Effect of Combined Mouth Closure and Chin Lift on Upper Airway Dimensions during Routine Magnetic Resonance Imaging in Pediatric Patients Sedated with Propofol

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Background: In pediatric patients, obstruction of the upper airway is a common problem during general anesthesia. Chin lift is a commonly used technique to improve upper airway patency. However, little is known about the mechanism underlying this technique.

Methods: The authors studied the effect of the chin lift maneuver on airway dimensions in 10 spontaneously breathing children (aged 2–11 yr) sedated with propofol during routine magnetic resonance imaging. The minimal anteroposterior and corresponding transverse diameters of the pharynx were determined at the levels of the soft palate, dorsum of the tongue, and tip of the epiglottis before and during the chin lift maneuver. Additionally, cross-sectional areas were calculated at these sites, including tracheal areas 2 cm below the glottic level.

Results: Minimal anteroposterior diameter of the pharynx increased significantly during chin lift at all three levels in all patients. The diameters of the soft palate, tongue, and epiglottis increased from 6.7 ± 2.8 mm (SD) to 9.9 ± 3.6 mm, from 9.6 ± 3.6 mm to 16.5 ± 3.1 mm, and from 4.6 ± 2.5 mm to 13.1 ± 2.8 mm, respectively. The corresponding transverse diameter of the pharynx also increased significantly at all three levels in all patients but without significant predominance. The diameters at the levels of the soft palate, tongue, and epiglottis increased from 15.8 ± 5.1 mm to 22.8 ± 4.5 mm, from 13.5 ± 4.9 mm to 18.7 ± 5.3 mm, and from 17.2 ± 3.9 mm to 21.2 ± 3.7 mm, respectively. Cross-sectional pharyngeal areas increased significantly at all levels (soft palate, from 0.88 ± 0.58 cm² to 1.79 ± 0.82 cm²; tongue, from 1.15 ± 0.45 cm² to 2.99 ± 1.30 cm²; epiglottis, from 1.17 ± 0.70 cm² to 3.04 ± 0.99 cm²), including the subglottic level (from 0.44 ± 0.15 cm² to 0.50 ± 0.14 cm²).

Conclusions: This study shows that all children had a preserved upper airway at all measured sites during propofol sedation. Chin lift caused a widening of the entire pharyngeal airway that was most pronounced between the tip of the epiglottis and the posterior pharyngeal wall. In pediatric patients, chin lift may be used as a standard procedure during propofol sedation. (Key words: Airway patency; children; equipment; intravenous anesthetics; pharyngeal airway.)

AIRWAY management in deeply sedated or anesthetized children undergoing magnetic resonance imaging (MRI) remains controversial. The use of propofol or pentobarbital and spontaneous ventilation without any airway adjunct has been advocated by some investigators,1,2 others prefer to intubate their patients.3 Maintenance of a patent airway is of critical importance during sedation for diagnostic procedures. Airway obstruction is often attributed to occlusion of the oropharynx by the tongue.4 However, other studies indicate that obstruction may reside at other levels, such as the epiglottis5 or the soft palate.6 The aim of the present study was to localize the sites of upper airway narrowing or potential obstruction during propofol sedation and to determine the effect of the chin lift maneuver in clearing or preserving the airway in pediatric patients.

Materials and Methods

Study Population
Ten children (aged 2–11 yr) scheduled for elective MRI of the head were consecutively examined. The protocol was approved by the Ethics Committee of the Children’s Hospital, Basel. Before a patient’s participation in the study, relatives gave their written informed consent.
The head position was standardized, with the head being slightly extended and the chin unsupported with an angle of 110° between the horizontal plane of the operating table and the line connecting the lateral corner of the eye and the tragus of the ear. In the second series of measurements, a tape (lift vector 60°) was fixed to the chin of the patient at one end and to the uppermost part of the head coil frame at the other end to obtain chin lift and mouth closure, with the head remaining in the same position as for the first measurements.

Anesthesia

No premedication was given. After pretreatment of the skin with lidocaine-prilocaine cream (EMLA cream 5%, Astra Chemicals, Södertälje, Sweden), a 22-gauge intravenous catheter was started, and deep sedation was induced with 3 mg/kg of propofol; additional boluses of 1 mg/kg were administered as needed to prepare the child on the MRI table. After the child stopped moving, a propofol infusion of 8–10 mg·kg\(^{-1}\)·h\(^{-1}\) was started, and the child was positioned in the scanner. The head position was standardized, with the head being slightly extended and the chin unsupported with an angle of 110° between the horizontal plane of the operating table and the line connecting the lateral corner of the eye and the tragus of the ear (fig. 1). Elevated above the table. All patients were monitored with pulse oximetry, electrocardiography, and blood pressure measurement using a BPLife monitor (Bruker Group, Karlsruhe, Germany). Nasal prongs were used to administer oxygen through one nostril and to measure partial pressure of carbon dioxide of the exhaled air through the other nostril. To clinically assess airway patency, obstruction was scored as follows: 1—normal breathing sounds detected by auscultation over the trachea; 2—stridor over the trachea detected by stethoscope; 3—stridor detected without auscultation; 4—no airway sound detectable over the trachea.

Magnetic Resonance Imaging

Magnetic resonance imaging was performed on a 1.5-T unit with a circular polarized head coil. A three-dimensional (3D) gradient echo sequence (3D magnetization-prepared rapid gradient echo; Siemens, Erlangen, Germany) was used. The sagittally orientated slab (field of view, 250 mm; matrix, 192 × 256; 64 partitions; thickness, 130 mm; effective slice thickness, 2.0 mm) was positioned on an axial localizer to cover the whole pharynx. Additional parameters included 10-ms repetition time, 4-ms echo time, 300-s inversion time, and 10° flip angle. The acquisition time was 3.02 min for each measurement. Baseline measurement was performed with the head positioned as described previously and the patient’s chin unsupported. In the second series of measurements, a tape was fixed to the chin of the patient at one end and to the uppermost part of the head coil frame at the other end to obtain chin lift with mouth closure with the head remaining in the same position as for the first measurements (fig. 1). This maneuver is comparable to the chin lifting that is routinely performed during anesthesia and resulted in mouth closure in all patients.

Image Analysis

The images were stored on an optical disc for subsequent analyses. After image magnification, the images were analyzed in duplicate by two independent radiologists. The minimal anteroposterior diameters of the pharynx in the midsagittal plane were determined at the levels of the soft palate and the dorsal surface of the tongue and between the tip of the epiglottis and the dorsal pharyngeal wall (fig. 2). In addition, the corresponding transverse diameters of the pharynx were determined at the three levels by measuring the distance of a line drawn rectangular to the first line obtained in the sagittal direction (fig. 3). Additionally, cross-sectional areas were
Fig. 2. Midline sagittal magnetization-prepared rapid gradient echo images. Minimal anteroposterior diameter of the pharynx in the midsagittal plane at the level of the soft palate, the dorsum of the tongue, and between the epiglottis and the dorsal pharyngeal wall were measured before (left) and during mouth closure and chin lift (right). Additionally, cross-sectional areas were calculated at these sites, including tracheal areas 2 cm below the glottic level.

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All measurements were performed at identical sites for baseline and during chin lift on the workstation of the MRI.

Statistical Analyses
Measurements made before and during chin lifting were compared using the Student-Newman-Keuls test for paired observations. Analysis of score values was made using Wilcoxon matched pairs test. Spearman rank correlation coefficient ($r_s$) was used to analyze possible relationships between variables. A $P$ value less than 0.05 was considered to be significant. For all calculations, the

Statistica/Windows software package (StatSoft, Tulsa, Oklahoma) was used.

Results
Ten children (aged 2–11 yr) were studied (mean, 5 yr; SD, 3 yr). Body weight ranged from 9 to 48 kg (mean ± SD, 21 ± 12 kg), and height ranged from 95 to 151 cm (115 ± 20 cm). Patients’ medical histories revealed that five children snored at night without episodes of apnea. These children had high stridor scores at baseline (two children had scores of 3, and three children had scores of 2). There was no correlation between snoring and airway dimensions. At baseline, the median stridor score

Fig. 3. Axial reconstructed image at the level of the dorsum of the tongue at baseline (left) and during chin lift (right) in the same patient. Anteroposterior diameter (vertical arrows) and corresponding transverse diameter (horizontal arrows) were measured as described in figure 2.
was 2; however, each child had a patent airway, and in no instance was the procedure interrupted because of airway obstruction. The median score was 1 during chin lift, which was significantly lower than the baseline mean value. There was a significant correlation between the stridor score and anteroposterior airway dimensions at the level of the soft palate (r = -0.45), the transverse airway dimensions at the level of the tongue (r = -0.55), and the cross-sectional areas at these two levels (r = -0.51 and r = -0.50, respectively; pooled data of both baseline and chin lift values). The other diameters and cross-sectional areas showed no correlations between acoustic scoring and the degree of airway caliber. The mean respiratory frequency was 24 breaths/min (range, 19-27) at baseline and 22 breaths/min (range, 17-27) during chin lift. Pulse oximetry remained unchanged when chin lift was applied (saturation ranging 98-100%).

Minimal anteroposterior diameter of the pharynx increased significantly during chin lift at all three levels in all patients, with a statistically significant predominance at the level of the tip of the epiglottis (table 1, fig. 4). The corresponding transverse diameter of the pharynx also increased significantly at all three levels in all patients but without significant predominance (table 1, fig. 4). Cross-sectional pharyngeal areas increased significantly at all levels, including the subglottic level (table 1, fig. 5).

**Discussion**

Our major finding was that chin lift caused a widening of the anteroposterior and transverse diameters of the entire pharyngeal airway. The lift maneuver had differential effects on the various sites of the upper airway. The predominant location of anteroposterior widening was the epiglottis, whereas an increase of the transverse dimension occurred mainly at the level of the soft palate. The upper airway of spontaneously breathing patients tends to obstruct during anesthesia.6,7 The magnetic resonance technique does not allow conclusions regarding anatomic changes that occur during the respiratory cycle. Therefore, slight narrowing of the pharyngeal walls that may occur during inspiration may not be visible. Slight extension of the head reduces the risk of obstruction.5 With a standardized degree of extension, we found an open airway in all children as revealed in the MRIs. We kept the degree of head extension constant during the measurements. At baseline, the mouth was open in all patients. The lift of the chin using a tape resulted in mouth closure. Although we positioned the patient's head carefully, measurements obtained on the midsagittal plane revealed that head extension was minimally affected, with an increase of 0-5° that presumably did not influence our study results based on the fact that no correlation was found with other parameters.

We did not perform pharyngeal suction to empty secretions from the upper airway, and vibrations from secretions may have had an impact on the cause of airway sounds. Recent results showed that stimulation of the larynx with distilled water during propofol anesthesia caused various alterations in laryngeal behavior.8 We found significant correlations between acoustic scoring and airway dimensions at the level of the soft palate and dorsum of the tongue. Thus, it is likely that airway sounds are generated by the airway caliber and a combination of secretions and concomitant changes in laryngeal characteristics.

The upper airway is, at least in part, a collapsible tube. In the awake state, muscles such as the tongue, genioglossus, geniohyoid, cervical strap, sternohyoid, and sternothyroid resist pharyngeal airway collapse that may occur as a result of negative intraluminal pressures.9,11 Anesthetic agents may inhibit respiratory activity of the upper airway muscles more than the diaphragm.12,13 Thus, with continued diaphragmatic activity, the presence of a collapsible segment of the upper airway cre-
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Fig. 4. Individual changes of minimal anteroposterior (left) and transverse (right) diameters at the levels of the soft palate, the tongue, and the epiglottis before (baseline) and during the chin lift maneuver.

ates the potential for its narrowing or complete closure during anesthesia. Upper airway muscle activity is substantially reduced because of the increased sensitivity of the muscles to halothane anesthesia; reduction of upper airway muscle activity contributes to the likelihood of a collapse of the tube in a dose-dependent manner. No such data exist for propofol anesthesia. In the present study, as well as in others, MRIs reveal a preserved upper airway patency during propofol anesthesia. The imbalance between upper airway muscle depression and diaphragmatic muscle depression may be less pronounced with propofol than with halothane anesthesia.

It has been shown in adults that ketamine preserves the hypopharyngeal size, whereas with midazolam muscle activity decreases significantly, and subsequently airway obstruction may occur. Administration of thiopental is frequently associated with airway obstruction and accompanied by significant increases in phasic muscle action that does not overcome the obstruction. The pattern of changes observed in patients anesthetized with thiopental suggests that loss of tonic activity in the sternothyroid and sternohyoid muscles is associated with airway obstruction. Appropriate studies should be done to investigate the effect of different anesthetics on upper airway muscle depression and airway geometry.

Our MRI findings with a preserved airway at baseline are consistent with other results obtained recently in adults. The conventional wisdom has been that airway obstruction associated with general anesthesia is generally attributable to reduced genioglossus activity with consequent posterior displacement of the tongue. In contrast to this traditional view, based on results from adult patients, our findings, in conjunction with other observations, suggest that the tongue is unlikely to be an important cause of impaired airway patency in anesthetized children. In our patients, the smallest anteroposterior diameter at baseline was at the level of the epiglottis, reflecting a downward fold of the epiglottis, whereas the largest anteroposterior dimensions were measured at the level of the tongue.

Investigations of chin lift and other airway-clearing maneuvers were performed 40 yr ago. Studies of pharyngeal radiographs showed that this maneuver produced a satisfactory pharyngeal clearance of the anteroposterior distance between the tongue and posterior pharynx in paralyzed adults; however, because of technical limitations at the time it was not possible to show the detailed effects of chin lift on airway geometry. In our study, chin lifting caused a widening of the entire pharyngeal airway. The degree of widening was most pronounced anteroposteriorly between the tip of epiglottis and the posterior pharyngeal wall. Thus, chin lifting counteracts the downward fold of the epiglottis and preserves the airway. We suggest that the improvement of airway caliber during chin lift is caused by a combination of tensing of the pharyngeal muscles and forward movement of the muscles attached to the jaw. This is consistent with studies using lateral-view radiographs of the pharynx and suggests that prevention of upper airway obstruction is produced by mouth closure, which results in stretching of the anterior neck structures. In contrast, mouth opening increases upper airway collapsibility during sleep and may contribute to the occurrence of sleep-related breathing abnormalities.
Because the mandible anchors the genioglossal and associated muscles that are attached to the hyoid bone, mouth closure is associated with anterior movement of the genioglossal muscle and increased tension on the muscles attached to the hyoid, which lead to a greater opening of the oropharyngeal airway. The increase in pharyngeal airway caliber may be closely related to the advancement in space of the mandible to which the tongue is attached. A further step, namely applying mandibular protrusion (jaw thrust), may additionally increase airway cross-sectional areas, as it has been shown to do in adults with obstructive sleep apnea.25

In our sedated patients, chin lift improved airway patency at all measured levels. The anterior movement of the soft palate may be caused by some tension exerted on the palatoglossal muscle, which is attached to the genioglossal muscle, and by adhesion of the oral surface to the surface of the tongue. The increase in subglottic dimensions may be explained by the stretching of the strap muscles and forward displacement of ventral neck structures, leading to a subsequent widening of the upper part of the trachea.

The normal upper airway is laterally wider than anteroposteriorly.26 In adult patients with obstructive sleep apnea caused by an anteroposterior configuration, i.e., lateral narrowing, the lateral pharyngeal walls are important in mediating upper airway caliber.26,27 In children with sleep-disordered breathing, primary closure occurs at the level of hypertrophied adenoids and tonsils.28 Airway geometry changes during anesthesia in patients with normal airways may be different compared with those in patients with obstructive sleep apnea. However, we believe that the lateral dimensions are important in mediating a preserved airway patency. In our patients, chin lifting produced a transverse widening of airway caliber, reflecting a certain capacity of airway patency to improve in the lateral dimension. At the level of the tongue, this may be explained by the soft tissue of the lateral pharyngeal walls caused by the anterior movement of the tongue.

Thus, in addition to the position of the epiglottis, the anteroposterior diameter at the level of the soft palate and the transverse diameter at the level of the dorsum of the tongue are important for airway patency. In our patients, transverse diameters also increased at all measured levels.

In conclusion, all children had preserved upper airways at all measured sites during propofol sedation. Chin lift caused a widening of the entire pharyngeal airway that was most pronounced between the tip of
the epiglottis and the posterior pharyngeal wall. However, for preserving airway patency in spontaneously breathing pediatric patients during MRI investigations, thin lift may initially be the treatment of choice because it is effective and more easily applied than other techniques.

References


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