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Comparison of propofol and ketamine induced anatomical upper airway changes in children at magnetic resonance imaging.

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Abstract

Background: Children are susceptible to airway obstruction with sedative agents because of smaller dimensions of their airways. The aim of our study was to localize and compare propofol versus ketamine induced morphologic upper airway changes in children using the MRI.

Patients and methods: 44 children with ASA physical status class I or II, aged 1-4 years, scheduled for elective MRI of the head were enrolled into this study. Each patient was randomly allocated to either propofol (Group P) or ketamine (Group K) groups. T1 weighted axial slices were used to measure the minimal anterior posterior and transverse diameters of the pharynx at the level of either the dorsum of the tongue or at the level of the soft palate and measurements were compared between the groups.

Results: There were no significant differences among the two groups with respect to age, weight or gender. The cross-sectional area was smallest at the level of soft palate in 32 (72.7 %) children and smallest at the level of tongue in 12 (27.3 %) children. The groups did not differ with regard to the place of the narrowest level, the anteroposterior diameter, the transverse diameter and area of the narrowest sites.

Conclusion: The results suggest that the patients in either group did not differ with regard to the place of the narrowest level, the anteroposterior and transverse diameters and area of the narrowest site of their upper airways. However, tongue was shown to become an important cause of impaired airway patency in anesthetized children.

Keywords: Pediatrics, Airway management, Magnetic resonance imaging.

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Introduction

Most of the diagnostic radiological procedures require immobilization of the patients. A proper sedation and/or anesthesia technique which is safe and compatible with MRI is essential especially for the children [1-3]. Sedative agents such as barbiturates and benzodiazepines cause loss of airway muscle tone and an increase in airway resistance [4,5].

The exact anatomical site of anesthesia-induced airway obstruction is controversial [3,6-11]. The traditional knowledge postulates that the posterior movement of the tongue by a reduced genioglossus activity is the major cause of airway obstruction [12-14]. More recent studies suggest that the airway obstruction occurs at different sites, such as at the level of epiglottis or soft palate [6-9,11]. Children are more susceptible to airway obstruction because of smaller dimensions of their airways and the high incidence of tonsillar or adenoidal hypertrophy causing increased resistance [13]. However, the configurational changes leading to obstruction in the upper airway during anesthesia in children are not definite [12].

The aim of our study was to localize and compare propofol versus ketamine induced morphologic upper airway changes in children regarding the site of airway narrowing and the smallest cross-sectional area of the airway using the Magnetic Resonance Imaging (MRI). We purposed to determine the effects of these drugs on airway diameters which will help the clinicians to select the appropriate drugs for the outpatient sedation of the children.

Materials and Methods

Ethical approval for this study was provided by Ethical Committee of Baskent University Hospitals, Ankara, Turkey (Registration date and number: February 2002, KA02/93). Written informed consent was signed by each patient/parent. We enrolled 44 children with American Society of Anesthesiologists (ASA) physical status class I or II, aged 1-4 years, scheduled for elective MRI of the head into this prospective, randomized study. Those with suspected elevated intracranial pressure, history of obstructive sleep apnea, pathology of the upper airway, craniofacial anomalies and developmental delay were excluded from the study.

Anesthesia

None of the children was premedicated. Each patient was randomly allocated to either propofol (Group P) or ketamine (Group K) groups with the closed envelope method. Baseline values for heart rate (HR), respiratory rate (RR) and arterial oxygen saturation (SpO_2) were obtained immediately on arrival of the child in the scanner room. During the whole procedure, including induction of and recovery from anesthesia, HR, RR and SpO_2 were monitored continuously in all patients with the MRI compatible pulse oximeter device (Model 3500, Medrad, USA). The head position was standardized, with the head being slightly extended. Neither the occiput of the head nor the shoulders were elevated above the table. An intravenous cannula was inserted and atropine 0.02 mg/kg and loading doses of either propofol (1 mg/kg) for the patients in Group P or ketamine (1 mg/kg) for the patients in Group K were administered to each patient. Bolus doses of 1 mg/kg of each drug were repeated until the disappearances of cornea reflexes were provided. Infusion of propofol at the rate of 50-100 µg/kg/min or ketamine at the rate of 25-75 µg/kg/min was administered by infusion pump (Model SP-500, JMS, Japan). If the immobilization of the patient could not be managed with these infusion doses, additional bolus doses of 1 mg/kg of the drugs were repeated and each additional bolus was recorded. All patients remained in spontaneous ventilation and received supplemental oxygen (4 L/min) via a nasal cannula.

Anesthesia was considered satisfactory when imaging quality was not disturbed by motion artefacts and HR, RR and SpO_2 were maintained in the normal range at steady-state level. Bradycardia was defined as a 15% decrease in HR from baseline and desaturation was defined as an oxygen saturation value <90%. Any cause of desaturation relative to baseline level was immediately checked. The anesthesiologist was prepared to assist ventilation with a bag and mask system, insert an oral airway, or intubate the trachea at any time during the procedure.

After the imaging sequences were completed, infusions of the drugs were discontinued. In the recovery room, the patients were observed and monitored with standard monitoring equipment until full recovery of consciousness and motor control were complete. Total dose of propofol or ketamine, total procedure time, number of the repeated sequences due to the movement of the patient, recovery time, discharge time and respiratory or hemodynamic complications throughout the procedure and in the recovery room were recorded. 'Recovery time' was defined as the time needed for the patient to open his/her eyes with a gentle call or touch of the anesthesiologist and to be transferred from the scanner room to the recovery room. 'Discharge time' was the time required to spend in the recovery room until the patients' discharge from the hospital.

Magnetic Resonance Imaging

The magnetic resonance scanning was performed on a 1.5 Tesla Magnetom Symphony device [Siemens AG, Erlangen, Germany]. After finishing requested head examination, two additional sequences were obtained through the upper airway level. T1 weighted sagittal and axial sequences were performed when deep sedation was managed. The parameters were as follows:

[1] Sagittal TR: 500 ms, TE:14 ms, FOV: 220 × 220 mm, matrix size: 128 × 256, slice thickness: 5 mm;

[2] Axial TR: 450 ms, TE:14 ms, FOV: 130 × 230 mm, matrix size: 128 × 256, slice thickness: 3 mm.

The narrowest site of the upper airway was determined by using sagittal image as either the base of the tongue or the soft palate. A work station Leonardo 5.8 software (Siemens AG, Erlangen, Germany) was used to make the measurements. Axial slices were used to measure the minimal anterior posterior (A-P) and transverse diameters of the pharynx at the level of either the dorsum of the tongue or at the level of the soft palate depending on the narrowest site identified with the sagittal sections (Figure 1). Cross-sectional areas at these sites were calculated by tracing freehand the edges of the airway by using a cursor. Measurements were made by two radiologists who were blinded to drugs used for sedation. The quality of the whole MR examination images were judged from '0' being the worst; to '5' being the best quality by the same radiologists.

Statistical Analyses

The study sample size was calculated using the power *t*-test. Differences among groups were assessed by one way Anova test for parametric measures and chi-square test for non-parametric ones. A significance level of $p<0.05$ indicated statistical significance.

Results

There were no significant differences among the two groups with respect to age, weight or gender (Table 1). Hemodynamic parameters remained within safe limits throughout the procedure for both groups. However heart rates and mean arterial pressures in Group P were significantly lower at some measurement times than Group K. Spontaneous respiration was maintained in all patients and no mechanical ventilation support was required. We

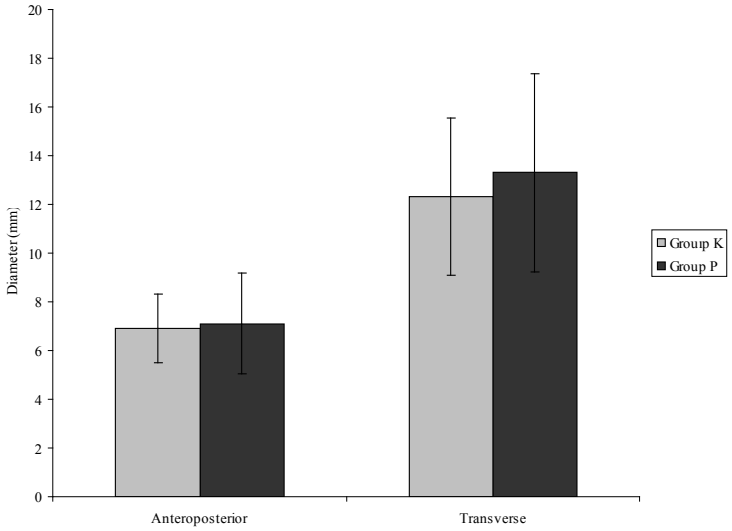

Figure 1. *Anteroposterior and transverse diameters of the airways of the patients*

did not encounter any significant difference between the arterial oxygenation of the groups. Total amount of drugs administered, time to complete recovery and discharge times were not significantly different between the two groups (Table 2).

The cross-sectional area was smallest at the level of soft palate in 32 (72.7 %) children and smallest at the level of tongue in 12 (27.3 %) children (Table 3). However the groups did not differ with regards to the place of the narrowest level, the anteroposterior diameter, the transverse diameter and area of the narrowest sites (Figure 2).

Requirement of an additional drug in order to provide a complete immobilization was significantly different in Group K (p=0.021). Although 6 patients in Group K required extra drug, none of the patients in Group P needed additional drug. Repeated number of sequences because of motion artefacts compromising the diagnostic quality of MRI images and duration of anesthesia in Group K were significantly higher than Group P (p<0.001 and p=0.036, respectively) (Table 2). Also quality of the images of the patients in Group P were significantly better than the ones in Group K (p=0.021). Figure 3 demonstrates the typical upper airway obstruction at the sagittal section of MRI.

Discussion

The results of this prospective, randomized study suggest that the patients in either group did not differ with regard to the place of the narrowest level, the anteroposterior and the transverse diameters and area of the narrowest site of their upper airways. However, tongue was demonstrated to become an important cause of impaired airway patency in anesthetized children.

Nandi et al. used conventional radiography to assess changes in airway patency in anesthetized adults in their study. The universal change that was demonstrated was the posterior movement of the soft palate [6]. Their results were similar to those of Morikawa's, in which the anesthesia reduced the tonus of muscles of both the tongue and soft palate without anesthesia [6,10].

Table 1. *Demographic data of the groups [Mean ± standard deviation (min-max)]*

	Group K (n=22)	**Group P (n=22)**
Age (year)	2.18 ± 0.83 (1-3.5)	2.35 ± 0.84 (1-4)
Sex (M/F)	10/12	14/8
Weight (kg)	12.77 ± 2.64 (7-16)	11.77 ± 2.16 (8-15)
MRI		
Cranial	18	17
Thoracal	1	-
Orbital	1	2
Nasopharynx	2	-
Abdominal	-	1
Cervical	-	1
Lombar	-	1

Magnetic resonance imaging allows extensive evaluation of the oral and oropharyngeal soft tissue [15]. Our findings were remarkably similar to those of Mathru et al. who used MRI in order to identify the narrowest part of the airway in adult patients [3]. They demonstrated that upper airway anteroposterior dimension decreased at the level of soft palate but remained unchanged at the level of the dorsum of the tongue and tip of the epiglottis during propofol anesthesia. Posterior displacement of the tongue did not occur and the airway obstruction occurred primarily at the level of the soft palate after induction of the propofol anesthesia [3]. We could not manage to obtain basal images to compare them with the ones after the anesthesia induction, since it is not possible to keep children immobile without anesthesia.

Nandi et al. demonstrated that apparent radiographic occlusion of the airway occurred most consistently at the level of the epiglottis, but the tongue base did not touch the posterior pharyngeal wall in any patient [6]. Traction on

Table 2. *Time to complete recovery and discharge times (Mean ± standard deviation (min-max))*

	Group K (n=22)	**Group P (n=22)**
Total drug amount (mg)	86.59 ± 48.50 (10-200)	94.55 ± 75.62 (30-350)
Procedure time* (min)	42.86 ± 23.49 (20-110)	30.45 ± 13.08 (15-60)
Recovery time (min)	13.50 ± 15.97 (1-50)	5.66 ± 6.75 (1-25)
Discharge time (min)	57.38 ± 19.34 (28-100)	39.47 ± 28.15 (15-120)
Repeated sequences+ (n)	2.0 ± 1.8 (0-6)	0.1 ± 0.6 (0-3)
Quality of the procedures	4.23 ± 0.75 (3-5)	4.68 ± 0.47 (4-5)

*p=0.035, +p<0.01

Table 3. *The cross-sectional area (Mean ± standard deviation (min-max))*

	Narrowest site (soft palate/tongue)	**Anteroposterior diameter (mm)**	**Transverse diameter (mm)**	**Cross-sectional area (mm^2)**
Group K (n=22)	15/7	6.91 ± 1.41 (3.50-9.30)	12.32 ± 3.23 (6.90-18.70)	81.08 ± 34.06 (26.00-174.00)
Group P (n=22)	16/5	7.10 ± 2.06 (2.80-11.30)	13.30 ± 4.07 (6.70-22.30)	83.61 ± 41.51 (27.00-186.00)

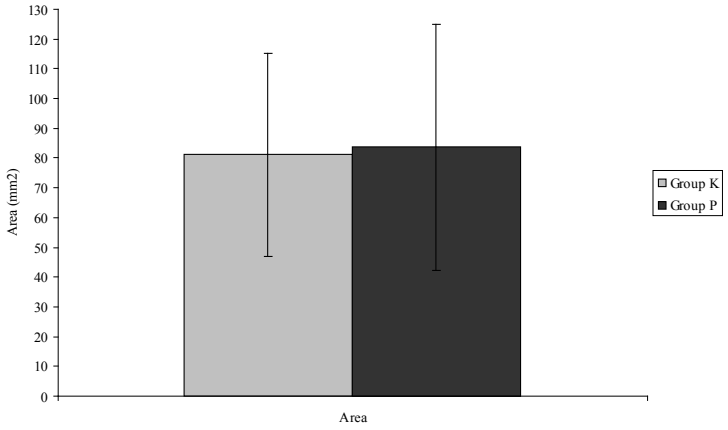

Figure 2. *Area of the airways of the patients*

the tongue failed to clear the nasopharyngeal obstruction, as well. Boidin indicated in his study that tongue is not the only factor concerned with the upper airway obstruction [8]. In our study, similarly, tongue was not found to be an important cause of impaired airway patency in anesthetized children. However, no differences between the two anesthetic agents with regards to the airway patency could be identified in our study. Both agents had tendencies to obstruct the airway in children at the level of the soft palate. Unfortunately, the magnetic resonance imaging technique does not allow conclusions about the anatomic changes that occur during the respiratory cycle [16]. Thus, it was not possible for us to visualize slight narrowing of the pharyngeal walls that might occur during inspiration.

The mechanism underlying these anesthesia-induced changes in upper airway patency is still controversial. General anesthesia dose-dependently decreases respiratory activity of upper airway muscles and, to a lesser extent, the activity of intercostal muscles and the diaphragm [2,17,18]. During sedation, there is a tendency toward upper airway obstruction, probably due to the susceptibility of the muscles at the pharyngeal level which are more susceptible to anesthetic drugs than in the diaphragm [19,20]. Litman et al. provided further evidence of the complexity of the effects of anesthetics on upper airway musculature and they suggested that propofol might be associated with a different effect not only between the diaphragm and upper airway but also between the separate pharyngeal dilator muscles [14].

The ideal anesthetic should allow for adequate oxygenation and ventilation with spontaneous respiration, give the anesthesiologist the ability to titrate and maintain

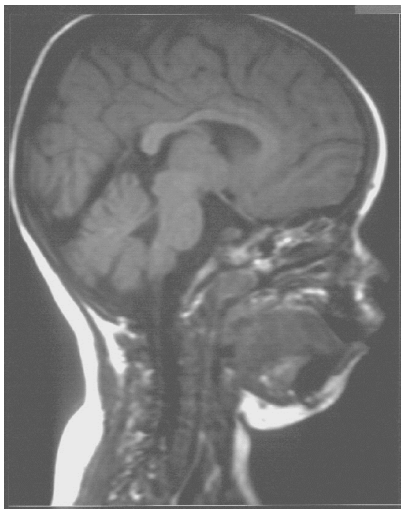

Figure 3. *Sagittal section of upper airway (obstructed by tongue)*

stable drug concentrations, provide rapid induction and recovery, produce a minimum of side effects such as nausea and dysphoria and have minimal need for special MRI-compatible machines [21]. We found that requirement of an additional drug in order to provide a complete immobilization was significantly higher in Group K. Repeated number of sequences because of motion artefacts compromising the diagnostic quality of MRI images and duration of anesthesia in Group K were significantly higher than Group P.

General anesthesia with tracheal intubation would be unnecessary if there was a reliable and safe alternative, but while several techniques have been advocated for pediatric MRI, most of them have major disadvantages [1]. Propofol has a suitable pharmacokinetic profile, acceptable cardiorespiratory side effects in this setting, and decreases cerebral blood flow and metabolism [22,23]. Careful observation for airway obstruction is very important in successful management of sedation for pediatric patients [24]. Monitored intravenous sedation using propofol is the most widely used for healthy children; general anesthesia with a laryngeal mask airway or endotracheal intubation and controlled ventilation is required for a critically ill child [25].

Drummond reported that administration of ketamine was not associated with loss of airway patency or with a decrease in airway muscle activity, consistent with previous animal studies, whereas there was marked loss of airway muscle activity and airway patency with administration of midazolam [26]. Comparison of the patient images when awake and after anesthesia might provide exact conclusions in our study about the differences of the anesthetic agents. The limitations of our study were the small sized patient population and the lack of assessment of the depth of anesthesia.

Herein, we would like to clarify one point about the depth of anesthesia in our study. Although BIS is an appropriate method in order to evaluate the depth of anesthesia, we did not have a MRI compatible BIS equipment. Therefore, we assumed the depth of anesthesia as 'adequate' enough to be able to perform the MRI scan without any necessity to re-scan. We scheduled a similar study in which we will use MRI compatible BIS equipment in order to screen the depth of anesthesia. Unfortunately, we do not have the baseline values or a control group in order to compare our results, since we cannot perform the MRI scans in awaken children.

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