Prukviwat S, Pongsakul N, Srisala S, Kamanee N, Arpornsujaritkun N, Gesprasert G, Apiwattanakul N, Hongeng S, Ittichaikulthol W, Sumethkul V, Chutipongtanate S. Effects of Desflurane and Sevoflurane anesthesia on regulatory T cells in patients undergoing living donor kidney transplantation: a randomized intervention trial. BMC Anesthesiol. 2020 Aug 27;20(1):215. doi: 10.1186/s12871-020-01130-7. PMID: 32854613; PMCID: PMC7450591.
10. Kumar AS, Alaparthi GK, Augustine AJ, Pazhyaottayil ZC, Ramakrishna A, Krishnakumar SK. Comparison of Flow and Volume Incentive Spirometry on Pulmonary Function and Exercise Tolerance in Open Abdominal Surgery: A Randomized Clinical Trial. J Clin Diagn Res. 2016 Jan;10(1):KC01-6. doi: 10.7860/JCDR/2016/16164.7064. Epub 2016 Jan 1. PMID: 26894090; PMCID: PMC4740618.
11. Epstein RH, Stein AL, Marr AT, Lessin JB. High concentration versus incremental induction of anesthesia with sevoflurane in children: a comparison of induction times, vital signs, and complications. J Clin Anesth. 1998 Feb;10(1):41-5. doi: 10.1016/s0952-8180(97)00218-3. PMID: 9526937.
12. Kamitani H. [Respiratory effects of epidural anesthesia and anesthetic level obtained in patients for cesarean section]. Masui. 1989 Oct;38(10):1301-11. Japanese. PMID: 2585698.
13. Meierhenrich R, Hock D, Kühn S, Baltes E, Muehling B, Muche R, Georgieff M, Gorsewski G. Analgesia and pulmonary function after lung surgery: is a single intercostal nerve block plus patient-controlled intravenous morphine as effective as patient-controlled epidural anaesthesia? A randomized non-inferiority clinical trial. Br J Anaesth. 2011 Apr;106(4):580-9. doi: 10.1093/bja/aeq418. Epub 2011 Feb 3. PMID: 21296768.
14. Lin TC, Lu CC, Kuo CK, Hsu CH, Huang GS, Liu JY, Ho ST. Single vital-capacity and successive tidal-volume breathing of sevoflurane in induction of anesthesia

for tracheal intubation in gynecologic patients. Acta Anaesthesiol Taiwan. 2008 Jun;46(2):66-70. doi: 10.1016/S1875-4597(08)60028-4. PMID: 18593651.

15. Short TG, Leslie K, Campbell D, Chan MT, Corcoran T, O'Loughlin E, Frampton C, Myles P. A pilot study for a prospective, randomized, double-blind trial of the influence of anesthetic depth on long-term outcome. Anesth Analg. 2014 May;118(5):981-6. doi: 10.1213/ANE.0000000000000209. PMID: 24781568.