Research Article / Araştırma Makalesi

Sedation in Pediatric Patients Undergoing Magnetic Resonance Imaging: An Observational Comparison

Manyetik Rezonans Görüntülemesi Geçiren Pediatrik Hastalarda Sedasyon: Gözlemsel Bir Karşılaştırma

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Abstract

Background: This study aimed to compare sedation methods in pediatric patients undergoing magnetic resonance imaging (MRI) using three different anesthetic agents (sevoflurane, thiopental, and propofol) regarding safety, efficacy, time management, and side effects.
Materials and Methods: An observational study was conducted with 126 pediatric patients divided into three groups, each receiving one of the three sedative agents: Group S (n = 43), Group T (n = 41), and Group P (n = 42). Patients in Group S received induction with 8% sevoflurane, Group T received 5 mg kg^{1} of thiopental intravenously, and Group P received 2 mg kg^{-1} of propofol intravenously, followed by maintenance via infusion.
Results: The mean age was 37.3 ± 2 months. Cranial MRI was most frequently requested (64.5%). Group P had higher desaturation (p = 0.029) and respiratory depression (p = 0.008) rates. Group T had the shortest induction time (p <0.001), while Group S showed the fastest wake-up times (p = 0.002; p = 0.001).
Conclusions: Sevoflurane is distinguished by its rapid emergence from sedation and low incidence of side effects. Thiopental has a quick induction time, whereas propofol is associated with minimal agitation but higher respiratory complications. These findings can guide clinicians in selecting the most appropriate sedation method for pediatric MRI.

Keywords: Deep sedation**,** Magnetic resonance imaging, Propofol, Sevoflurane, Thiopental

Öz

Amaç: Bu çalışma, manyetik rezonans görüntüleme (MRG) geçiren pediatrik hastalarda üç farklı anestezik ajan (sevofluran, tiyopental ve propofol) kullanılarak yapılan sedasyon yöntemlerini güvenlik, etkinlik, zaman yönetimi ve yan etkiler açısından karşılaştırmayı amaçladı.
Materyal ve Metod: Gözlemsel bir çalışma 126 pediatrik hasta ile gerçekleştirildi ve hastalar üç gruba ayrıldı; her grup üç sedatif ajanından birini aldı: Grup S (n = 43), Grup T (n = 41) ve Grup P (n = 42). Grup S'deki hastalara %8 sevofluran ile indüksiyon, Grup T'deki hastalara 5 mg kg^{-1} tiyopental intravenöz yolla, Grup P'deki hastalara ise 2 mg kg^{-1} propofol intravenöz yolla indüksiyon yapıldı ve ardından infüzyon yoluyla idame sağlandı.
Bulgular: Ortalama yaş 37,3 ± 2 ay olarak belirlendi. En sık istenen MRG türü kranial MRG idi (%64,5). Grup P'de desatürasyon (p = 0,029) ve solunum depresyonu (p = 0,008) oranları daha yüksekti. Grup T en kısa indüksiyon süresine sahipti (p < 0,001), Grup S ise en hızlı uyanma sürelerini gösterdi (p = 0,002; p = 0,001).
Sonuç: Sevofluran, sedasyondan hızlı derlenme ve düşük yan etki insidansı ile öne çıkmaktadır. Tiyopental, hızlı bir indüksiyon süresine sahipken, propofol minimal ajitasyon ancak daha yüksek solunum komplikasyonları ile ilişkilidir. Bu bulgular, pediatrik MRG için en uygun sedasyon yöntemini seçmede klinisyenlere rehberlik edebilir.

Anahtar Kelimeler: Derin sedasyon, Manyetik rezonans görüntüleme, Propofol, Sevofluran, Tiyopental

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Introduction

Magnetic resonance imaging (MRI) is a commonly used imaging technique due to its safety and non-ionizing radiation properties (1). In pediatric patients, ensuring immobility is crucial for obtaining clear images. Since MRI procedures often last 10 min or more, sedation is frequently required, particularly in children aged 1 to 8 years. The sedation used during MRI is generally at the "deep sedation" level, which is similar to general anesthesia (2). Deep sedation suppresses consciousness and protective reflexes, and patients may only respond to painful or repeated stimuli. The primary risks associated with deep sedation include respiratory depression and aspiration, which may necessitate airway management. Cardiovascular function, however, is generally preserved. Proper monitoring of vital signs is critical when determining the sedative agents or anesthetics to use (3).

During MRI sedation, oxygen saturation can decrease, so capnography is essential to detect early signs of apnea by measuring end-tidal carbon dioxide levels. Chest plethysmography belts are also used to monitor chest movement, ensuring regular respiratory monitoring (5). These MRI-compatible devices provide continuous respiratory data and help detect apnea in real-time (6).

Dexmedetomidine is commonly used for pediatric MRI in patients without cardiac risk, whereas propofol is more effective when administered by anesthesiologists or pediatric critical care specialists (5,7). Small doses of ketamine or nalbuphine, given toward the end of sedation with sevoflurane, have been shown to reduce emergence agitation without delaying recovery (8). Buccal dexmedetomidine, with or without oral midazolam, has been found to provide adequate sedation for MRI with few side effects, though the failure rate suggests dose adjustments may be necessary (9). Deep sedation is frequently required to ensure immobility during MRI in pediatric patients; however, the safety and efficacy profiles of the sedative agents used for this purpose vary. Therefore, the primary objective of this study was to compare the safety of sevoflurane, thiopental, and propofol in terms of respiratory depression and oxygen desaturation (SpO_2 <%92) in pediatric patients undergoing MRI. Secondary objectives included the evaluation of induction and recovery times, hemodynamic and airway safety, sedation success rates, agitation scores, requirement for additional dosing, and incidence of adverse events.

Materials and Methods

This cross-sectional observational study was conducted between September 2021 and December 2022 at university hospital, in accordance with the Declaration of Helsinki, and was approved by the local ethics committee (decision number: 2021/30-02, 14.09.2021). Pediatric MRI sedation was performed biweekly, with different sedative agents administered on alternating days. Blinding was not implemented to allow the anesthesia team and patients to be aware of the medications and potential side effects.

Patient Selection

The sample size of 75 patients was calculated with a 0.47 effect size, 80% power, and a 5% error margin using G-Power 3.1 software (Heinrich-Heine-Universität Düsseldorf, Germany), based on peripheral oxygen saturation values from the study by Oğurlu et al., which investigated sevoflurane concentrations for MRI sedation in pediatric patients (10). While the Oğurlu et al. study utilized a baseline SpO_2 value of 95%, our study employed a 92% threshold for defining desaturation, in accordance with clinical observations in our patient population. This distinction was considered during the sample size calculation. The sample size calculation was based on a one-way ANOVA comparing the three sedation groups (sevoflurane, thiopental, and propofol), using the incidence of desaturation as the primary endpoint. However, to increase the reliability of the results, the sample size was increased to 126 patients with the approval of the institutional ethics committee. This adjustment was made to reduce heterogeneity and enhance the robustness of subgroup analyses. The study was approved as an observational, cross-sectional study. Patients were recruited over 12 months based on predefined inclusion and exclusion criteria. Patients were by administering a different sedative drug each MRI day. The 126 patients were divided into three groups: Group S (sevoflurane, n = 43), Group T (thiopental, n = 41), and Group P (propofol, n = 42).

Children aged 1 month to 12 years with American Society of Anesthesiologists (ASA) scores of I–III undergoing elective MRI under sedation were included. Exclusion criteria included patients <1 month or >12 years, ASA score IV, Mallampati class IV, respiratory infections, craniofacial anomalies, non-fasting status, ıntensive care unit (ICU) admission, trauma-related imaging, severe cardiopulmonary disease, sleep apnea, imaging >60 min, sedation with non-study drugs, and those undergoing general anesthesia with intubation or LMA insertion.

Anesthesia Procedures

Informed consent was obtained from the parents, and the patients were escorted to the MRI unit (Philips Ingenia 1.5 Tesla 2015, Netherlands). To standardize the procedures and practices prior to drug administration in the MRI room, all patients underwent a uniform preparation protocol. All steps were performed in the same sequence and by the same anesthesia team for all patients to maintain consistency. Upon arrival at the MRI unit, patients were monitored using pulse oximetry, noninvasive blood pressure cuffs, and spirometry belts for chest movements. To minimize the potential discomfort caused by MRI-related noise, all patients were provided with noise-canceling headphones. These measures were implemented in accordance with routine institutional practice to reduce auditory stimulation and prevent noise-induced arousal, which can interfere with sedation levels. Preoxygenation with 100% oxygen at 5 L/min was per-

formed for all patients for 3 minutes. Additionally, intravenous access was secured, and atropine (10 µg/kg) was administered to reduce secretions and prevent bradycardia. The induction time (seconds) was recorded as the time elapsed from the patient's entry into the MRI room, including these standardized preparation steps, until the start of imaging. Patients were randomly assigned to sedation groups, with the same drug used for all procedures on a given day. The sedation drug doses were determined based on our institutional clinical protocols, supported by a comprehensive literature review and a pilot study conducted to achieve a target Ramsey sedation score of 5–6. This approach ensured consistent sedation levels while optimizing imaging quality during MRI.

Patients in Group S were induced with 8% sevoflurane (Sevorane®, AbbVie, Türkiye) at a fresh gas flow of 5 L min^{-1} of oxygen, targeting a deep sedation level of Ramsey 5–6. Once the desired sedation was achieved, the sevoflurane dose was reduced to 1.5% minimum alveolar concentration (MAC), and if movement occurred during MRI, the concentration was increased to 2% MAC. Sevoflurane was discontinued 3 min before the procedure ended.

In Group T, thiopental sodium (Pentothal Sodium®, IE, Türkiye) was administered intravenously at a dose of 5 mg kg^{-1}. If movement was observed, an additional 1 mg kg^{-1} was given, with oxygen support at 5 L min^{-1} via nasal cannula. After 15 min, further doses of 3 mg kg^{-1} were administered every 10 min as required.

In Group P, patients were induced with 2 mg kg^{-1} propofol (Propofol-PF® 1%, Polifarma, Türkiye) followed by a maintenance infusion at a rate of 150 µg kg^{-1} min^{-1} using an infusion pump (Medbar, İzmir). If movement occurred, 0.5 mg kg^{-1} propofol was added or the infusion rate was increased to 200 µg kg^{-1} min^{-1}. Oxygen support was provided at 5 L min^{-1} via nasal cannula, and propofol was discontinued 3 min before the procedure ended.

Baseline peripheral oxygen saturation values were recorded after the completion of anesthesia induction, rather than during the awake state. This approach was chosen to assess the effects of different sedation methods on the initial and final saturation values. During MRI, end-tidal carbondioxide, heart rate, oxygen saturation, chest movements (monitored via belt plethysmography), and respiratory rate were recorded every 5 min. If spontaneous breathing did not resume, options such as laryngeal mask airway (LMA) insertion or endotracheal intubation were considered. Time metrics, including "induction time" (entry into MRI room until imaging start), "wake-up time" (time to spontaneous response), and “total procedure time”, were recorded. The total amount and dose of anesthetic agents administered, the type of MRI and use of contrast, were noted. Airway-related events during induction and MRI were scored (Figure 1 and 2). Sedation was deemed 'successful' if imaging was acceptable to the radiologist and adequate airway safety and sedation were achieved. In the recovery room, airway safety scores (Figure 3), ‘recovery status (modified Aldrete score)’ (Figure 4), 'recovery time (s)', and the 'patient calmness/agitation status at 5-10 min (Weldon agitation scale)' were recorded (Figure 5) (11). Recovery was considered complete when the modified Aldrete score reached 9 or higher. The Weldon agitation scale used in this study is an observer-rated scale commonly applied in pediatric anesthesia recovery. Any adverse events from induction to discharge were documented, including stridor, snoring, hiccup, cough, dizziness, desaturation, need for jaw thrust, prolonged desaturation, oropharyngeal tube placement, procedure failure, inadequate induction, severe agitation (agitation score average of 3 or 4), movement during MRI and sequence repetition (each movement counted as an adverse event), vomiting, micturition/defecation, prolonged sedation, unexpected hospital admission or ICU need, severe hypotension, bradycardia, and nystagmus.

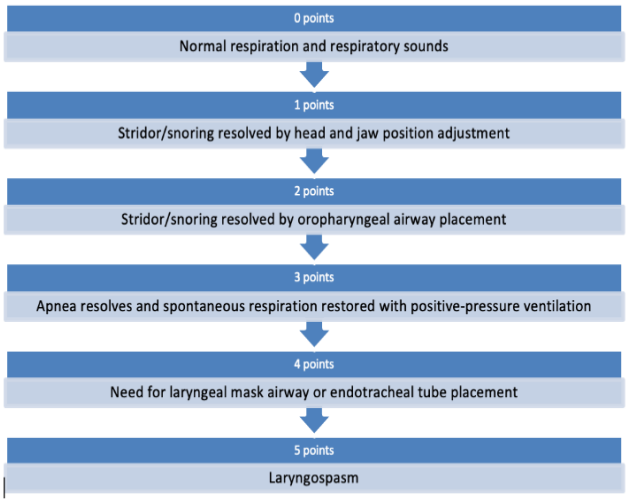

Figure 1. Post-Induction Airway Safety

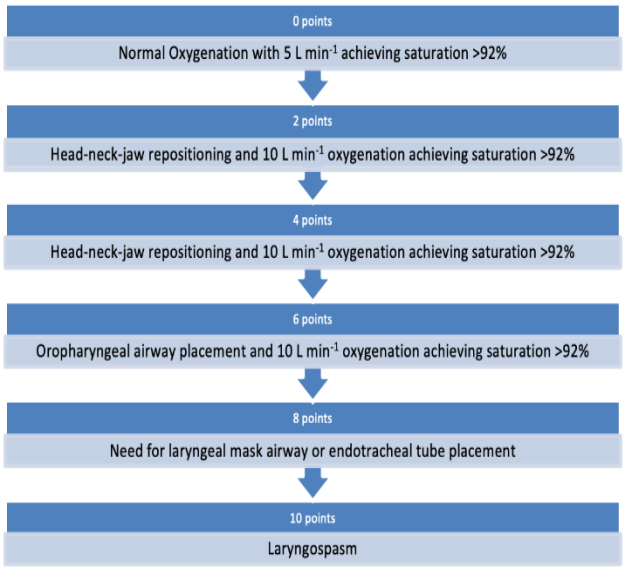

Figure 2. Airway safety during the MRI procedure

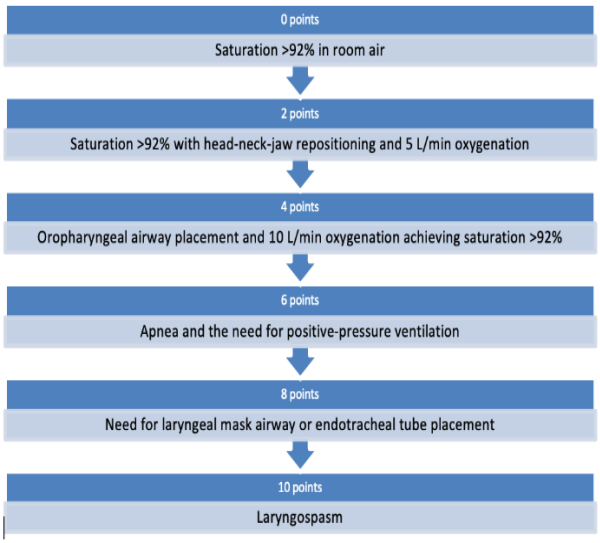

Figure 3. Airway Safety in the Recovery Room

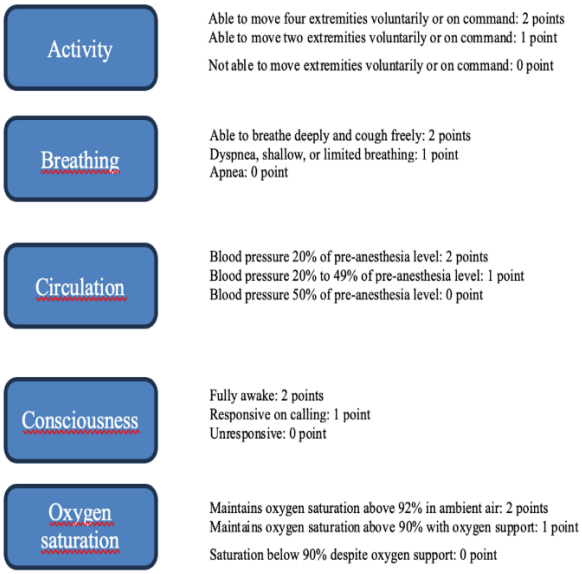

Figure 4. Modified Aldrete Score System

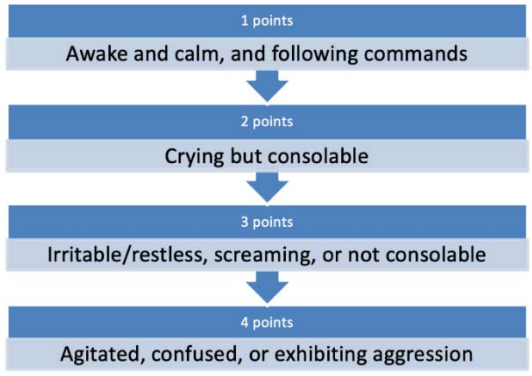

Figure 5. Weldon Agitation Score After Anesthesia

Statistical Analysis

The required sample size was calculated using G-Power 3.1 software (Heinrich-Heine-Universität Düsseldorf, Germany) based on the primary outcome—incidence of desaturation (SpO_2 < 92%)—across three sedation groups using one-way ANOVA. An effect size (f) of 0.47, α = 0.05, and power of 80% were used, yielding a minimum sample size of 75. To allow for subgroup analyses and improve statistical power, this was increased to 126 with ethics approval.

Normality of distribution was assessed using the Shapiro–Wilk test due to the small sample sizes in each group (n<50). To further support normality, we also evaluated mean-median closeness, skewness, kurtosis, and used histograms and Q–Q plots.

For categorical variables with expected cell frequencies <5, Fisher's Exact Test was applied; otherwise, Pearson's Chi-square test was used. Continuous variables were compared using ANOVA (normal distribution) or Kruskal–Wallis test (non-normal). Tukey's HSD test was used as a post-hoc method. Statistical significance was set at p<0.05. SPSS version 22 was used for all analyses.

Results

This study included 126 patients who were randomly assigned to three groups: Group S (sevoflurane, n = 43), Group T (thiopental, n = 41), and Group P (propofol, n = 42). Of the participants, 58.7% were male, and 41.3% were female. The mean age was 37.3 ± 2 months, and the average weight was 14.0 ± 8 kg. There were no significant differences among the groups in terms of age, gender, or ASA scores. MRI requests were predominantly for neurological indications and cranial imaging (Table 1).

Significant differences were noted in the desaturation status among the groups. Group P exhibited significantly higher desaturation rates than the other groups (p =0.029). Group P also had lower oxygen saturation levels, both initially and after completing the MRI, with statistically significant differences compared to Groups S and T (p = 0.001, p = 0.004, p = 0.002) (Table 2). Agitation scores, as measured post-anesthesia, were significantly higher in Group S compared to Group P (p = 0.037).

No significant differences in heart rate, respiratory rate, or blood pressure changes were found between the groups during the imaging procedure (p = 0.677, p = 0.38, respectively). However, hypotension was significantly more common in Group T compared to Group S (p = 0.018, p = 0.041) (Table 2).

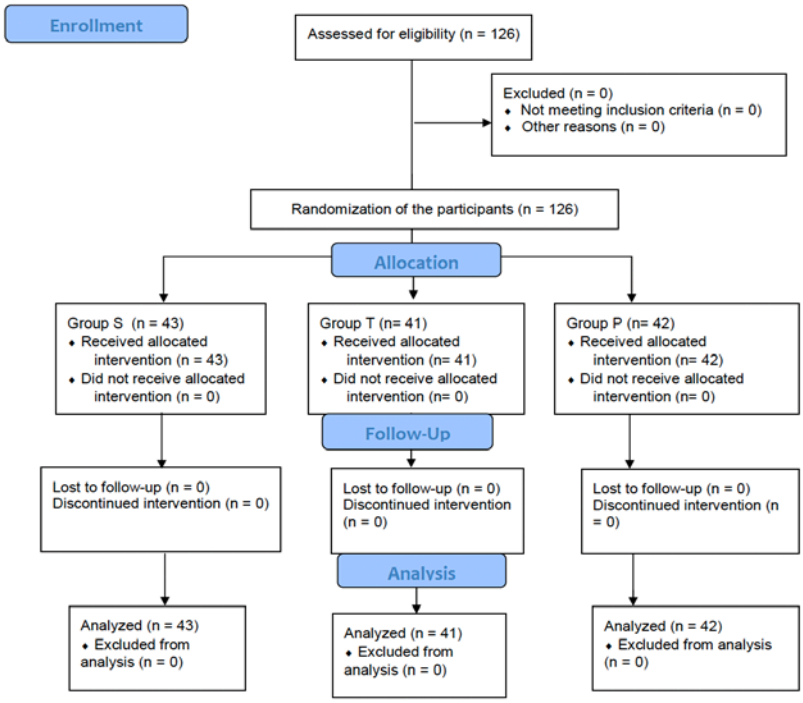

Figure 6. Consort diagram showing patient recruitment

Table 1. Distribution of age, age category, and ASA scores across the groups

		Sevoflurane		Thiopental		Propofol		p
Age (month), (n, %)		31.29 ± 20.63		43.85 ± 29.32		36.93 ± 32.18		0.152[x]
Age category, (n, %)	**≤12 months**	10	23.3	5	12.2	9	21.4	0.387[y]
	>12 months	33	76.7	36	87.8	33	78.6	
ASA scores, (n, %)	**ASA 1**	26	60.5	22	53.7	23	54.8	0.950[y]
	ASA 2	15	34.9	16	39.0	17	40.5	
	ASA 3	2	4.7	3	7.3	2	4.8	

*[x] Kruskal–Wallis analysis, [y] Chi-square/Fisher's Exact Test analysis. *p < 0.05 indicates significant difference. ASA: American Society of Anesthesiologists.*

Table 2. Changes in vital signs and agitation scores across groups

		Sevoflurane		Thiopental		Propofol		p
Desaturation; (n,%)	**Yes**	2	4.7 [a,b]	1	2.4[a]	8	19.0[b]	**0.029[x]***
	No	41	95.3	40	97.6	34	81.0	
Baseline saturation, (Mean±SD)		97.02 ± 2.02[a]		97.61 ± 1.76[a]		95.60 ± 2.80[b]		**0.001[y]***
Final saturation, (Mean±SD)		96.35 ± 2.25[a,b]		97.34 ± 2.31[a]		95.40 ± 3.34[b]		**0.004[y]***
Average mean saturation, (Mean±SD)		96.69 ± 1.99 [a,b]		97.48 ± 1.77[a]		95.50 ± 2.84[b]		**0.002[y]***
Change in pulse rate, (Mean±SD)		0.30 ± 17.99		-4.34 ± 18.10		0.45 ± 16.33		0.677[x]
Change in respiratory rate, (Mean±SD)		-0.30 ± 4.27		-1.46 ± 4.01		-0.55 ± 3.40		0.638[y]
Change in systolic BP (mmHg), (Mean±SD)		-2.33 ± 16.38[a]		-9.27 ± 10.87[b]		-7.00 ± 12.01[a,b]		**0.018[y]***
Change in diastolic BP (mmHg), (Mean±SD)		-3.33 ± 11.13[a]		-9.56 ± 9.66[b]		-4.69 ±9.87[a,b]		**0.041[y]***
Agitation score, (Mean±SD)		1.45 ±0.63[a]		1.28 ±0.51[a,b]		1.18 ±0.45[b]		**0.037[y]***

*[x]Chi-square /Fisher's Exact Test analysis, [y]Kruskal-Wallis analysis. *p < 0.05, a statistically significant difference. [a,b] The group responsible for the difference. BP; Blood Pressure, SD; Standard Deviation.*

When evaluating airway safety scores post-induction, no significant difference was found among the groups (p = 0.935). However, during MRI, Group P showed significantly more frequent respiratory depression compared to Groups S and T (p = 0.008). Airway safety scores in the recovery room revealed no statistically significant differences among the groups (p = 0.368). Overall, Group P had more respiratory depression incidents than Group T, showing a significant difference between these two groups (p = 0.042) (Table 3). Induction times were significantly shorter in Group T (p <0.001), and Group S demonstrated shorter wake-up and recovery times compared to the other groups (p = 0.002, p = 0.001, respectively). There were no significant differences between the groups in terms of the total duration of the procedure (p = 0.067) (Table 3).

The overall success rate of the sedation procedures was 96.04%, with Group S achieving the highest success rate (97.7%). Group T and Group P had similar success rates (95.1% and 95.2%, respectively), with no significant differences between the groups (p = 0.742). Group P required significantly more additional doses during the procedure compared to Groups S and T (p <0.001). Group S did not require any additional doses during induction, while 12.2% of patients in Group T and 45.2% of patients in Group P required extra dosing (Table 3).

In terms of adverse events, there were no significant differences in the overall number of events among the three groups (p = 0.376). Group P had the highest number of respiratory-related adverse events (26 out of 32), and Group T had more movement-related adverse events (8 out of 25) compared to the other groups (Table 3).

Table 3. Comparison of sedation process and its success among groups

		Sevoflurane		Thiopental		Propofol		p
Airway safety, (Mean±SD)	**Post-induction**	0.30±0.60		0.24±0.49		0.33±0.65		0.935[x]
	During MRI	0.19 ±.73[a]		0.15±.53[a]		0.76±1.46[b]		0.008[y]*
	In the recovery room	0.00±0.00		0.00±0.00		0.05±0.31		0.368[x]
	Total	0.49 ±1.16 [a,b]		0.39 ±0.74[a]		1.14 ±2.14[b]		0.042[y]
Duration of MRI procedure (s), (Mean±SD)	**Duration of MRI**	778.26±314.78		1,019.63±543.04		930.95±531.64		0.067[x]
	Induction time	324.00±57.53[a]		221.71±77.88[b]		301.83±128.70[a]		<0.001[x]*
	Emergence time	99.47±99.35[a]		222.78±203.96[b]		195.12±149.77[b]		0.002*
	Recovery time	226.74±101.27[a]		396.10±287.06[b]		367.33±217.83[b]		0.001*
Sedation success (n; %)	**Successful**	42	97.7	39	95.1	40	95.2	0.742[z]
	Unsuccessful	1	2.3	2	4.9	2	4.8	
Need for additional doses (n; %)	**Yes**	0	0.0[a]	5	12.2[a]	19	45.2[b]	<0.001*
	No	43	100.0	36	87.8	23	54.8	
Movement during the MRI procedure	**Yes**	3	7.0	4	9.8	2	4.8	0.635[z]
	No	40	93.0	37	90.2	40	95.2	
Number of movements (Mean±SD)		1.00±0.00		1.75±0.96		1.50±0.71		0.456[y]
Number of sequences (Mean±SD)		1.33±0.58		3.00±1.63		2.00±-		0.330[y]
Adverse events/Number of patients (Mean±SD)		0.44±0.80		0.61±0.98		0.76±1.32		0.376[y]

*[x]Kruskal–Wallis analysis, [y]One-Way ANOVA, [z]Chi-square or Fisher's Exact Test analysis. *p < 0.05 indicates significant difference. [a,b]Group responsible for the difference. MRI; magnetic resonance imaging, SD; Standard Deviation.*

Discussion

This study compared the safety, efficacy, time management, and side effects of sevoflurane, thiopental, and propofol for MRI sedation in pediatric patients. Sevoflurane stands out with a high success rate, low incidence of side effects, shorter wake-up times, minimal respiratory complications, and hemodynamic stability. Therefore, it may be preferred in centers with the appropriate equipment for neonates and patients with compromised general condition. Thiopental is advantageous due to its low rate of respiratory complications, airway safety, and fast induction time. However, attention is needed for patients with compromised general condition due to the risks of hypotension and bradycardia. Propofol is beneficial for its anxiolytic effect, low incidence of agitation, and ability to ensure patient immobility, but has a

higher risk of respiratory complications.

Kol et al. reported 22.7% movement in the propofol group, while no movement was observed in the sevoflurane group (12). Malviya et al. found a 15% incidence of movement due to inadequate sedation in a study with 922 patients (13). Dalal et al. reported a 1.4% movement rate in the propofol group, 12.2% in the pentobarbital group, and 22.5% in the chloral hydrate group among infants aged 0–12 months (14). Machata et al. detected 2.2% movement in a propofol-based MRI sedation study and administered additional doses accordingly (15). The movement rates in our study were similar to those reported in the literature, with no significant differences between the three anesthetic agents. Propofol rapidly distributes into brain tissue due to its high lipophilicity and undergoes hepatic metabolism. This pharmacokinetic property can lead to an increased need for additional doses during prolonged MRI procedures, as observed in our study, where 45.2% of patients in the propofol group required supplemental doses (16).

In this study, propofol resulted in the lowest average saturation (95.5%), while thiopental provided the highest (97.4%). Machata et al. found an average saturation of 98% using low dose propofol for MRI sedation in 500 patients (15). Atalay et al. reported an average saturation of 98.8% with thiopental in 300 MRI patients (17). Bloomfield et al. found an average saturation of 96.7% with propofol, noting that initial saturations tend to be lower, followed by an increase (18). Briggs reported an average saturation of 97.9% with sevoflurane in 640 newborns and infants undergoing MRI (19). Our findings align with the literature, except for the lower average saturation with propofol, which may be due to the higher propofol dose used in our study.

This study did not find any significant difference in prolonged desaturation rates between propofol and other anesthetic agents. Machata et al. administered propofol sedation to 500 patients and reported that only 0.4% required mask ventilation (15). Dalal et al. encountered respiratory events requiring mask ventilation and LMA placement in 2.9% of patients sedated with propofol for MRI (14). Atalay et al. sedated 300 patients with thiopental for MRI and did not report any cases requiring advanced airway management (17). Briggs found severe respiratory depression in 0.3% of newborns and infants sedated with sevoflurane for MRI (19). In this study, no patient required mask ventilation, LMA placement, or intubation. However, prolonged desaturation can be considered a significant airway event. All serious airway events in our study were associated with propofol. We believe that using propofol without the supervision of anesthesiologists is a risk factor for MRI procedures requiring sedation.

In this study, induction time refers to the duration from the start of induction to the beginning of the imaging procedure. Thiopental had the fastest induction time (around 3.6 min) in our study. Üstün et al. found an induction time of 2.3 min in the ketamine-propofol group and 0.9 min in the thiopental group (20). Thiopental is known for its rapid onset, being highly soluble in blood and quickly crossing the blood-brain barrier (21). Our results are consistent with the literature, where numerous studies show that thiopental induces anesthesia rapidly. However, in contrast to our findings, another study comparing only propofol and thiopental reported significantly shorter induction and recovery times in the propofol group (22). This difference may be related to variations in dosing, sedation protocols, or study design.

Based on the findings of this study, it can be concluded that sevoflurane resulted in a shorter discharge time compared to the other two agents, considering wake-up and recovery periods. In previous studies, the sum of awakening and recovery times is referred to as total recovery or discharge time. In this study, the total recovery time with sevoflurane was approximately 5.3 minutes, which is notably shorter than previously reported values in the literature. For instance, earlier studies reported average recovery durations of around 11.5 to 15 minutes following sevoflurane sedation in pediatric MRI patients (23,24). This difference may be explained by the shorter imaging durations and the use of a lower maintenance dose of sevoflurane in our protocol compared to those studies.

Post-anesthesia delirium and agitation are important concerns. Trapani et al. reported that low dose propofol (1.2 mg kg-1) has anxiolytic effects (25). Michel and Constantin found that sevoflurane can cause agitation and delirium (26). In Machata et al.'s study, 500 pediatric patients underwent propofol-based sedation for MRI, with no cases of agitation reported (15). In our study, none of the patients experienced post-sedation delirium or agitation requiring medication. When comparing agitation scores across drug groups for all imaging procedures, sevoflurane had the highest incidence of agitation, while propofol had the lowest. This difference was significant. Although the effect of age on agitation scores was not analyzed separately, the age distribution was similar among the groups; therefore, we believe the potential influence of age on agitation outcomes is minimal.

In large-scale studies on pediatric MRI sedation, the incidence of bradycardia was reported to be low across different agents. For instance, with sevoflurane, bradycardia was observed in only 0.3% of cases (23), and no cases were reported in a 300-patient cohort receiving thiopental (17). In contrast, rectal administration of thiopental was associated with a 6.6% bradycardia rate, whereas none occurred with rectal midazolam (27). In our study, none of the patients experienced bradycardia, bradypnea, hypertension, or hypotension requiring intervention. The routine use of low-dose atropine may have prevented bradycardia. Additionally, atropine's anticholinergic effects may have reduced airway secretions, enhancing sedation safety.

Mongodi et al. reported a 6.2% overall complication rate with sevoflurane sedation, including airway obstruction, laryngospasm, central respiratory depression, bronchospasm, coughing fits, hypersalivation, inadequate sedation, hiccups, severe agitation, seizures, bradycardia, and prolonged sedation (23). In our study, propofol had the highest number of adverse events, with respiratory-related problems being the

most common across all three groups. These events reduced patient satisfaction and increased the complexity of sedation.

One of the limitations of our study was the necessity to use a drip set for propofol infusion due to the absence of an MRI-compatible infusion pump. It was challenging to accurately adjust the infusion rate using drip sets, especially considering the typically small veins in children.

Conclusion

In conclusion, sevoflurane, thiopental, and propofol are widely used anesthetic agents for pediatric MRI sedation, each with distinct advantages. Sevoflurane demonstrates a high success rate, fewer adverse events, and faster recovery times, making it ideal for situations where efficient patient turnover is critical. Thiopental provides excellent airway security with the lowest rate of respiratory complications, particularly beneficial in vulnerable patient populations. Propofol, while effective in reducing post-anesthetic agitation, poses a higher risk of respiratory-related issues. This study provides clinicians with practical insights into selecting the most appropriate anesthetic agent, emphasizing the need for tailored sedation strategies based on individual patient profiles and clinical settings.

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