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Effect of common airway manoeuvres on upper airway dimensions and clinical signs in anaesthetized, spontaneously breathing children

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Chin lift, jaw thrust and these manoeuvres combined with continuous positive airway pressure (CPAP) can be used to improve the patency of the upper airway during general anaesthesia. We used video endoscopy and measurement of stridor to compare the efficacy of these manoeuvres in 24 children (3–10 yr) with adenotonsillar hyperplasia. A bronchofibrescope was passed via the nose while the children were breathing spontaneously, to identify (i) the shortest transverse distance between the tonsils during inspiration and during expiration and (ii) the distance from the tip of the epiglottis to the posterior pharyngeal wall. Chin lift or jaw thrust lifted the epiglottis and, when combined with CPAP (10 cm H_2O), there was a significant lateral displacement of the tonsils. Both chin lift plus CPAP and jaw thrust plus CPAP reduced stridor significantly compared with the unsupported condition. In conclusion, in spontaneously breathing children with large tonsils, chin lift plus CPAP is recommended, whereas jaw thrust plus CPAP is no better and may cause post-operative discomfort.

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Maintenance of the airway is an important aspect of the safe administration of anaesthesia to children. Failure to maintain a patent airway can result in hypoxaemia despite an increase in inspired oxygen fraction. The airway obstruction associated with general anaesthesia is generally attributed to reduced genioglossus activity and consequent posterior displacement of the tongue.[1 2] Any drug that reduces the activity of the pharyngeal muscles can reduce airway patency and thereby increase upper airway resistance.[3] Obstruction can be caused by occlusion of the oropharynx by the tongue[4] or by the epiglottis or soft palate.[5] Although the positions of the head and mandible affect upper airway obstruction, knowledge of the respiratory changes in airway dimensions is still only fragmentary in spontaneously breathing, anaesthetized infants and children. The chin lift manoeuvre is considered to produce a satisfactory upper airway in subjects with a flaccid upper airway.[6] Airway patency is also improved by jaw thrust with continuous positive airway pressure (CPAP) to dilate or splint the upper airway, but little is known about how these techniques work. We studied airway patency using clinical signs and endoscopy to describe the effects of common airway manoeuvres on airway patency in children.

Patients and methods

We studied 24 children (3–10 yr) scheduled for elective adenotonsillectomy. Children with craniofacial abnormalities, deformities of the chest or spine, and myopathies were excluded. The study was approved by the Ethics Committee of the Children's Hospital, Basel, and parents gave written informed consent.

Anaesthesia

Each patient was premedicated with midazolam 0.3 mg kg^{-1} rectally 15 min before anaesthesia. Anaesthesia was induced with ≤3 vol% halothane via a face mask, with oxygen in 50% nitrous oxide from a circle system. Inspired halothane concentration was adjusted to give an end-tidal concentration of 1.0 vol%. Electrocardiogram, pulse oximetry and capnography with breathing frequency were recorded

(Capnomac Ultima; Datex, Helsinki, Finland). The head position was standardized. The head was slightly extended using a special pillow, to obtain an angle of 110° between the horizontal plane of the operating table and a line connecting the lateral corner of the eye and the tragus of the ear, with neither the occiput of the head nor the shoulders raised above the operating table. We used this angle because a study of adults by Boidin[7] and our own clinical observations in anaesthetized children (unpublished) suggest that this allows maximal widening of the upper airways.

Airway monitoring

We adapted a special airway endoscopy mask[8] and a standardized fixation system (Secutape; TechniMed Ltd, Basel, Switzerland) to tailor the mask to each patient. A bronchofibrescope with an outer diameter of 3.5 mm (Olympus Optical, Volketswil, Switzerland) was inserted through the mask and one nostril into the nasopharynx, leaving the other nostril patent. The tongue and laryngeal structures were examined while the child was breathing spontaneously. The light source for the endoscopy was a xenon lamp (CLV-U40, Olympus Optical Co., Tokyo, Japan). For all measurements, the tip of the fibrescope was kept at the edge of the soft palate to give comparable views at baseline (chin unsupported) and during the subsequent manoeuvres. The manoeuvres were standardized and performed by the same investigator in all children to eliminate inter-investigator variability. A baseline measurement was made with the adapted facemask with the patient's chin unsupported. Then chin lift was done with one hand without making the mandible protrude. The teeth were in light contact and the lips remained open, so the mouth was not completely closed. Then, in addition to chin lift, CPAP of 10 cm H_2O was applied from the circle system to dilate or splint the upper airway. Jaw thrust was applied with both hands, displacing the jaw upwards and anteriorly (Esmarch manoeuvre), which allowed the mouth to remain open. This was done with maximal mandibular protrusion at zero end-expiratory airway pressure and then with CPAP of 10 cm H_2O. After the measurements, the patient's trachea was intubated for subsequent surgery.

Airway patency was assessed clinically as follows: stridor score 1, normal breathing sounds detected by auscultation over the trachea; 2, stridor over the trachea detected by stethoscope; 3, stridor detected without auscultation (audible); 4, no airway sound detectable over the trachea.

Video transformation and image analysis

Records were made for 1 min during each of the different airway manoeuvres on a Super VHS tape (SV-9500 MDP; Sony, Tokyo, Japan). The video sequences were transferred to a Macintosh computer using a frame grabber card (miroMotion DC 20; Miro Computer Products, Braunschweig, Germany). Video information (72 dots per inch, 25 frames per second) was transposed to a PICT format (Adobe Premiere 4.2.1; Adobe Systems Inc., San Jose, CA, USA) and analysed with an image analysis software package (Adobe Photoshop 4.0; Adobe Systems Inc.). The person who performed the image analysis was blinded as to a patient's group. The images with the most narrowed and widened airway dimensions (corresponding to end-inspiration and end-expiration) were identified for the different conditions. The shortest distance between the tonsils (transverse dimension) and the distance between the tip of the epiglottis and the posterior pharyngeal wall (anteroposterior dimension) were measured. These are the most important pharyngeal airway distances during breathing in anaesthetized children.[9]

Statistical analysis

Airway dimensions were expressed as a percentage of distance from baseline, with the chin unsupported. Percentages instead of absolute values were used to reduce the problems of different distance and characteristics between subjects and radial distortion of images caused by the optical characteristics of the fibrescope.[10] The different conditions were compared by repeated-measures analysis of variance. For *post hoc* comparisons, Tukey's test was applied and probability values calculated. Score values were analysed by means of the non-parametric Friedman's test for repeated-measures analysis. Spearman's rank correlation coefficient (r_s) was applied to analyse possible relationships between variables. A P value of <0.05 was considered significant. For all calculations, Statistica/w 4.5 software (StatSoft, Tulsa, OK, USA) was used.

Results

Patient characteristics are presented in Tables 1 and 2. There was no relationship between patient characteristics and subsequent findings.

Both chin lift with CPAP and jaw thrust with CPAP reduced stridor (median score 1.0 (25%–75% interquartile range 0.0) for both) significantly compared with baseline (2.0 (1.5)) and chin lift (2.0 (1.0)) (Figure 1). There was no relationship between inspiratory airway dimensions and stridor scoring, except for the jaw thrust with a CPAP condition (r_s –0.46, $P<0.05$).

All manoeuvres lifted the epiglottis significantly during inspiration (Figure 2). The inspiratory and expiratory

Table 1 Patient characteristics. Data for age, weight and height are mean (SD) (range)

Age (yr)	5.8 (1.8) (3–10)
Body weight (kg)	19.6 (4.7) (12.5–25.8)
Height (cm)	112 (12) (90–126)
History of snoring (*n*)	18/24
History of apnoea (*n*)	8/24

Table 2 Effect of airway manoeuvres on heart rate and breathing frequency. Data are mean (SD) (range). CPAP, continuous positive airway pressure

	Baseline	Chin lift	Chin lift + CPAP	Jaw thrust	Jaw thrust + CPAP
Heart rate, beats min^{-1}	94 (21) (58–150)	92 (19) (62–146)	91 (19) (63–146)	99 (21) (61–146)	98 (23) (64–157)
Breathing frequency, bpm	35 (7) (22–53)	33 (7) (22–49)	36 (8) (22–61)	34 (8) (21–50)	38 (8) (24–62)

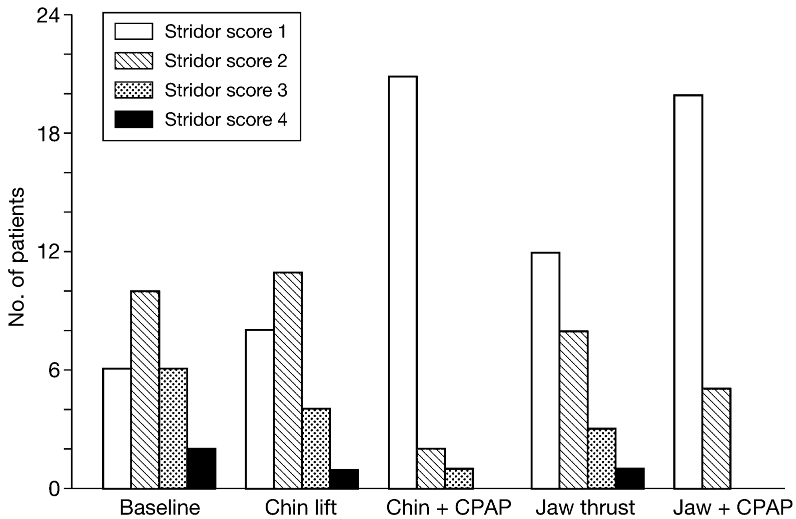

Fig 1 Histogram showing pattern of stridor scoring for airway manoeuvres. Stridor score 1, normal breathing sounds detected by auscultation over the trachea; 2, stridor over the trachea detected by stethoscope; 3, stridor detected without auscultation; 4, no airway sounds detectable over the trachea. CPAP, continuous positive airway pressure.

dimension changes were significantly correlated during all the manoeuvres (P<0.001): chin lift: r_s=0.92; chin lift with CPAP: r_s=0.88; jaw thrust: r_s=0.86; jaw thrust with CPAP: r_s=0.92.

Chin lift with CPAP and jaw thrust with CPAP increased the transverse dimension best and were equally effective. Chin lift and jaw thrust manoeuvres without CPAP reduced the transverse distance during inspiration in 10 and six patients, respectively (Figure 3). The inspiratory and expiratory dimension changes were significantly correlated during all the manoeuvres (P<0.001): chin lift: r_s=0.74; chin lift with CPAP: r_s=0.88; jaw thrust: r_s=0.81; jaw thrust with CPAP: r_s=0.77.

Discussion

We found that in spontaneously breathing children with large tonsils, chin lift or jaw thrust lifted the epiglottis. When combined with CPAP, the tonsils were moved apart.

Effect of anaesthesia

During anaesthesia, a collapsible segment in the upper airway may narrow or close during inspiration.[11] In a study of thoracoabdominal motion in children, clinically significant upper airway obstruction was found at 2 MAC (minimal alveolar concentration) sevoflurane.[12] We identified airway collapse during late inspiration, which is similar to reports of collapse during sleep.[13] Severe inspiratory collapse may be associated with a marked decrease in intraluminal pressure.[13] The distal pharynx is 'sucked' in and may even obstruct. The lateral walls of the pharynx have a complex architecture, with a number of muscles that have different biomechanical relationships with each other and with other pharyngeal structures.[14 15] In addition to the depression of the activity of upper airway muscles with halothane,[16] other factors, such as the thickness of the lateral pharyngeal wall, may play a critical role.[15 17] Large tonsils also seem to increase airway collapsibility during inhalational anaesthesia. Our study also supports previous findings that the position of the epiglottis in relation to the posterior pharyngeal wall affects airway patency.[18] However, lateral narrowing and posterior displacement of the epiglottis cannot be assessed clinically, for example by airway sounds.

Effect of chin lift (without protrusion of the mandible)

We found that chin lift did not improve the patency of the airway. Upper airway narrowing during inspiration results from an imbalance between inspiratory muscle activity and the negative intraluminal pressure generated during inspiration. Halothane anaesthesia affects phasic activity of inspiratory muscles in a dose-dependent manner.[16] Both

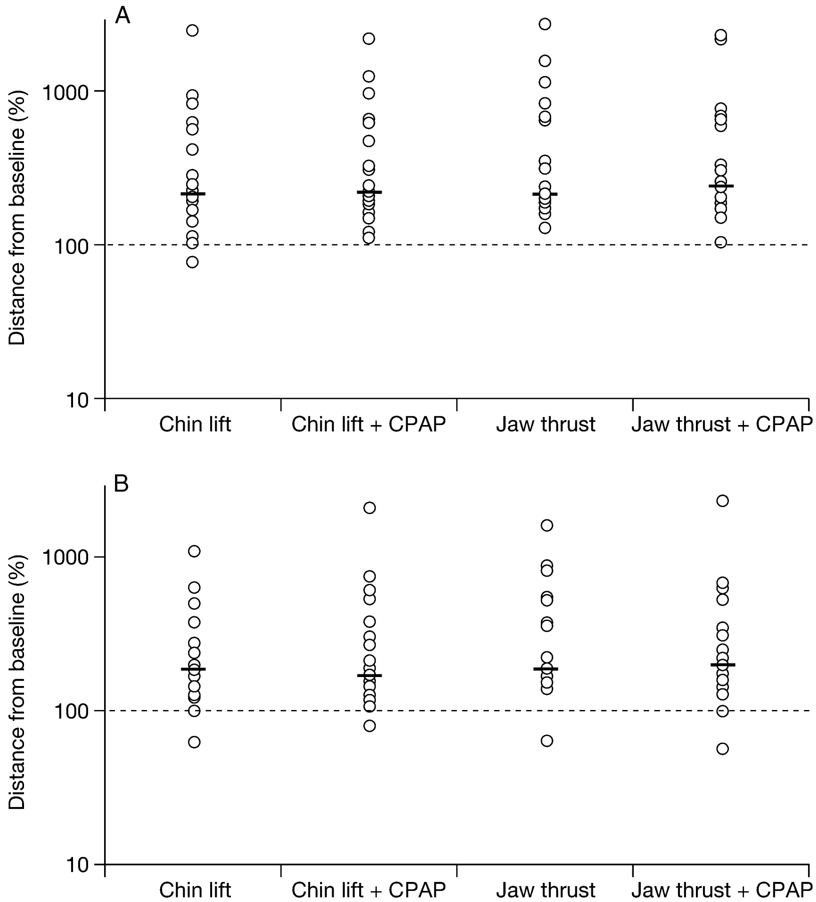

Fig 2 Effect of airway manoeuvre on anteroposterior airway dimensions (distance between the tip of the epiglottis and the posterior pharyngeal wall) during inspiration (A) and expiration (B). Baseline (chin unsupported=100%), dotted line; CPAP, continuous positive airway pressure. Data are skewed and are therefore presented as dot plot and median—on a logarithmic scale. There were no significant differences between the manoeuvres.

anaesthetic agent and the chin-lift manoeuvre affect upper airway muscle tension. The action of negative intraluminal pressure is no longer balanced by the action of the upper airway dilator muscles[19] and severe collapse, with or without complete obstruction, may occur. Lifting the chin could increase pharyngeal compliance so that the tonsils are 'sucked in' without counterbalance from muscle activity. During propofol anaesthesia, chin lift alone could preserve airway patency;[18] however, these children had normal tonsils and this study used magnetic resonance imaging, which did not follow dynamic airway changes.

Effect of jaw thrust (mouth open with maximal mandibular protrusion)

Compared with chin lift, jaw thrust has the advantage that the tension from the tongue and suprahyoid muscles is greater, thus pulling the hyoid ventrally against the root of the tongue and actively widening the pharynx. In addition, the mouth is opened and breathing becomes easier than during chin lift.[20] However, there is no correlation between the degree of the mandibular protrusion and the widening of the pharynx in adults.[21] Mouth opening without mandibular protrusion increases upper airway collapsibility during sleep.[22] We found that jaw thrust manoeuvres, which may cause post-operative discomfort, worsened airway calibre during inspiration, although impairment of airway patency occurred in fewer patients during jaw thrust (six patients) compared with chin lift (10 patients).

Effect of additional CPAP

Continuous positive airway pressure may have several effects, including interactions between changes in chest wall stability, pulmonary mechanics, lung volume and respiratory muscle dynamics.[23 24] Continuous positive airway pressure increases airway volume and airway area within the retropalatal and retroglossal regions and increases lateral dimensions more than anterior–posterior dimensions.[15] In our study, CPAP restored airway patency in children with large tonsils during chin lift and jaw thrust by dilating or splinting the upper airway.

In conclusion, in spontaneously breathing children with adenotonsillar hyperplasia, chin lift plus CPAP is recom-

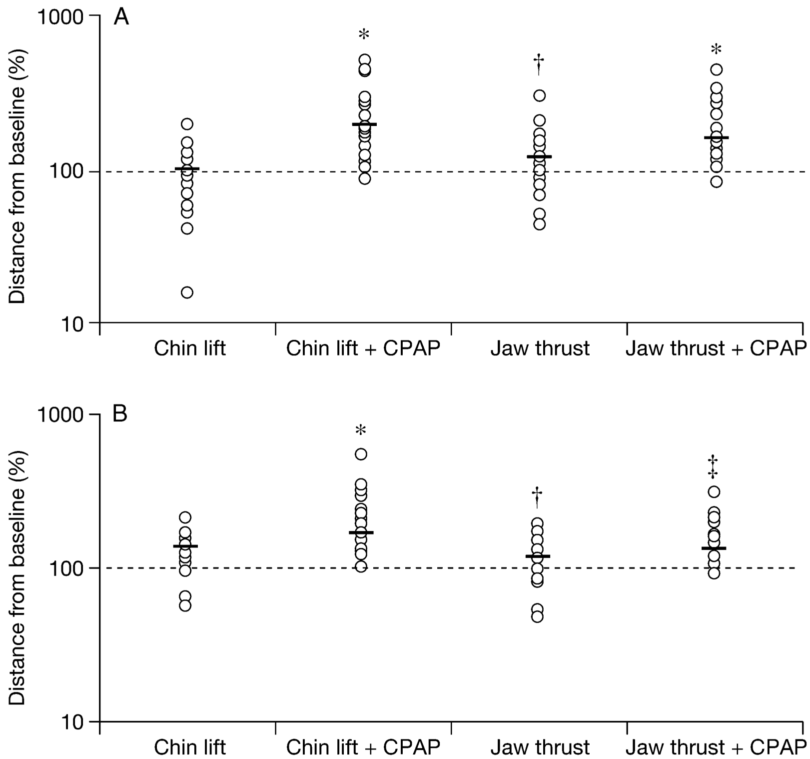

Fig 3 Effect of airway manoeuvre on transverse airway dimensions (the shortest distance between the tonsils) during inspiration (A) and expiration (B). Data are skewed and are therefore presented as dot plot and median—on a logarithmic scale. Baseline (chin unsupported=100%), dotted line; CPAP, continuous positive airway pressure. *Significantly different from chin lift ($P<0.05$); †significantly different from chin lift with CPAP; ‡significantly different from jaw thrust.

mended; jaw thrust plus CPAP is no better and may cause post-operative discomfort. Although little is known about the biomechanics of the upper airway and how the various soft tissues interact mechanically to control the dimensions of the upper airway, the degree of stridor may indicate the efficacy of airway manoeuvres.

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References

1 Safar P, Escarraga LA, Chang F. Upper airway obstruction in the unconscious patient. *J Appl Physiol* 1959; **14**: 760–4
2 Morikawa S, Safar P, DeCarlo J. Influence of the head–jaw position upon airway patency. *Anesthesiology* 1961; **22**: 265–70
3 Montravers P, Dureuil B, Desmondt JM. Effects of i.v. midazolam on upper airway resistance. *Br J Anaesth* 1991; **66**: 157–62
4 Fink BR. Roentgenographic studies of the oropharyngeal airway. *Anesthesiology* 1957; **18**: 711–18
5 Mathru M, Esch O, Lang J, *et al.* Magnetic resonance imaging of the upper airway. Effects of propofol anesthesia and nasal continuous positive airway pressure in humans. *Anesthesiology* 1996; **84**: 273–9
6 Ruben HM, Elam JO, Ruben AM, Greene DG. Investigation of upper airway problems in resuscitation. 1. Studies of pharyngeal X-rays and performance by laymen. *Anesthesiology* 1961; **22**: 271–9
7 Boidin MP. Airway patency in the unconscious patient. *Br J Anaesth* 1985; **57**: 306–10
8 Frei FJ, Wengen DF, Rutishauser M, Ummenhofer W. The airway endoscopy mask; useful device for fiberoptic evaluation and intubation of the pediatric airway. *Paediatr Anaesth* 1995; **5**: 319–24
9 Reber A, Paganoni R, Frei FJ. Dynamic imaging of the pediatric upper airway during general anesthesia. *J Clin Monit* 1998; **14**: 199–202
10 Forkert L, Watanabe H, Sutherland K, Vincent S, Fisher JT. Quantitative videobronchoscopy: a new technique to assess airway calibre. *Am J Respir Crit Care Med* 1996; **154**: 1794–803
11 Hwang J, St John WM, Barlett D Jr. Respiratory-related hypoglossal nerve activity: influence of anesthetics. *J Appl Physiol* 1983; **55**: 785–92
12 Motoyama EK. Inspiratory muscle incoordination and upper airway obstruction during inhalation anesthesia. *Int Anesthesiol Clin* 1997; **35**: 45–7
13 Woodson BT, Wooten MR. Comparison of upper-airway evaluations during wakefulness and sleep. *Laryngoscope* 1994; **104**: 821–8
14 Drummond GB. Influence of thiopentone on upper airway muscles. *Br J Anaesth* 1989; **63**: 12–21
15 Schwab RJ, Gupta KB, Gefter WB, *et al.* Upper airway and soft tissue anatomy in normal subjects and patients with sleep-

disordered breathing. Significance of the lateral pharyngeal walls. *Am J Respir Crit Care Med* 1995; **152**: 1673–89

16 Ochiai R, Guthrie RD, Motoyama EK. Differential sensitivity to halothane anesthesia of the genioglossus, intercostals, and diaphragm in kittens. *Anesth Analg* 1992; **74**: 338–44

17 Shelton KE, Woodson H, Gay S, Suratt PM. Pharyngeal fat in obstructive sleep apnea. *Am Rev Respir Dis* 1993; **148**: 462–6

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* 1999; **90**: 1617–23

19 Schwab RJ, Gefter WB, Pack AI, Hoffman EA. Dynamic imaging of the upper airway during respiration in normal subjects. *J Appl Physiol* 1993; **74**: 1504–14

20 Pickering DN, Beardsmore CS. Nasal flow limitation in children. *Pediatr Pulmonol* 1999; **27**: 32–6

21 Hochban W, Neumann I, Ziegler A. Mechanisch-/prothetische Unterkieferprotrusion: Auswirkungen auf den Pharynx [Mechanical/prosthetic protrusion of the mandible]. *Pneumologie* 1996; **50**: 919–23

22 Meurice J-C, Marc I, Carrier G, Sériès F. Effects of mouth opening on airway collapsibility in normal sleep subjects. *Am J Respir Crit Care Med* 1996; **153**: 255–9

23 Deegan PC, Nolan P, Carey M, McNicholas WT. Effects of positive airway pressure on upper airway dilator muscle activity and ventilatory timing. *J Appl Physiol* 1996; **81**: 470–9

24 Locke R, Greenspan JS, Shaffer TH, Rubenstein SD, Wolfson MR. Effect of nasal CPAP on thoracoabdominal motion in neonates with respiratory insufficiency. *Pediatr Pulmonol* 1991; **11**: 259–64