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Nitrous oxide anesthesia in children for MRI: a comparison with isoflurane and halothane

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Aim: To compare the anesthetic effects of nitrous oxide, isoflurane, and halothane on hemodynamic stability and recovery characteristics in pediatric patients during magnetic resonance imaging (MRI).

Materials and methods: The present study includes 60 ASA I-II children aged 1-12 years undergoing MRI. After endotracheal intubation, patients were randomly assigned into 1 of 3 anesthetic groups. Group N (n = 20) received nitrous oxide and oxygen (N_2O:O_2 60:40), Group I (n = 20) received 0.5% isoflurane and oxygen, Group H (n = 20) received 0.5% halothane and oxygen to maintain anesthesia. At the completion of the procedure, inhalation anesthetic was discontinued. Extubation, emergence, recovery times, and adverse events were recorded throughout the duration of the procedure.

Results: There was no significant difference in the demographic data among the groups. In the nitrous oxide group 5 children (25%), in the halothane group 2 children (10%), and in the isoflurane group 1 child (5%) moved during MRI and supplemental inhalation anesthesia was required for these patients. Emergence time after nitrous oxide anesthesia was slightly shorter than after isoflurane anesthesia (3.15 ± 2.56 min compared with 4.65 ± 2.64 min, P = 0.162) but significantly shorter than after halothane anesthesia (5.35 ± 2.47 min, P = 0.023). Early recovery time after nitrous oxide and isoflurane anesthesia was significantly more rapid than after halothane anesthesia (4.60 ± 2.58 min and 3.65 ± 1.63 min compared with 7.00 ± 2.15 min, P < 0.05).

Conclusion: After induction with propofol, nitrous oxide may provide anesthesia for MRI in pre-medicated children. However, complete immobility was not achieved in all patients with nitrous oxide alone. Nitrous oxide and isoflurane resulted in faster emergence and recovery than halothane, but there was no significant difference between nitrous oxide and isoflurane. Discharge times from the hospital were similar for all 3 groups.

Key words: Magnetic resonance imaging, pediatrics, anesthesia, nitrous oxide, isoflurane, halothane, recovery

MRI çekilen çocuklarda nitröz oksit anestezisi: İzofluran ve halotanla bir karşılaştırma

Amaç: Manyetik rezonans görüntüleme (MRI) sırasında çocuklarda nitröz oksit, izofluran ve halotan anestezisinin hemodinamik denge, ayılma ve derlenme üzerine etkilerinin karşılaştırılmasıdır.

Yöntem ve gereç: MRI çekilecek ASA I, II grubu 1-12 yaşları arasında 60 hasta çalışmaya dahil edildi. Endotrakeal entübasyonu takiben hastalar rastgele 3 anestezi grubuna ayrıldılar. Anestezi idamesi için Grup N (n = 20) nitröz oksit ve oksijen (N_2O:O_2 60:40), Grup I (n = 20) % 0,5 izofluran ve oksijen, Group H (n = 20) ise % 0,5 halotan ve oksijen aldı. Anestezinin sonlandırılmasıyla ektübasyon, ayılma, erken derlenme zamanları ve işlem sürecinde istenmeyen etkiler kayıt edildi.

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Bulgular: Hastaların demografik verilerinde farklılık yoktu. Nitröz oksit grubunda 5 çocuk (% 25), halotan grubunda 2 çocuk (% 10), izofluran grubunda 1 çocuk (% 5) MRI sırasında hareket etmiş ve bu hastalarda ek inhalalasyon anesteziğine gereksinim olmuştur. Nitröz oksit anestezisi sonrasında ayılma süresi izofluran anestezisine göre kısa olmasına karşın (3,15 ± 2,56 dk ile 4,65 ± 2,64 dk karşılaştırıldığında, P = 0,162), bu süre halotan anestezisine göre istatistiksel anlamda daha kısaydı (5,35 ± 2,47 dk P = 0,023). Erken derlenme zamanı ise nitröz oksit ve izofluran anestezisi sonrasında halotan anestezisine göre anlamlı derecede kısaydı (4,60 ± 2,58 dk ve 3,65 ± 1,63 dk ile 7,00 ± 2,15 dk karşılaştırıldığında, P < 0,05).

Sonuç: MRI çekilen premedike çocuklarda, propofol indüksiyonu sonrasında nitröz oksit anestezi idamesi sağlayabilir. Ancak tek başına nitröz oksit ile hastaların tümünde tam bir hareketsizlik sağlanamaz. Nitröz oksit ve izofluran sonrasında ayılma ve derlenme halotana göre daha hızlıdır. Ancak nitröz oksit ve izofluran arasında anlamlı bir fark yoktu. Taburcu edilme süreleri her üç anestezik için benzerdi.

Anahtar sözcükler: Manyetik rezonans görüntüleme, çocuk, anestezi, nitröz oksit, izofluran, halotan, derlenme

Introduction

The magnetic resonance imaging (MRI) examination is extremely sensitive to motion artifacts and children may not remain immobile long enough to allow a sequence to be completed. The optimal anesthesia technique for pediatric patients undergoing MRI should be safe and rapid. General anesthesia or deep sedation is often required for children undergoing MRI in order to obtain complete immobility of the patient. The potential complications of deep sedation include hypoventilation, apnea, airway obstruction, laryngospasm, and cardiopulmonary impairment (1). Therefore, general anesthesia is often preferred for the diagnostic procedures rather than sedation, because general anesthesia is regarded as a safe, controllable, and relatively easy procedure to perform (2,3).

Maintenance of anesthesia using inhalation agents is still standard in pediatric anesthesia. New short-acting inhalation anesthetics such as sevoflurane and desflurane have acquired widespread acceptance in pediatric anesthesia because of their rapid uptake and elimination. However, these anesthetics are associated with increased cost compared with older inhaled anesthetics and may be associated with an increased incidence of side effects and complications (4).

Agitation on emergence from general anesthesia is a frequent phenomenon and clearly increases after sevoflurane- and desflurane-based anesthesia in children (5,6). Previous studies have reported that the incidence of emergence agitation after sevoflurane was greater than that observed after halothane (7-11) and isoflurane (12). Davis et al. (13) found that the incidence of emergence agitation after desflurane was greater than that observed after halothane. This phenomenon, which is commonly observed in children, demands increased nursing care in the post anesthesia care unit, delays reunion with parents, and may lead to adverse sequelae in some cases (14).

Nitrous oxide (N_2O) has both analgesic and sedative-hypnotic effects. It is commonly used both as an adjunct to balanced general anesthesia and as the sole agent in dental and obstetric anesthesia (15). Inhalation of a mixed blend of 50% N_2O and 50% O_2 induces a degree of analgesia similar to that of 10 mg of morphine (16). Nitrous oxide concentration greater than 50% leads to sedation-hypnosis and at 70% concentration leads to loss of consciousness in healthy volunteers (17). In adult patients, 60% N_2O in oxygen combined with propofol and remifentanil has been shown to prevent movement during laryngoscopy and orotracheal intubation (18). Inhalation of an equimolar blend of N_2O/O_2 uneventfully provided helpful muscle tone suppression and endotracheal intubation in preterm neonates (16). This mixture has also been found to be effective in children for sedation and pain (19,20). It is combined with intranasal midazolam for dental procedures in pediatric patients as an alternative to general anesthesia (21).

Many studies in the literature have compared the effects and recovery profiles of various inhalational anesthetics in pediatric patients undergoing ambulatory anesthesia. However, we have not yet found any study which compares the effects of nitrous oxide to isoflurane and halothane in pediatric patients during MRI.

The aim of this study was to investigate whether nitrous oxide anesthesia alone is sufficient for the maintenance of anesthesia in premedicated children that were intubated after induction with propofol and muscle relaxant. The second aim was to compare the hemodynamic stability and recovery characteristics of nitrous oxide anesthesia with those of isoflurane or halothane.

Materials and methods

After the approval of the local institutional ethics committee and written parental consent were obtained, 60 children aged 1 to 12 years were included in this randomized, prospective study. The children were classified as the American Society of Anesthesiologists' physical status I-II and were all undergoing MRI under general anesthesia on an outpatient basis. Patients with respiratory distress, heart disease, hepatic-renal failure, suspected high intracranial pressure, or allergy to any of the drugs studied were excluded from the study. No child was taking any medication regularly that might affect anesthesia or recovery.

All children were fasted from solid foods for 6 h and from clear liquids for 2 h before anesthesia. For premedication, doctors orally administered 0.5 mg kg^{-1} midazolam and 0.04 mg kg^{-1} atropine to the children 30 min prior to the induction of anesthesia. Before the induction of the anesthesia, an intravenous access was established in the preanesthetic room, located adjacent to the MRI scanner room, and a mix solution of 5% dextrose and 0.9% NaCl (1/3) was administered during the anesthesia at the maintenance rate appropriate for the child's weight and fasting interval.

In the scanner room, all the patients were monitored with the standard monitors, including electrocardiogram (ECG), non-invasive blood pressure (NIBP), and pulse oximeter (SpO_2) (Omni-Trac MRI noninvasive signs monitor system, Inviva Research Inc., Florida, USA). Anesthesia induction was provided by 1 mg kg^{-1} of lidocaine 1% and propofol 2.5 mg kg^{-1} and tracheal intubation was facilitated with the use of rocuronium bromide 0.6 mg kg^{-1}. Each patient's endotracheal tube was connected to the anesthesia machine (MRI compatible apparatus, PneuPAC, Lamtec 800). All the patients were monitored by continuous capnography (Omni Cap 3112-1 End Tital CO_2 analyzer for MRI) until the endotracheal extubation. The lungs were mechanically ventilated via a circle circuit at a respiratory rate and fresh gas flow (4-6 L min^{-1}) was provided to maintain normocapnia.

After the patients' endotracheal intubation, they were randomized by sealed envelope assignment into 1 of 3 anesthetic groups according to a single-blind study design. For maintenance of anesthesia, Group N (Nitrous oxide, n = 20) received nitrous oxide and oxygen (N_2O:O_2 60:40), Group I (Isoflurane, n = 20) received 0.5% isoflurane and oxygen, Group H (Halothane, n = 20) received 0.5% halothane and oxygen. Inadequate anesthesia was defined as difficulty in completing the procedure because of movement or a 20% increase in the heart rate and blood pressure above the preinduction values during MRI scanning. The isoflurane or halothane concentration was increased to 1%, if any movement occurred in Groups I or H. For children in the nitrous oxide group, anesthesia was maintained with nitrous oxide and followed by isoflurane 0.5% if any movement occurred. Muscle relaxation maintenance was provided by 0.15 mg kg^{-1} rocuronium bromide, if required.

Immediately prior to anesthesia induction, baseline vital signs (Time 0), including heart rate (HR), systolic arterial pressure (SAP), mean arterial pressure (MAP), diastolic arterial pressure (DAP), and hemoglobin oxygen saturation (SpO_2) were recorded. After the tracheal intubation, these parameters were continuously monitored and recorded every 5 min until leaving the MRI scanner room and being transferred to the post-anesthesia care unit (PACU). Any undesired or unexpected effects (laryngospasm, coughing, bronchospasm, nausea and vomiting, excitatory movement, agitation, or any other unanticipated events) which occurred throughout the anesthesia and the recovery period were noted. Total anesthesia time was considered as the time from the start of induction to the endotracheal extubation.

At the completion of the procedure, inhalation anesthetic was discontinued and ventilation was continued at the fresh gas flow and 4 L min^{-1} of 100% oxygen until the return of a cough reflex.

Neuromuscular blockade was antagonized with 0.02 mg kg^{-1} atropine and 0.05 mg kg^{-1} neostigmine. The tracheal tube was removed in the scanner room when the patient demonstrated regular spontaneous ventilation, a cough or gag reflex, grimace, or purposeful movement.

A single-blind, independent anesthesiologist evaluated each patient during the emergence and early recovery phases. Extubation time was defined as the time from discontinuation of anesthetic to tracheal extubation. Emergence time was defined as the time from discontinuation of anesthetic to open eyes. Early recovery time was measured as the time from extubation to until achieving a score of 8-10 on the modified Aldrete's recovery score (activity, respiration, circulation, consciousness and color, with each criteria ranging from 0 to 2) (22). When the extubated airways were secure, the child was transported to the post-anesthesia care unit and observed by a nurse who was not informed about the anesthetic agents that the patient had received during anesthesia. Each patient's hemoglobin oxygen saturation was also continuously monitored during the recovery period in the PACU. Supplemental oxygen or respiratory assistance was administered if oxygen saturation was less than 90% for more than 30 s. Any episodes of desaturation ($SpO_2 < 90\%$) were recorded. Emergence agitation was evaluated using a 4 point agitation scale (1 = awake and calm, cooperative; 2 = crying, requires consoling; 3 = irritable/restless, screaming, inconsolable; 4 = combative, disoriented, thrashing). Agitation scores higher than 3 were considered agitated (23). Home discharge criteria included stable vital signs, no nausea and vomiting, orientation to name and place, and the ability to sit and walk unaided if appropriate for the patient's age. Home discharge time, the interval between arriving at the PACU being discharged home, was recorded for every patient.

Statistical analyses were performed using a statistical software package (SPSS 15.00, SPSS Inc., USA). The data were analyzed using parametric and non-parametric tests as appropriate. Frequency distribution was compared with the chi-square test or Fisher's exact test. Several group comparisons were made using one-way ANOVA for the data in normal distribution and Kruskal-Wallis test for the non-parametric data. Tukey's HSD test or Mann-Whitney U test was applied respectively as post-hoc tests where a significant difference was observed. In all calculation α was set to 0.05 and a calculated P value of less than 0.05 was accepted as significant

Results

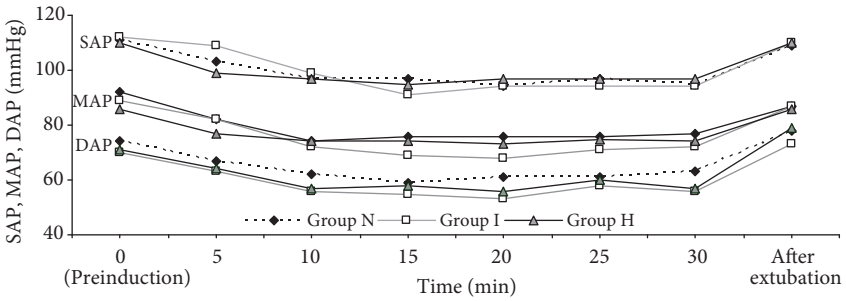
Sixty children (29 girls and 31 boys) ranging in age from 1 to 12 years who were scheduled for elective MRI were enrolled in the study. Data from the 60 patients were analyzed. The 3 groups did not differ significantly in terms of gender, age, weight, or duration of anesthesia (Table 1).

Changes in arterial blood pressure are shown in Figure 1. SAP, DAP, and MAP decreased in all groups following induction compared with the baseline value and also were maintained during the anesthesia. After tracheal extubation, they elevated to

Table 1. Demographic data and duration of anesthesia.

	Group N	Group I	Group H
	(n = 20)	(n = 20)	(n = 20)
Gender (Female/Male)	12 / 8	8/12	9 / 11
Age (year)	4.55 ± 3.94	3.45 ± 2.33	3.45 ± 3.60
Weight (kg)	18.15 ± 11.24	15.10 ± 5.38	15.32 ± 6.80
Duration of Anesthesia (min)	37.55 ± 8.92	41.05 ± 24.10	37.25 ± 11.02

Results presented as mean (SD) or ratios. Group N: Nitrous oxide, Group I: Isoflurane, Group H: Halothane



SAP: Systolic arterial pressure,MAP: Mean arterial pressure,DAP: Diastolic arterial pressure
Group N: Nitrous oxide, Group I: Isoflurane, Group H: Halothane

Figure 1. Comparative distribution of arterial blood pressure in all three groups.

the preinduction level in all groups. However, there were no statistically significant differences among the groups in terms of arterial blood pressure ($P > 0.05$). Mean heart rate and SpO_2 values were similar and there were no statistically significant differences among the 3 groups during all study periods ($P > 0.05$), (Figure 2).

With respect to extubation times, also there were no statistically significant differences among the 3 groups ($P > 0.05$). The time to emergence after nitrous oxide anesthesia was somewhat more rapid than after isoflurane anesthesia (3.15 ± 2.56 min compared with 4.65 ± 2.64 min, $P = 0.162$) but significantly shorter than after halothane anesthesia (5.35 ± 2.47 min, $P = 0.023$). Early recovery time after nitrous oxide and isoflurane anesthesia was significantly more rapid than after halothane anesthesia (4.60 ± 2.58 min and 3.65 ± 1.63 min compared with 7.00 ± 2.15 min, $P < 0.05$). However, emergence and recovery times between nitrous oxide and isoflurane were not significantly different ($P > 0.05$). The mean time to meet discharge criteria from the post-anesthesia care unit was not significantly different among the groups (Table 2).

Table 3 gives the incidence of adverse events during the anesthesia and recovery periods. Movement during MRI was the most common event, affecting 5 children (25%) in the nitrous oxide group, 2 children (10%) in the halothane group, and 1 child (5%) in the isoflurane group. Supplemental inhalation anesthesia was required for these patients. Although the percentage of children who moved was higher in nitrous group than in the halothane and isoflurane groups, these differences were not statistically significant among the 3 groups. All of the patients' scanning procedures were successfully completed and without interruption. Laryngospasm was observed in 1 patient in the nitrous oxide group immediately after extubation. It was resolved quickly by use of the jaw-thrust maneuver and face mask ventilation with

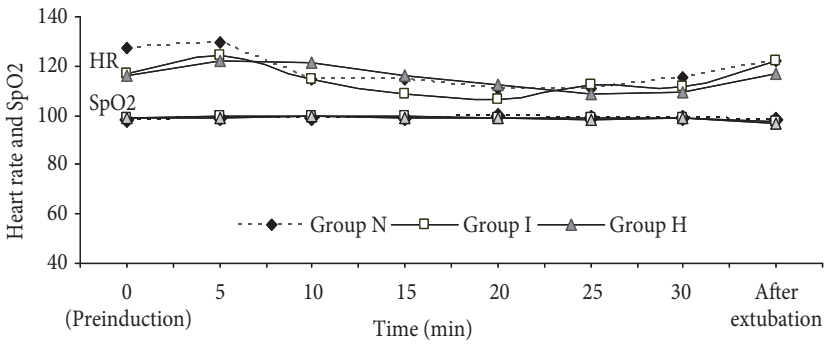


Figure 2. Comparative distribution of heart rate and peripheral oxygen saturation in all 3 groups.

Table 2. Emergence, recovery, and discharge times after discontinuation of the inhaled agents (min).

	Group N	Group I	Group H
Extubation time	2.40 ± 1.27	2.62 ± 1.47	3.80 ± 2.82
Emergence time	3.15 ± 2.56*	4.65 ± 2.64	5.35 ± 2.47
Recovery time	4.60 ± 2.58*	3.65 ± 1.63*	7.00 ± 2.15
Discharge time	102.15 ± 23.7	104.05 ± 19.11	115.65 ± 17.52

Values are expressed as mean ± SD. * = $P < 0.05$
Group N: Nitrous oxide, Group I: Isoflurane, Group H: Halothane
Emergence time: N versus H: $P = 0.023$
Recovery time: N versus H: $P = 0.003$, I versus H: $P < 0.001$

Table 3. Adverse events during anesthesia and recovery.

	Group N	Group I	Group H
Movement	5	1	2
Laryngospasm	1	0	0
Coughing	6	4	4
Nausea – Vomiting	0	3	2
Emergence agitation	2	3	4

Group N: Nitrous oxide, Group I: Isoflurane,
Group H: Halothane

100% oxygen. No episode of hypoxemia was noted in the recovery room. Emergence agitation occurred infrequently and equally in the 3 groups. Differences in the frequency of adverse events among the 3 study groups were not significant during the anesthesia and recovery period.

Discussion

The results of the present study suggest that nitrous oxide, isoflurane, and halothane anesthesia after intubation are comparable in efficacy for children undergoing MRI.

In this study, adequate anesthesia maintenance was provided successfully with the isoflurane and halothane in children (95% and 90%, respectively) without the need for additional anesthetic agents. We observed movement during MRI scanning in 5 children undergoing nitrous oxide anesthesia. Although nitrous oxide has analgesic properties and leads to a loss of consciousness, inadequate anesthesia was determined in 25% of patients in the nitrous oxide group during MRI scanning and supplemental inhalation anesthesia was required for these patients. This problem may have resulted from an insufficiency of nitrous oxide to maintain anesthesia in these children. The inhaled anesthetic concentration was also increased for 1 patient in the isoflurane group (5%) and 2 patients in the halothane group (10%). However, all of the patients' scans were completed successfully and without interruption.

In this study, patients were premedicated with oral midazolam, and anesthesia induction was induced with propofol and maintained with volatile anesthetic agents. Premedication decreases stress before the induction of anesthesia and contributes to a smooth induction and recovery from anesthesia (8,24). Propofol is a short-acting intravenous anesthetic agent used for induction due to its unique pharmacokinetic properties and clinical advantages. Both premedication and intravenous induction influence the cardiorespiratory and recovery parameters.

In our study, after anesthesia induction with propofol, arterial blood pressure decreased in

comparison to preinduction values and stayed stable during the maintenance of anesthesia in all study groups. Reductions in arterial blood pressure and heart rate usually occur during the induction of anesthesia with propofol and are influenced by the dose and the rate of administration (25). Volatile anesthetic agents also induce dose-related changes on cardiac hemodynamics in normal and diseased hearts. However, in this study no significant differences were observed in arterial blood pressure or heart rate among the 3 groups during all study periods.

Wolf et al. (26) compared the hemodynamic and cardiovascular effects of isoflurane and halothane in unpremedicated children. They found that neither halothane nor isoflurane altered heart rate significantly from preinduction values, but mean blood pressure decreased significantly in both groups during induction. However, the observed alterations in heart rate and blood pressure were similar in both anesthetic groups when anesthetic concentrations were equipotent, a finding which was consistent with our own. Rivenes et al. (27) compared the cardiovascular effects of sevoflurane, isoflurane, halothane, and fentanyl-midazolam in children. They found that mean arterial pressure decreased for 2 anesthetic concentrations out of all 4 groups. The greatest decrease in MAP was noted in the halothane group. Halothane preserved HR at baseline levels, but isoflurane caused an increase in HR. When Dalal et al. (28) compared the cardiovascular effects of sevoflurane and isoflurane, both anesthetic agents caused a significant decrease in MAP but no significant decrease HR from baseline values.

In our study, nitrous oxide provided sufficient anesthesia in 75% children for MRI and promoted hemodynamic stability during the maintenance of anesthesia. Milesi et al. (16) evaluated the administration of an equimolar mixture of N_2O and O_2 for tracheal intubation in preterm neonates with respiratory distress syndrome. They reported no significant differences between pre-procedure and post-procedure values for heart rate and mean arterial blood pressure. In their study, the N_2O and O_2 mixture provided sufficient endotracheal intubation condition and hemodynamic stability without major side effects in premature neonates. Barr et al. (17) investigated the effects of adding N_2O to intravenous anesthesia with fentanyl and midazolam during surgical stimulation in adult patients. They found that mean arterial pressure and heart rate changes were small and not significant. Wood et al. (21) also reported that N_2O combined with intranasal midazolam produced minimal hemodynamic changes in pediatric dental patients.

In this study, we found that emergence and recovery after N_2O and isoflurane were faster than after halothane. Fisher et al. (29) compared the effects of enflurane, halothane, and isoflurane with N_2O for diagnostic and therapeutic procedures in unpremedicated children with malignancies. They found that emergence time (spontaneous eye opening) was faster with enflurane (4.7 ± 4.4 min) than with isoflurane (6.2 ± 3.9 min) or halothane (6.2 ± 4.5 min). There was no significant difference between isoflurane and halothane, which was consistent with our findings.

The rate of emergence from inhalational anesthesia depends on the solubility of the anesthetic, duration of exposure, concentration of anesthetic during the maintenance period, and the patient's ability to metabolize the anesthetic (7). In this study, isoflurane and halothane concentrations were the same and the duration of anesthesia was also similar among the 3 groups. The blood/gas partition coefficients of isoflurane and halothane are 1.46 and 2.4, respectively. Isoflurane has very similar solubility characteristics to halothane. Its pungency has limited its utility for inhalational induction; however, it remains a commonly used drug for the maintenance of anesthesia (30). Halothane is an old inhalation agent but it is still used for the gaseous induction of anesthesia and maintenance in pediatric patients. Its low cost, relative safety, and nonpungent airway properties make it a useful agent in pediatric anesthesia. Despite its popularity, however, halothane is not an ideal induction agent because of its potential adverse effects (6). Halothane is more soluble than nitrous oxide and isoflurane, which leads to a longer induction of and emergence from anesthesia. As halothane also has a higher oil:gas partition coefficient, it binds to fatty tissue in greater amounts, which can result in prolonged recovery. This usually occurs during longer operative procedures but for

short procedures, such as myringotomies, a minimal amount of halothane is likely to have reached fatty tissues and, hence, early recovery is more rapid (31). Low solubility of nitrous oxide (0.47) is its major advantage since this indicates that anesthetic recovery of nitrous oxide would be more rapid than with isoflurane and halothane (7).

Additionally, residual effects of drugs used for premedication, opiates, and muscle relaxants may interact with the anesthetics to delay the onset of early recovery (4). Cox et al. (32) reviewed literature regarding the use of oral midazolam for premedication and concluded that it is effective in reducing both separation anxiety and induction anxiety in children, with minimal effect on recovery times. Propofol has a quick onset and is rapidly cleared, which may produce a shorter emergence and earlier time to discharge when compared to thiopental (30). Furthermore, due to its high metabolic clearance rate, it can be assumed that emergence time is minimally influenced by propofol. In our study, emergence and recovery from these_inhalation anesthetics were consistent with their relative blood solubilities. However, discharge times from hospital were similar for all 3 anesthetics.

Postoperative nausea and vomiting is the most common anesthesia-related complication limiting hospital discharge. Sandner-Kiesling et al. (33) evaluated types and incidences of post-procedure side-effects within 72 h of inhalational anesthesia in children for cerebral MRI. They reported the incidence of nausea and vomiting as 44% after halothane and 18% after isoflurane. Murray et al. (34) reported a low incidence of nausea (9%) and vomiting (8%) after inhalation anesthesia for MRI. They concluded that inhalation anesthesia might be a less important cause of postoperative vomiting than factors such as the type of operative procedure, use of opioids, or the presence of postoperative pain. Bhatt et al. (35) evaluated the efficacy of a N_2O and O_2 mixture (50:50) for minor eyelid surgery in adults. They found that incidence of nausea after entonox was 8% compared to 2% the air group. However, Zier et al. (20) found a lower incidence of nausea and vomiting (3%) in their study despite using N_2O at a concentration of 70% for urethral catheterization in children. In our study, a lower incidence of nausea in the post anesthesia period occurred with nitrous oxide than with isoflurane or halothane. Antiemetic therapy was not required for any patient, however. The risk of early postoperative nausea and vomiting associated with a propofol-based anesthetic appears to be lower than anesthesia maintained with potent inhalation agents and some studies suggest that propofol may have inherent antiemetic effects (30).

Agitation on emergence was low and similar among the 3 groups. The phenomenon of agitation is commonly associated with sevoflurane but it also occurs with other inhalation anesthetics. It was initially thought to be related in part to inadequate analgesia; however, agitation may be observed even if there is no painful stimulus, as in our study (14). Possible etiologic factors include separation from parents, premedication, rapid awakening in unfamiliar settings, stress during induction, a noisy environment, age, pain, duration of anesthesia, type of anesthesia, concurrent medications, and genetic predisposition (36). A meta-analysis evaluating emergence agitation prevention demonstrated that propofol, pain prevention, ketamine, and alpha-2 agonists appear to be effective (37). In all of our patients, anesthesia induction was provided by propofol, which might have contributed to the prevention of emergence agitation.

In summary, nitrous oxide may provide anesthesia and hemodynamic stability after induction with propofol in premedicated children undergoing MRI. However, a complete immobility of all the patients was not achieved by nitrous oxide alone and an additional anesthetic agent was required. Emergence and recovery times with nitrous oxide and isoflurane anesthesia were faster than with halothane anesthesia. These times were not significantly different between nitrous oxide and isoflurane, however. Adverse events and discharge from hospital times were similar for the nitrous oxide, isoflurane, and halothane anesthesia.

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