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Original Research Article

Prospective Comparative Study on Various Drugs used for Procedural Sedation and Analgesia Practice in the PICU

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Abstract

Background: Procedural sedation and analgesia (PSA) are integral to pediatric intensive care, enabling children to undergo diagnostic and therapeutic procedures with minimal distress. A variety of drugs including ketamine, propofol, midazolam-fentanyl, dexmedetomidine, and their combinations are used, each with distinct efficacy and safety profiles. There is limited comparative data from Indian PICU settings, making evaluation of outcomes crucial.

Aim: To compare the efficacy, safety, and recovery characteristics of various sedative and analgesic regimens used for procedural sedation in children admitted to the PICU.

Methods: This prospective comparative study was conducted at Tx Children's Hospitals, Hyderabad, between June 2024 and July 2025. A total of 165 children requiring PSA for procedures such as lumbar puncture, central venous catheter insertion, bone marrow aspiration, endoscopy, and imaging were included. Patients received one of the following regimens: ketamine, propofol, midazolam-fentanyl, dexmedetomidine, or ketamine-dexmedetomidine combination. Outcomes assessed included onset and depth of sedation, adequacy of analgesia, recovery time, procedural success, and adverse events. Statistical analysis was performed using SPSS version 26.0, with $p < 0.05$ considered significant.

Results: Propofol provided the fastest onset (1.2 ± 0.4 minutes) and shortest recovery (18.6 ± 4.3 minutes), but was associated with transient desaturation and apnea in 15% of patients. Ketamine showed effective sedation with superior analgesia and airway safety, though recovery was longer (32.8 ± 6.1 minutes) and emergence reactions occurred in 10.9%. The midazolam-fentanyl group had moderate onset (3.5 ± 0.8 minutes) and recovery (26.4 ± 5.2 minutes), with respiratory events in 11%. Dexmedetomidine provided cooperative sedation with minimal respiratory events but had delayed onset (6.4 ± 1.2 minutes) and bradycardia/hypotension in 25%. The ketamine-dexmedetomidine combination yielded balanced sedation and analgesia with fewer emergence reactions. Overall, adverse events occurred in 16.4% of cases, but no child required intubation or resuscitation.

Conclusion: This study demonstrated that while propofol is optimal for short procedures due to rapid onset and recovery, ketamine and its combinations remain superior for painful and prolonged procedures owing to better analgesia and safety. Dexmedetomidine is useful for cooperative sedation but requires caution due to cardiovascular effects. No single drug was ideal, reinforcing the need for individualized drug selection and standardized protocols to optimize safety and efficacy in pediatric intensive care.

Keywords: Procedural sedation, PICU, ketamine, propofol, dexmedetomidine, midazolam-fentanyl, pediatric analgesia.

Introduction

Procedural sedation and analgesia (PSA) have become an integral part of pediatric intensive care, providing comfort, anxiolysis, and pain relief during invasive or painful procedures such as central venous catheterization, lumbar puncture, bone marrow aspiration, endoscopy, and imaging studies. The primary goal is to achieve adequate sedation and analgesia while maintaining spontaneous ventilation and stable hemodynamics. Unlike general anesthesia, PSA is associated with shorter recovery times, lower costs, and the ability to perform procedures outside the operating room [1]. Globally, an estimated 8–12% of pediatric intensive care unit (PICU) admissions require procedural sedation at least once during hospitalization, reflecting the high demand for safe and effective sedation protocols [2]. A variety of sedatives and analgesics are commonly used, including benzodiazepines, opioids, ketamine, propofol, and dexmedetomidine. Each agent has unique advantages and limitations. Ketamine, for instance, provides profound analgesia with

preservation of airway reflexes, but may cause emergence reactions [3]. Propofol allows rapid onset and recovery but has a narrow therapeutic margin, with risks of hypotension and respiratory depression [4]. Dexmedetomidine has gained interest for its sedative and analgesic effects with minimal respiratory compromise, though bradycardia and hypotension are noted adverse effects [5].

Recent international studies, including multicentric trials, have compared the efficacy and safety of these agents. For example, in the PANDA trial, propofol provided shorter recovery times than midazolam-fentanyl combinations, though adverse respiratory events were more frequent [6]. Similarly, ketamine-dexmedetomidine combinations have been shown to provide effective sedation with reduced emergence delirium compared to ketamine alone [7]. Meta-analyses suggest that no single drug fulfills all criteria for an ideal sedative, underscoring the need for individualized drug selection and institutional protocols [8].

In India, PSA practices in pediatric critical care remain heterogeneous. A study from AIIMS, New Delhi, found that ketamine was used in 60% of PSA cases, while midazolam-fentanyl and propofol were less frequently administered, largely due to concerns regarding hemodynamic instability and availability [9]. Another multicentric Indian study reported significant variations in PSA protocols across hospitals, with inconsistent use of monitoring and airway support, highlighting the urgent need for standardized guidelines [10]. Data from South India showed that procedural sedation accounted for nearly 15% of PICU interventions, with ketamine remaining the drug of choice due to its affordability and safety profile [11]. Despite increasing procedural load in tertiary centers such as Hyderabad, there is a paucity of comparative data evaluating the performance of different sedative and analgesic agents in the Indian PICU setting.

The present study was therefore undertaken at Tx Children's Hospitals, Hyderabad, between June 2024 and July 2025, enrolling 165 children requiring PSA. The objectives were to compare the efficacy, safety, and recovery characteristics of various sedative and analgesic drugs, and to identify optimal regimens balancing procedural success with minimal complications.

The future outcome of this work is to generate region-specific evidence that can contribute to developing standardized, evidence-based sedation guidelines in India, thereby improving patient safety, minimizing complications, and enhancing procedural efficiency in pediatric intensive care.

Methodology

This study was designed as a prospective comparative study and was conducted in the Pediatric Intensive Care Unit (PICU) of Tx Children's Hospitals, Hyderabad. The study period extended from June 2024 to July 2025. A total of 165 children requiring procedural sedation and analgesia during their PICU stay were enrolled after obtaining informed consent from parents or guardians.

Children between the ages of 1 month and 18 years who required sedation for diagnostic or therapeutic procedures such as central venous catheter insertion, lumbar puncture, bone marrow aspiration, endoscopy, or imaging studies were included. Patients with significant hemodynamic instability, raised intracranial pressure, known hypersensitivity to study drugs, or those already on long-term sedative therapy were excluded.

After initial assessment and baseline stabilization, patients were allocated to different drug groups based on the sedative and analgesic regimen used, as per standard PICU practice and physician discretion. The commonly used regimens included ketamine, propofol, midazolam, fentanyl, dexmedetomidine, and their combinations. Each drug or drug combination was administered in weight-based doses according to institutional protocols. All patients received supplemental oxygen and were continuously monitored for heart rate, respiratory rate, oxygen saturation, blood pressure, and level of consciousness during and after the procedure.

Efficacy parameters assessed included onset of sedation, depth of sedation measured using the Modified Ramsay Sedation Scale, adequacy of analgesia assessed by the FLACC (Face, Legs, Activity, Cry, Consolability) scale for younger children and Wong-Baker scale for older children, procedural success, and recovery time. Safety was evaluated by recording adverse events such as desaturation, apnea, bradycardia, hypotension, airway obstruction, nausea, vomiting, and emergence reactions. Recovery was defined as the time taken to return to baseline consciousness and stable vital signs.

All data were collected in a structured proforma and subsequently entered into Microsoft Excel. Statistical analysis was performed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages.

Inter-group comparisons were made using independent t-test or ANOVA for continuous data and chi-square test for categorical data. A p-value

of less than 0.05 was considered statistically significant.

Ethical clearance for the study was obtained from the Institutional Ethics Committee prior to initiation. Written informed consent was obtained from parents or legal guardians of all participating children, and confidentiality of patient information was maintained throughout.

Results

A total of 165 children undergoing procedural sedation and analgesia were enrolled in the study, with an almost equal distribution of males and females. The majority of children belonged to the age group of 1–10 years, reflecting the higher need for sedation during invasive diagnostic and therapeutic procedures in younger patients. The most common procedures requiring sedation were lumbar puncture (32%), central venous catheter insertion (28%), bone marrow aspiration (20%), and endoscopic interventions (12%), while the remaining 8% included imaging procedures such as MRI and CT.

Among the drug regimens evaluated, ketamine was administered in 55 patients (33.3%), propofol in 40 patients (24.2%), midazolam-fentanyl in 35 patients (21.2%), and dexmedetomidine in 20 patients (12.1%). A smaller subset of 15 patients (9.1%) received a ketamine-dexmedetomidine combination, particularly in cases where prolonged sedation was required.

The onset of sedation was fastest with propofol (mean 1.2 ± 0.4 minutes), followed by ketamine (2.1 ± 0.6 minutes) and midazolam-fentanyl (3.5 ± 0.8 minutes), while dexmedetomidine showed a delayed onset (6.4 ± 1.2 minutes). Adequate sedation was achieved in over 90% of procedures across all groups, but ketamine and ketamine-dexmedetomidine combinations provided superior analgesia compared to propofol and midazolam-fentanyl, especially in painful procedures like bone marrow aspiration.

Recovery time was shortest in the propofol group (18.6 ± 4.3 minutes), followed by midazolam-fentanyl (26.4 ± 5.2 minutes), ketamine (32.8 ± 6.1 minutes), and was longest in the dexmedetomidine group (41.2 ± 7.5 minutes). The ketamine-dexmedetomidine combination provided stable sedation with recovery times averaging 38.4 ± 6.8 minutes.

Adverse events were recorded in 27 patients (16.4%). The most frequent events were transient desaturation and apnea, observed predominantly in the propofol (15%) and midazolam-fentanyl groups (11%). Emergence reactions were noted in 6 ketamine patients (10.9%). Dexmedetomidine was associated with bradycardia in 3 patients (15%) and hypotension in 2 patients (10%), though all were transient and managed conservatively. Overall, the incidence of serious adverse events requiring intervention was low, and no patient required endotracheal intubation or resuscitation.

When functional outcomes were compared, propofol was most suitable for short procedures due to rapid onset and recovery, whereas ketamine and ketamine-dexmedetomidine combinations were preferred for painful and longer procedures because of superior analgesia and stable sedation. Dexmedetomidine was effective for maintaining calm, cooperative sedation but was limited by delayed onset and cardiovascular effects. Overall, the study highlighted that each sedative regimen had specific strengths and limitations, and no single drug could be considered ideal. However, ketamine-based regimens provided the best balance of analgesia, safety, and procedural success in the pediatric intensive care setting, while propofol was most advantageous for rapid turnover procedures.

Table 1: Demographic Profile and Procedures (n = 165)

Variable	No. of Patients (%)
Age (years)	
1–5	68 (41.2%)
6–10	52 (31.5%)
11–18	45 (27.3%)
Sex	
Male	86 (52.1%)
Female	79 (47.9%)
Procedures Requiring Sedation	
Lumbar Puncture	53 (32.1%)
Central Venous Catheter	46 (27.9%)
Bone Marrow Aspiration	33 (20.0%)
Endoscopy	20 (12.1%)
Imaging (MRI/CT)	13 (7.9%)

Table 2: Sedation and Recovery Characteristics (n = 165)

Drug Regimen (n)	Onset of Sedation (min, Mean ± SD)	Recovery Time (min, Mean ± SD)	Adequate Analgesia (%)	Procedural Success (%)
Ketamine (55)	2.1 ± 0.6	32.8 ± 6.1	92.7%	94.5%
Propofol (40)	1.2 ± 0.4	18.6 ± 4.3	78.0%	95.0%
Midazolam-Fentanyl (35)	3.5 ± 0.8	26.4 ± 5.2	81.5%	91.5%
Dexmedetomidine (20)	6.4 ± 1.2	41.2 ± 7.5	85.0%	90.0%
Ketamine + Dexmed (15)	3.8 ± 0.9	38.4 ± 6.8	93.3%	93.3%

Table 3: Adverse Events Observed (n = 165)

Adverse Event	Ketamine (n=55)	Propofol (n=40)	Midazolam-Fentanyl (n=35)	Dexmedetomidine (n=20)	Ketamine+Dexmed (n=15)	Total (%)
Transient Desaturation	3 (5.4%)	6(15.0%)	3 (8.6%)	0 (0.0%)	0 (0.0%)	12 (7.3%)
Apnea	0 (0.0%)	2 (5.0%)	1 (2.9%)	0 (0.0%)	0 (0.0%)	3 (1.8%)
Emergence Reaction	6(10.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (3.6%)
Bradycardia	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (15.0%)	0 (0.0%)	3 (1.8%)
Hypotension	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (10.0%)	0 (0.0%)	2 (1.2%)
Nausea/Vomiting	4 (7.2%)	1 (2.5%)	2 (5.7%)	1 (5.0%)	1 (6.7%)	9 (5.5%)

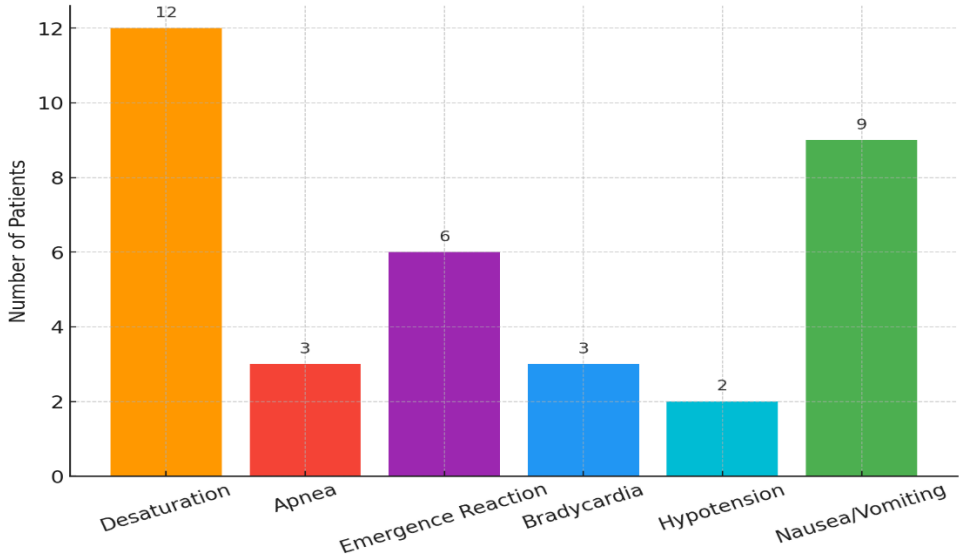

Figure 1: Distribution of Adverse Events in Study Population

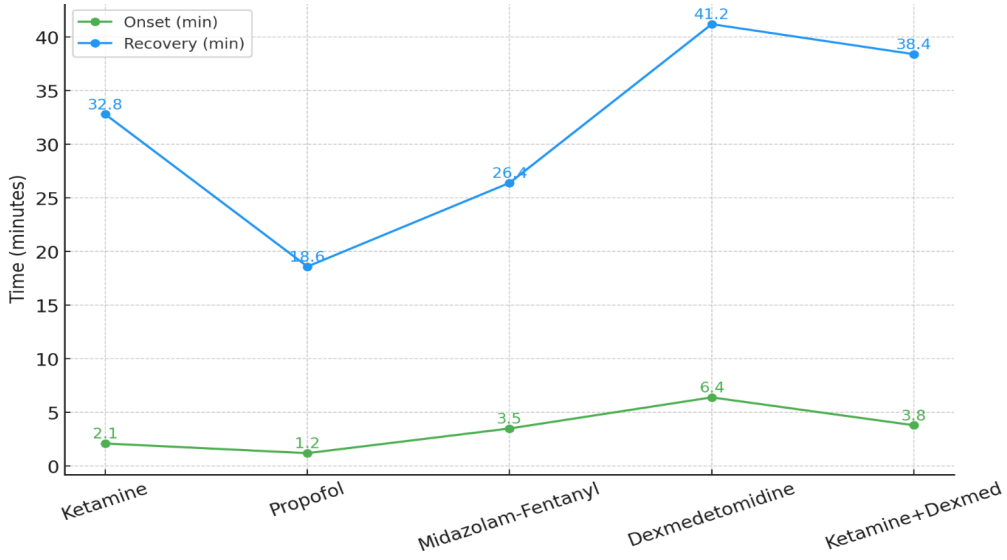

Figure 2: Line Diagram of Onset and Recovery Times across Sedative Regimens

Discussion

This prospective comparative study evaluated the efficacy, safety, and recovery characteristics of various sedative and analgesic regimens used for procedural sedation in a paediatric intensive care setting. A total of 165 children were enrolled, and the results showed that each drug had specific strengths and limitations, with no single agent fulfilling all criteria for the ideal sedative.

In the present study, propofol demonstrated the fastest onset of sedation (mean 1.2 minutes) and shortest recovery time (18.6 minutes), making it particularly suitable for short procedures. These findings are consistent with the prospective cohort of 5,000 pediatric cases reported by Babl, where propofol was associated with rapid onset and recovery but carried a higher risk of respiratory depression [4]. Similarly, Vardi observed that propofol provided quicker sedation compared to midazolam, although adverse respiratory events were more frequent [6].

Ketamine, used in one-third of the study population, provided effective sedation with superior analgesia and preservation of airway reflexes, but recovery was longer (32.8 minutes) and emergence reactions occurred in about 10% of patients. These findings mirror the guidelines by Green, who highlighted ketamine's safety in children with its unique dissociative profile, though emergence phenomena remain a concern [3]. A South Indian study by Ramesh also reported ketamine as the most frequently used sedative in PICU practice, with minimal respiratory adverse events [11]. Midazolam-fentanyl combination produced adequate sedation but with longer onset (3.5 minutes) and moderate recovery times (26.4 minutes). Adverse events such as desaturation and apnea were observed in approximately 11% of cases. This aligns with the systematic review by Bellolio, which showed that benzodiazepine-opioid combinations, although widely used, carried higher risks of respiratory compromise compared to single-agent protocols [8].

Dexmedetomidine, though used in fewer patients, was effective for producing calm, cooperative sedation with minimal respiratory depression. However, onset was delayed (6.4 minutes), and bradycardia and hypotension were recorded in 25% of cases. Mason also reported similar cardiovascular side effects, while recognizing the drug's advantage of preserving spontaneous ventilation [5]. In this study, the ketamine-dexmedetomidine combination provided stable sedation with effective analgesia and reduced emergence reactions compared to ketamine alone, corroborating Tosun's findings from pediatric cardiac catheterization [7]. Overall, adverse events occurred in 16.4% of children, with transient desaturation and apnea most commonly associated with propofol and midazolam-fentanyl. These results are comparable to Bellolio's meta-analysis, where the pooled incidence of adverse events in pediatric PSA was 11–20%, most of them minor and self-limited [8]. Importantly, no patient in the present study required endotracheal intubation or resuscitation, underscoring the overall safety of PSA when appropriate monitoring and protocols are followed.

In the Indian context, the findings resonate with the survey by Singhi, who noted heterogeneity in sedation practices and a predominance of ketamine due to its safety and cost-effectiveness [9]. Chawla further emphasized the lack of uniform protocols in Indian PICUs and called for multicentric data to standardize PSA practices [10]. The current study contributes to this need by providing comparative data from a tertiary care hospital in Hyderabad, suggesting that propofol is best suited for short procedures, while ketamine-based regimens remain preferable for painful and longer procedures.

Taken together, this study highlights that the choice of sedative regimen should be individualized, considering the type of procedure, duration, patient profile, and available resources. The findings reinforce the global consensus that no single drug is ideal, but rational selection based on evidence can optimize safety and procedural success in the pediatric intensive care environment.

Conclusion

This prospective comparative study on procedural sedation and analgesia in the PICU highlighted that different sedative regimens have distinct profiles, with no single drug fulfilling all criteria for the ideal agent. Propofol provided the fastest onset and recovery, making it highly suitable for short procedures, though respiratory adverse events were more frequent. Ketamine offered superior analgesia and airway safety, but was associated with longer recovery and occasional emergence reactions. The midazolam-fentanyl combination was effective but carried moderate risks of desaturation and apnea. Dexmedetomidine provided cooperative sedation with minimal respiratory compromise but had delayed onset and notable cardiovascular effects. The ketamine-dexmedetomidine combination balanced sedation and analgesia while reducing emergence reactions. Overall, ketamine-based regimens were found most useful for painful or prolonged procedures, while propofol was advantageous for quick interventions.

Limitations and Recommendations

This study was limited by its single-center design and relatively small sample size, which may reduce the generalizability of the findings. Allocation to drug regimens was based on physician discretion rather than randomization, which may have introduced selection bias. Long-term neurocognitive effects of repeated sedation were not assessed, and the study did not perform a cost-effectiveness analysis of different regimens. Despite these limitations, the findings provide important insights into sedation practices in the Indian PICU setting. It is recommended that drug choice for procedural sedation be individualized based on patient profile, procedure type, and available monitoring resources. Strict adherence to sedation protocols and continuous monitoring should be ensured to minimize adverse events. Larger multicentric randomized controlled trials are needed to further establish evidence-based guidelines. Incorporating training for PICU staff, establishing standardized PSA protocols, and including cost-effectiveness evaluations will help optimize sedation practices and improve patient safety in resource-constrained healthcare systems.

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