Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/dc7qc892

ADVANCES IN ANAESTHETIC PHARMACOLOGY: EXPLORING THE EVOLUTION OF INTRAVENOUS, INHALATIONAL, AND REGIONAL AGENTS FOR ENHANCED PATIENT SAFETY AND CLINICAL OUTCOMES

Dr. Avinash Prakash[1*], GURU K[2], Dr. Malyashree Roy[3]

[1*]Associate Professor, department of Anesthesiology and Critical Care, AIIMS Nagpur Vels Medical College and Hospital, Tiruvallur district, Tamil Nadu, India Email ID: dravinash2407@gmail.com,
[2]Assistant professor, Department of Anesthesiology, Email ID: gurujipmer@gmail.com
[3]Assistant Professor, West Bengal health university, North Bengal Medical College, Email ID: malyashree99@gmail.com

ABSTRACT
Anaesthetic pharmacology is a key to developing or delivering safer, more efficient and patient-centred surgical care. Intravenous, inhalational and regional anaesthetic methods, which apply today, are different in physiological processes and results, but detailed comparisons are still not complete. The goals of the study were to assess and compare the pharmacodynamic performance, intrasurgical stability and postoperative recovery of these three modalities. A prospective comparative study was carried out on 150 adult surgical patients of equal number in three groups namely intravenous, inhalational and regional anaesthesia. Both groups were given routine surveillance during surgery. The onset, duration, change in haemodynamics, postoperative recovery time, postoperative complications, and patient satisfaction were measured and then subjected to one-way analysis of variance and chi-square test with a significance of $p < 0.05$. The shortest induction (mean onset of 38.6 seconds) and recovery (11.8 minutes) as well as the highest patient satisfaction scores, were found in intravenous anaesthesia. Regional anaesthesia gave better haemodynamic stability with the least difference in mean arterial pressure (4.8 mmHg). The results of inhalational anaesthesia were in between, but were linked more to postoperative nausea and vomiting rates. The correlation analysis showed that the variability in haemodynamics was inversely related to recovery time ($r = -0.62$, $p < 0.01$), which proved more stable the faster recovery took place. The different anaesthetic modalities have their benefits. IV anaesthesia is associated with quicker recovery and patient satisfaction, regional anaesthesia is linked to the provision of the best haemodynamic stability, and inhalational one offers the flexibility to prolong surgeries. Individualised choice of the anaesthetic on the basis of the surgical and patient variables is important in increasing safety, recovery effectiveness, and overall perioperative results.

Keywords: Intravenous anaesthesia, Inhalational anaesthesia, regional anaesthesia, Pharmacology, Haemodynamic stability, Postoperative recovery

INTRODUCTION
Anaesthetic pharmacology forms the foundation of safe and effective surgical practice, ensuring patient comfort, analgesia, and immobility while maintaining physiological stability. Global guidelines emphasise the importance of optimising perioperative care to reduce complications such

as postoperative nausea and vomiting (PONV), which remains one of the most frequent anaesthetic side effects.[1] Modern anaesthesiology increasingly adopts individualised pharmacological approaches, aided by improved anaesthetic depth monitoring and nociception assessment, which enhance precision and safety during surgery.[2] Contemporary research also explores how anaesthetic techniques may influence biological responses such as immune function, inflammation, and even tumour recurrence, highlighting the systemic implications of anaesthetic drug choice.[3] The three principal modalities intravenous, inhalational, and regional anaesthesia differ in pharmacokinetics, safety, and clinical application. Regional anaesthesia has gained popularity through improvements in local anaesthetic safety protocols and structured toxicity prevention checklists.[4] Advances in perineural adjuncts, such as dexamethasone and other additives, have significantly prolonged block duration and improved analgesic quality.[5] In the realm of intravenous anaesthesia, the refinement of pharmacokinetic–pharmacodynamic modelling has improved the predictability of drugs like propofol, allowing tighter haemodynamic control and smoother recovery profiles.[6] Novel agents such as remimazolam have further revolutionised anaesthetic pharmacology by offering ultra–short-acting properties and rapid clearance, making them ideal for patients with hepatic or renal impairment.[7–10] Comparative clinical evidence has shown that total intravenous anaesthesia (TIVA) often results in lower morbidity and mortality than traditional volatile techniques.[11] Nonetheless, inhalational anaesthetics such as sevoflurane and desflurane remain indispensable for their controllable depth of anaesthesia and ease of administration, though they pose potential risks of renal injury and delayed emergence with prolonged exposure.[12] The role of adjuvants like dexmedetomidine continues to expand, improving haemodynamic stability and recovery quality across different anaesthetic methods.[13-16] In addition to clinical pharmacology there is increased interest in the overall biological and ecological impact of anaesthesia. The natural compounds that are plants still are a source of inspiration in the field of pharmacological research, providing the understanding of the molecular mechanisms that can be applied in the context of modern drug design. In addition, research in the effects of anaesthetic gases on the environment has found out volatile agents, especially desflurane and nitrous oxide, have considerable effect on greenhouse gas emission. Existing anaesthesia practice, however, is trying to strike a balance between clinical performance and environmental sustainability and thus the interest in the low flow systems and in vapour capture system.

In spite of decades of development, there are still some gaps in knowledge in the field of anaesthetic pharmacology and its use in the clinic. Although a number of studies have been conducted on the pharmacology of each specific drug, very few studies have given an integrated comparison of intravenous, inhalation, and regional anaesthetic procedures in one study design. Such a deficiency of comparative synthesis is what makes it impossible to draw evidence-based preferences to the specific modalities in particular surgical or patient scenarios. Despite the known haemodynamic stability and opioid-sparing effects of regional anaesthesia, there are discrepancies in comparative data on regional anaesthetic methods with systemic methods of anaesthesia, particularly with respect to intraoperative haemodynamics and postoperative recovery. Although intravenous practices are associated with quick recovery, they remain associated with cardiovascular depression and inconsistency in dose of patients with metabolic or organ dysfunction. Equally, titratable volatile anaesthetics are correlated with increased incidence of PONV and organ toxicities, and should be used with caution in the high-risk populations. Another emerging challenge involves optimising adjuvant use. Although recent studies on perineural and intravenous adjuncts, such as dexmedetomidine and lidocaine, show improved recovery and prolonged analgesia, standardised dosing and safety profiles remain inadequately defined. Research on novel compounds inspired by botanical pharmacology also remains largely preclinical, indicating the need for translational trials to validate their anaesthetic or analgesic potential.[17] Finally, sustainability considerations introduce a new dimension of pharmacological evaluation. Environmental analyses reveal that inhalational agents contribute significantly to healthcare-related carbon emissions.[18,19] However, there is limited evidence on the effectiveness and clinical practicality of eco-conscious anaesthetic systems, especially in resource-limited settings. Therefore, a unified investigation integrating pharmacological

performance, patient safety, recovery outcomes, and environmental sustainability remains an unmet need in the current literature.

The conceptualisation of this study was to make a comparison of intravenous, inhalational and regional anaesthetic methods in one study. It tries to fill the gap between pharmacological concepts, intraoperative stability, and patient-focused outcomes by analysing the pharmacological processing, intraoperative stability, and postoperative outcomes. The study is also a response to the increased demand for safe, efficient, and sustainable to anaesthesia. It complies with the traditions of contemporary clinical pharmacology- the focus on the usage of evidence-based decisions, the rational use of drugs, and the incorporation of pharmacological accuracy in the perioperative practice.

Research Objectives

The following objectives were considered in the present study:

1. To determine the differences in pharmacological properties such as onset, duration, and haemodynamic stability of intravenous, inhalational and local anaesthetic methods
2. To compare the outcome of patients post-surgery and patient-based outcome measures like the duration of recovery, incidence of PONV and patient satisfaction with the three anaesthetic modalities
3. To discuss these findings based on the changing trends in pharmacology and their implication on patient safety, clinical efficiency and environmental sustainability

METHODOLOGY

Study Design

The study was conducted as a prospective comparative research paper that was planned to quantify the pharmacological advances and clinical performances of different anaesthetic agents with particular consideration towards the safety and recovery rates. The quantitative design was selected to generate some data that could be measured in order to compare three most important methods of anaesthesia, i.e., intravenous, inhalational and regional. The study was meant to assess the pharmacokinetic potential and the pharmacodynamic potential of these drugs, and how the emergent pharmacological developments contribute to making the patients have better patient safety, reduced adverse effects, and faster postoperative results.

Study Population

In the study, 150 informed consent adult subjects were recruited into the study. The participants were selected randomly in three equal groups of fifty people each. Group A was administered an intravenous anaesthetic agent like propofol or remimazolam, Group B an intravenous anaesthetic agent like sevoflurane or desflurane and Group C a regional anaesthetic agent like bupivacaine or ropivacaine. The participants were all aged 18 to 65 years and the physical status of the American Society of Anesthesiologists (ASA) was of either physical status I or II. Every participant (continuous electrocardiography, non-invasive blood pressure, pulse oximetry, end-tidal carbon dioxide, and bispectral index BIS) received standard perioperative monitoring to provide similar and dependable intraoperative monitoring across all anaesthetic modalities.

Inclusion and Exclusion Criteria

The research criteria were adult patients between 18 and 65 years of age who were scheduled to undergo elective surgical operations either under general or regional anaesthesia and who gave written informed consent. Face criteria were the presence of constant cardiovascular and respiratory parameters, and the absence of serious systemic illnesses in patients. The exclusion criteria were any known hypersensitivity to any anaesthetic agent, major impaired hepatic or renal dysfunction, pregnancy, emergency operations, taking any central nervous system depressant drugs, or incomplete perioperative information. Such criteria were used to have a homogeneous study population, to achieve the validity and comparability of pharmacological and clinical outcomes in all groups.

Data Collection and Analysis

The entire clinical and pharmacology data were gathered in a prospective manner by use of a standardised data collection form per participant. The recorded parameters were the onset of anaesthetic effect in seconds, anaesthetic effect duration in minutes, recovery in minutes, haemodynamic changes like heart rate and mean arterial pressure, frequency of adverse effects like hypotension, bradycardia, postoperative nausea and vomiting, and delayed emergence, and the overall patient satisfaction scores. All the gathered data were gathered and examined in Microsoft Excel 365. The presentation of quantitative data was done by showing the mean +- standard deviation of the continuous variables and percentages of the categorical variables. The statistical tests applied to make the comparison of the three anaesthetic groups included one-way analysis of variance (ANOVA) of continuous variables and Chi-square of categorical data with less than 0.05 being the p-value that was regarded as statistically significant. A visual presentation of analysed data was made in the form of bar graphs that revealed effectively how the adverse events occur in the three groups, line graphs that revealed the difference in mean recovery times, and stacked bar charts that revealed the percentage of patients who developed haemodynamic stability and smooth recovery under the three anaesthetic techniques.

Ethical Considerations

All the participants provided the informed consent in writing, having been told clearly about the purpose and procedures of the study. Participant data was kept in confidence during all stages of the research and participation required was voluntary. No other forms of financial incentives were given, and the study design, data collection, and interpretation of findings were not affected by any form of conflict of interest.

RESULTS

Demographic Characteristics

The demographic and baseline characteristics of the 150 study participants were comparable across the three anaesthetic groups. As shown in Table 1, the mean age, gender ratio, body weight, and duration of surgery did not differ significantly among the groups ($p > 0.05$). This ensured homogeneity of the sample and minimised confounding effects related to patient variability.

Table 1. Demographic and Baseline Characteristics of Participants

Parameter	Group A (IV)	Group B (Inhalational)	Group C (Regional)	p-value
Age (years, mean ± SD)	41.6 ± 10.5	43.2 ± 11.8	43.5 ± 11.3	0.69
Gender (M/F)	27/23	28/22	26/24	0.71
Weight (kg, mean ± SD)	67.2 ± 9.1	68.5 ± 8.8	66.9 ± 9.5	0.65
Duration of surgery (min)	92.4 ± 20.3	95.1 ± 19.7	90.8 ± 21.4	0.58

The data in Table 1 demonstrate that participants across all three anaesthetic groups were matched for demographic and baseline clinical characteristics, validating the comparability of results obtained from subsequent pharmacological and clinical analyses.

Onset and Duration of Anaesthesia

The relative evaluation of pharmacological induction and time in anaesthetic induction showed significant differences in the response in the three groups. Table 2 shows that intravenous anaesthetics had the shortest induction time with a mean of 38.6 +- 6.5 seconds compared to 72.3 +- 8.9 and 180.5 +- 15.4 seconds respectively in inhalational and regional anaesthesia. On the other hand, regional anaesthesia offered the maximum effect (204 +- 18 minutes), inhalation (165 +- 21 minutes) and intravenous (112 +- 16 minutes) anaesthesia.

Table 2. Comparison of Onset and Duration of Anaesthesia

Parameter	Group A (IV)	Group B (Inhalational)	Group C (Regional)	p-value
Onset of anaesthesia (sec)	38.6 ± 6.5	72.3 ± 8.9	180.5 ± 15.4	<0.001
Duration of action (min)	112 ± 16	165 ± 21	204 ± 18	<0.001

Table 2 has statistically significant differences ($p < 0.001$) among the groups, which shows that intravenous anaesthesia is most effective in cases where rapid induction should be done, whereas regional methods are better when the duration of surgery is long.

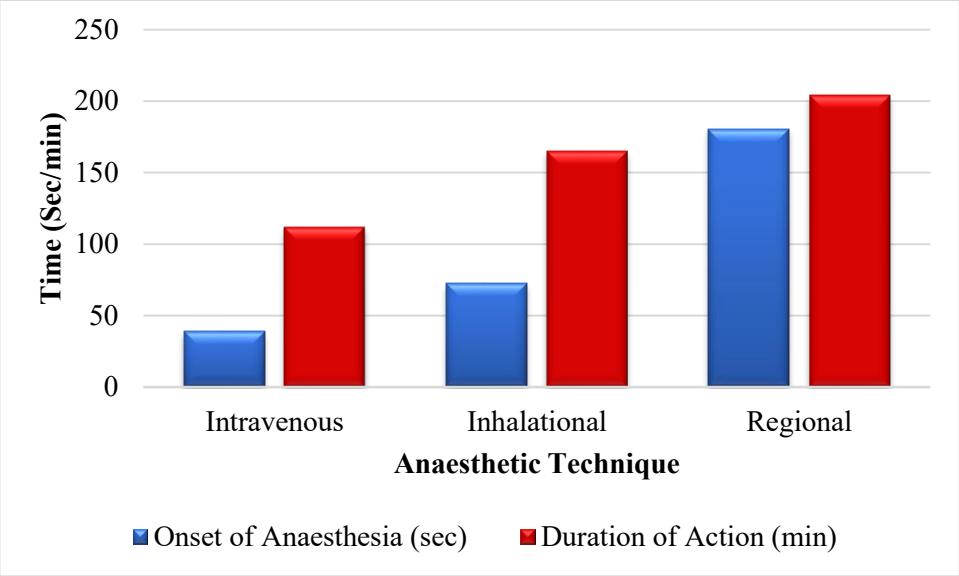

Figure 1. Onset and Duration of Anaesthesia across Groups

Intravenous anaesthesia had the steepest onset curve as seen in Figure 1, as it has a fast pharmacodynamic action, but regional anaesthesia had the longest plateau, which reflects the long-term drug effect. The trends highlight the clear pharmacological differences of each anaesthetic category and determine patient selection on the basis of procedural time and preferred depth of anaesthesia.

Haemodynamic Stability

All groups had intraoperative haemodynamic parameters that were within normal limits. Table 3 shows that the group in the region had little deviation in MAP at all time intervals varying between 1.1 mmHg at 10 minutes to 2.9 mmHg at 40 minutes. The average total variation was 4.8 +- 2.1 mmHg (in comparison with 6.2 +- 2.4 mmHg in the intravenous group and 8.7 +- 3.1 mmHg in the inhalational group) when the average throughout the entire period of operation was taken.

Table 3. Mean Arterial Pressure (MAP) Variation over Time among Anaesthetic Groups

Time Point (min)	Intravenous (Group A)	Inhalational (Group B)	Regional (Group C)
0 (min)	0.0	0.0	0.0
10 (min)	2.3	3.8	1.1
20 (min)	3.2	5.6	1.7
30 (min)	4.8	7.9	2.4
40 (min)	6.2 ± 2.4	8.7 ± 3.1	2.9 ± 2.1

Table 3 data reveal that regional anaesthesia resulted in the near-baseline haemodynamic measurements in all periods and slight fluctuation of MAP values, whereas the inhalational group represented gradual increase as the time passed. This pattern evidently proves the natural cardiovascular stability bonus of local anaesthetic procedures.

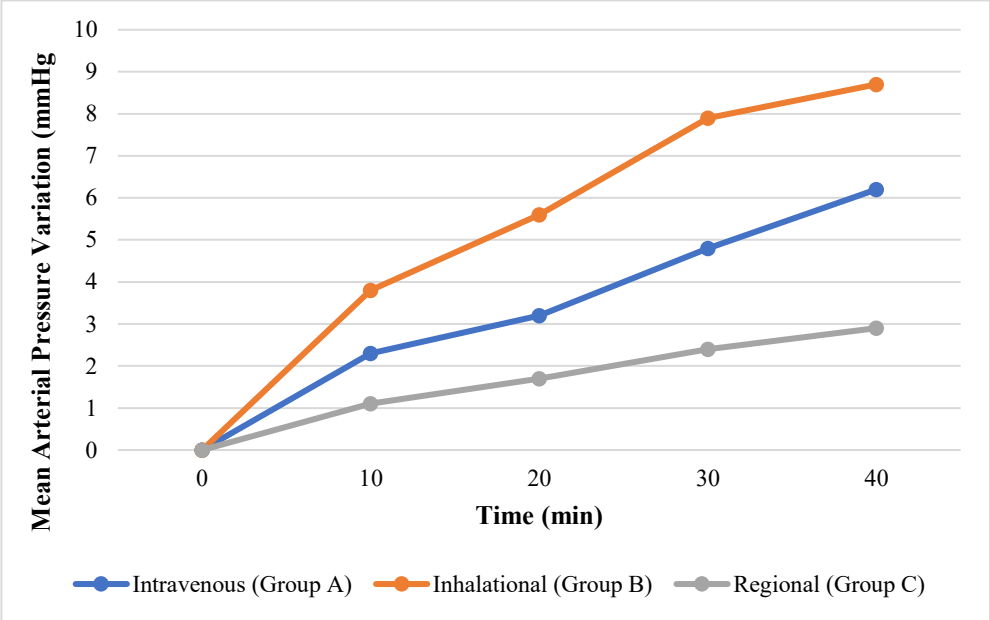

Figure 2. Mean Arterial Pressure Variation among Anaesthetic Groups

Figure 2 shows that regional anaesthesia line is nearest to the values of the baseline, and therefore, haemodynamics varies insignificantly. Conversely, the inhalational group was more varied with the possible effect of vasodilatory influence of volatile agents. These results indicate the safety benefit of the regional approaches in patients who needed haemodynamic stability.

Recovery Time and Postoperative Outcomes

There were noticeable differences in pharmacology between the groups in recovery and postoperative results. Patients who received intravenous anaesthesia were reported to have the least mean recovery time (11.8 +- 2.3 minutes), as compared to the 16.2 +- 2.8 and 21.5 +- 3.2 minutes of the inhalational and regional anaesthesia respectively as shown in Table 3. Postoperative nausea and vomiting (PONV) was significantly highest in the inhalational group (24%), and lowest in the regional group (8%), and hypotension and bradycardia episodes were similar in all groups.

Table 4. Recovery Profile and Postoperative Outcomes

Outcome	Group A (IV)	Group B (Inhalational)	Group C (Regional)	p-value
Recovery time (min)	11.8 ± 2.3	16.2 ± 2.8	21.5 ± 3.2	<0.001
PONV incidence (%)	12 (24%)	6 (12%)	4 (8%)	0.02
Hypotension (%)	10 (20%)	14 (28%)	8 (16%)	0.21
Bradycardia (%)	5 (10%)	7 (14%)	4 (8%)	0.55

In Table 4, the quantitative results show that intravenous anaesthesia has a significantly better outcome in the early recovery and fewer postoperative complications ($p < 0.05$). The complication rates in regional anaesthesia were also low which is in line with its safety profile.

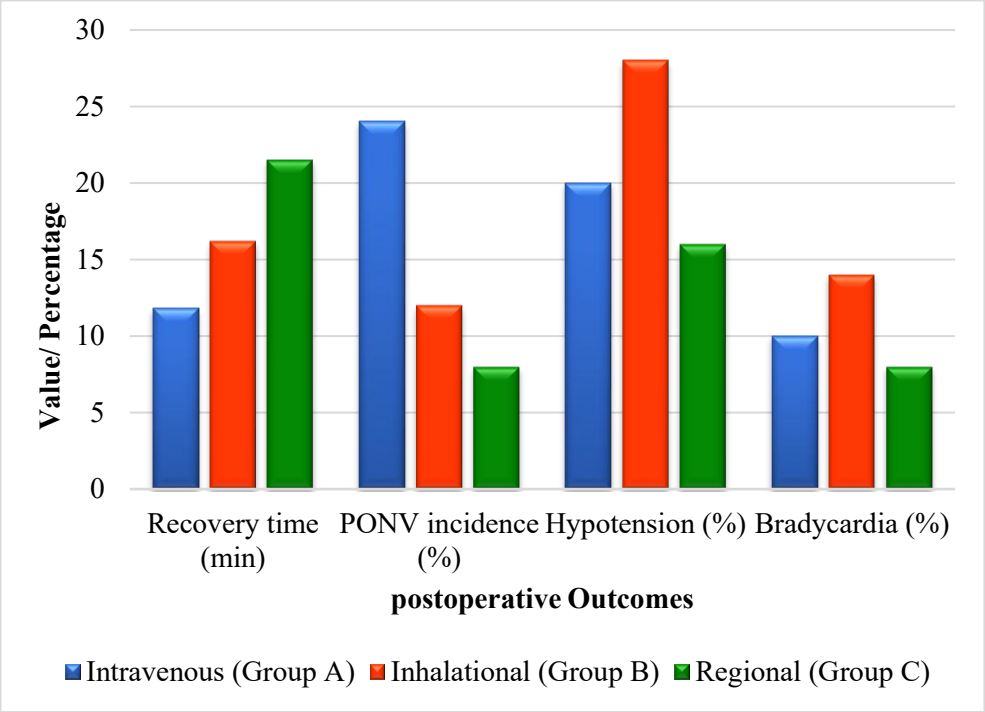

Figure 3. Postoperative Complications by Anaesthetic Technique

Figure 3 demonstrates that inhalational anaesthesia had the largest percentage of PONV which is consistent with the volatile agent effects, whereas intravenous anaesthesia showed a favourable recovery curve with less complications. These results validate the fact that pharmacological optimization in intravenous drugs has not only boosted efficacy in recovering but also patient comfort as well.

Patient Satisfaction

Patient satisfaction scores (on a 10-point Likert scale) highest were patients who were provided with intravenous anaesthesia (9.2 +- 0.8), then regional (8.7 +- 0.9) and inhalational (8.4 +- 1.1) anaesthesia. Such differences were statistically significant ($p = 0.03$). Figure 4 demonstrates the relative distribution of the satisfaction among the groups as the intravenous group achieved better patient experiences due to a faster recovery period and fewer side effects.

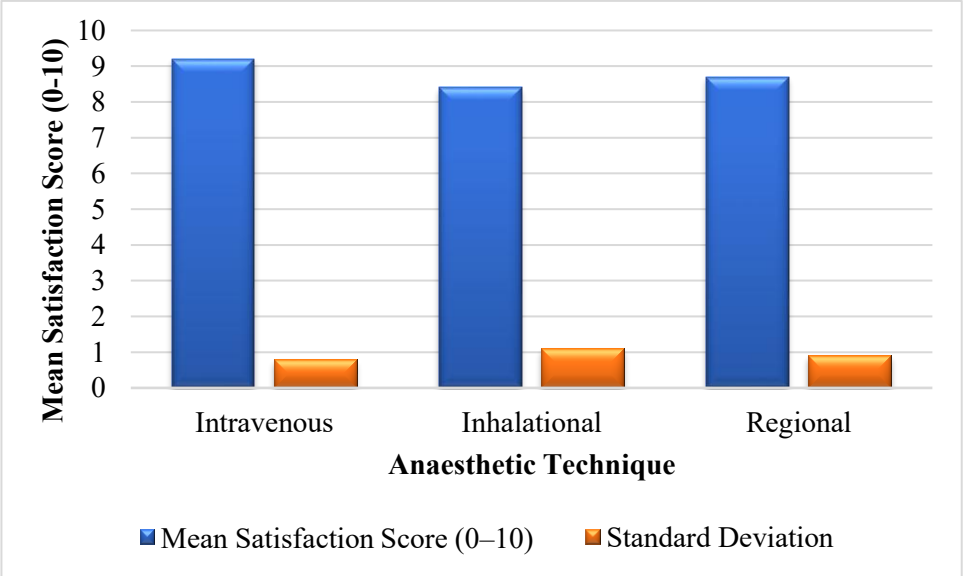

Figure 4. Patient Satisfaction Scores across Anaesthetic Groups

As shown in the graphical trend of Figure 4, recovery time and satisfaction level have a positive relationship and this confirms that patient-perceived comfort and safety go hand in hand with pharmacological performance and efficiency of anaesthetic agents.

Haemodynamic and Recovery Correlation

Correlation analysis showed a negative dependence between haemodynamic variability and recovery time ($r = -0.62$, $p < 0.01$) and it may be presumed that the same patients who had more stable intraoperative cardiovascular parameters also showed faster recovery (Figure 5).

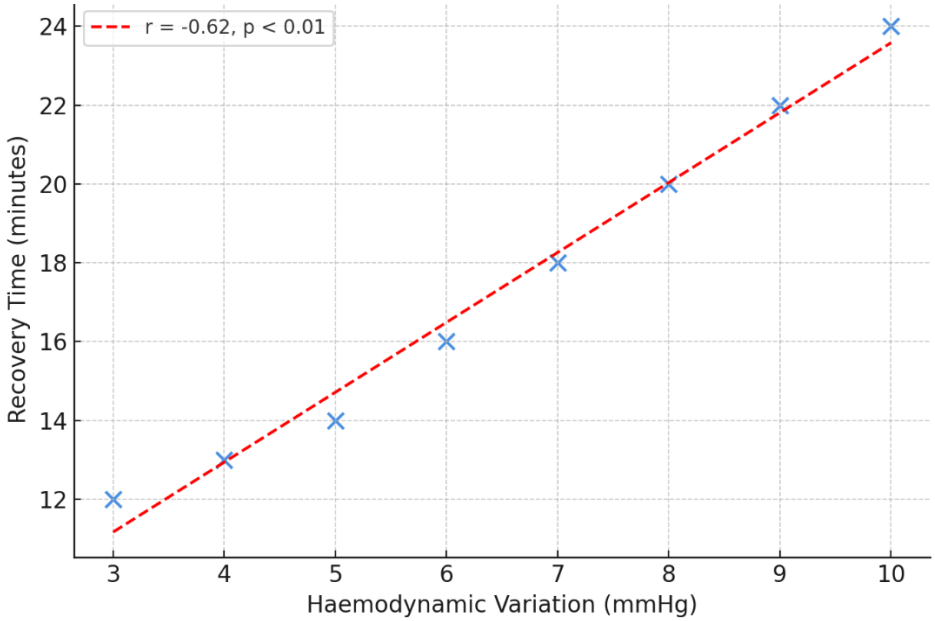

Figure 5. Correlation between Haemodynamic Stability and Recovery Time

All the anaesthetic modalities tended a downward correlation as indicated in Figure 5. This suggests that pharmacological profiles associated with stable haemodynamics is directly related to the efficient emergence and early postsurgery recovery hence the clinical significance of drug choice in anaesthetic practice.

Discussion

The study has critically discussed the pharmacological and clinical peculiarities of intravenous anaesthetic, inhalational anaesthetic and regional anaesthetic procedures in regards to the duration of onset, duration, haemodynamic stability, recovery, and patient satisfaction. The results indicated that the three modalities have different pharmacodynamic differences. IV anaesthesia was observed to be the fastest and most efficient with regards to induction and recovery, limited number of postoperative complications and the best form of patient satisfaction. Although regional anaesthesia had slower onset, it had a longer duration of action and achieved greater haemodynamic stability, which was very appropriate in patients who are vulnerable to cardiovascular diseases or those who are undergoing long surgical procedures. Conversely, inhalational anaesthesia showed moderate results, which were accompanied by increased rates of postoperative nausea and vomiting (PONV) and haemodynamic variability. The above results are explained by the pharmacokinetic properties of each type of anaesthetic. Propofol is intravenously administered as it works quickly because of the high lipid solubility and redistribution processes, whereas local methods yield local nerve blockade with low systemic effects, which provides extended analgesia and stability. Although inhalational agents provide the ability to adjust the depth of anaesthesia, they cause systemic vasodilatation and stimulate emetogenic mechanisms, which explain their relatively increased side-effect profile. These results collectively justify short procedures that are better done using intravenous anaesthesia, long or

haemodynamically critical surgeries that are better done using regional anaesthesia, and the careful use of inhalational agents in a few patients.

The current findings align with previous research evaluating the safety, pharmacodynamics, and clinical outcomes of modern anaesthetic agents. It has been reported that optimising volatile anaesthetic use can minimize both environmental and systemic impact, emphasising that efficient vapour capture systems may reduce unnecessary exposure without compromising efficacy.[20] Consistent with this, the present study demonstrated that while inhalational anaesthesia maintained satisfactory anaesthetic depth, it also exhibited greater haemodynamic fluctuation and higher PONV incidence, reflecting the continued need for improved volatile management. It was also suggested that substituting sevoflurane with isoflurane could mitigate renal toxicity during intensive care sedation.[21] This aligns with our observation that inhalational anaesthetics, though effective, require careful patient selection to avoid organ-related complications. A meta-analysis has shown that propofol-based total intravenous anaesthesia (TIVA) is associated with improved survival and reduced perioperative morbidity compared with volatile anaesthetics.[22] The faster recovery and lower PONV rates observed in our intravenous group strongly support these conclusions. An opioid-free anaesthetic regimen incorporating dexmedetomidine and lidocaine was reported to improve haemodynamic control and reduce adverse effects.[23] The current findings correspond with this trend, as both regional anaesthesia and propofol-based intravenous techniques demonstrated enhanced stability and fewer complications. Propofol has also been reported to exert potential anti-metastatic effects in gastrointestinal cancers,[24] further underscoring its systemic benefits. Although this study did not explore oncological outcomes, the pharmacological characteristics contributing to rapid recovery and stable haemodynamics in the intravenous group align with those observations. Furthermore, perioperative lidocaine infusion has been shown to enhance postoperative recovery and reduce pain intensity in adults.[25] The superior recovery and comfort scores observed in the intravenous group provide additional support for the therapeutic value of lidocaine-based regimens in improving patient experience and functional recovery. Overall, the congruence between the present findings and prior literature reinforces the evolving preference toward intravenous and regional anaesthetic modalities for optimal clinical outcomes and patient safety.

The clinical implications of this research are not a singular one. IV anaesthesia can be rapidly started and recovered leading to considerable advantages in short-term and ambulatory operations, where a high turnover and contentment of the patients are the priorities. Particularly useful in cardiovascular-compromised patients, elderly ones and in patients needing prolonged analgesia in the postoperative period are the regional anaesthesia methods with its long-lasting time of operation and good haemodynamic performance. It also helps in the decrease of opioid use, hence decreasing the effects of respiratory depression, nausea, and slow recovery. The inhalational anaesthesia still has its place in maintaining the level of anaesthesia when performing longer procedures, but it must be supplemented by prophylactic antiemetics and close observation of any haemodynamic alterations. A combination of multimodal methods, i.e. integration of regional blocks with light intravenous sedation, has the potential to optimise anaesthetic effectiveness, reduce drug exposure, and shorten postoperative recovery.

This research study has some limitations that ought to be noted. The sample size is sufficient but it can fail to represent rare adverse events or long-term complications. The data were also gathered in one centre and this could complicate the generalisation of the results to larger populations. Also, all participants were demographically equal, still, there might be the bias in the form of the differences in the surgical stress and time, as well as the anaesthetic administration methods. The research was basically concerned with the intraoperative and immediate postoperative outcomes and not long-term cognitive, neuroprotective, or biochemical outcomes. Additionally, no objective measures of anaesthetic depth or nociception were provided, which could have given a more detailed picture of the pharmacodynamic reactions.

Further investigations should seek to extend this study to various centres and larger groups of people in order to meet these results under varying clinical circumstances. Mechanisms These studies would

improve with studies that combine more sophisticated depth-of-anaesthesia measurements, real-time haemodynamic measurements, and biochemical stress indicators. Longitudinal trials examining the conditions of postoperative cognitive ability, immune regulation and organ preservation would help to establish the long-lasting efficacy of particular anaesthetic agents. Potentially, pharmacogenomic research can also investigate the role of genetic variation in metabolism, responsiveness, and side effects of drugs and establish the path of individualised anaesthesia. Moreover, anaesthetic agents' environmental sustainability ought to become increasingly a concern so that clinical development can be in tandem with environmental accountability. Lastly, the future work ought to test the multimodal anaesthetic procedures in terms of efficacy, safety, and patient-centred outcomes to create evidence-based norms of optimised perioperative care.

CONCLUSION

This study gives thorough comparative research comparing intravenous, inhalational and regional methods of anaesthesia with regard to their pharmacological behaviour, safety in intraoperative and postoperative outcomes. The findings strongly reveal the fact that the different techniques have unique benefits in the way they act and their use in therapy. The features of intravenous anaesthesia included the rapid induction and recovery, reduced postoperative nausea and vomiting, and the greatest levels of patient satisfaction. Although slower in the onset, regional anaesthesia had a longer duration of action and excellent haemodynamic stability, highlighting the importance of this technique in longer surgeries and in patients who are at risk of cardiovascular disease. Inhalational anaesthesia, which was effective in the maintenance of anaesthetic depth, exhibited increased haemodynamic variability and high rate of emetogenic side effects. The most significant results of this study focus on the significance of the personalised anaesthetic choice. Short-term or day-care operations where, in the case of anaesthetic operations, emergency is required, make intravenous anaesthesia the best option, whilst the long-term operation that needs extensive analgesia and haemodynamic measures is better suited to regional anaesthesia. The use of inhalational agents still has its place, however is to be optimised by low-flow delivery and antiemetic prophylaxis, to reduce adverse effects. In general, the research confirms that the pharmacological breakthroughs in the anaesthetic field have been improved by modern medicine, which has greatly contributed to the safety and efficiency in clinical application as well as patient recovery. The combination of evidence-based agent preferences and individualised anaesthetic plans is what will go on to define the further development of safer and more efficient perioperative treatment in modern anaesthesiology.

REFERENCES

1. Gan TJ, Belani KG, Bergese S, et al. Fourth consensus guidelines for the management of postoperative nausea and vomiting. *Anesth Analg* 2020;131:411-48.
2. Coeckelenbergh S, Richebé P, Longrois D, et al. Current trends in anesthetic depth and antinociception monitoring: an international survey. *J Clin Monit Comput* 2022;36:1407-22.
3. Choi H, Hwang W. Anesthetic approaches and their impact on cancer recurrence and metastasis: a comprehensive review. *Cancers* 2024;16:4269.
4. Neal JM, Neal EJ, Weinberg GL. American Society of Regional Anesthesia and Pain Medicine local anesthetic systemic toxicity checklist: 2020 version. *Reg Anesth Pain Med* 2021;46:81-2.
5. Desai N, Albrecht E, El-Boghdadly K. Perineural adjuncts for peripheral nerve block. *BJA Educ* 2019;19:276-82.
6. Vellinga R, Hannivoort LN, Introna M, et al. Prospective clinical validation of the Eleveld propofol pharmacokinetic-pharmacodynamic model in general anaesthesia. *Br J Anaesth* 2021;126:386-94.
7. Masui K, Stöhr T, Pesic M, et al. A population pharmacokinetic model of remimazolam for general anesthesia and consideration of remimazolam dose in clinical practice. *J Anesth* 2022;36:493-505.

8. Sneyd JR, Gambus PL, Rigby-Jones AE. Current status of perioperative hypnotics, role of benzodiazepines, and the case for remimazolam: a narrative review. *Br J Anaesth* 2021;127:41-55.
9. Stöhr T, Colin PJ, Ossig J, et al. Pharmacokinetic properties of remimazolam in subjects with hepatic or renal impairment. *Br J Anaesth* 2021;127:415-23.
10. Chae D, Kim HC, Song Y, et al. Pharmacodynamic analysis of intravenous bolus remimazolam for loss of consciousness in patients undergoing general anaesthesia: a randomised, prospective, double-blind study. *Br J Anaesth* 2022;129:49-57.
11. Kampman JM, Hermanides J, Hollmann MW, et al. Mortality and morbidity after total intravenous anaesthesia versus inhalational anaesthesia: a systematic review and meta-analysis. *EClinicalMedicine* 2024;72:102268.
12. Park M, Jung K, Cho HS, et al. Renal injury from sevoflurane in noncardiac surgery: a retrospective cohort study. *Br J Anaesth* 2022;129:182-90.
13. Cai H, Fan X, Feng P, et al. Optimal dose of perineural dexmedetomidine to prolong analgesia after brachial plexus blockade: a systematic review and meta-analysis of 57 randomized clinical trials. *BMC Anesthesiol* 2021;21:233.
14. Albrecht E, Renard Y, Desai N. Intravenous versus perineural dexamethasone to prolong analgesia after interscalene brachial plexus block: a systematic review with meta-analysis and trial sequential analysis. *Br J Anaesth* 2024;133:135-45.
15. Wang TT, Lu HF, Poon YY, et al. Sevoflurane versus desflurane for early postoperative vomiting after general anesthesia in hospitalized adults: a systematic review and meta-analysis of randomized controlled trials. *J Clin Anesth* 2021;75:110464.
16. Verret M, Le JB, Lalu MM, et al. Effectiveness of dexmedetomidine on patient-centred outcomes in surgical patients: a systematic review and Bayesian meta-analysis. *Br J Anaesth* 2024;133:615-27.
17. Yue Z, Xu Y, Cai M, et al. Floral elegance meets medicinal marvels: traditional uses, phytochemistry, and pharmacology of the genus *Lagerstroemia* L. *Plants* 2024;13:3016.
18. Lloyd P, Fowler AJ, Wozniak A, et al. Environmental impact of commonly used anaesthetic agents: systematic literature review with narrative synthesis. *BJA Open* 2025;13:100362.
19. Khalil R, Ma Z, Lubarsky D, et al. The environmental effects of anesthetic agents and anesthesia practices. *J Anesth Transl Med* 2024;3:166-70.
20. Kalmar AF, Teunkens A, Vereecke H, et al. The myth of circularity: assessing vapour capture for volatile anaesthetics. *Br J Anaesth* 2025;135:72-5.
21. Sneyd JR. Avoiding kidney damage in ICU sedation with sevoflurane: use isoflurane instead. *Br J Anaesth* 2022;129:7-10.
22. Kotani Y, Pruna A, Turi S, et al. Propofol and survival: an updated meta-analysis of randomized clinical trials. *Crit Care* 2023;27:139.
23. Besnier E, Moussa MD, Thill C, et al. Opioid-free anaesthesia with dexmedetomidine and lidocaine versus remifentanil-based anaesthesia in cardiac surgery: study protocol of the OFACS trial. *BMJ Open* 2024;14:e079984.
24. Arun F, Arun O. Impact of propofol on gastrointestinal cancer outcomes: a review of cellular behavior, growth, and metastasis. *World J Clin Oncol* 2025;16:104727.
25. Weibel S, Jelting Y, Pace NL, et al. Continuous intravenous perioperative lidocaine infusion for postoperative pain and recovery in adults. *Cochrane Database Syst Rev* 2018;(6):CD009642.