

Timeliness of care and adverse event profile in children undergoing general anesthesia or sedation for MRI: An observational prospective cohort study

ABSTRACT

Background and Aims: Anaesthesia for children undergoing magnetic resonance imaging (MRI) ranges from moderate to deep sedation in order to facilitate uninterrupted completion of the scan. While various intravenous and inhalational techniques of anaesthesia have their own merits and demerits, there is a paucity of comparative literature between the two in children undergoing diagnostic MRI.

Materials and Methods: This prospective observational cohort study was conducted at the Radiology suite of a 2800-bedded tertiary care hospital, wherein 107 unpremedicated children between the ages of 6 months to 15 years received either sedation with propofol infusion (Group GSP, $n = 57$) or inhalational anaesthesia with a laryngeal mask airway (Group GAL, $n = 50$). Primary outcome measures included time to induction and time to recovery. Secondary outcomes comprised the incidence of respiratory and non-respiratory adverse events in the two groups.

Results: The median time to induction was significantly shorter in GSP than GAL [7.00 (IQR 5.0, 10.0) versus 10.00 minutes (IQR 8.8, 13.0), $P < 0.001$]; the incidence of desaturation [8 (16.0%) in GAL, 1 (1.8%) in GSP, $P = 0.012$], laryngospasm [11 (22.4%) in GAL, 1 (1.8%) in GSP, $P = 0.001$] and emergence delirium (5 (10%) in GAL, 0 in GSP, $P = 0.047$) were significantly greater in the GAL group. There was no difference in the time to emergence, nausea and vomiting or bradycardia between the two groups.

Conclusion: Sedation with propofol infusion during paediatric MRI scan offers a short turnover time and favourable adverse event profile when compared to inhalational anaesthesia with an LMA.

Key words: Anaesthesia recovery period; cohort analysis; general anaesthesia; inhalational anaesthesia; magnetic resonance imaging; propofol

Introduction

Diagnostic Magnetic Resonance Imaging (MRI) in children mandates moderate to deep sedation or general anaesthesia (GA) to ensure complete stillness for successful

completion of the scan. Most children presenting at the MRI suite have additional neurological co-morbidities, which predispose them to a higher risk of complications

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under sedation/anaesthesia.^[1] Therefore while confronting the challenges of paediatric anaesthesia and anaesthesia at a remote location, the objectives are to “provide optimal anaesthetic care to minimize psychological trauma and maximize the potential for amnesia, maximize patient safety, reduce adverse effects and curtail delays, while aiding the acquisition of the finest quality images”.^[2]

Many techniques of anaesthesia for performing MRI have been described in literature.^[3] The choice of the technique depends not only on patient factors such as co-morbidities, airway anatomy, current respiratory tract infection and fasting status, but also the proficiency of the anaesthesiologist with a particular technique. Each technique has its own advantages and disadvantages.^[4] There are several excellent reviews comparing sedation with general anaesthesia for children undergoing MRI study.^[3,5,6]

However, there is a dearth of studies comparing these techniques in developing countries, where the cost of the anaesthetic and want of trained personnel need to be weighed against the demand for an interruption-free scan to facilitate greater patient numbers. As the line between sedation and general anaesthesia draws thinner, it is important to distinguish between the pros and cons of each in resource-challenged settings with the ultimate objective of maximizing patient safety without compromising the scan quality. This study was designed to compare the 2 techniques used for anaesthesia in children undergoing MRI at our hospital which are propofol sedation and inhalational anaesthetic with a laryngeal mask airway (LMA).

Materials and Methods

Ethics and study design

This prospective, observational cohort study was carried out at the MRI suites of the Radiology Department at a 2800-bedded tertiary care hospital, after obtaining the approval of the hospital's independent Ethics Committee and Institutional Review Board, and in accordance with the Helsinki declaration of 1975, as revised in 2000. Informed written consent was obtained from the parents/legal guardians of the children included in the study.

Eligibility criteria

All children aged 6 months to 15 years who underwent elective MRI procedures under sedation or general anaesthesia from June to August 2018 were included in the study. Children who had anticipated difficult airway, contraindication to sedative agents (propofol, midazolam) or volatile agents (sevoflurane, isoflurane), who required

tracheal intubation or had an endotracheal tube *in situ*, children diagnosed with symptomatic gastroesophageal disease, sleep apnea (based on a positive sleep study), congenital heart disease, ASA physical status III or more, and those for whom written consent could not be obtained were excluded from the study.

Data collection

On the morning of the MRI scan, the anaesthesiologist reviewed the patient's history, physical examination and fasting status. Children who satisfied the inclusion criteria were recruited into the study with written parental consent. The choice of anaesthetic technique was left to the discretion of the concerned anaesthesiologist. For the purpose of the study, patients were grouped into either the GSP (Group Sedation with Propofol) or the GAL (Group Anaesthesia with LMA). Monitoring included continuous pulse oximetry, heart rate and respiratory rate (using a sidestream capnometer) in every case. All children were induced with sevoflurane, after which a peripheral intravenous access was secured. In the GAL group, an appropriate-sized LMA was inserted and anaesthesia maintained on spontaneous ventilation with a mixture of air-oxygen-isoflurane. In the GSP group, anaesthesia was maintained with a bolus of 1 to 2 milligrams per kilogram of propofol followed by infusion ranging from 75-200 micrograms/kilogram/minute (Medfusion 3500 Syringe Pump, Smith Medical ASD, Inc. St Paul, MN, USA, which was placed inside the MRI suite, more than 8 feet from the isocentre of the 1.5 Tesla MRI scanner, as per the manufacturer's instructions for the MRI Conditional pump), along with supplemental oxygen via face mask. Adequacy of sedation was assessed using the University of Michigan Sedation Scale (UMSS) immediately prior to wheeling the child into the MRI gantry. At the conclusion of the scan the anaesthetic agents were discontinued, and the child was monitored in the recovery suite till awake. During recovery the frequency of airway events, nausea and vomiting, and emergence delirium were noted; sedation score was assessed every 5 minutes using the UMSS scale. Emergence delirium was evaluated as defined by a Paediatric Anaesthesia Emergence Delirium (PAED) score of 10 or more. The child was discharged after satisfactorily meeting the post anaesthesia care unit (PACU) discharge criteria - a modified Aldrete's recovery score of 10. The quality of the scan was commented on by the radiologist who was unaware of the anaesthetic technique being used. There were no participants who were lost to observation or who dropped out of the study.

Study outcomes and data sources

The primary outcomes of this study were to compare the time to induction and time to recovery between children who underwent MRI scan in the GAL and GSP groups.

The secondary objectives were to assess the frequency of respiratory and non-respiratory complications between the two groups. The various definitions used to characterise the study outcomes and adverse events are enumerated in Tables 1 and 2.

Statistical methods

The sample size for this study was calculated to be 53 in each arm based on available literature to achieve 80% power and 5% α - error, to detect a difference of 7.1 minutes between the two groups with respect to time to recovery from anaesthesia, using nMaster 2.0 sample size software (copyright Department of Biostatistics, Christian Medical College, Vellore).^[7,8] The median values (interquartile range) were used to describe time to induction and recovery, while adverse events during the scan and in the PACU were expressed as frequencies and percentages. The independent sample *t* test or Mann-Whitney U test were used to compare the time to induction and recovery based on the normality assumption across the two groups. Association between the 2 study groups with respect to adverse events during the scan and in the PACU was assessed using Chi square test/Fisher's

exact test or Yate's continuity correction. Data was analysed using SPSS 21.0 software.

Results

Baseline characteristics

107 patients undergoing elective MRI study and who satisfied the inclusion criteria, were recruited into the study over a period of 3 months. Of these, 67 (62.6%) children were males. Median age was 4 years (IQR 2.0,6.5). Median body weight was 13.5 kg (IQR 10.0,18.0). 57 (53.3%) children underwent MRI with sedation, and 50 (46.7%) under general anaesthesia with LMA. The mean MRI duration was 43.9 ± 15.5 minutes. Relevant demographic data are summarised in Table 3.

Time profiles

With regard to the co-primary outcomes, the time to induction in the GSP group was shorter compared to the GAL group [7.0 minutes (IQR 5.0, 10.0) versus 10.0 minutes (IQR 8.8, 13.0), $P < 0.001$] as depicted in Figure 1, panel a. However, there was no difference in the median recovery time between the two groups [25.0 minutes (IQR 15.0, 40.0) versus 20.0 minutes (IQR 10.0, 31.3), P value 0.136], as depicted in Figure 1 panel b. All scans were completed successfully. The quality of images procured was reported by the radiologist to be good in every case.

Adverse events

Respiratory: A greater incidence of desaturation and laryngospasm were noted in the GAL group [8 patients (16%) versus 1 patient (1.8%), $P = 0.012$] [Table 4]. 3 (5.3%) patients in the GSP group required conversion to general anaesthesia due to persistent upper airway obstruction. Of these, 1 patient required placement of the LMA even before the commencement of the scan, while in the other 2 cases, the scan sequence had to be interrupted to insert the LMA, owing to airway obstruction due to propofol boluses given to control movements.

Movements: 16 out of the 107 patients were noted to have moved during the scan, which resulted in interruption of the scan sequence in only 4 cases. Of the 4 cases where the MRI sequence required repetition, 2 patients each belonged to the GSP and GAL groups, respectively (P value 0.418). One patient in the GSP group was noted to require three pauses in the scan owing to movement, while the other 3 patients necessitated only one pause each in the MRI sequence.

Non-respiratory adverse events: 5 (10%) patients in the GAL group were noted to have emergence delirium ($P = 0.047$),

Table 1: Definitions of variables used to measure primary and secondary outcomes

Variables measured	Definitions
Time to induction	Time from induction of anaesthesia till deemed ready to be shifted into MRI gantry, as judged by a UMSS score of 2 or more
Time to emergence	From discontinuation of anaesthetic modality till wakefulness (eye opening, purposeful movement to command)
Respiratory adverse events	Inclusive of but not limited to apnea, laryngospasm, bronchospasm, airway obstruction requiring intervention in the form of chin lift, head tilt, insertion of oral airway or LMA
Non-respiratory adverse events	Inclusive of but not limited to bradycardia, emergence delirium (assessed by PAED scale), oversedation and frequency of nausea and vomiting

This table defines the primary outcomes (time to induction and time to recovery) and secondary outcomes (adverse event profiles) as defined in the study (UMSS=University of Michigan Sedation Scale; PAED=Paediatric Anaesthesia Emergence Delirium score)

Table 2: Definition of adverse events

Adverse event	Definition
Apnea	Cessation of visible breathing movements for 10 sec or more, with or without oxygen desaturation
Airway obstruction	Noisy breathing requiring chin lift, head tilt, insertion of oral airway or LMA
Oxygen desaturation	Saturation of <94% of any duration, whether or not intervention was required
Laryngospasm	Complete or partial, requiring intervention with 100% oxygen, continuous positive airway pressure, jaw thrust, propofol bolus or succinylcholine
Bradycardia	Decrease in heart rate of >25% from baseline or <60 per minute

This table defined respiratory and non-respiratory adverse events which were included in the secondary outcomes studied

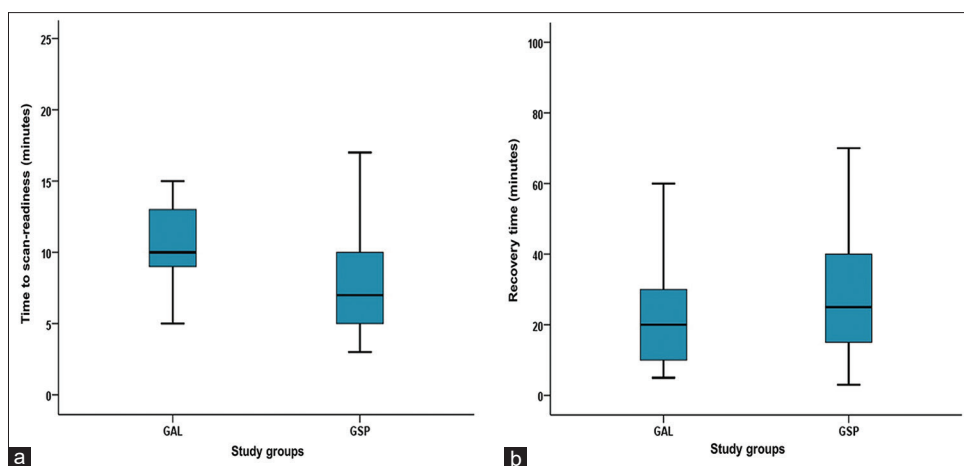


Figure 1: (a) Box plot depicting the median time to induction in the general anaesthesia (GAL) and propofol sedation (GSP) groups [10.0 minutes (IQR 8.8, 13.0) versus 7 minutes (IQR 5.0, 10.0), $P < 0.001$] respectively. (b) Box plot showing the median time to recovery in the GAL and GSP groups (20.0 minutes (IQR 10.0, 31.3), P value 0.13) versus 25.0 minutes (IQR 15.0, 40.0)

Table 3: Demographic data

Variables	Total (%) $n=107$	GSP (%) $n=57$	GAL (%) $n=50$	P
Age (years) ^a	4.0 (2.0, 6.5)	4.0 (2.0, 7.0)	3.0 (1.5, 6.0)	0.241
Male	67 (62.6)	39 (68.4)	28 (56.0)	0.185
Weight (kilograms) ^a	13.5 (10.0, 18.0)	14.0 (11.0, 19.0)	12.0 (9.0, 16.9)	0.029
Indications for Scan:				
Developmental delay	47 (43.9)	28 (49.1)	19 (38.0)	0.247
Behavioural disorders	28 (26.2)	16 (28.1)	12 (24.0)	0.722
Tumours	21 (19.6)	12 (21.1)	9 (18.0)	
Epilepsy	20 (18.7)	12 (21.1)	8 (16.0)	
Hearing loss	7 (6.5)	2 (3.5)	5 (10.0)	
Follow-up	17 (15.9)	9 (15.8)	8 (16.0)	
Others	14 (13.1)	6 (10.5)	8 (16.0)	
On antiepileptic medication	44 (41.1)	26 (45.6)	18 (36.0)	0.313
Bronchial asthma	3 (2.8)	2 (3.5)	1 (2.0)	1.000
Current respiratory infection	15 (14.0)	11 (19.3)	4 (8.0)	0.093
Recent respiratory infection	11 (10.3)	9 (15.8)	2 (4.0)	0.045
MRI site				
Brain	78 (72.9)	42 (73.7)	36 (72.0)	-
Brain and spine	5 (4.7)	2 (3.5)	3 (6.0)	
Extremity	4 (3.7)	3 (5.3)	1 (2.0)	
Pelvis	3 (2.8)	2 (3.5)	1 (2.0)	
Spine	6 (5.6)	4 (7.0)	2 (4.0)	
Abdomen	2 (1.9)	2 (3.5)	0 (0.0)	
Head and neck	7 (6.5)	2 (3.5)	5 (10.0)	
Thorax	2 (1.9)	0 (0.0)	2 (4.0)	
MRI scan duration (min) ^b	43.9±15.5	44.1±16.9	43.7±13.9	0.885

^aMedian and Inter Quartile Range (IQR); ^bMean and Standard Deviation (SD)

compared to none in the GSP group. There was no difference in the frequency of bradycardia, nausea or vomiting between the two groups.

Discussion

Our study compared the time and adverse event profiles of 2 anaesthetic techniques routinely used at our hospital for children undergoing MRI: propofol sedation (GSP group) or inhalational anaesthesia with an LMA (GAL group).

Additionally, we evaluated the incidence of respiratory and non-respiratory adverse events in the 2 groups. We observed a statistically significant shorter time to induction in the propofol sedation group, while there was no significant difference in recovery time between the two groups. Complications such as desaturation, laryngospasm and emergence delirium were significantly higher in the GAL group.

The median time to induction noted in our study [10.0 minutes (IQR 8.8, 13.0) in the GAL group and

Table 4: Frequency of adverse events in the GSP and GAL groups

Variables	Total (%) n=107	GSP (%) n=57	GAL (%) n=50	P
Desaturation	9 (8.4)	1 (1.8)	8 (16.0)	0.012
Airway obstruction	8 (7.5)	2 (3.5)	6 (12.0)	0.143
Laryngospasm	12 (11.3)	1 (1.8)	11 (22.4)	0.001
Bradycardia	6 (5.6)	5 (8.8)	1 (2.0)	0.212
Nausea	1 (0.9)	-	1 (2.0)	0.947
Vomiting	3 (2.8)	1 (1.8)	2 (4.0)	0.598
Emergence delirium	5 (4.7)	-	5 (10.0)	0.047

Adverse Events in the GSP and GAL groups: There is a greater frequency of respiratory adverse events such as desaturation and laryngospasm, as well as non-respiratory adverse events such as emergence delirium, in the GAL group

7.0 minutes (IQR 5.0, 10.0) in the GSP group] was nearly similar to that noted in certain prior published studies, where the average time ranged from 3 minutes to 8 minutes.^[8,9] Heard *et al.* noted a median induction time of 3 minutes in the propofol group and 4 minutes in the isoflurane/N₂O/LMA group.^[8] This short duration of induction might possibly be due to the fact that the children were induced with sevoflurane inside the MRI scanner with subsequent placement of the intravenous line and commencement of propofol infusion or placement of the LMA soon after. Bryan *et al.* noted an induction time of 8 minutes in both the sevoflurane and propofol groups, wherein the child was induced in the induction room with sevoflurane, a peripheral intravenous access was secured, and subsequently, either an LMA was inserted or a propofol bolus was given prior to the child being transferred to the MRI suite.^[9] This was almost similar to the time to induction noted in our study as well. Although the statistically significant difference between the induction time in both groups may not translate into clinically relevant time profile, this needs to be interpreted in the clinical context: in a high volume centre such as ours, these few minutes could add up through the day to allow for accommodation of an additional patient time slot.

We found no significant difference between the two groups with respect to time to recovery [25.0 minutes (IQR 15.0, 40.0) in the GSP group versus 20 minutes (IQR 10.0, 31.3) in the GAL group, $P = 0.136$). This is different from the results of other studies where a wide range of recovery times with significant differences between the sedation and general anaesthesia groups were noted. Bryan *et al.* recorded a median PACU time of 25 minutes and 31 minutes with LMA and propofol, respectively (P value ≤ 0.001).^[9]

However, Malviya *et al.* documented a mean recovery time of 28.8 minutes in the sedation group and 70 minutes in the general anaesthesia group.^[7] This sizeable difference might be attributed to the fact that the latter included children, who were intubated with an endotracheal tube for the MRI,

wherein the extubation time may be longer than that with an LMA. Moreover, their sedation group included a diverse range of single and combinations of multiple agents, including chloral hydrate, benzodiazepines and barbiturates which might account for a relatively shorter emergence time. The lack of difference in emergence time between the 2 groups in our study might be due to the small number of patients studied as well as due to the wide and varied doses of propofol infusion used for sedation.

Respiratory adverse events in the recovery phase were significantly higher in patients receiving general anaesthesia with LMA compared to the propofol sedation group in our study. While some authors quote no difference in respiratory complications between sedation and GA modalities,^[9-11] other investigators highlight the incidence of adverse events in the two groups. Bryan reported an incidence of 2.5% for respiratory events, including apnea and laryngospasm, with no significant difference between the LMA and sedation groups.^[9] Machata reported a low incidence (1%, $n = 5$) of respiratory events, including airway obstruction and desaturation, in children undergoing MRI under propofol infusion, none of which required intubation.^[12] Heard *et al.* also reported a significantly higher frequency of airway adverse events (airway obstruction, haemoglobin desaturation) in the LMA group compared to the propofol group.^[8] This higher incidence of adverse events in the LMA group in this study as well as previously published literature might be owing to the airway intervention involved. Other contributory factors may include the presence of a current or recent upper respiratory tract infection and the plane of anaesthetic at which the LMA was removed at the conclusion of the case. Similar to the results in our study, Oberer *et al.* demonstrated the lower incidence of acute airway responses during propofol anaesthesia compared with sevoflurane anaesthesia, at a similar anaesthetic depth, when using saline to trigger apnea and laryngospasm.^[13] We would also like to add that our study might actually underestimate the difference in the respiratory events between the GA and sedation groups in lieu of the fact that the anaesthesiologists were free to choose the mode of anaesthetic in each case; hence, there was a tendency to avoid airway instrumentation with LMA in children with a current or recent respiratory tract infection.

With respect to non-respiratory adverse events, our study showed that 5 patients (10%) in the inhalational group manifested with emergence delirium. Although sevoflurane was used for a few minutes at induction in the propofol group as well, it may have well been eliminated before emergence from anaesthesia. This might explain the absence

of emergence agitation in the propofol group. Bryan verified a significantly higher agitation score (based on the PAED scale) in the LMA group compared to the propofol group (9% versus 4%, $P \leq 0.001$),^[9] while Cravero reported that up to 60% of non-premedicated children undergoing MRI with sevoflurane had emergence agitation.^[14]

Although it might be tempting to guess that a sedation technique facilitates a faster flow of cases owing to the shorter induction time, we found that the number of patient movements during the scan was more in the sedation group than the LMA group. These findings concurred with those of Bryan *et al.* wherein patients in the sedation group having more pauses during the scan owing to both patient movement as well as monitoring artefact, compared to those who received general anaesthesia with LMA.^[9] However, significant movements causing interruptions to the scan procedure were similar in both the groups in our study. This might be related to the dose of propofol infusion used, which was left to the discretion of the concerned anaesthesiologist. The infusion doses used in our study ranged from 75 to 200 mcg/kg/min, usually preceded by a bolus of 1 to 2 milligrams per kilogram. 8 patients additionally received bolus of midazolam (0.02 to 0.05 milligrams per kilogram) in the GSP group. A varied range of propofol has been described in paediatrics for MRI scanning, the dose widely varying with age, and use of concurrent opioids or other sedative agent. Conventionally, propofol bolus of 2 to 6 mg/kg and maintenance of 100 to 250 mcg/kg/min have been quoted in paediatric MRI from various sources.^[9,15] Maldini and Miskulin observed that children undergoing knee arthroscopies required doses more than 150 mcg/kg/min for immobility.^[11] As the level of surgical stimulation for MRI is expected to be less than that for invasive procedures, lesser doses might be warranted. Pedersen *et al.*, in their study comparing propofol-remifentanyl versus sevoflurane, also found more movement in the intravenous group as compared to those receiving the inhalation agent.^[16] The mean infusion dose used was 56 mcg/kg/min of propofol alongside remifentanyl. On the other hand, Heard used a propofol infusion regimen of 300 mcg/kg/min initially without a preceding bolus, and 10 minutes later reduced to 250 mcg/kg/min.^[8]

The key limitations of our study is the relatively small sample size and the discretionary practice of the attendant anaesthesiologist with respect to the modality of anaesthetic used to anaesthetise children for MRI. Furthermore, the wide range of propofol infusion used in the TIVA group could not be regulated as the choice of the bolus and infusion dose, as well the decision for an adjuvant (such as midazolam) was entirely at the discrimination of the

consultant anaesthesiologist. As financial constraints restrict choice of anaesthetic in resource-strapped settings such as ours, it would have been preferable to have performed a cost-benefit analysis between the two groups, as the cost of propofol adds to the standard anaesthesia charges at our centre.

Conclusion

Our study shows a positive inclination towards favouring sedation with propofol over a conventional general anaesthetic with an inhalational agent and airway instrumentation in children undergoing MRI, with regards to timeliness of care and patient safety profile. The propofol group showed a shorter time to induction and lower frequency of respiratory adverse events such as desaturation and laryngospasm, as well as a lower incidence of emergence delirium, when compared to the group with general anaesthetic with an inhalational agent. However, further research is needed to identify the appropriate dosing of propofol to further fine-tune this technique of anaesthesia. Finally, a cost-benefit analysis—though beyond the scope of this study—might also contribute to a tilt in the debate between the techniques, especially in resource-poor settings.

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Conflicts of interest

There are no conflicts of interest.

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