Anesthesiology 2001; 95:299–306

Risk Factors for Perioperative Adverse Respiratory Events in Children with Upper Respiratory Tract Infections

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Background: **Anesthesia for the child who presents for surgery with an upper respiratory infection (URI) presents a challenge for the anesthesiologist. The current prospective study was designed to determine the incidence of and risk factors for adverse respiratory events in children with URIs undergoing elective surgical procedures.**

Methods: **The study population included 1,078 children aged 1 month to 18 yr who presented for an elective surgical procedure. Parents were given a short questionnaire detailing their child's demographics, medical history, and presence of any symptoms of a URI. Data regarding the incidence and severity of perioperative respiratory events were collected prospectively. Adverse respiratory events (any episode of laryngospasm, bronchospasm, breath holding > 15 s, oxygen saturation < 90%, or severe cough) were recorded. In addition, parents were contacted 1 and 7 days after surgery to determine the child's postoperative course.**

Results: **There were no differences between children with active URIs, recent URIs (within 4 weeks), and asymptomatic children with respect to the incidences of laryngospasm and bronchospasm. However, children with active and recent URIs had significantly more episodes of breath holding, major desaturation (oxygen saturation < 90%) events, and a greater incidence of overall adverse respiratory events than children with no URIs. Independent risk factors for adverse respiratory events in children with active URIs included use of an endotracheal tube (< 5 yr of age), history of prematurity, history of reactive airway disease, paternal smoking, surgery involving the airway, the presence of copious secretions, and nasal congestion. Although children with URIs had a greater incidence of adverse respiratory events, none were associated with any long-term adverse sequelae.**

Conclusions: **The current study identified several risk factors for perioperative adverse respiratory events in children with URIs. Although children with acute and recent URIs are at greater risk for respiratory complications, these results suggest that most of these children can undergo elective procedures without significant increase in adverse anesthetic outcomes.**

This article is accompanied by an Editorial View. Please see: Coté CJ: The upper respiratory tract infection (URI) dilemma: Fear of a complication or litigation? ANESTHESIOLOGY 2001; 95:283–5.

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Received from the Department of Anesthesiology, University of Michigan Health Systems, Ann Arbor, Michigan. Submitted for publication July 17, 2000. Accepted for publication February 15, 2001. Supported by grant No. GM61971 from the National Institutes of Health, Bethesda, Maryland (to Dr. Tait).

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SEVERAL studies suggest that anesthesia for the child with an upper respiratory tract infection (URI) is associated with an increased risk of perioperative respiratory complications.[1–7] However, differences in study design have made interpretation and comparisons difficult, such that the clinical importance of these findings remains controversial. Although these studies have described associations between URIs and adverse events, only one has identified predictors of adverse events in children with URIs.[8] The current prospective study was therefore designed to examine the incidence of and independent risk factors for perioperative respiratory complications in children who present for elective surgery with a URI. The hypothesis to be tested is that children undergoing elective surgical procedures with symptoms of an active URI or history of a recent (within 4 weeks) URI have a higher incidence of adverse perioperative respiratory events compared with children with no URI symptoms.

Materials and Methods

The study was approved by The University of Michigan's institutional review committee (Ann Arbor, Michigan), and informed consent was obtained from the parents or legal guardians of each patient. The study sample consisted of 1,078 pediatric patients between the ages of 1 month and 18 yr who were scheduled to undergo elective surgical procedures with general anesthesia at a large tertiary care pediatric hospital. Before surgery, parents–guardians were asked to complete a short questionnaire eliciting information with respect to the family's demographics, history of respiratory infection or disease, prematurity (< 37 weeks), allergies, and parental smoking habits. In addition, information was collected regarding the surgical service and whether the surgery involved the airway. Children were assigned to one of three groups (active URI, n = 407; recent URI, n = 335; or control, n = 336) depending on the presence or absence of symptoms of a URI. Diagnosis of an active URI required that the patient present with a minimum of two URI symptoms (rhinorrhea, sore or scratchy throat, sneezing, nasal congestion, malaise, cough, or fever < 38°F) together with confirmation by a parent. Children in the recent-URI group included those who did not fulfill the criteria for a URI at the time of surgery but had a history of URI within 4 weeks before surgery. Children in the control group included those who did not fulfill the criteria for a URI at the time of surgery and had no

recent history of a URI. Patients were excluded from the study if, in the opinion of the individual anesthesiologist, proceeding with surgery would present substantial risk to the patient, *e.g.*, evidence of severe upper respiratory infection, lower respiratory involvement, or bacterial infection. Choice of airway and anesthetic management of each patient was at the discretion of the individual anesthesia care provider.

Data were documented by the anesthesia provider managing the case. Although none of the providers was involved in the study, they were generally unblinded to the patient's URI status. Whenever possible, a research assistant was present to ensure completeness of the documentation. Information was documented intraoperatively with respect to the anesthetic technique and agent used, the use of an airway device, and the duration of anesthesia and surgery. The patient was monitored throughout the perioperative period for the appearance of any respiratory event but specifically at the following time points: induction of anesthesia, placement of an airway device (if applicable), throughout the duration of surgery, removal of an airway device (if applicable), and throughout the postanesthesia care unit stay. At each time point, the lowest arterial oxygen saturation was recorded together with the appearance of any episodes of cough, breath holding, secretions, laryngospasm, bronchospasm, airway obstruction, excitement–delirium, and arrhythmias. Furthermore, each complication was scored according to its severity, *i.e.*, from 1 (no complication) to 4 (most serious). The scoring system for complications is based on a previously published scale[9] and is described in table 1. Scores were obtained at each of the aforementioned time points and were added to obtain an overall composite score for each potential complication. Patients receiving an endotracheal tube (ETT) or laryngeal mask airway (LMA) were scored at all five time points, and those with a face mask scored at three time points. Depending on the airway device used, patients could therefore receive a composite score of 5–20 (ETT or LMA) or 3–12 (face mask) for each complication. For the purpose of this study, adverse respiratory events were defined as any episode of perioperative airway obstruction–laryngospasm, bronchospasm, oxygen desaturation less than 90% (for $\geq$ 10 s), breath holding ($\geq$ 15 s), severe coughing, and any requirement for unanticipated endotracheal intubation. The depth of anesthesia (awake *vs.* asleep) at which the ETT or LMA were removed was recorded. Patients were considered asleep–deep if they were breathing 100% oxygen and 1.5–2 minimum alveolar concentration of volatile anesthetic, had a regular respiratory pattern, and were nonresponsive to stimulation such as suctioning. Patients were deemed awake if they responded to commands to open their eyes, were responsive to suctioning, and had return of protective gag or swallow reflexes. In addition, any episode of emergence excitement–delirium and postoperative nausea and vomiting was documented.

At 1 and 7 days after their child's surgery, parents–guardians were contacted by telephone to determine the presence of any new URI symptoms or the exacerbation or attenuation of existing symptoms together with any respiratory-related complications or adverse sequelae. The incidences of postoperative sore throat and postoperative nausea and vomiting were also recorded. Details of any readmissions to the hospital were obtained from the parents and confirmed by review of the medical records.

Statistical Analysis

Statistical analysis was performed using SPSS® statistical software (SPSS Inc., Chicago, IL). In a study by Cohen and Cameron,[1] children with URIs were shown to have a sevenfold increase in respiratory complications compared with asymptomatic children. In determining sample size, we assumed that respiratory complications in children with a recent history of URI would be greater than asymptomatic children but slightly less than children with active URIs. Using the sevenfold figure of Cohen and Cameron as a guide for children with URIs, we believed that it would be important to detect at least a fivefold (compared with asymptomatic children) increase in respiratory complications for children with recent URIs. If we assume that the incidence of respiratory complications in asymptomatic children is approximately 5%, we would expect an incidence of 35% (sevenfold) in children with active URIs and an incidence of 25% (fivefold) in those with a recent URI. Based on these

Table 1. Scoring System for Each of Six Respiratory Events

	Severity Scores			
	1	2	3	4
Spo_2 (%)	95–100	90–94	80–89	< 80
Cough (n)	None	1 or 2	3 or 4	Continuous
Breath holding (s)	None	< 15	15–30	> 30
Laryngospasm	None	Partial—reposition airway	Partial—CPAP	Complete—muscle relaxant
Bronchospasm	None	Expiration only	Expiration and inspiration	Difficult to ventilate: treatment
Secretions	None	Minimal—no suction	Moderate—suction 1×	Copious—suction > 1×

Spo_2 = arterial oxygen saturation; CPAP = continuous positive airway pressure.

Table 2. Demographics

	URI (n = 407)	Recent URI (n = 335)	No URI (n = 336)
Age (yr)	4.0 ± 3.8*	4.5 ± 4.0*	5.3 ± 4.4
Gender (M/F, %)	56/44	61/39	60/40
Race			
White	335 (84.2)	274 (82.3)	280 (86.2)
African-American	25 (6.3)	19 (5.7)	24 (7.4)
Hispanic	6 (1.5)	8 (2.4)	2 (0.6)
Other	32 (8.0)	32 (9.6)	19 (5.8)
ASA status I/II/III (%)	57.3/35.3/7.4	60.1/34.7/5.1	55.5/37.3/7.2
Duration of anesthesia (min)	84.7 ± 71.3	92.1 ± 73.5	96.7 ± 75.4
Duration of surgery (min)	53.9 ± 57.4	58.9 ± 59.3	61.2 ± 62.5
Airway			
FM	91 (22.8)	68 (20.6)	59 (17.9)
LMA	124 (31.0)	97 (29.4)	105 (31.9)
ETT	185 (46.3)	165 (50.0)	165 (50.2)
Anesthesiology staff			
CA-1	43 (10.6)	43 (12.9)	30 (9.0)
CA-2	64 (15.8)	54 (16.2)	57 (17.1)
CA-3	60 (14.8)	54 (16.2)	58 (17.4)
CRNA	177 (43.6)	135 (40.4)	131 (39.3)
Faculty alone	47 (11.6)	39 (11.7)	40 (12.0)
Surgical service			
Otolaryngology	147 (36.3)	117 (34.9)	83 (24.9)
Urology	47 (11.6)	50 (14.9)	49 (14.7)
Orthopedics	41 (10.1)	24 (7.2)	44 (13.2)
Pediatric surgery	85 (21.0)	76 (22.7)	85 (25.5)
Other	85 (21.0)	68 (20.3)	72 (21.6)

Data are presented as mean ± SD or n (%).

* $P < 0.05$ *versus* no URI.

URI = upper respiratory infection; FM = face mask; LMA = laryngeal mask airway; ETT = endotracheal tube; CA-1 = Clinical Anesthesia year 1, CA-2 = Clinical Anesthesia year 2; CA-3 = Clinical Anesthesia year 3; CRNA = certified registered nurse anesthetist.

expected frequencies, a sample size of 328 children per group ($\beta = 20\%$, $\alpha = 5\%$, two-tailed) was required to demonstrate a significant difference between the active-URI and recent-URI groups (*i.e.*, 25–35%). Incidence data were analyzed by chi-square and Fisher exact test as appropriate. Relative risks were calculated for each independent variable using the formula: relative risk = incidence of adverse event in URI group/incidence of adverse event in non-URI group.

Parametric data such as age, anesthesia, and surgical times were analyzed by analysis of variance. Significant differences by analysis of variance were followed by *post hoc* pairwise comparisons using Tukey honestly significant difference, Newman–Keuls, or Dunnett C depending on equal group sizes and assumption of equality of variances. Nonparametric data were analyzed by Mann–Whitney U and Kruskal–Wallis tests. Factors that were shown to be significantly associated with respiratory events by univariate analysis were entered into a multivariate logistic regression model to identify independent risk factors. Data are expressed as percentages and mean ± SD. Significance was accepted at the 5% level ($P < 0.05$).

Results

Seventy-three children who would have been eligible for the study had their surgery canceled. Of these, 26 (35.6%) were canceled because of a respiratory infection (*e.g.*, URI, pneumonia, influenza), 30 (41.1%) because the child was "sick" (as reported by the parent), 11 (15.1%) because of high fever, and 6 (8.2%) for other reasons. A total of 1,139 parents were approached to consent to their child's participation in this study, of which 61 declined. Data are therefore presented for 1,078 children. The demographics of the study sample are described in table 2. There were no differences between the three groups with respect to the gender and race of the children, nor in the distribution of surgical services or experience of the anesthesia staff. In addition, there were no differences in the socioeconomic status and levels of education of the parents. However, children in the active-URI and recent-URI groups were significantly younger than the control group ($P < 0.05$). The seasons in which patients were recruited were similar for all groups. The most common presenting symptoms in children with active URIs were as follows: rhinorrhea (66.6%), nasal congestion (37.4%), nonproductive cough (34.4%), sneezing (29%), productive cough (26.5%), sore throat (8.2%), and fever (parental self-report, 7.4%). The average preoperative temperature of children with URIs was 36.9°C (range, 35.2–39.0°C).

The incidences of perioperative adverse respiratory events are shown in table 3. The overall incidences of

Table 3. Incidence of Perioperative Adverse Respiratory Events by URI Status [n (%)]

	Breath Holding	Laryngospasm		Bronchospasm	Severe Cough	$Spo_2 < 90\%$	Adverse Event
URI (n = 407)	124 (30.5)*†	8 (2.0)‡	9 (2.2)§	23 (5.7)	40 (9.8)*†	64 (15.7)*	122 (30.0)*
Recent URI (n = 335)	78 (23.3)	9 (2.7)‡	5 (1.5)§	9 (2.7)	19 (5.7)	49 (14.7)*	81 (24.2)*
No URI (n = 336)	60 (17.9)	8 (2.4)‡	5 (1.5)§	11 (3.3)	14 (4.2)	26 (7.8)	60 (17.9)

* $P < 0.05$ *versus* no URI. † $P < 0.05$ *versus* recent URI. ‡ Laryngospasm requiring positive airway pressure. § Laryngospasm requiring succinylcholine.
URI = upper respiratory infection; Spo_2 = oxygen saturation measured by pulse oximetry.

airway obstruction–laryngospasm in the active-URI, recent-URI, and control groups were 11.1, 11.0, and 8.6%, respectively. However, the table reflects only cases requiring either positive airway pressure or succinylcholine administration. Although there were no differences in the incidences of laryngospasm and bronchospasm among the three groups, children with active and recent URIs had significantly higher incidences of major arterial oxygen desaturation and overall adverse respiratory events than children with no URIs. Children with active URIs also had a significantly higher incidence of severe coughing compared with children with no URIs. This was particularly evident in children who were intubated (13 *vs.* 3.6%; $P = 0.002$). However, because the active-URI and recent-URI groups were significantly younger than the control group, we compared the age stratum–specific event rates between the groups as a means to control for the potential confounding effect of age. Analysis showed that children in the active-URI and recent-URI groups had higher incidences of respiratory events independent of age.

There were no differences in the overall severity of perioperative bronchospasm, laryngospasm, or arterial oxygen desaturation among the three groups. However, the overall severity of breath holding (5.2 on a scale of 3–20, range 3–14 *vs.* 4.9, range 3–8), cough (6.0, 3–15 *vs.* 5.5, 3–11) and secretions (6.7, 3–15 *vs.* 5.8, 3–12) was significantly greater ($P < 0.05$) in children with active URIs compared with children with no URIs.

Table 4 describes the incidence of adverse respiratory events in children with active URIs relative to the airway device used and the various time points during the perioperative period. The use of an ETT in these children resulted in an increased incidence of breath holding, severe cough, arterial oxygen desaturation less than 90% ($P < 0.05$), and overall adverse respiratory events compared with children receiving anesthesia by face mask ($P < 0.05$). The ETT was also associated with a greater incidence of major desaturation and overall adverse respiratory events compared with the LMA ($P < 0.05$). Furthermore, the severity of complications was dependent on the airway device used. In patients who received a face mask, there were no differences in severity scores among the three groups. However, patients in the active-URI group who received an LMA or ETT had more severe episodes of breath holding, secretions, cough, and oxygen desaturation (ETT only) than children with no URIs. Table 4 also shows that the majority of complications occurred during removal of an ETT and in the postanesthesia care unit. Removal of the ETT in these children was associated with a significant ($P < 0.05$) increase in the incidence of breath holding (> 15 s), severe cough, and major oxygen desaturation. Figure 1 describes the incidence of adverse respiratory events in children with recent URIs by the number of days since the URI occurred. Results showed that the incidence of adverse respiratory events was similar between the URI group and recent-URI group and that this similarity persisted for at least 4 weeks after the URI.

The depth of anesthesia (awake *vs.* deep) at which the ETT or LMA were removed had no effect on the incidence of respiratory events. Children with active URIs

Table 4. Incidence of Adverse Respiratory Events by Airway Device and Time Points in Children with Active URIs [n (%)]

	Breath Holding	Laryngospasm‡	Bronchospasm	Severe Cough	$Spo_2 < 90\%$	Adverse Event
Airway device						
ETT (n = 185)	74 (40.2)*	10 (5.4)	14 (7.6)	24 (13.0)*	40 (21.9)*†	75 (40.5)*†
LMA (n = 124)	39 (31.7)*	6 (4.8)	5 (4.1)	11 (8.9)	13 (10.7)	30 (24.2)
FM (n = 91)	9 (9.8)	2 (2.2)	3 (3.3)	4 (4.3)	8 (8.7)	15 (16.5)
Time-points						
Induction (n = 407)	10 (2.5)	4 (1.0)	3 (0.7)	5 (1.2)	16 (3.9)	55 (13.5)
ETT placement (n = 185)	4 (2.2)	2 (1.1)	5 (2.7)	4 (2.2)	8 (4.4)	26 (14.1)
LMA placement (n = 118)	2 (1.7)	1 (0.8)	0 (0)	2 (1.7)	1 (0.9)	7 (5.9)
Intraoperative (n = 407)	4 (1.0)	3 (0.7)	8 (2.0)	3 (0.7)	13 (3.2)	33 (8.1)
ETT removal (n = 185)	12 (6.6)	3 (1.6)	4 (2.2)	10 (5.6)	14 (8.2)	45 (24.3)
LMA removal (n = 118)	3 (2.5)	0 (0.0)	1 (0.8)	2 (1.7)	2 (1.9)	13 (11.0)
PACU (n = 407)	17 (4.2)	5 (1.2)	10 (2.5)	18 (4.4)	31 (7.6)	87 (21.4)

* $P < 0.05$ *versus* FM. † $P < 0.05$ *versus* LMA. ‡ Laryngospasm requiring positive airway pressure or succinylcholine.
URI = upper respiratory infection; Spo_2 = oxygen saturation measured by pulse oximetry; ETT = endotracheal tube; LMA = laryngeal mask airway; FM = face mask; PACU = postanesthesia care unit.

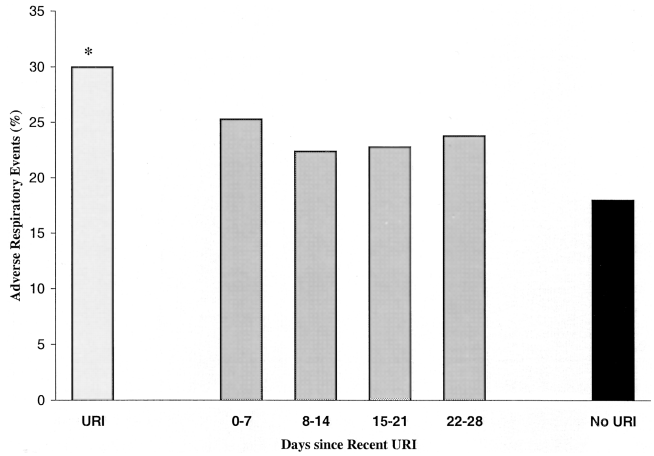

Fig. 1. Incidence of adverse events by upper respiratory tract infection (URI) status and days since recent URI. *$P < 0.05$ *versus* no URI.

receiving an ETT had a higher incidence of postoperative sore throat (25.7%) compared with those receiving an LMA (16.5%; $P = 0.06$) or face mask (12.6%; $P < 0.05$). One week after surgery, these differences had resolved. The course of URI symptoms was followed postoperatively. At 1 and 7 days, respectively, 34.9 and 13.8% of parents reported that their child's URI was about the same, 41.5 and 66.6% reported that the URI had improved, and 12.8 and 6.4% reported that the URI had worsened.

There were no differences in the incidence of adverse respiratory events by anesthetic techniques, *i.e.*, inhalational *versus* intravenous, for any of the groups. There were also no differences in respiratory events by inhalational agent used for induction, *i.e.*, halothane *versus* sevoflurane. However, children with URIs who were maintained with isoflurane had a significantly increased incidence of adverse respiratory events compared with

Table 5. Incidence of Adverse Respiratory Events by Anesthestic Agent and URI Status

	Adverse Event [n (%)]		
	URI	Recent	No URI
Induction			
Halothane	23 (29.9)	19 (35.2)	5 (38.5)
Sevoflurane	87 (29.5)	56 (22.7)	49 (18.3)
Maintenance			
Halothane	25 (26.9)	14 (23.0)	4 (19.0)
Sevoflurane	4 (11.1)*	5 (20.0)	6 (22.2)
Isoflurane	91 (33.8)	59 (24.6)	50 (17.8)
Induction–maintenance			
Halothane–halothane	10 (20.8)	8 (27.6)	5 (10.9)
Halothane–isoflurane	11 (47.8)	9 (40.9)	3 (42.9)
Sevoflurane–sevoflurane	3 (8.3)†	5 (21.7)	6 (23.1)
Sevoflurane–isoflurane	70 (32.6)	45 (23.3)	42 (18.6)

* $P < 0.05$ *versus* isoflurane. † $P < 0.05$ *versus* halothane–isoflurane and sevoflurane–isoflurane.

URI = upper respiratory infection.

Table 6. Incidence of Adverse Respiratory Events by Surgical Procedure and Service [n (%)]

	URI	Recent URI	No URI
Surgery procedure			
Airway related	27 (49.1)*	15 (50.0)*	10 (30.3)*
Non–airway related	95 (27.0)†‡	56 (19.6)	49 (16.3)
Surgical service			
ENT	47 (32.0)	36 (30.8)	15 (18.1)
Urology	14 (29.8)	11 (22.0)	9 (18.4)
Pediatric surgery	29 (34.1)	17 (22.4)	15 (17.6)
Ophthalmology	8 (22.9)	5 (20.0)	5 (22.2)
Orthopedics	10 (24.4)	4 (16.7)	5 (11.4)
Radiology	6 (31.6)	4 (26.7)	4 (18.2)
Other	8 (25.8)	5 (17.9)	6 (18.8)

* $P < 0.05$ *versus* nonairway surgery. † $P < 0.05$ *versus* recent URI. ‡ $P < 0.05$ *versus* no URI.

URI = upper respiratory infection; ENT = ear, nose, and throat.

those maintained with sevoflurane (33.8 *vs* 11.1%, respectively; $P < 0.05$). It should be noted, however, that children maintained with isoflurane underwent longer procedures (61.6 ± 57.5 *vs.* 32.4 ± 35.3 min; $P < 0.05$) and were more likely to be intubated (54.5 *vs* 22.2%; $P < 0.001$) than children maintained with sevoflurane. Differences in outcome between maintenance anesthetic agents was not evident in the recent-URI and control groups. Children with active URIs who received sevoflurane for induction and maintenance had significantly fewer adverse respiratory events compared with children who received other anesthetic regimens (table 5). Children with active URIs receiving halothane for induction and isoflurane for maintenance had the highest incidence of respiratory events. Children with URIs maintained on isoflurane had a higher incidence of emergence excitement (40.1%) than those maintained with sevoflurane (36.1%; P = nonsignificant) or halothane (24.7%; $P < 0.05$).

There was a higher incidence of adverse respiratory events in children undergoing surgical procedures involving the airway, *e.g.*, tonsillectomy and adenoidectomy, direct laryngoscopy, and bronchoscopy. This finding was consistent for all three groups (table 6). Although there was a trend toward a higher incidence of overall adverse respiratory events in children less than 5 yr of age with a URI, this was not statistically significant. Children less than 5 yr of age with active URIs who received an ETT, however, had a significantly increased risk of respiratory events than those with no URI (47.4 *vs.* 19.8%; $P < 0.0001$). With respect to specific complications, infants less than 6 months of age with active URIs had a higher incidence of bronchospasm than older children (20.8 *vs.* 4.7%; $P = 0.08$), and children less than 2 yr of age had a higher incidence of arterial oxygen desaturation less than 90% (21.5 *vs* 12.5%; $P = 0.023$) than older children.

Before logistic regression analysis, we performed exploratory univariate analyses on numerous variables to-

Table 7. Independent Risk Factors for Adverse Respiratory Events in Children with Active URIs

Factor	Wald Statistic	Significance
Copious secretions	14.87	0.0001
ETT in child aged < 5 yr	13.52	0.0002
History of prematurity (< 37 weeks)	7.25	0.0071
Nasal congestion	6.00	0.0142
Paternal smoking	5.61	0.0179
History of reactive airway disease	4.86	0.0275
Surgery involving the airway	4.09	0.0430

URI = upper respiratory infection; ETT = endotracheal tube.

determine their association with the development of adverse respiratory events in children with active URIs. Variables included the timing of the URI (onset, middle, end), season of URI (spring, summer, fall, winter), respiratory history (*e.g.*, history of croup, pneumonia, bronchitis), American Society of Anesthesiologists status, type of surgery (by specialty and airway *vs.* nonairway), duration of anesthesia and surgery, depth of anesthesia for extubation (awake *vs.* asleep), history of reactive airway disease or allergies, presenting symptoms (*e.g.*, sore throat, rhinorrhea), demographics (gender, age–age group, socioeconomic status, race), parental smoking habits (paternal, maternal, both, any), anesthetic agent (induction and maintenance, inhalation *vs.* intravenous), airway device (face mask, LMA, ETT), history of prematurity (< 37 weeks), anesthesia personnel responsible for the case, and the use of anticholinergics. Of these, several factors were found to be significantly associated with the development of adverse respiratory events in children with active URIs. These included use of an ETT (relative risk [95% confidence interval], $P = 1.9$ [1.4, 2.6], $P \leq 0.0001$), paternal smoking (1.6 [1.2, 2.1], $P = 0.02$), history of reactive airway disease (1.8 [1.3, 2.7], $P = 0.005$), American Society of Anesthesiologists status greater than I (1.1 [0.9, 1.3], $P = 0.008$), isoflurane as a maintenance agent (1.5 [1.1, 2.1], $P = 0.026$), history of prematurity (< 37 weeks) (2.3 [1.6, 3.2], $P \leq 0.0001$), presence of copious secretions (3.9 [1.8, 8.8], $P \leq 0.0001$), surgery involving the airway (1.8 [1.3, 2.5], $P = 0.001$), and presence of nasal congestion (1.4 [1.0, 1.8], $P = 0.049$). These factors (and their interactions) found to be significant by univariate analysis were subsequently entered into a logistic regression model with backward selection. Multivariate analysis of these factors yielded several independent risk factors for respiratory events in children with active URIs. Results of these analyses are shown in table 7.

Only three patients required unanticipated hospital admission. One patient with a recent URI required hospital admission for stridor, and two with active URIs were admitted for pneumonia. Each of these children had uneventful recoveries.

Discussion

Despite the clinical importance of anesthetizing a child with a URI, there are relatively few studies addressing this issue, and, furthermore, the results have been equivocal and difficult to compare. Most studies suggest that the child anesthetized while having a URI is at increased risk for perioperative respiratory complications, including laryngospasm,[1,2,6] bronchospasm,[3,7] and arterial oxygen desaturation.[5,7,9] Other studies, however, report minimal morbidity associated with anesthetizing a child with a URI.[10–12] A recent study by Parnis *et al.*[8] identified eight factors predictive of adverse events in children undergoing elective surgical procedures. These included the method of airway management, parental confirmation of the child's cold, presence of nasal secretions, child who snores, child who is a passive smoker, choice of induction agent, sputum production, and use of a reversal agent. The current study confirmed some of these findings, lending some external validity to our data.

Results from the current study suggest that children with active and recent URIs are at increased risk of perioperative respiratory complications, and that children in these groups appear to behave similarly. The latter finding is consistent with previous studies. In one study from our institution, children with a recent URI (within 2 weeks) had a higher incidence of respiratory complications than children with acute URIs.[12] In another study, Skolnick *et al.*[13] showed that the risk of airway complications was greatest in children at the time of URI and for the first few days after but remained high for up to 6 weeks after the URI. Although the precise mechanism is unclear, morphologic damage to the respiratory epithelium and mucosa after a viral respiratory infection may sensitize the airway to potentially irritant anesthetic gases and secretions, resulting in activation of irritant receptors and smooth airway muscle contraction.[14,15] Indeed, previous studies have shown that airway reactivity is altered for up to 6–8 weeks after a URI.[15–17]

Of concern in anesthetizing a child with a URI is the presence of increased secretions and airway hyperreactivity. In the current study, nasal congestion and copious secretions were found to be risk factors for adverse events in children with active URIs. These findings are supported by the results of a recent study by Parnis *et al.*[8] that identified nasal congestion and sputum production as predictors of anesthetic adverse events.[8] Because of the potential for airway hyperreactivity in a child with a URI, anesthetic management is aimed at reducing stimulation of a potentially irritable airway. In general, the face mask has been considered the method of choice for airway management in children with URIs because it involves minimal stimulation of the airway. The ETT, on the other hand, has been associated with an 11-fold increase in respiratory complications in these children.[1]

In lieu of an ETT, the LMA has been shown to produce fewer respiratory complications in children with URIs. We recently reported that the LMA was associated with significantly lower incidences of mild bronchospasm, major desaturation events (oxygen saturation $< 90\%$), and overall respiratory events than the ETT.[18] The current study supports these findings and identifies the use of an ETT as an independent risk factor for adverse respiratory events.

A history of prematurity was identified as an independent risk factor for adverse respiratory events in children with URIs. This finding was not evident in the other groups. Surprisingly, this did not appear to be related to the age of the child at the time of surgery or a history of frequent respiratory infections. Although it is well documented that the ex-premature infant is at risk for a pulmonary and neurologic sequelae,[19,20] it is unclear from our data as to why prematurity presented as such a strong risk factor for complications in this population of children. Furthermore, the precise age at which this risk resolves remains to be delineated.

Although paternal smoking *per se* has not been previously identified as an independent risk factor for respiratory complications in children with URIs, this finding was not surprising because several studies have shown that children of parents who smoke have a higher incidence of respiratory disorders, bronchial hyperreactivity, exacerbation of asthma symptoms, and a higher incidence of respiratory complications after anesthesia.[8,21–24] Given the associations between exposure to tobacco smoke, anesthesia, and the development of respiratory complications, it follows that children with URIs would be at further risk as a result of virus-induced airway hyperreactivity and altered pulmonary physiology. In interpreting the results regarding parental smoking, it is, however, important to consider the potential for report bias because smoke exposures were based on parental self-report rather than measurements of nicotine metabolites (*e.g.*, cotinine). As a result, it is possible that parents may have underreported their smoking habits in an attempt to downplay the negative impact that their smoking might have on their children's health. The precise reason why paternal rather than maternal smoking was identified as a risk factor, however, remains uncertain.

Because we had attempted to capture all adverse respiratory events, the incidence of some appear high. However, it should be noted that despite this fact, their overall severities were low. Furthermore, all were easily managed perioperatively, and only three patients suffered adverse sequelae requiring escalation of care. One child with a history of recent URI was admitted postoperatively for stridor; however, review of the medical records revealed that the stridor had existed before surgery. Two children with active URIs were admitted postoperatively with viral pneumonia. Review of the medical records suggested that both children may have been inappropriately selected for surgery. Based on their presenting symptoms, it appears that both had evidence of existing or developing lower respiratory infection and, as such, should have had their surgery postponed. All children had uneventful recoveries.

Although the design of this study allowed us to examine the influence of many factors on outcome in children with URIs, there are limitations that necessitate caution in interpreting the results. In particular, this is a nonrandomized, nonblinded study and as such may be subject to some selection or observer bias. Although we acknowledge the potential for bias, we believe that any effect would be minimized by the large sample size and the fact that observers had no vested interest in the study's outcome. Furthermore, details of the child's URI symptoms were collected by research assistants such that the anesthesia provider was not always fully aware of the symptoms recorded preoperatively.

Another concern in this type of study is the definition of a URI. Although in previous studies we used specific criteria to define an URI,[9,11,12] a retrospective study by Schreiner *et al.*[6] suggested that these criteria are too stringent and that parental confirmation of a URI is a better predictor of laryngospasm than the use of predetermined criteria.[6] Therefore, for the purposes of this study, although we took into consideration the patients' presenting symptoms, diagnosis of a URI also required confirmation by a parent or guardian. Although the criteria used in this study were slightly less stringent than those previously described, results showed that the incidences of both laryngospasm–airway obstruction and overall adverse respiratory events were similar regardless of whether diagnosis was based on criteria alone (11.1 and 32.2%, respectively) or on parental confirmation alone (11.0 and 30.8%, respectively).

Results of the current study show that children with active and recent URIs (within 4 weeks) are at increased risk for adverse respiratory respiratory events, particularly if they have a history of reactive airway disease, require surgery involving the airway, have a history of prematurity, are exposed to environmental tobacco smoke, have nasal congestion or copious secretions, or require placement of an ETT. Despite this, it appears that with careful management, most of these children can undergo elective procedures safely without increased morbidity. This does not imply that all children with URIs should be anesthetized, but that decisions to proceed with elective surgery be individualized with careful consideration for the severity of presenting symptoms, the patient's respiratory history, the need for an ETT, choice of anesthetic agent, and the anesthesiologist's overall comfort with anesthetizing children with URIs.

The authors thank Philip Rubin, B.S. Agnieszka Trzcinka (undergraduate), and Nisha Shajahan, B.S. (all from the Department of Anesthesiology, University of

Michigan, Ann Arbor, Michigan), for help with data collection, patient recruitment, and follow-up.

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