

ORIGINAL RESEARCH



Ketamine versus Diazepam for Pediatric MRI Sedation in Northern Malawi: A Retrospective Analysis

Lin Liu^{1,2}, Joel Moyo³, Blessed Kondowe⁴, Patrick Manda⁴, Jingping Zhang^{4,5}, Junyi Ren^{3,6}

1.Department of Anesthesiology, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, China

2.Department of Anesthesiology, Kamuzu Central Hospital, Lilongwe, Malawi

3.Department of Anesthesiology, Mzuzu Central Hospital, Mzuzu, Malawi

4.Department of Radiology, Mzuzu Central Hospital, Mzuzu, Malawi

5.Department of Medical Imaging, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, China

6.Department of Anesthesiology, Baoji Central Hospital, Baoji, China

*Corresponding Author: Junyi Ren; Email: 76427340@qq.com

Abstract

Background

Magnetic resonance imaging (MRI) in children requires adequate sedation to ensure procedural success. In resource-limited settings, sedative options are often restricted, and comparative data on ketamine and diazepam are scarce. This study aimed to evaluate the efficacy, safety, and MRI completion rates of ketamine versus diazepam for pediatric sedation at a low-resource hospital in northern Malawi.

Methods

We conducted a single-center, retrospective study including children aged 0–14 years who underwent MRI with ketamine ($n = 20$) or diazepam ($n = 36$) at Mzuzu Central Hospital between August 2025 and March 2026. Sedation success was defined as Ramsay Sedation Score 4–5 with stable vital signs and absence of movement during MRI. Primary outcomes were sedation onset time, sedation success rate, recovery time, adverse events, and MRI completion rates.

Results

Baseline characteristics were similar between groups. Ketamine was associated with a shorter sedation onset (mean 1.55 ± 0.39 min vs 3.43 ± 0.45 min, $P < 0.01$), higher sedation success rate (19 (95%) vs 24 (67%), $P < 0.05$), and longer recovery time (mean 58.64 ± 7.14 min vs 43.10 ± 5.04 min, $P < 0.01$) compared with diazepam. The incidence of adverse events was similar between the two groups, with no severe complications observed. First-pass MRI completion (19 (95%) vs 21 (58%), $P < 0.01$) and overall scan success rates (20 (100%) vs 25 (69%), $P < 0.05$) were higher in the ketamine group.

Conclusions

In this low-resource setting, ketamine provided faster, more reliable pediatric MRI sedation than diazepam, with higher procedural success and a favorable safety profile. Ketamine may be considered the preferred sedative for pediatric MRI in similar resource-limited hospitals, provided continuous monitoring and anesthetic oversight.

Keywords: pediatric sedation; MRI; ketamine; diazepam; resource-limited settings; Malawi

Introduction

Magnetic resonance imaging (MRI) is a non-invasive and radiation-free imaging modality widely used in pediatric patients for the evaluation of neurological, musculoskeletal, and abdominal conditions. However, successful image acquisition requires the patient to remain motionless for a prolonged period, which is often challenging in young children due to anxiety, fear, and limited ability to cooperate^{1,2,3}. Therefore, procedural sedation is frequently required to ensure adequate image quality and completion of the examination.

In high-resource settings, commonly used sedative agents for pediatric MRI include propofol and dexmedetomidine, which provide reliable sedation with rapid onset and predictable recovery profiles^{1,4,5,6}. However, in many low-resource settings, including many regions of Malawi, access to these agents and the necessary monitoring equipment is limited. As a result, more readily available and cost-effective medications, such as ketamine and diazepam, are commonly

used in clinical practice despite limited evidence comparing their efficacy and safety in this specific context^{7,8,9}.

At Mzuzu Central Hospital, there is currently no standardized protocol for pediatric MRI sedation, and the choice of sedative agent is largely based on clinician preference and drug availability. The clinical effectiveness, safety profile, and impact on scan success of ketamine and diazepam in this setting remain unclear.

Therefore, this study aimed to retrospectively evaluate sedation practices for pediatric MRI at Mzuzu Central Hospital, and to compare the efficacy, safety, and scan success rates between ketamine and diazepam. The findings may provide context-specific evidence to inform sedation strategies in similar resource-limited settings.

Materials and Methods

Study Design

This single-center, retrospective study was conducted in accordance with the principles of the Declaration of

Table 1. Baseline characteristics and sedation status

Variable	Ketamine group (n =20)	Diazepam group (n = 36)	P-value
Age (month)	41.25 ± 58.38	60.11 ± 55.18	0.235
Sex, female (n, %)	14(70)	26 (72)	0.438
Weight (kg)	19.57 ± 19.17	19.96 ± 10.03	0.920
ASA			
I (n, %)	18(90)	31 (86)	0.562
II (n, %)	2(10)	5 (14)	0.562
Scan site:			
Brain (n, %)	14 (70)	25 (69)	1.000
Abdomen (n, %)	3 (15)	6 (17)	1.000
Others (n, %)	3 (15)	5 (14)	1.000
Scan duration (min)	8.95 ± 5.88	9.61 ± 6.25	0.700
Dosage (mg/kg)	4.17 ± 0.34	0.10 ± 0.00	<0.001
Route			
IM (n, %)	1	0	<0.001
IV (n, %)	0	1	<0.001

Abbreviations: IM, intramuscular; IV, intravenous.

Table 2. Sedation efficacy between two groups

Variable	Ketamine group (n =20)	Diazepam group (n =36)	P-value
Onset time (min)	1.6 ± 0.39	3.4 ± 0.45	<0.001
Sedation success rate (n, %)	19 (95)	24 (67)	0.038
Recovery time (min)	58.6 ± 7.14	43.1 ± 5.04	<0.001
Agitation (n, %)	3 (15)	5 (14)	1.000
Respiratory depression (n, %)	0 (0)	0 (0)	1.000
Tachycardia (n, %)	0 (0)	0 (00)	1.000
Nausea/vomiting (n, %)	1 (5)	3 (8)	1.000
Total adverse events (%)	4 (20)	8 (22)	1.000

Table 3. MRI scan success rate

Variable	Ketamine group	Diazepam group	P-value
First-pass success (n, %)	19 (95)	21 (58)	0.009
Scan failure/rescheduling (n, %)	0 (0)	2 (6)	0.747
Poor imaging quality as judged by the radiologist(n, %)	0 (0)	9 (25)	0.039
Overall scan success rate (n,%)	20 (100)	25 (69)	0.016

Helsinki and was reviewed and approved by the Human Ethics Committee of Mzuzu university [Approval number:MZUNIERC/DOR /26/39]. The requirement for written informed consent was waived due to the retrospective nature of the study. All patient data were anonymized prior to analysis.

Study Population

We consecutively screened pediatric patients aged 0–14 years who underwent MRI examinations between 20 August 2025 and 20 March 2026. Inclusion criteria: 1. age between 0 and 14 years; 2. underwent MRI at Mzuzu Central Hospital; 3. received sedation with either ketamine or diazepam; 4. availability of complete clinical, sedation, and imaging records. Exclusion criteria: 1. MRI completed without sedation; 2. American Society of Anesthesiologists (ASA) physical status $\geq$ III; 3. hemodynamic instability or severe cardiopulmonary dysfunction. Ultimately, a total of 56 patients were included and categorized into a ketamine group (n = 20) and a diazepam group (n = 36) based on the primary sedative agent administered.

Sedation Protocol

Sedation was administered according to routine clinical practice and drug availability. Ketamine group: Ketamine 4-5 mg/kg administered intramuscularly. Diazepam group: Diazepam 0.1 mg/kg administered intravenously. The differences in dose and route reflected routine clinical practice rather than protocolized treatment. Successful sedation standard: Ramsay Sedation Score 4–5, with stable vital signs, no restlessness or movement during scanning. No standardized institutional sedation protocol was in place during the study period.

Sedation depth was assessed using the Ramsay Sedation Scale. Adequate sedation was defined as a Ramsay score of 4–5, with stable vital signs and absence of purposeful movement during image acquisition.

If the patient moved during scanning, rescue doses of ketamine 2 mg/kg intravenously were given in both groups. The duration required to complete the scan was recorded. The number of repeated sequences taken to complete them were noted.

Standard monitoring during MRI included heart rate, respiratory rate, and peripheral oxygen saturation, when available.

Data collection and outcome measures

Demographic and clinical variables included age, sex, body weight, ASA classification, MRI indication/site, scan duration, sedative dose, and route of administration. Sedation-related outcomes included: 1. sedation onset time: time from drug administration to achievement of adequate sedation; 2. sedation success: completion of MRI without need for additional sedative dosing or significant patient movement; 3. recovery time: time from completion of MRI to return to baseline consciousness. The patient's recovery was assessed using the Modified Aldrete Score (MAS). The time taken to achieve MAS $\geq$ 9 or more after the end of the procedure was noted.; 4. adverse events: predefined as any occurrence of agitation, respiratory depression ($\text{SpO}_2 < 92\%$ or need for airway intervention), tachycardia, nausea/vomiting, or hypersalivation. MRI scan outcomes includes: 1. first-pass success: completion of MRI without interruption; 2. interrupted scan: temporary interruption requiring reassurance or repositioning; 3. scan failure: inability to complete MRI requiring rescheduling; 4. Poor imaging quality as judged by the same radiologist: A radiologist who was blinded to the group allocation rated the quality of sedation based on image quality; "poor" meant blurred image in 4 or more sequences; 5. overall scan success: completion of MRI regardless of interruptions.

Statistical Analysis

Statistical analysis was performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean $\pm$ standard deviation (SD) or median (interquartile range [IQR]) depending on data distribution, which was assessed using the Shapiro-Wilk test. Categorical variables were expressed as counts and percentages. Between-group comparisons were performed using the independent samples t-test or Mann-Whitney U test for continuous variables, and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Given the observational nature of the study and potential baseline imbalances between groups, exploratory analyses were performed to assess the association between sedative type and primary outcomes. A two-sided P-value < 0.05 was considered statistically significant.

Results

Baseline characteristics and sedation status

A total of 56 pediatric patients were included in the analysis, with 20 patients in the ketamine group and 36 in the diazepam group. There were no statistically significant differences between the two groups in terms of age, sex, body weight, ASA physical status, MRI examination site, or scan duration (all $P > 0.05$). The two groups differed significantly in both medication dosage and route of administration ($P < 0.05$).

Comparison of sedation efficacy

The ketamine group demonstrated a shorter sedation onset time (1.6 ± 0.39 vs 3.4 ± 0.45) and a higher sedation success rate (95% vs 67%) compared with the diazepam group (both $P < 0.05$). Recovery time was longer in the ketamine group than in the diazepam group (58.6 ± 7.14 vs 43.1 ± 5.04 , $P < 0.05$). The overall incidence of adverse events was similar in the ketamine group compared with the diazepam group (20%

vs 22% , $P > 0.05$). Reported adverse events in both groups included agitation and nausea/vomiting. No severe adverse events, such as clinically significant respiratory depression, tachycardia, hypotension, or anaphylaxis, were observed.

Comparison of MRI Scan Success Rate

The ketamine group had higher first-pass MRI completion rates (95% vs 58%) and overall scan success rates (100% vs 69%) compared with the diazepam group (both $P < 0.05$). Additionally, the rates of scan interruption requiring intervention and scan failure requiring rescheduling were similar in both groups ($P > 0.05$). In contrast, the incidence of poor imaging quality, as judged by the radiographer, was lower in the ketamine group ($P < 0.05$).

Discussion

Effective sedation is essential for successful MRI in pediatric patients, particularly in young children who are unable to remain motionless during image acquisition^{2,10}.

This challenge is further amplified in low-resource settings, where access to advanced anesthetic agents and monitoring equipment is limited. In such contexts, the selection of sedative agents is often constrained by availability, cost, and feasibility of administration. At Mzuzu Central Hospital, ketamine and diazepam represent the most commonly used agents for pediatric MRI sedation, yet comparative data regarding their clinical performance have been lacking.

The results show that there were no statistically significant differences between the two groups about the Baseline characteristics. In addition, detailed behavioral and neurological characteristics were not consistently documented because of the retrospective nature of this study and therefore could not be comprehensively analyzed. These factors may influence children's responses to sedation and represent potential sources of residual confounding. Nevertheless, as shown in Table 1, there was no significant difference between the two groups in the proportion of children undergoing brain MRI, suggesting that the prevalence of underlying neurological conditions was broadly comparable between the study cohorts. Although this variable cannot fully represent behavioral status or neurological characteristics, it provides some indirect support for the baseline comparability of the two groups. Future prospective studies should incorporate standardized assessments of behavioral and neurological characteristics to improve baseline characterization and further reduce potential confounding.

Although there were no statistically significant differences in baseline characteristics between the two groups, substantial differences existed in the drug dosages and routes of administration. These choices were made after comprehensively considering the safer routes of administration and onset times of both ketamine and diazepam. In a resource-limited setting with restricted monitoring capabilities, intramuscular administration of ketamine and intravenous administration of diazepam were selected as they could provide rapid onset of action while maintaining a safer administration profile¹¹.

In the present study, ketamine was associated with a shorter onset time and a higher sedation success rate compared with diazepam. These findings are consistent with the known pharmacodynamic profile of ketamine, which provides rapid onset of dissociative sedation, analgesia, and amnesia, while largely preserving spontaneous respiration and airway reflexes^{12,13,14,15}.

In contrast, benzodiazepines such as diazepam typically produce lighter and less predictable sedation, which may be insufficient for procedures requiring prolonged immobility, such as MRI¹⁶.

An important limitation of the present study is that ketamine and diazepam were administered via different routes (intramuscular versus intravenous). Variations in drug absorption, onset of action, and pharmacokinetic characteristics associated with these administration routes may have influenced sedation success, recovery time, and the incidence of adverse events. Consequently, some of the observed differences should not be interpreted as being solely attributable to the intrinsic pharmacological properties of the two sedative agents. Future prospective studies using comparable administration routes or standardized sedation protocols are needed to minimize this potential confounding effect.

Regarding MRI sedation success, we evaluated four distinct outcome measures: first-pass MRI success, scan failure/rescheduling, image quality, and overall MRI completion. Each of these represents a different clinical endpoint rather than a single composite outcome. First-pass MRI success reflects the effectiveness of the initial sedation strategy, whereas overall MRI completion reflects the effectiveness of the entire clinical management pathway. Scan failure/rescheduling and image quality provide complementary information regarding procedural performance and diagnostic adequacy.

The higher MRI completion rates observed in the ketamine group are likely attributable to its ability to achieve a more reliable depth of sedation^{17,18}. Inadequate sedation, as may occur with diazepam, can result in patient movement, scan interruption, and the need for repeated imaging, thereby reducing procedural efficiency and potentially increasing cumulative drug exposure^{16,19}.

It should be noted that rescue ketamine was administered only after failure of the initial sedation regimen and was therefore considered a secondary intervention rather than part of the primary treatment strategy. Accordingly, first-pass MRI success was used to evaluate the effectiveness of the initial sedative regimen, while overall MRI completion reflected the effectiveness of the complete clinical management pathway, including the use of rescue sedation when necessary. This distinction should be considered when interpreting the comparative efficacy of the two initial sedation strategies.

Interestingly, the incidence of adverse events was similar between the both groups in this study. This finding differs from some reports in higher-resource settings, where ketamine has been associated with increased rates of hypersalivation or emergence reactions^{20,21}. Several factors may explain this discrepancy. First, the relatively conservative dosing strategy and careful patient selection in our cohort may have contributed to a favorable safety profile. Second, differences in monitoring practices and definitions of adverse events may limit direct comparability across studies. Therefore, these findings should be interpreted with caution. Importantly, the results of this study should be interpreted within the context of a resource-limited healthcare environment. In many centers across Malawi and similar settings, access to agents such as propofol or dexmedetomidine is restricted, and continuous infusion techniques or advanced airway management may not be readily available. Under these conditions, ketamine offers several practical advantages, including multiple routes

of administration, minimal requirement for infusion devices, and a relatively stable hemodynamic profile, making it a pragmatic option for pediatric MRI sedation.

The current study indicates that recovery time was longer in the ketamine group than in the diazepam group. The longer recovery time associated with ketamine may have practical implications in busy MRI services by prolonging post-procedural observation and reducing patient throughput. However, in many resource-limited hospitals in Malawi, MRI examinations are scheduled in relatively small numbers each day, and patient safety and successful image acquisition are generally prioritized over rapid turnover. Therefore, although recovery time should be considered when selecting a sedative agent, the higher first-pass MRI success and lower requirement for rescue sedation observed with ketamine may outweigh the disadvantage of prolonged recovery in this setting.

This study has several limitations. First, its retrospective design introduces the potential for selection bias and unmeasured confounding, as the choice of sedative agent was not randomized. Second, the sample size was relatively small, which may limit statistical power and the detection of less frequent adverse events. Third, this was a single-center study, which may affect the generalizability of the findings to other institutions with different patient populations or clinical practices. Fourthly, this study excluded children with an ASA physical status $\geq$ III, hemodynamic instability, or severe cardiopulmonary dysfunction. Therefore, the findings primarily apply to low-risk pediatric patients undergoing routine MRI sedation and should not be directly generalized to children requiring more complex anesthetic management. In addition, physiological monitoring during MRI examinations was limited by the availability of MRI-compatible monitoring equipment. Although all patients were continuously observed by an anesthesiologist, with oxygen saturation and heart rate monitored continuously. Respiratory status was assessed using MRI respiratory gating together with direct clinical observation. We acknowledge that the limited availability of MRI-compatible monitoring equipment represents a limitation of this study and may have affected the consistency of safety monitoring and adverse event detection. Finally, only two sedative agents were evaluated, and therefore the results cannot be extrapolated to other commonly used agents in pediatric sedation. Despite these limitations, this study provides real-world evidence reflecting current sedation practices for pediatric MRI in a low-resource setting. The findings may help inform context-specific clinical decision-making and contribute to the development of standardized sedation protocols in similar environments.

This study provides a solid foundation for future research on pediatric MRI sedation. Building upon these findings, future prospective, randomized, double-blind studies are warranted to further validate the present results. In addition, future research could be expanded beyond northern Malawi to include Kamuzu Central Hospital in Lilongwe and Queen Elizabeth Central Hospital in Blantyre, enabling multicenter studies across different regions of Malawi. Such multicenter investigations would strengthen the evidence base, improve the robustness and generalizability of the findings, and facilitate the development of standardized pediatric MRI sedation protocols.

Conclusion

In this retrospective study, ketamine was associated with faster onset of sedation, higher sedation success rates, and improved MRI completion rates compared with diazepam in pediatric patients. In resource-limited settings, ketamine may represent a practical and effective option for pediatric MRI sedation. However, its use should be accompanied by appropriate monitoring and clinical oversight to ensure patient safety. Further prospective, multi-center studies are warranted to validate these findings and to optimize sedation strategies for pediatric imaging in low-resource environments.

References

1. Kim JY, Kim KN, Kim DW, Lim HJ, Lee BS. Effects of dexmedetomidine sedation for magnetic resonance imaging in children: a systematic review and meta-analysis. *J Anesth*. 2021;35(4):525-535.
2. Ruess L, O'Connor SC, Mikita CP, Creamer KM. Sedation for pediatric diagnostic imaging: use of pediatric and nursing resources as an alternative to a radiology department sedation team. *Pediatr Radiol*. 2002;32(7):505-510.
3. Schulte-Uentrop L, Goepfert MS. Anaesthesia or sedation for MRI in children. *Curr Opin Anaesthesiol*. 2010;23(4):513-517. doi:10.1097/ACO.0b013e32833bb524.
4. Tang Y, Meng J, Zhang X, Li J, Zhou Q. Comparison of dexmedetomidine with propofol as sedatives for pediatric patients undergoing magnetic resonance imaging: A meta-analysis of randomized controlled trials with trial sequential analysis. *Exp Ther Med*. 2019;18(3):1775-1785.
5. Nagoshi M, Reddy S, Bell M, et al. Low-dose dexmedetomidine as an adjuvant to propofol infusion for children in MRI: A double-cohort study. *Paediatr Anaesth*. 2018;28(7):639-646.
6. Ahmed SS, Unland TL, Slaven JE, Nitu ME. Dexmedetomidine versus Propofol: Is One Better Than the Other for MRI Sedation in Children?. *J Pediatr Intensive Care*. 2017;6(2):117-122.
7. Simonini A, Brogi E, Cascella M, Vittori A. Advantages of ketamine in pediatric anesthesia. *Open Med (Wars)*. 2022;17(1):1134-1147.
8. Geetha K, Padhy S, Karishma K. Comparison of single-shot nebuliser protocol between dexmedetomidine and ketamine in children undergoing magnetic resonance imaging. *J Perioper Pract*. 2022;32(12):346-353.
9. Gyanesh P, Haldar R, Srivastava D, Agrawal PM, Tiwari AK, Singh PK. Comparison between intranasal dexmedetomidine and intranasal ketamine as premedication for procedural sedation in children undergoing MRI: a double-blind, randomized, placebo-controlled trial. *J Anesth*. 2014;28(1):12-18.
10. Cravero JP, Blike GT, Beach M, Gallagher SM, Hertzog JH, Havidich JE, et al. Incidence and nature of adverse events during pediatric sedation/anesthesia for procedures outside the operating room. *Pediatrics*. 2006;118(3):1087-1096.
11. Jung SM. Drug selection for sedation and general anesthesia in children undergoing ambulatory magnetic resonance imaging. *Yeungnam Univ J Med*. 2020 Jul;37(3):159-168. doi: 10.12701/yujm.2020.00171.
12. Jain A, Kaushal A, Trivedi S, Thaware P, Chaudhary N, Jain S. Intramuscular ketamine provides better sedation and scan conditions in children undergoing magnetic resonance imaging: A single-blinded observational study. *J Neurosci Rural Pract*. 2023;14(3):477-481.
13. Jung SM. Drug selection for sedation and general anesthesia in children undergoing ambulatory magnetic resonance imaging. *Yeungnam Univ J Med*. 2020 Jul;37(3):159-168.
14. Kim JG, Lee HB, Jeon SB. Combination of dexmedetomidine and ketamine for magnetic resonance imaging sedation. *Front Neurol*. 2019;10:416. doi: 10.3389/fneur.2019.00416
15. Sedation for magnetic resonance imaging using propofol with or without ketamine at induction in pediatrics: a prospective randomized double-blinded study. *Paediatr Anaesth*. 2018;28:264-274.
16. Malviya S, Voepel-Lewis T, Eldevik OP, Rockwell DT, Wong JH, Tait AR. Sedation and general anaesthesia in children undergoing MRI and CT: adverse events and outcomes. *Br J Anaesth*. 2000; 84(6): 743-748. doi:10.1093/oxford journals. Bja .a013586.
17. Hu Y, Xu W, Cao F. A meta-analysis of randomized controlled trials: combination of ketamine and propofol versus ketamine alone for procedural sedation and analgesia in children. *Intern Emerg Med*. 2019;14(7):1159-1165.
18. Sahyoun C, Cantais A, Gervais A, Bressan S, Lollgen R, Krauss B, et al. Pediatric procedural sedation and analgesia in the emergency department: Surveying the current European practice. *Eur J Pediatr*. 2021;180:1799-813.
19. Severe and prolonged sedation in five neonates due to persistence of active diazepam metabolites. *Eur J Pediatr*. 2001;160(6):378-381. doi: 10.1007/s004310100745.
20. Belloio MF, Gilani WI, Barrionuevo P, Murad MH, Erwin PJ, Anderson JR, et al. Incidence of adverse events in pediatric procedural sedation in the emergency department: a systematic review and meta-analysis. *BMJ*. 2016;354:i3453.
21. Grunwell JR, Travers C, McCracken C, Scherrer PD, Stormorken A, Chumtazi CE, et al. Procedural sedation outside of the operating room using ketamine in children: a report from the Pediatric Sedation Research Consortium. *Anesth Analg*. 2016;122(6):1874-1880.