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Original Article

Airway Dimensions in Children with Neurological Disabilities During Dexmedetomidine and Propofol Sedation for Magnetic Resonance Imaging Study

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Abstract

Objective: Children with neurological disabilities are at an increased risk of airway complications during anaesthesia for magnetic resonance imaging (MRI) with spontaneous respiration. The primary objective of this study was to evaluate airway dimensions during propofol and dexmedetomidine sedation for MRI in children with neurological disabilities. The secondary objective was to examine the adverse respiratory and sedation-related events.

Methods: Seventy-two children aged 1–6 years undergoing MRI were randomly selected to receive sedation with either 2 mg kg^{-1} h^{-1} of propofol or 2 μg kg^{-1} h^{-1} of dexmedetomidine. The airway dimensions were measured at soft palate, the base of tongue and mid-epiglottis. Adverse airway events were noted, and the quality of sedation was determined based on the need for dose modification, patient movement and repeat imaging requirements.

Results: There was no significant difference in airway dimensions observed between the dexmedetomidine and propofol groups, except for maximum and minimum transverse diameter (15.4±3.4 vs. 13.4±4.7, p=0.04 and 14.6±3.3 vs. 12.4±4.7, p=0.02 respectively) at soft palate and for cross sectional area difference at the base of tongue (14.5±13.9 vs. 20.1±19.3, p=0.03). Airway obstruction (2/36 vs. 3/36), apnoea (0/36 vs. 3/36) and desaturation (0/36 vs 2/36) occurred less frequently with dexmedetomidine. Additional requirement of sedation (6 vs. 3 patients; p=0.48), movement during imaging (9 vs. 5 patients; p=0.37) and poor image quality necessitating re-acquisition (4 vs. 0 patients; p=0.08) were more frequent with propofol.

Conclusion: Airway dimensions were similar during dexmedetomidine and propofol sedation, except for the transverse diameters at soft palate, and for cross-sectional area difference at the base of tongue in spontaneously breathing children with neurological disabilities. Airway complications were less frequent and the quality of sedation was better with dexmedetomidine.

Keywords: Airway, children, dexmedetomidine, propofol, magnetic resonance imaging

Introduction

Airway abnormalities and respiratory complications are frequent in children with neurological disorders such as epilepsy, attention-deficit/hyperactivity disorder and congenital pathologies such as Joubert syndrome and Chiari malformation (1-4). Providing anaesthesia for these children for diagnostic studies such as magnetic resonance imaging (MRI) hence becomes challenging, especially when the airway is unprotected. Several studies have examined and documented airway complications in children undergoing MRI studies with different anaesthetic drugs (5-7). Few studies have also evaluated the effects of anaesthetic drugs such as propofol and dexmedetomidine on airway diameters (8-12). These studies have observed alteration in the shape of airway with propofol (11), while airway collapsibility (8) and upper airway narrowing (10) were seen with high doses (4–6 μg mL^{-1} effect site concentration and 240 μg kg^{-1} min^{-1} infusion of propofol, respectively). Maintenance of airway patency was observed with low-dose (5 mg kg^{-1} h^{-1}) propofol (9), and minimal change in airway measurements was observed with dexmedetomidine even at a high dose of 3 μg kg^{-1} h^{-1} (12). Because propofol and dexmedetomidine are the two drugs most commonly used for sedation in children for MRI study in our hospital, we decided to compare these two drugs in this study. Our hypothesis was that sedation with dexmedetomidine will result in better airway dimensions as compared to propofol. The primary objective of this study was to evaluate the upper airway dimensions in children with neurological disorders during sedation for MRI study with dexmedetomidine and propofol. The secondary objective was to examine the adverse airway events and sedation quality during MRI study with these drugs.

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Methods

This prospective randomised study was approved by the institutional ethics committee, and written informed consent was obtained from a parent. This trial is registered with the clinical trials registry of India (CTRI/2016/03/006721). Seventy-six children aged 1-6 years who were scheduled to undergo MRI study of the brain for their neurological illnesses over a period of 18 months were recruited. After excluding 4 patients, 72 children were selected using centralised computer-generated random numbers to receive either propofol or dexmedetomidine for sedation. The participants and outcome assessors were blinded to the study drug. The study recruitment process is illustrated by a CONSORT flow diagram (Figure 1). Children with endotracheal tube or tracheostomy, significant anatomic airway abnormalities, major cardio-respiratory problems, a history of obstructive sleep apnoea (OSA), or a history of propofol or dexmedetomidine intolerance were excluded.

Anaesthetic technique: In the MRI patient-holding area, details about the clinical status, fasting, laboratory findings and consent were obtained. As per randomisation, sedation was administered and maintained with either propofol 2 mg kg^{-1} followed by 2 mg kg^{-1} h^{-1}, or dexmedetomidine 2 μg kg^{-1} followed by 2 μg kg^{-1} h^{-1}, using a MRI-compatible syringe pump. The depth of sedation was targeted and maintained to a score of ≤3 using the Observer's Assessment Alertness/Sedation (OAA/S) Scale. The OAA/S score was measured after the administration of a bolus sedation dose and at frequent intervals during the MRI study. OAA/S Score was additionally determined immediately before the acquisition of MRI images for airway measurements. This dose was selected based on our clinical experience and previous literature (13, 14). In the event of movement during the procedure, which resulted in the distortion of images, the infusion rate was increased by 1 mg kg^{-1} h^{-1} in the propofol group and 1 μg kg^{-1} h^{-1} in the dexmedetomidine group, up to a maximum of 4 mg kg^{-1} h^{-1} or 4 μg kg^{-1} h^{-1} for propofol and dexmedetomidine, respectively, after administering another bolus at half strength (e.g. for propofol, 1 mg kg^{-1} bolus). In case of an airway obstruction leading to a decrease in SpO_2<90%, appropriate airway interventions were undertaken by the attending anaesthesiologist, and they were documented. Interventions included a decrease in the sedation dose, repositioning of head and neck and if the obstruction was persistent, application of an artificial airway such as nasal airway or laryngeal mask airway. The cardio-respiratory parameters were monitored [heart rate from electrocardiogram (ECG), noninvasive blood pressure (NIBP), respiratory rate (RR), oxygen saturation (SpO_2) and end tidal carbon dioxide ($ETCO_2$)] via a slave monitor in the MRI console, and children were observed for movement via a video camera and through direct visualisation. Ear plugs were used to minimise the stimulation caused by noise during the MRI scan. All children were placed in a similar position during the study. After the study was completed, sedation was discontinued, and children were moved to the observation room.

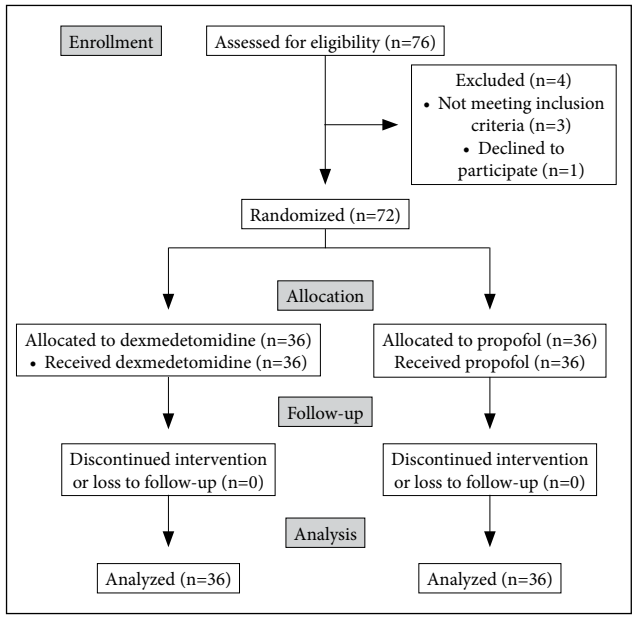

Figure 1. Flow diagram showing participation of patients in the study

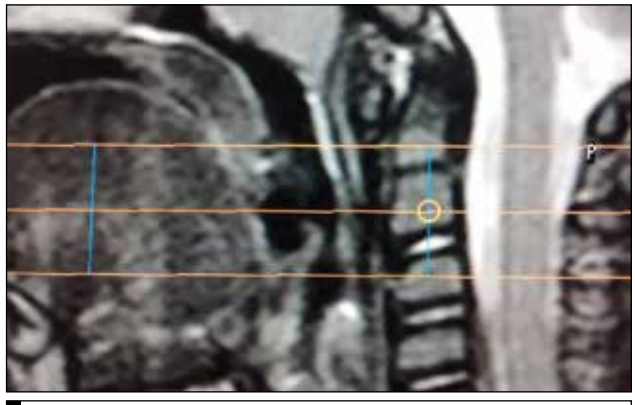

Figure 2. Sagittal view of MRI of the upper airway showing three levels of image acquisition at soft palate, base of the tongue and mid-level of epiglottis during dexmedetomidine infusion

Data collection: Airway dimensions (minimum and maximum dimensions in antero-posterior, transverse directions and cross-sectional area) at three levels-soft palate, the base of tongue and mid-epiglottis-were collected in all children under steady-state anaesthesia. To avoid the influence of changes in sedation depth or airway interventions, these measurements were made when drug infusions were stabilised and cardio-respiratory parameters were stable. In addition, the following parameters were also collected and analysed: evidence of airway obstruction and interventions required for relieving the obstruction, cardio-respiratory parameters, the quality of sedation as evaluated by the need for an additional dose of sedative drug, patient movement during the procedure and re-acquisition of sequences due to poor imaging quality. Heart rate and blood pressure were measured every 5 min till the end of procedure.

Airway imaging and measurements: Dynamic airway study was conducted on a 3 Tesla Achieva magnet (Philips Medical

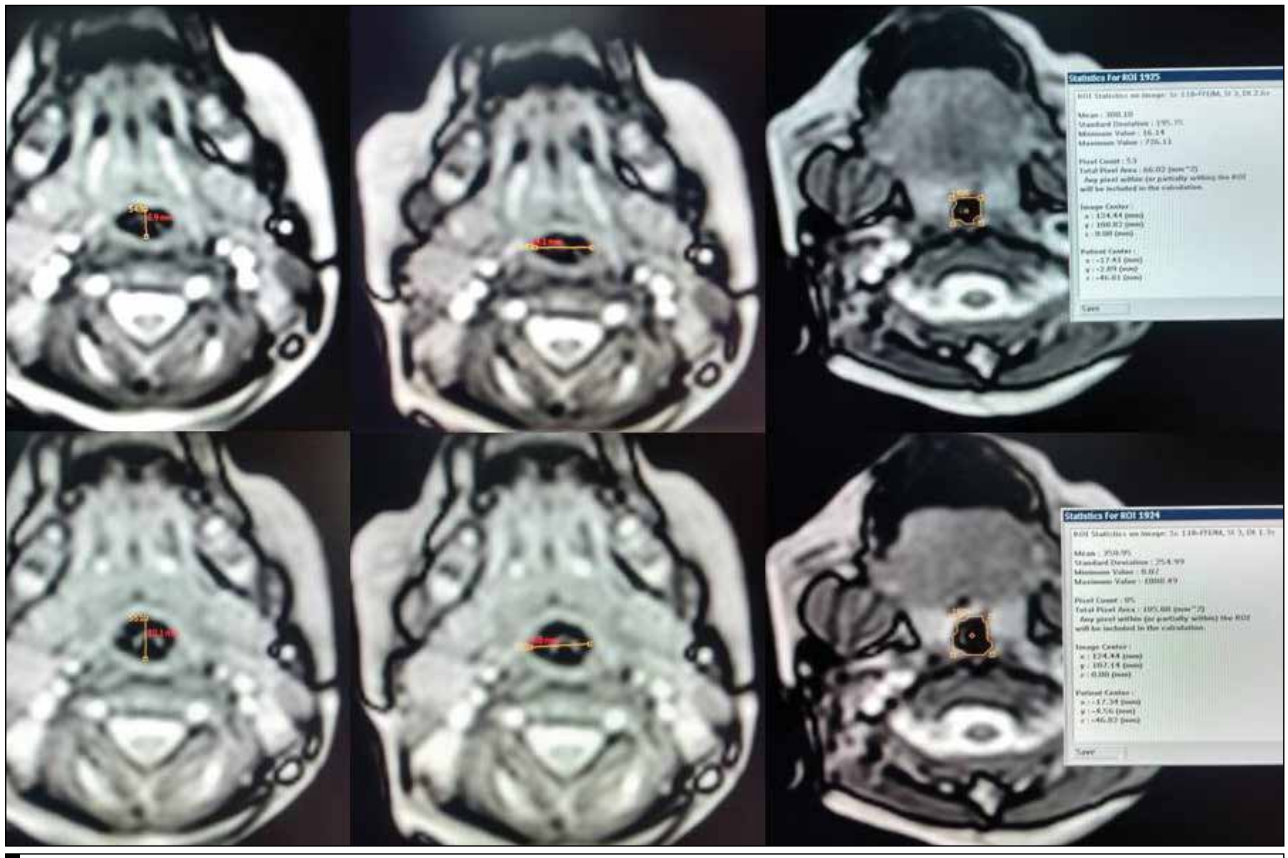

Figure 3. Airway dimensions at the mid-level of epiglottis in a child with dexmedetomidine sedation (Upper left and lower left: Antero-posterior minimum and maximum diameter. Upper middle and lower middle: Transverse minimum and maximum diameter. Upper right and lower right: Minimum and maximum cross-sectional area)

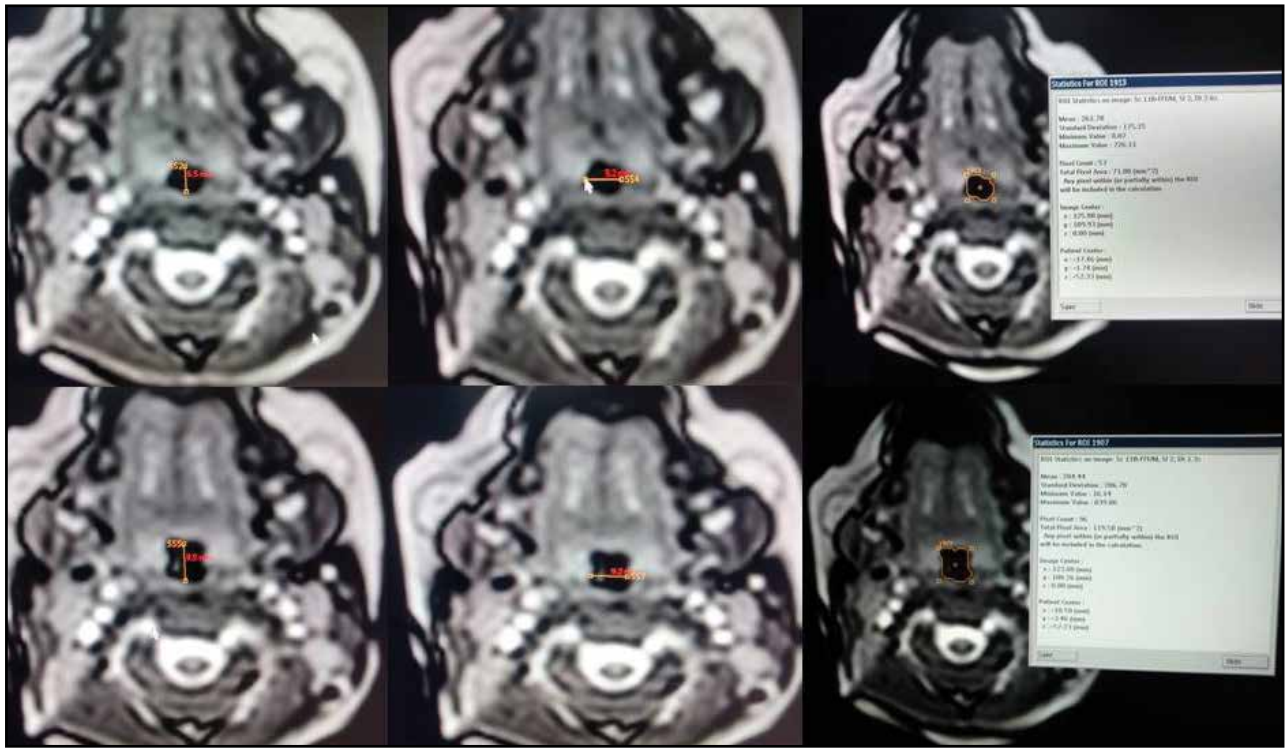

Figure 4. Airway dimensions at the base of tongue level in a child with dexmedetomidine sedation (Upper left and lower left: Antero-posterior minimum and maximum diameter. Upper middle and lower middle: Transverse minimum and maximum diameter. Upper right and lower right: Minimum and maximum cross-sectional area)

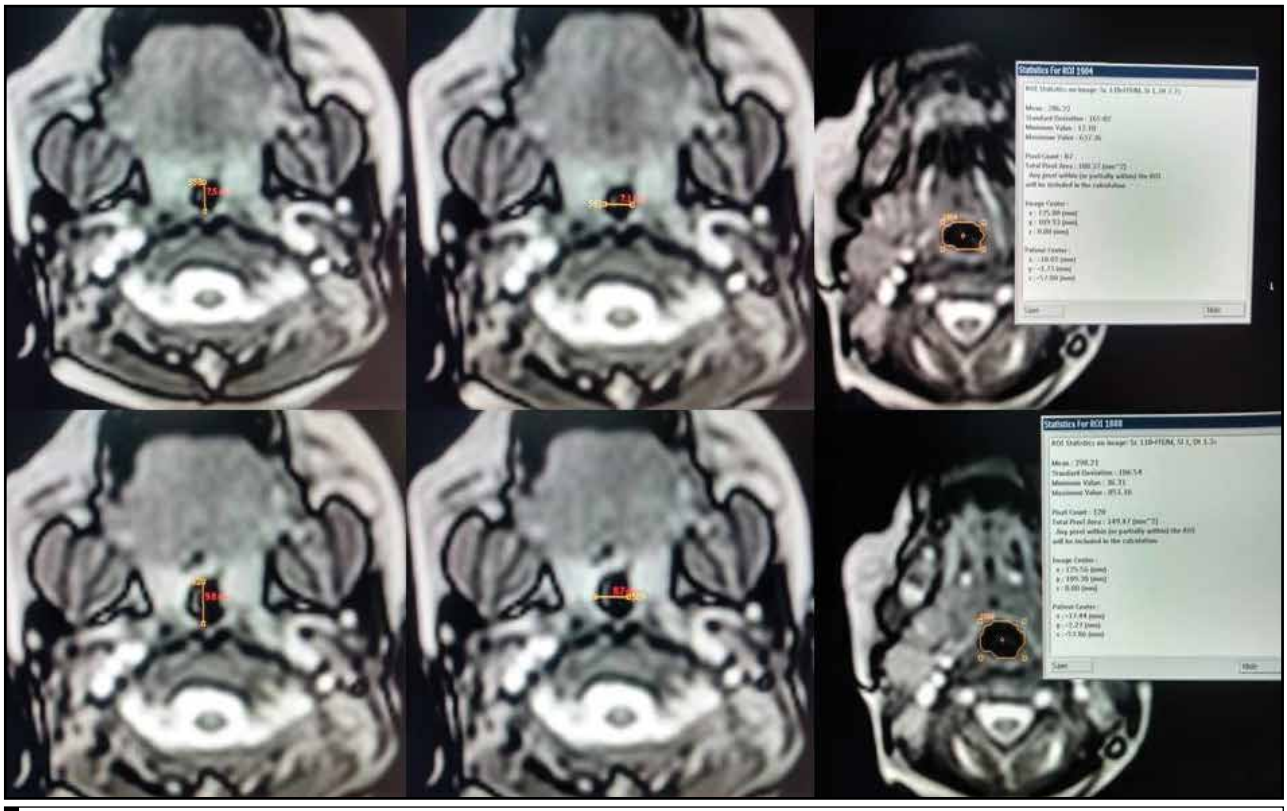

Figure 5. Airway dimensions at the soft palate level in a child with dexmedetomidine sedation (Upper left and lower left: Antero-posterior minimum and maximum diameter. Upper middle and lower middle: Transverse minimum and maximum diameter. Upper right and lower right: Minimum and maximum cross-sectional area)

Systems, Netherlands) with the following acquisition details: Turbo field Echo (TFE) TR 3.8 msec; TE 1.69 msec; with scan time of 0.13 s/dynamic, and the total number of dynamics at 30. Matrix 176 x 156; Flip angle 15 degree; TFE factor of 13.NSA 1; slice thickness=8 mm. The total acquisition time for this study was 64 s. MR fluoroscopy was planned on the initially acquired survey images in three planes. One acquisition was done in the sagittal plane (Figure 2), and three in the axial plane at the soft palate, the base of tongue and the mid-epiglottis level (Figures 3-5). The measurement analyses were done using a vendor-supplied workstation ViewForum Philips Medical Systems and image analysis software. Because timing of the respiratory cycle was not possible in spontaneously breathing children, the maximum and the minimum dimensions at each level were determined from the 30 dynamic images obtained during MR fluoroscopy of the airway at each level.

Statistical analysis

The sample size was determined based on an earlier study that examined airway dimensions. Sixty-two patients were deemed to be necessary for an effect size of 2.4 and 95% confidence interval of 1.78–3.02 (minimum anterior-posterior diameter between the two groups of 4.9 mm and 2.5 mm, respectively) with 80% power and 5% α error (15). To compensate for possible attrition, we included 72 children in this study. The propofol and dexmedetomidine groups were compared for sedation score, airway dimensions and quality of sedation using the independent samples t test, and Chi-squared or Fisher's exact test for categorical variables. A repeated measures analysis of variance was used to analyse differences in heart rate and blood pressure between dexmedetomidine and propofol over several time points of monitoring. A p value <0.05 was considered to be significant. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS Inc.; Chicago, IL, USA, version 17.0).

Results

The demographics of the children are presented in Table 1. There were more male children in the dexmedetomidine group than in the propofol group (p=0.03). Most of the children (18/72) were diagnosed with global developmental delay. Other diagnoses included seizure disorder (n=15), neurosurgical pathology (n=11), metabolic disorder affecting the central nervous system (n=8), cerebrovascular disease (n=5), neuroinfection (n=4), dystonia (n=3) and miscellaneous neurological diagnoses (n=8). All children achieved and maintained the OAA/S score of ≤3. Airway obstruction, apnoea and desaturation were less frequent, and the mean oxygen saturation was higher in the dexmedetomidine group than in the propofol group (Table 2). Apnoea and airway obstruction were observed immediately after a bolus dose of propofol in 3 children. Physical stimulation with the jaw-thrust manoeuvre restored spontaneous respiration and relieved obstruction in these children. No

patient required the placement of nasal or laryngeal mask airway or discontinuation of imaging or sedation. Movement during sedation was observed more frequently in propofol-sedated children than in dexmedetomidine-sedated children. Similarly, more children in the propofol group required supplemental doses of sedative drug and repeat imaging due to poor quality of sequences than in the dexmedetomidine group, although these differences were statistically insignificant. A statistically significant difference was observed at the level of soft palate between the two groups for maximum and minimum transverse diameter (Table 3). A greater change in the cross-sectional area reflecting collapsibility of the airway at the level of tongue was observed with propofol (Table 4). No difference in the airway dimensions was observed at the mid-level of epiglottis between the two groups (Table 5). The heart rate was lower and systolic blood pressure was higher (Figures 6 and 7, respectively) with dexmedetomidine, but this difference

Table 1. Demographics of children undergoing MRI study with dexmedetomidine and propofol sedation

Parameters	Dexmedetomidine (n=36) Mean±SD or n (%)	Propofol (n=36) Mean±SD or n (%)	p
Age (years)	3.1±1.4	3.2±1.5	0.87
Weight (kg)	11.6±3.9	12.8±3.9	0.18
Male gender	27 (75)	17 (47)	0.03
Duration of procedure (minutes)	40.9±10.2	44.7±10.1	0.13
Diagnosis			
Global developmental delay	10 (28)	8 (22)	0.79
Others	26 (72)	28 (78)	

Independent sample t test for age, weight, duration of procedure and Fischer's exact test for gender and diagnosis

Table 2. Respiratory events and sedation quality in children undergoing MRI study under anaesthesia

Parameters	Dexmedetomidine	Propofol	p
Airway obstruction (n)	2/36	3/36	1.00
Oxygen saturation (%)	97.7±1.4	95.4±9.6	0.15
Desaturation incidents (n)	0/36	2/36	0.49
Apnoea (>20s) incidents (n)	0/36	3/36	0.24
Movement during sedation (n)	5/36	9/36	0.37
Additional requirement of sedation (n)	3/36	6/36	0.48
Re-acquisition of imaging sequences (n)	0/36	4/36	0.08

Independent sample t test for mean oxygen saturation, and Fischer's exact test for other variables

Table 3. Airway dimensions at the level of soft palate

Parameters (mm or mm^2)	Dexmedetomidine Mean±SD	Propofol Mean±SD	p
Antero-posterior diameter minimum	7.6±3.3	7.5±4.1	0.97
Antero-posterior diameter maximum	8.5±3.5	8.3±4.2	0.85
Antero-posterior diameter difference	0.9±1.4	0.8±0.7	0.58
Transverse diameter minimum	14.6±3.3	12.4±4.7	0.02
Transverse diameter maximum	15.4±3.4	13.4±4.7	0.04
Transverse diameter difference	0.8±1.0	1.0±1.2	0.41
Cross-sectional area minimum	122.2±47.5	109.6±69.7	0.37
Cross-sectional area maximum	137.7±54.3	130.8±77.0	0.67
Cross-sectional area difference	15.5±16.6	21.2±19.2	0.18

Independent sample t test

Table 4. Airway dimensions at the base of tongue

Parameters (mm or mm^2)	Dexmedetomidine Mean±SD	Propofol Mean±SD	p
Antero-posterior diameter minimum	7.9±3.2	8.3±2.3	0.29
Antero-posterior diameter maximum	8.5±3.4	9.3±2.5	0.12
Antero-posterior diameter difference	0.6±0.6	1.0±1.1	0.05
Transverse diameter minimum	14.8±3.4	13.8±3.9	0.21
Transverse diameter maximum	18.1±17.0	14.9±3.7	0.27
Transverse diameter difference	3.3±16.6	1.1±1.2	0.44
Cross-sectional area minimum	123.5 ± 56.7	128.2 ± 43.7	0.70
Cross-sectional area maximum	138.1±63.3	148.3±50.1	0.26
Cross-sectional area change	14.5±13.9	20.1±19.3	0.03

Independent sample t test

Table 5. Airway dimensions at the mid-level of epiglottis

Parameters (mm or mm^2)	Dexmedetomidine Mean±SD	Propofol Mean±SD	p
Antero-posterior diameter minimum	7.3±2.4	7.8±2.3	0.35
Antero-posterior diameter maximum	8.2±2.6	9.1±2.6	0.17
Antero-posterior diameter difference	0.95±1.0	1.1±1.7	0.76
Transverse diameter minimum	12.0±5.8	11.1±5.3	0.51
Transverse diameter maximum	13.2±5.7	12.6±5.8	0.67
Transverse diameter difference	1.2±1.2	1.5±2.7	0.56
Cross-sectional area minimum	94.0±54.8	94.5±53.3	0.97
Cross-sectional area maximum	111.0±54.1	117.9±64.5	0.63
Cross-sectional area difference	17.0±15.7	23.4±32.7	0.30

Independent sample t test

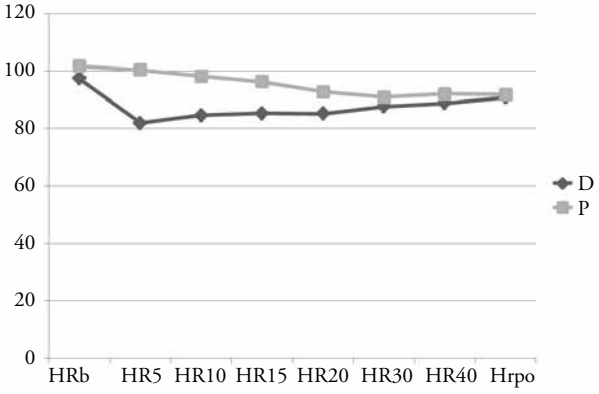

Figure 6. Changes in the heart rate over time in the dexmedetomidine and propofol groups

was significant for systolic blood pressure (p=0.01) and not for the heart rate (p=0.96).

Discussion

In this study, we observed similar airway dimensions in children undergoing MRI with dexmedetomidine and propofol sedation, except for two measurements: transverse diameters at the level of soft palate and cross-sectional area difference at the level of tongue. These changes in airway dimensions were similar to those observed in a recent study (16), but in another study, the changes were observed at all measured levels of the upper airway (17). Fewer adverse respiratory events were observed, and the quality of imaging in case of dexmedetomidine sedation was noted to be superior compared to propofol. However, these clinical differences were statistically insignificant.

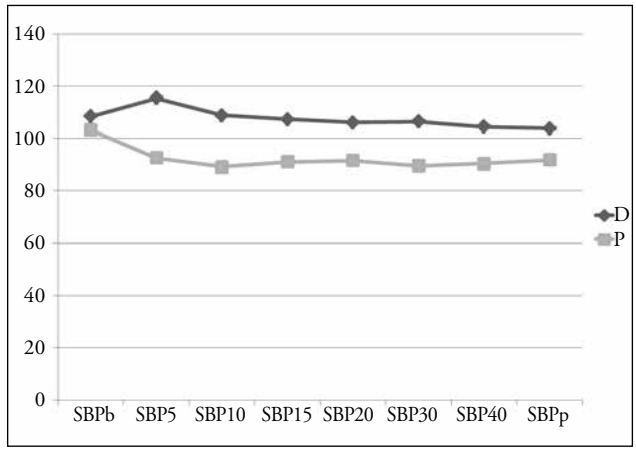

Figure 7. Changes in the systolic blood pressure over time in the dexmedetomidine and propofol groups

Traditionally, propofol has been used for procedural sedation outside the operating room. However, over the last few years, dexmedetomidine is increasingly used as an alternative to propofol. The probable reason behind this change in practice could be an increased collapsibility of the upper airway with an increasing depth of propofol anaesthesia and subsequent airway-related adverse events (8,10). This dose-related effect of propofol on the airway is a result of depression of central respiratory output to upper airway dilator muscles and suppression of the upper airway reflexes (8). These changes may be unwarranted, especially in vulnerable children with neurological disabilities.

Several modifications in the sedation protocols and positioning techniques have been made to overcome the problem of airway obstruction during propofol anaesthesia (16-18). In a study evaluating the effect of propofol and continuous positive airway pressure (CPAP) on airway measurements, the authors observed that increasing the depth of anaesthesia with propofol from 80 to 240 μg kg^{-1} min^{-1} decreased the airway calibre at each anatomical level, while the CPAP application reversed this propofol-induced decrease in airway dimensions (17). Similarly, widening of the airway was observed following the chin-lift manoeuvre in children sedated with propofol (18). A recent study comparing airway dimensions with and without neck collar demonstrated that the application of soft neck collar increased the airway dimensions at the base of the tongue and soft palate in children undergoing MRI study with 50–100 μg kg^{-1} min^{-1} propofol infusion and 0.1 mg kg^{-1} intramuscular midazolam sedation (16).

In contrast, upper airway changes associated with increasing dexmedetomidine doses (from 1 to 3 μg kg^{-1} h^{-1}) in children were small in magnitude and not associated with clinical signs of airway obstruction (12). Similarly, the airway dimensions

remained unchanged or even increased, and airway intervention was less required with an increasing dose of dexmedetomidine (from 1 to 3 μg kg^{-1} h^{-1}) compared to propofol (from 100 μg kg^{-1} min^{-1} to 200 μg kg^{-1} min^{-1}) in children with OSA (19). These observations were confirmed in our study as well, where adverse airway events were less frequent with dexmedetomidine compared to propofol. Hence, dexmedetomidine appears to be an attractive agent for MRI study when the airway is unprotected. A recent study in contrast observed no difference in airway dimensions between dexmedetomidine (1 μg kg^{-1} h^{-1}) and propofol (250–300 μg kg^{-1} min^{-1}) during MRI study (20). However, this study had important limitations such as measurement of airway patency at only one level (posterior mid-tongue) and possible residual effect of sevoflurane on airway measurements.

The problems in children with neurological disorders are not limited only to airway collapsibility, but they are also related to respiratory control. Dexmedetomidine has a better ability to preserve respiratory control when used at high doses (21, 22), unlike propofol that is advantageous in children with syndromic neurological disorders. The use of dexmedetomidine also eliminates the need for external manipulation of airway such as the CPAP application, placement of neck collar, or positioning changes.

In our study, we used 2 mg kg^{-1} h^{-1} of propofol (low dose) for maintenance of sedation, while the dexmedetomidine dose (2 μg kg^{-1} h^{-1}) was comparatively higher than recommended. These doses of propofol and dexmedetomidine were chosen based on our previous clinical experience and published literature. Higher propofol dose, while reducing the patient movement and improving the image quality, results in respiratory compromise from airway collapsibility (8). Similar results were observed in 9 children, where increasing the propofol dose from 80 to 240 μg kg^{-1} min^{-1} decreased the airway calibre at all anatomical levels (17). Airway patency is however maintained with low-dose (5 mg kg^{-1} h^{-1}) propofol sedation for MRI (9). In our study, we too observed that airway dimensions were largely preserved with the low-dose propofol sedation.

One of the major limitations of this study was that we did not time the cine image acquisitions to the two phases of respiratory cycle. It is impractical to acquire images accurately during inspiration and expiration in spontaneously breathing children. The placement of an artificial airway and controlled ventilation to calculate true inspiration and expiration measurements will not only affect the native airway dimensions, but it will also require a higher sedation dose, prolonging the recovery. In these circumstances, we considered the maximum and minimum measurements to reasonably represent the inspiratory and expiratory dimensions respectively and the difference to reflect the airway collapsibility. The second limitation is the lack of comparative measurements in the awake state to truly associate the airway changes with the drug effect. This again is impractical in children with neurological disabilities. Lastly, whether the two doses of dexmedetomidine and propofol we studied are truly comparable is not known, as that would require a MRI compatible target-controlled infusion system or measurement of plasma drug concentrations, which was not feasible in our setup.

Conclusion

Overall, the airway measurements during propofol and dexmedetomidine sedation for MRI study in spontaneously breathing children with neurological disability were similar, except for narrower transverse dimensions at the level of soft palate, and greater airway collapsibility at the base of tongue with propofol sedation. Clinically observed adverse airway events and image re-acquisitions due to patient movement, although more frequent in the propofol group, were statistically insignificant. Future studies should evaluate if these findings are valid in non-neurological populations as well.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of National Institute of Mental Health and Neurosciences.

Informed Consent: Written informed consent was obtained from patients' parents who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.K., J.S.; Design – S.K., J.S.; Supervision – S.V., S.K., J.S.; Resources – K.T., S.K., J.S.; Data Collection and/or Processing – S.K., K.T.; Analysis and/or Interpretation – S.K., J.S.; Literature Search – S.K., S.V., K.T., J.S.; Writing Manuscript – S.K.; Critical Review – J.S., K.T., S.V.

Conflict of Interest: No conflict of interest was declared by the authors.

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References

1. Losurdo A, Dittoni S, Testani E, Di Blasi C, Scarano E, Mariotti P, et al. Sleep disordered breathing in children and adolescents with Chiari malformation type I. J Clin Sleep Med 2013; 9: 371-7. [CrossRef]
2. Goraya JS, Cruz M, Valencia I, Kaleyias J, Khurana DS, Hardison HH, et al. Sleep Study Abnormalities in Children With Attention Deficit Hyperactivity Disorder. Pediatr Neurol 2009; 40: 42-6. [CrossRef]
3. Sriganesh K, Vinay B, Jena S, Sudhir V, Saini J, Umamaheswara Rao GS. Anesthetic management of patients with Joubert syndrome: a retrospective analysis of a single-institutional case series. Paediatr Anaesth 2014; 24: 1180-4. [CrossRef]
4. Kaleyias J, Cruz M, Goraya JS, Valencia I, Khurana DS, Legido A, et al. Spectrum of Polysomnographic Abnormalities in Children With Epilepsy. Pediatr Neurol 2008; 39: 170-6. [CrossRef]

5. Heard C, Harutunians M, Houck J, Joshi P, Johnson K, Lerman J. Propofol anesthesia for children undergoing magnetic resonance imaging: A comparison with isoflurane, nitrous oxide, and a laryngeal mask airway. Anesth Analg 2015; 120: 157-64. [CrossRef]
6. Bryan YF, Hoke LK, Taghon TA, Nick TG, Wang Y, Kennedy SM, et al. A randomized trial comparing sevoflurane and propofol in children undergoing MRI scans. Paediatr Anaesth 2009; 19: 672-81. [CrossRef]
7. Mahmoud M, Gunter J, Donnelly LF, Wang Y, Nick TG, Sadhasivam S. A comparison of dexmedetomidine with propofol for magnetic resonance imaging sleep studies in children. Anesth Analg 2009; 109: 745-53. [CrossRef]
8. Eastwood PR, Platt PR, Shepherd K, Maddison K, Hillman DR. Collapsibility of the Upper Airway at Different Concentrations of Propofol Anesthesia. Anesthesiology 2005; 103: 470-7. [CrossRef]
9. MacHata AM, Kabon B, Willschke H, Prayer D, Marhofer P. Upper airway size and configuration during propofol-based sedation for magnetic resonance imaging: An analysis of 138 infants and children. Paediatr Anaesth 2010; 20: 994-1000. [CrossRef]
10. Evans RG, Crawford MW, Noseworthy MD, Yoo SJ. Effect of increasing depth of propofol anesthesia on upper airway configuration in children. Anesthesiology 2003; 99: 596-602. [CrossRef]
11. Litman RS, Weissend EE, Shrier DA, Ward DS. Morphologic changes in the upper airway of children during awakening from propofol administration. Anesthesiology 2002; 96: 607-11. [CrossRef]
12. Mahmoud M, Radhakrishman R, Gunter J, Sadhasivam S, Schapiro A, McAuliffe J, et al. Effect of increasing depth of dexmedetomidine anesthesia on upper airway morphology in children. Paediatr Anaesth [Internet]. 2010; 20: 506-15. [CrossRef]
13. Siddappa R, Riggins J, Kariyanna S, Calkins P, Rotta AT. High-dose dexmedetomidine sedation for pediatric MRI. Paediatr Anaesth 2011; 21: 153-8. [CrossRef]
14. Wu J, Mahmoud M, Schmitt M, Hossain M, Kurth D. Comparison of propofol and dexmedetomedine techniques in children undergoing magnetic resonance imaging. Paediatr Anaesth 2014; 24: 813-8. [CrossRef]
15. Ciscar MA, Juan G, Martínez V, Ramón M, Lloret T, Mínguez J, et al. Magnetic resonance imaging of the pharynx in OSA patients and healthy subjects. Eur Respir J 2001; 17: 79-86. [CrossRef]
16. Moustafa MA, Emara DM, Nouh MR. Effect of a neck collar on upper airway size in children sedated with propofol-midazolam combination during magnetic resonance imaging. Paediatr Anaesth 2015; 25: 421-7. [CrossRef]
17. Crawford MW, Rohan D, Macgowan CK, Yoo SJ, Macpherson BA. Effect of propofol anes- thesia and continuous positive airway pressure on upper airway size and configuration in infants. Anesthesiology 2006; 105: 45-50. [CrossRef]
18. Reber A, Wetzel SG, Schnabel K, Bongartz G, Frei FJ. Effect of combined mouth closure and chin lift on upper airway dimensions during routine magnetic resonance imaging in pediatric patients sedated with propofol. Anesthesiology 2016; 90: 1617-23. [CrossRef]
19. Mahmoud M, Jung D, Salisbury S, McAuliffe J, Gunter J, Patio M, et al. Effect of increasing depth of dexmedetomidine and propofol anesthesia on upper airway morphology in children and adolescents with obstructive sleep apnea. J Clin Anesth 2013; 25: 529-41. [CrossRef]
20. Watt S, Sabouri S, Hegazy R, Gupta P, Heard C. Does dexmedetomidine cause less airway collapse than propofol when used for deep sedation? J Clin Anesth 2017; 35: 259-67. [CrossRef]
21. Ehsan Z, Mahmoud M, Shott SR, Amin RS, Ishman SL. The effects of Anesthesia and opioids on the upper airway: A systematic review. Laryngoscope [Internet]. 2016; 126: 270-84. [CrossRef]
22. Mason KP, Robinson F, Fontaine P, Prescilla R. Dexmedetomidine offers an option for safe and effective sedation for nuclear medicine imaging in children. Radiology 2013; 267: 911-7. [CrossRef]