Published in final edited form as:

JAMA Otolaryngol Head Neck Surg. 2013 June ; 139(6): 636–638. doi:10.1001/jamaoto.2013.3279.

An Adverse Effect of Positive Airway Pressure on the Upper Airway Documented With Magnetic Resonance Imaging

Dr. Robert J. Fleck Jr, MD, Dr. Mohamed Mahmoud, MD, Mr. Keith McConnell, MS, Dr. Sally R. Shott, MD, Dr. Ephraim Gutmark, PhD, and Dr. Raouf S. Amin, MD

Departments of Radiology (Dr Fleck), Anesthesiology (Dr Mahmoud), Pulmonary Medicine (Mr McConnell and Dr Amin), and Otolaryngology–Head and Neck Surgery (Dr Shott), University of Cincinnati College of Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio; and Department of Aerospace Engineering and Engineering Mechanics, University of Cincinnati, Cincinnati (Dr Gutmark)

Abstract

Importance—Positive pressure air is used during basic life support to provide respirations and applied as continuous positive airway pressure to maintain a patent airway during sleep or anesthesia. These functions are more critical in children with obstructive sleep apnea, who often have smaller airway dimensions and increased airway collapsibility.

Observations—We report 2 cases of boys with Down syndrome and a history of obstructive sleep apnea in whom adverse narrowing of the retroglossal airway is caused by continuous positive airway pressure applied via face mask as documented with magnetic resonance imaging.

Conclusions and Relevance—Administration of continuous positive airway pressure by means of face mask to patients can result in adverse effects on the airway patency by pushing the tongue posteriorly. Awareness of this effect on patients with open mouths and large tongues, as present in Down syndrome, is important for sleep apnea treatment, anesthesia, and emergency respiratory support. Generalization of our observation is not possible at this time. Additional prospective studies of the effects of continuous positive airway pressure on airway patency in sedated and/or anesthetized children are required to confirm our anecdotal observations.

Maintenance of airway patency is a primary consideration during administration of anesthesia or sedation¹ and during basic life support. These functions are more critical in children with obstructive sleep apnea (OSA), who often have smaller airway dimensions and

Correspondence: Robert J. Fleck Jr, MD, Department of Radiology, Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave, MLC 5031, Cincinnati, OH 45229 (robert.fleck@cchmc.org).

Conflict of Interest Disclosures:

None reported.

Previous Presentation: This study was presented at the Society for Pediatric Radiology Annual Meeting; April 18, 2012; San Francisco, California.

Author Contributions: All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Fleck, Mahmoud, Shott, and Amin. *Acquisition of data:* Fleck, McConnell, and Amin. *Analysis and interpretation of data:* Fleck, Mahmoud, Shott, Gutmark, and Amin. *Drafting of the manuscript:* Fleck, Mahmoud, and Amin. *Critical revision of the manuscript for important intellectual content:* All authors. *Obtained funding:* Amin. *Administrative, technical, and material support:* Fleck, McConnell, and Gutmark. *Study supervision:* Fleck, Shott, and Amin.

increased airway collapsibility.² During anesthesia or sedation and basic life support, airway maneuvers such as jaw thrust and chin lift are commonly used to improve airway patency.³

We report 2 pediatric patients, both with Down syndrome and a history of OSA, who experienced further narrowing of the pharyngeal airway when continuous positive airway pressure (CPAP) was applied via face mask. We suggest that this phenomenon is a potential cause of airway obstruction when positive airway pressure is used during resuscitation or as a means of maintaining airway patency during anesthesia or sleep.

REPORT OF CASES

Two patients, both with Down syndrome and a history of OSA, presented for magnetic resonance imaging (MRI) sleep study evaluations. Anesthesia was maintained with dexmedetomidine infusion, and each patient's head and neck was placed in a vascular coil. Imaging was performed on a 1.5-T HDxt MRI scanner (software version 16; General Electric). The imaging sequence was a 3-dimensional (3D) fast spin echo with proton density weighting (CUBE) with end inspiratory respiratory triggering. This sequence uses a modulated flip angle to decrease blurring and parallel imaging to reduce time. The advantage of this sequence is an isotropic data set allowing retrospective review in any plane and 3D reconstructions of the airway. The specific parameters were repetition time, 3156; echo time, 35.022; flip angle, modulated; echo train length, 64; field of view, 240 mm; matrix, 256 by 256; slice thickness, 1.60 mm; and slice interval, 0.80 mm. This specific sequence results in 0.8-mm isotropic resolution with minimal blurring due to respiratory motion and is approximately a 5-minute acquisition depending on respiratory triggering efficiency. A similar sequence is commercially available from other MRI manufacturers: VISTA (Philips) and SPACE (Siemens). No artificial airway (eg, oral airway or nasal trumpet) or positioning aid (eg, shoulder roll) was used during the MRI.

PATIENT 1

The first patient (an 8-year-old boy) was imaged with CPAP initially set at 0 cm H₂O. After initial localizer images were obtained, an end inspiratory triggered 3D proton density-weighted sequence was performed uneventfully (Figure, A), followed by midline sagittal and axial cine imaging for evaluation of airway dynamics. Next, 15 cm H₂O CPAP was applied by means of face mask for the purpose of measuring airway compliance and the imaging was repeated. When CPAP was applied, the tongue shifted posteriorly, narrowing the retropharyngeal airway (Figure, B). Airway measurements are summarized in the Table. We subsequently reasoned that the airway narrowing was due to oral CPAP pushing the tongue posteriorly and decided that future patients should be imaged with the mouth closed.

PATIENT 2

The second patient (a 10-year-old boy) was imaged with the mouth closed with face mask CPAP at 0 cm H₂O; application of 15 cm H₂O CPAP by means of face mask caused the lips to part, and the tongue shifted posteriorly, narrowing the retroglossal airway (Figure, C). The mouth was subsequently closed and the imaging repeated, at which time a much improved

caliber in the retroglossal airway was noted (Figure, D). The changes in the airway dimensions are summarized in the Table.

DISCUSSION

Although all patient airways (normal or abnormal) are susceptible to collapse during anesthesia because of the inhibitory effects of anesthetics and sedative agents on the airway musculature,^{4,5} children are at greater risk because of a combination of their relatively smaller caliber airway and frequent hypertrophy of the adenoids and tonsils.⁶ Children with OSA are especially vulnerable to the development of upper airway obstruction during anesthesia and sedation.⁷ Factors affecting the upper airway collapsibility in Down syndrome include hypotonia, obesity, midface hypoplasia, relative macroglossia, and excessively large tonsils and adenoids. The decrease in airway muscular tone associated with anesthesia and sedation, as well as the supine position, lead to changes in the anatomic positioning of structures that surround the airway. These changes are more pronounced in children with Down syndrome than in other children, and often they demonstrate increased dynamic airway collapse, contributing to the clinical findings in OSA.

It is important for practitioners who administer anesthetic or sedative agents to understand this risk and to know how to improve airway patency. Maneuvers used to counteract pharyngeal airway narrowing include chin lift or jaw thrust combined with CPAP.¹ It has previously been shown that opening the mouth without mandibular protrusion (jaw thrust) increases airway collapsibility because of reduced tension of the upper airway muscles.^{1,8} In our observations, we noted that opening the mouth during face mask CPAP administration also allows the positive pressure to push the tongue posteriorly and further compromise the airway.

Our observation is important not only during sedation but also in the context of emergency resuscitation. Use of a face mask with bag-mask ventilation could result in the tongue being pushed posteriorly, potentially causing further airway obstruction and complicating resuscitation. Application of a jaw thrust maneuver and closure of the mouth, or use of an appropriately sized oral airway, would allow air to pass freely from the oral cavity into the pharynx and prevent this complication. We believe that this complication may go unrecognized during resuscitation with positive pressure ventilation. Early use of an oral airway would avoid this problem.

Patients with OSA who have Down syndrome typically have enlarged tongues relative to their oral cavity and are more predisposed to airway collapse.⁷ Therefore, generalization of our observations to other patients is not possible at this time. Additional prospective studies of the effects of CPAP on airway patency in sedated and/or anesthetized children are required to confirm our anecdotal observations.

Acknowledgments

Funding/Support: This study was supported by National Institutes of Health grant RO1HL105206-01.

References

1. Reber A, Paganoni R, Frei FJ. Effect of common airway manoeuvres on upper airway dimensions and clinical signs in anaesthetized, spontaneously breathing children. *Br J Anaesth*. 2001; 86(2): 217–222. [PubMed: 11573663]
2. Isono S, Tanaka A, Nishino T. Dynamic interaction between the tongue and soft palate during obstructive apnea in anesthetized patients with sleep-disordered breathing. *J Appl Physiol*. 2003; 95(6):2257–2264. [PubMed: 12937025]
3. Phillips BM, Mackway-Jones K, Jewkes F. The European Resuscitation Council's paediatric life support course 'Advanced Paediatric Life Support. ' *Resuscitation*. 2000; 47(3):329–334. [PubMed: 11114466]
4. Eastwood PR, Platt PR, Shepherd K, Maddison K, Hillman DR. Collapsibility of the upper airway at different concentrations of propofol anesthesia. *Anesthesiology*. 2005; 103(3):470–477. [PubMed: 16129969]
5. Evans RG, Crawford MW, Noseworthy MD, Yoo SJ. Effect of increasing depth of propofol anesthesia on upper airway configuration in children. *Anesthesiology*. 2003; 99(3):596–602. [PubMed: 12960543]
6. Litman RS, Kottra JA, Berkowitz RJ, Ward DS. Upper airway obstruction during midazolam/nitrous oxide sedation in children with enlarged tonsils. *Pediatr Dent*. 1998; 20(5):318–320. [PubMed: 9803430]
7. Ankichetty S, Wong J, Chung F. A systematic review of the effects of sedatives and anesthetics in patients with obstructive sleep apnea. *J Anaesthesiol Clin Pharmacol*. 2011; 27(4):447–458. [PubMed: 22096275]
8. Meurice JC, Marc I, Carrier G, Sériès F. Effects of mouth opening on upper airway collapsibility in normal sleeping subjects. *Am J Respir Crit Care Med*. 1996; 153(1):255–259. [PubMed: 8542125]

Figure.

Patients 1 and 2. All magnetic resonance images were obtained with 3-dimensional fast spin echo (proton density) with end inspiratory respiratory gating. Patient 1: A, With 0 cm H₂O continuous positive airway pressure (CPAP) via face mask. Note patency between the oral airway and the retroglossal airway (arrowhead) and the tongue in neutral position with the mouth open. B, With 15 cm H₂O CPAP via face mask, the retroglossal airway is narrowed by the tongue (short arrow), which is pushed back by the CPAP. Note the convexity of the anterior superior portion of the tongue (long arrow) and the occlusion of the oral airway (arrowhead) by opposition of the tongue and soft palate. Patient 2: C, With 15 cm H₂O CPAP via face mask with the mouth open, the retroglossal airway is narrowed by the tongue (short arrow), which is pushed back by oral CPAP pressure. Similar to patient 1, there is convexity (long arrow) of the anterior superior tongue. D, With 15 cm H₂O CPAP via face mask with the mouth closed, the pressure opens the nasopharyngeal airway (small arrows) and retroglossal airway (short arrow).

Table

Measurements During Minimum Caliber Phase of Respiration

Patient	Anterior Posterior, mm		Transverse, mm		Area, mm ²	
	15 cm H ₂ O CPAP		15 cm H ₂ O CPAP		15 cm H ₂ O CPAP	
	0 cm H ₂ O CPAP	Mouth Open	Mouth Closed	0 cm H ₂ O CPAP	Mouth Open	Mouth Closed
1	2.5	1.5	NA	8.3	23.1	NA
2	6.0	4.4	12.0	8.2	25.0	24.5
					26.6	31.0
					33.2	111.5
						225.3

Abbreviations: CPAP, continuous positive airway pressure; NA, not applicable.