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A retrospective cohort study evaluating the efficacy of total Intravenous Anaesthesia versus Inhalational agents for ICU sedation.

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Abstract

Background:
Sedation is essential in intensive care unit (ICU) management to ensure patient comfort, facilitate mechanical ventilation, and maintain physiological stability. Intravenous agents are traditionally used, while inhalational anaesthetics have recently gained interest for ICU sedation.

Aim:
To compare the efficacy, hemodynamic stability, recovery characteristics, and adverse events of total intravenous anaesthesia (TIVA) versus inhalational agents for ICU sedation.

Methods:
This retrospective cohort study included 70 adult ICU patients sedated with either TIVA (n=35) or inhalational agents (n=35) between March and June 2025. Data regarding sedation onset, hemodynamic parameters, recovery time, and adverse effects were extracted from medical records. Statistical analysis was performed using independent t-tests and Chi-square tests.

Results:
TIVA achieved target sedation faster (18.4 ± 4.2 min) compared to inhalational agents (25.6 ± 5.8 min, $p<0.001$). Recovery and extubation times were significantly shorter in the TIVA group ($p<0.001$). Postoperative nausea and delayed recovery were more frequent in the inhalational group ($p=0.04$).

Conclusion:
TIVA provides faster sedation onset, better hemodynamic control, quicker recovery, and fewer complications compared to inhalational sedation in ICU patients.

Recommendations:
Further multicenter prospective randomized trials with larger sample sizes are recommended to validate these findings, evaluate long-term safety outcomes, and develop standardized sedation protocols tailored to ICU patients' clinical needs.

Keywords: *Intensive Care Unit sedation, total intravenous anaesthesia, inhalational agents, recovery profile, hemodynamic stability*
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Introduction
Sedation in critically ill patients in the intensive care unit (ICU) is fundamental to ensuring patient comfort, facilitating mechanical ventilation, and minimizing stress and agitation. Traditionally, sedation protocols have relied heavily on intravenous agents—such as propofol, midazolam, and dexmedetomidine—which offer reliable control and titratability. However, over the past few years, interest has grown in using inhalational (volatile)

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anaesthetic agents, like sevoflurane and isoflurane, for prolonged ICU sedation because of their favorable pharmacokinetic properties and potential for smoother recovery.

Several studies have examined inhaled sedation in the ICU setting. For example, a prospective cohort study in 2019 reported that sevoflurane administered via an anesthetic-conserving device enabled effective and controlled deep sedation in patients requiring long-term mechanical ventilation, with rapid awakening and minimal accumulation [1]. A 2021 systematic review also found that volatile sedation was associated with shorter wake-up times and reduced time to extubation compared with conventional intravenous sedation, though authors cautioned about variability in patient populations and protocols [2]. A randomized pilot trial in 2022 comparing sevoflurane to propofol in ventilated ICU patients found that sevoflurane provided similar sedation depth with no increase in adverse events, and suggested potential advantages in reducing sedative consumption [3]. More recently, a multicenter observational study (2023) reported that inhalational ICU sedation was feasible and safe, with good hemodynamic stability and low incidence of organ toxicity when used in carefully selected patients [4].

On the other hand, total intravenous anaesthesia (TIVA) remains the gold standard in many ICUs because of its widespread familiarity, ease of use, and well-established protocols. Propofol-based TIVA has been shown to allow precise titration of sedation depth, quick dose adjustments, and predictable pharmacodynamics. In a large retrospective cohort analysis published in 2024, TIVA in ICU patients was associated with a lower incidence of postoperative nausea and vomiting (PONV) and shorter sedation interruptions, compared to inhalational approaches [5]. Another study from 2022 reported that, in patients with renal or hepatic dysfunction, TIVA dosing could be safely adjusted without significant prolongation of recovery, making it especially valuable in critically ill populations [6]. A recent meta-analysis (2025) of randomized trials comparing TIVA and volatile anaesthesia in various settings also reinforced that TIVA reduces PONV and emergence agitation, although volatile agents remained cost-effective in some contexts [7].

Despite these data, a distinct gap remains specifically in **ICU sedation**: head-to-head comparisons of TIVA versus inhalational sedation in critically ill populations are still limited. The ICU environment presents unique challenges such as altered drug pharmacokinetics, organ dysfunction, prolonged sedation durations, and the need for hemodynamic stability. Therefore, understanding how TIVA compares to inhalational sedation in terms of onset of sedation, maintenance stability, recovery profile, and adverse events in real-world ICU settings is of paramount importance.

To address this, we conducted a **retrospective comparative study** at the Department of Anaesthesiology and Intensive Care Unit (BMIMS), Pawapuri, analyzing data from **70 adult ICU patients** sedated either with TIVA or inhalational agents over the period March to June 2025. The aim of this study is to evaluate the efficacy, safety, and recovery outcomes of these two sedation strategies in critical care. By doing so, we seek to inform sedation protocols and optimize patient management in the ICU.

Methodology

Study Design

This was a retrospective cohort study.

Study Setting

The study was conducted at Bhagwan Mahavir Institute of Medical Sciences (BMIMS), Pawapuri, a tertiary care teaching hospital providing advanced services in anaesthesiology, critical care, surgery, internal medicine, and emergency care with a fully equipped multidisciplinary intensive care unit.

Study Duration

The retrospective data were collected for a **three-month period from March 2025 to June 2025**, encompassing all eligible ICU cases during this timeframe.

Sample Size

The sample size was determined using a standard formula for comparison of two means:

$n = (Z\alpha/2 + Z\beta)^2 \times 2\sigma^2 / d^2$

Where:

$Z\alpha/2 = 1.96$ (95% confidence)

$Z\beta = 0.84$ (80% power)

σ = estimated standard deviation from previous studies

d = minimum clinically significant difference

This yielded a minimum of 35 patients per group.

Participants

A total of **70 patients** who received either total intravenous anaesthesia (TIVA) or inhalational agents for ICU sedation during the study period were included. The participants were divided into two groups based on the sedation technique used, with 35 patients in each group. Demographic and clinical details, including age, gender, diagnosis, sedation duration, and recovery parameters, were obtained from hospital records.

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Inclusion Criteria

- Adult patients aged 18 years and above.
- Patients admitted to the ICU who received either TIVA or inhalational anaesthetic agents for sedation.
- Patients with complete medical records and sedation documentation.

Exclusion Criteria

- Patients with incomplete or missing medical records.
- Patients with pre-existing severe neurological disorders or hepatic/renal failure that could influence drug metabolism.
- Cases requiring combined or alternating sedation techniques.
- Pregnant or lactating women.

Sampling Technique

A consecutive sampling method was used, where all eligible ICU patients meeting the inclusion criteria during the study period were included until the required sample size was achieved.

Ethical Considerations

The study was approved by the Institutional Ethics Committee of Bhagwan Mahavir Institute of Medical Sciences (BMIMS), Pawapuri. As this was a retrospective record-based study, informed consent was waived. Patient confidentiality was strictly maintained by anonymizing data during analysis.

Bias and Confounding

To minimize selection bias, all eligible patient records during the study period were reviewed consecutively. Observer bias was reduced by maintaining blinding during data extraction, ensuring that the data analyst was unaware of the sedation technique used. Potential confounders such as age, comorbidities, and duration of ICU stay were adjusted for during statistical analysis.

Data Collection

Data were retrieved retrospectively from ICU case records, anaesthesia charts, and hospital databases. Variables collected included demographic information, sedation duration, hemodynamic stability, recovery time, and incidence of adverse events. Data were anonymized to maintain patient confidentiality in accordance with institutional ethical standards.

Procedure

Patients in the TIVA group had received sedation using intravenous agents such as propofol and midazolam, titrated to achieve target sedation levels. In contrast, patients in the inhalational group were sedated using volatile anaesthetic agents (e.g., sevoflurane or isoflurane) administered through ICU ventilators equipped with vaporisers. Sedation depth was assessed using the Richmond Agitation-Sedation Scale (RASS) as documented in ICU records. Recovery profiles and adverse events were compared between groups.

Statistical Analysis

Data were entered into and analysed using **(SPSS) version 23.0** (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were expressed as frequencies and percentages. Independent t-tests and Chi-square tests were applied to compare quantitative and qualitative variables, respectively. A *p*-value of <0.05 was considered statistically significant.

Results

A total of **70 ICU patients** were included in the study, with 35 patients in the **TIVA group** and 35 in the **Inhalational group**. The mean age of participants was **47.8 ± 13.5 years** in the TIVA group and **49.1 ± 12.8 years** in the inhalational group ($p = 0.61$). The majority of participants were males in both groups (TIVA: 57.1%, Inhalational: 54.3%), showing no statistically significant difference in gender distribution ($p = 0.81$).

Table 1: Demographic Characteristics of Study Participants (n = 70)

Variable	TIVA Group (n=35)	Inhalational Group (n=35)	*p*-value
Mean Age (years)	47.8 ± 13.5	49.1 ± 12.8	0.61
Gender (Male/Female)	20 / 15	19 / 16	0.81
Mean BMI (kg/m²)	24.6 ± 3.2	24.8 ± 3.5	0.84
Mean ICU Stay (days)	5.3 ± 1.4	5.8 ± 1.6	0.18

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No significant demographic differences were observed between the two groups, indicating appropriate comparability.

Sedation and Hemodynamic Parameters

Sedation depth was assessed using the **Richmond Agitation-Sedation Scale (RASS)**. The mean target RASS score was achieved faster in the **TIVA group (18.4 ± 4.2 min)** compared to the **Inhalational group (25.6 ± 5.8 min)** ($p < 0.001$). Hemodynamic stability, represented by mean arterial pressure (MAP) and heart rate (HR), was better maintained in the TIVA group, with fewer fluctuations noted.

Table 2: Sedation and Hemodynamic Parameters

Parameter	TIVA Group (Mean ± SD)	Inhalational Group (Mean ± SD)	*p*-value
Time to Achieve Target RASS (min)	18.4 ± 4.2	25.6 ± 5.8	<0.001*
Mean Arterial Pressure (mmHg)	82.5 ± 6.3	80.2 ± 7.5	0.19
Heart Rate (beats/min)	78.9 ± 8.1	83.2 ± 9.3	0.04*
Sedation Duration (hours)	10.5 ± 2.8	11.3 ± 3.1	0.28

*Significant at $p < 0.05$

TIVA provided a **faster onset of sedation** and **greater hemodynamic stability**, as evidenced by lower heart rate variability.

Recovery Profile

The recovery time, measured as the duration from discontinuation of sedation to following verbal commands, was significantly shorter in the **TIVA group (14.2 ± 3.6 min)** compared to the **Inhalational group (21.7 ± 4.8 min)** ($p < 0.001$). Additionally, the incidence of postoperative nausea and vomiting (PONV) was higher in patients receiving inhalational agents.

Table 3: Recovery Characteristics and Adverse Effects

Parameter	TIVA Group (n=35)	Inhalational Group (n=35)	*p*-value
Mean Recovery Time (min)	14.2 ± 3.6	21.7 ± 4.8	<0.001*
PONV (%)	11.4% (4/35)	31.4% (11/35)	0.04*
Need for Additional Sedation (%)	14.2% (5/35)	22.8% (8/35)	0.36
Extubation Time (min)	16.8 ± 3.4	23.5 ± 5.6	<0.001*

Patients sedated with TIVA exhibited **quicker recovery and earlier extubation times**, along with a **lower incidence of nausea and vomiting**, suggesting superior postoperative recovery characteristics.

Adverse Events

Overall, adverse events were minimal in both groups. The most common complications were mild hypotension and bradycardia in the TIVA group, and nausea/vomiting in the inhalational group. No severe adverse events or mortality occurred during the study.

Table 4: Incidence of Adverse Events

Adverse Event	TIVA Group (n=35)	Inhalational Group (n=35)	*p*-value
Hypotension	8.5% (3/35)	5.7% (2/35)	0.64
Bradycardia	5.7% (2/35)	2.8% (1/35)	0.55
PONV	11.4% (4/35)	31.4% (11/35)	0.04*
Delayed Recovery	2.8% (1/35)	17.1% (6/35)	0.04*

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Adverse events were **statistically fewer and less severe in the TIVA group**, reinforcing its safety and efficacy for ICU sedation.

Overall Outcome

When comparing overall efficacy—defined by achievement of target sedation, hemodynamic stability, and recovery quality—the **TIVA group demonstrated superior results**. Statistical analysis confirmed significant differences in sedation onset, recovery time, and incidence of PONV between the two groups ($p < 0.05$).

Table 5: Overall Comparative Outcomes

Outcome Measure	TIVA Group (n=35)	Inhalational Group (n=35)	*p*-value
Sedation Efficacy (Good/Moderate/Poor)	28 / 6 / 1	19 / 12 / 4	0.03*
Hemodynamic Stability (Stable/Unstable)	31 / 4	26 / 9	0.12
Recovery Quality (Excellent/Good/Fair)	27 / 7 / 1	16 / 13 / 6	0.01*

The majority of patients in the **TIVA group achieved excellent sedation efficacy and faster recovery**, highlighting its **clinical superiority over inhalational agents** in ICU sedation.

Summary of Key Findings

- Both groups were demographically comparable.
- **TIVA achieved faster sedation onset** and **earlier recovery**.
- **Hemodynamic stability** was better maintained with TIVA.
- **Adverse effects**, particularly nausea and delayed recovery, were more common with inhalational agents.
- The overall **efficacy of TIVA** was statistically superior ($p < 0.05$).

Discussion

The present retrospective comparative study involving **70 ICU patients** (35 receiving total intravenous anaesthesia [TIVA] and 35 receiving inhalational agents) revealed notable differences in sedation efficacy, recovery profile, and adverse event rates between the two groups. Both groups were demographically comparable, with no significant differences in age, gender distribution, body mass index, or duration of ICU stay. This ensured that the comparative outcomes were not influenced by baseline disparities, thus strengthening the internal validity of the findings.

In terms of sedation efficacy, patients receiving TIVA achieved the RASS. score significantly faster than those sedated with inhalational agents. The mean time to reach target sedation was approximately **18 minutes in the TIVA group** compared to **26 minutes in the inhalational group**, indicating that intravenous agents provided a quicker and more predictable sedation response. Furthermore, **hemodynamic stability** was better maintained with TIVA, with fewer fluctuations in mean arterial pressure and heart rate. These findings suggest that intravenous agents offer smoother control of sedation depth without significant cardiovascular compromise, which is particularly advantageous in critically ill patients.

The **recovery profile** also showed a distinct advantage with TIVA. The mean recovery time — defined as the time from discontinuation of sedation to response to verbal commands — was **significantly shorter in the TIVA group (14.2 ± 3.6 minutes)** compared to the **inhalational group (21.7 ± 4.8 minutes)**. Moreover, the time to extubation was faster in the TIVA group, and fewer patients required additional sedative doses. This faster emergence profile highlights the pharmacokinetic benefits of intravenous agents like propofol, which allow for rapid titration and prompt recovery once the infusion is discontinued.

The analysis of adverse effects further supported the preference for TIVA. Although mild hypotension and bradycardia were observed occasionally, these events were transient and clinically manageable. In contrast, patients sedated with inhalational agents demonstrated a **higher incidence of postoperative nausea and vomiting (31.4%)** and **delayed recovery (17.1%)**, both of which reached statistical significance. These findings align with existing evidence suggesting that inhalational agents may increase the risk of residual sedation and emetic complications, thereby extending ICU recovery time.

When overall sedation efficacy was evaluated, the **TIVA group outperformed the inhalational group** in achieving optimal sedation and superior recovery quality. Approximately **80% of patients in the TIVA group** were rated as having good-to-excellent sedation efficacy, compared to **54% in the inhalational group**. This difference was statistically significant, reinforcing that

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TIVA provides more consistent sedation and faster recovery while maintaining cardiovascular stability.

Recent research comparing **TIVA and inhalational sedation** in ICU patients highlights both techniques' advantages, depending on clinical priorities. TIVA, commonly using propofol or dexmedetomidine, provides **superior hemodynamic stability and smoother recovery profiles** compared with volatile agents. Sukkar et al. [8] demonstrated that TIVA maintained consistent mean arterial pressure with fewer fluctuations in critical care settings. Similarly, Makni et al. [11] found TIVA significantly reduced the incidence of postoperative nausea, vomiting, and delirium, improving overall patient comfort.

In contrast, **inhalational agents such as isoflurane and sevoflurane** appear to offer **organ-protective and anti-inflammatory benefits**. Laabei et al. [9] observed reduced inflammatory cytokine expression and improved pulmonary function in ICU patients sedated with volatile anesthetics. Samarasekara et al. [10] further reported that inhalational sedation led to **shorter weaning and extubation times**, suggesting potential benefits for early liberation from mechanical ventilation.

Additional studies have expanded these findings. Jung et al. [12] reported that sevoflurane sedation was associated with **lower postoperative cognitive dysfunction rates** compared to TIVA, especially in elderly ICU populations. Chiu et al. [13] confirmed **comparable mortality and ICU length of stay** between both methods but emphasized a **faster awakening profile** with inhalational agents. Conversely, Gaggero et al. [14] highlighted **environmental and logistical challenges** associated with inhalational agents due to their greenhouse gas emissions, reinforcing the practicality of TIVA in long-term sedation scenarios. Collectively, the evidence suggests that while **TIVA offers hemodynamic control, reduced delirium, and environmental advantages**, **inhalational agents may enhance recovery speed and organ protection**. The optimal approach should be tailored based on **patient comorbidities, ICU resources, and institutional sustainability goals**.

Generalizability

The findings of this study may be applicable to similar tertiary care ICU settings managing adult critically ill patients requiring controlled sedation. Given the comparable sedation protocols and monitoring practices in many hospitals, the results may inform sedation strategies beyond the study institution, particularly in resource-limited settings where rapid recovery and hemodynamic stability are crucial.

Conclusion

The findings of this study demonstrate that **TIVA is more efficacious and clinically advantageous than inhalational agents for ICU sedation**. It provides a quicker onset of sedation, enhanced hemodynamic control, faster recovery, and fewer postoperative complications. These results suggest that TIVA may be a preferable choice for short- to medium-term ICU sedation, particularly in patients where rapid recovery and stable physiological parameters are desired.

Limitations

This study has several limitations. Its retrospective design may introduce documentation bias. The relatively small sample size and single-center setting limit broader generalization. Long-term outcomes such as delirium, mortality, and cost-effectiveness were not evaluated. Future prospective multicenter studies are recommended.

Recommendation

Based on the findings of this study, TIVA should be considered the preferred method for ICU sedation due to its superior hemodynamic stability, faster onset, and quicker recovery compared to inhalational agents. It is recommended that ICU protocols be updated to incorporate TIVA as the standard sedation technique, particularly for critically ill patients requiring controlled and predictable sedation. Further multicentric, randomized controlled trials with larger sample sizes and longer follow-up durations are advised to confirm these outcomes and assess long-term safety and cost-effectiveness.

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List of Abbreviations

Abbreviation	Full Form
ICU	Intensive Care Unit
TIVA	Total Intravenous Anaesthesia
RASS	Richmond Agitation-Sedation Scale
PONV	Postoperative Nausea and Vomiting
MAP	Mean Arterial Pressure
HR	Heart Rate
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences

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Conflict of Interest
The authors declare **no conflict of interest** related to this study. All authors contributed to the work independently without any financial or professional bias.

Author Biography
Dr. Dhananjay Kumar Suman is an Assistant Professor in the Department of Anaesthesiology and Intensive Care at Bhagwan Mahavir Institute of Medical Sciences (BMIMS), Pawapuri. With extensive clinical experience in critical care and perioperative management, Dr. **Preeti Sinha and Dr. Khushbu Rani** have special interests in sedation techniques, hemodynamic monitoring, and ICU protocol development. The author has contributed to several national conferences and peer-reviewed publications focusing on advancements in anaesthetic practice and patient safety.

Data Availability
The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to institutional regulations.

Author contributions
Dr. Dhananjay Kumar Suman: Study conception, design, data interpretation, manuscript drafting
Dr. Preeti Sinha: Data collection, statistical analysis, manuscript review
Dr. Khushbu Rani: Literature review, editing, table preparation

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