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Incidence and risk factors of perioperative respiratory adverse events in children undergoing elective surgery

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Summary

Background: Adverse respiratory events remain one of the major causes of morbidity during anaesthesia, especially in children. The purpose of this prospective study was to determine the incidence of perioperative respiratory adverse events (PRAE) during elective paediatric surgery and to identify the risk factors for these events.

Methods: Potential risk factors (atopy, eczema, rhinitis, food allergy, previous allergic tests, pollens or animal allergy, passive smoking, obstructive sleep disorders) were assessed using the International Society on Allergy and Asthma (ISAAC) questionnaire, which was submitted to the parents during preoperative anaesthetic assessment. Anaesthetic and surgical conditions were systematically recorded. A multivariate logistic regression explaining PRAE was developed in 800 children.

Results: The intraoperative incidence of respiratory adverse events was 21% and the incidence in the postanesthetic care unit was 13%. According to the multivariate analysis, children not anaesthetized by a specialist paediatric anaesthesiologist have 1.7 increased risk to present PRAE (95% CI = 1.13–2.57). Children anaesthetized for ear, nose, throat (ENT) surgery had a 1.57-fold higher risk of PRAE compared with other procedures (95% CI = 1.01–2.44). Furthermore, there was a synergistic interaction when two risk factors: residents and ENT surgery, were concomitant: the odds ratio (OR) of PRAE during non-ENT surgical procedures was 1.43 (95% CI = 0.91–2.24), but increased to 2.74-fold (95% CI = 1.15–4.32) for ENT surgery. The risk of PRAE was significantly lower when the anaesthetic technique included tracheal intubation with relaxants (OR = 0.6, 95% CI = 0.45–0.95) and decreased by 8% with each increasing year of age.

This work was carried out in the Department of Anaesthesia, Geneva Children's Hospital, Geneva, Switzerland.

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Conclusions: This study demonstrates a high incidence of PRAE in paediatric surgical patients without respiratory tract infections, which appears to be primarily determined by the age of the child and the anaesthetic care rather than by the child's medical history.

Keywords: children; ENT surgery; morbidity; anaesthesia; respiratory adverse events; respiratory complications; perioperative morbidity; risk factors

Introduction

In the early 1990s, adverse respiratory events were the major cause of perioperative adverse outcomes (1–3). During the last decade, the development of new monitoring devices and the introduction of new pharmacological products have contributed to a dramatic reduction in perioperative mortality and the occurrence of critical incidents (4). Despite the establishment of new guidelines to improve anaesthetic practice (5), perioperative respiratory adverse events are still one of the major causes of claims reported in children (3,6).

Recently, Tay *et al*. (7) reported that more than two-thirds of perioperative critical events were related to the respiratory system. Although most studies of perioperative respiratory adverse events (PRAE) have focused on different risk factors, such as asthma, upper respiratory tract infection (URTI) (1,8,9), or passive smoking (10), they did not consider possible interaction between several risk factors. Except for PRAE in the context of respiratory tract infections (9,11), the incidence of PRAE in a general paediatric population was not prospectively determined, but was essentially reported by retrospective review of medical charts.

Therefore, the aim of the present study was to determine prospectively the incidence of PRAE during elective paediatric surgical procedures and to identify the potential risk factors or combinations thereof contributing to the occurrence of such events.

Methodology

After approval by our Institutional Ethics Committee, oral consent was obtained from parents of each child included in the study.

From June 1999 to September 2000, all children aged 1–14 years undergoing preoperative assessment for general anaesthesia were included in the study. Exclusion criteria: based on our institutional policy, acute symptoms (fever, moist cough) of URTI in the previous 2 weeks or mild symptoms following recent URTI, congenital heart disease, pulmonary pathology such as cystic fibrosis or cor pulmonale, and when at least one parent was unable to understand French.

The day of the anaesthetic ambulatory assessment, parents were asked by a specially trained medical student to answer the International Society on Allergy and Asthma (ISAAC) questionnaire (12) which has been widely used and was validated in French by the 'back translation' technique (Dr Annesi-Maesano, INSERM, Paris, France) (13). This questionnaire yields informations on the following potential predictive risk factor: atopy, eczema, rhinitis, food allergy, previous allergic tests, pollens or animal allergy, passive smoking and obstructive sleep disorders.

Anaesthesiologists in charge of the patient were asked to report on an anonymous chart: whether they were registrars or specialized paediatric consultants, surgical procedure, induction (inhalation or intravenous) and maintenance technique, the airway management, use of narcotics or regional anaesthesia and use of muscle relaxants.

The occurrence of respiratory complications and the time of events were recorded by the anaesthesiologist in charge and the nurse specialist, both during anaesthesia and in the postanaesthesia care unit (PACU). Thus, episodes of laryngospasm, airway obstruction, bronchospasm, oxygen desaturation <95% and coughing were documented. Respiratory adverse events were defined as following:

Laryngospasm: complete airway obstruction associated with muscle rigidity of abdominal wall, chest wall, unrelieved by manoeuvres to relieve soft tissue obstruction.

Airway obstruction: partial airway obstruction with snoring noise and respiratory efforts without deep desaturation. This was relieved easily by jaw-thrust manoeuvre, application of positive airway pressure and/or a Guedel airway.

Bronchospasm: an increase in respiratory effort, especially expiration, associated with hypercapnoea and oxygen desaturation, wheeze on auscultation, capnography changes in ventilated patients with increase in the slope of the plateau, and increase in airway peak pressure.

Oxygen desaturation: with $SpO_2 < 95\%$.

Descriptive statistics are given in frequencies and percentages. The PRAE were the dependent variable of interest. The potential relation to PRAE was first explored for each independent variable by univariate analysis. Statistical significance was estimated by *P*-value of chi-square and 95% confidence interval. Several models were then performed using multivariate logistic regression.

Variable definitions were categorized as follows: age categories were ≤2, 2–6 and ≥6 years. Origin categories were Switzerland, Southern Europe (Italy, France, Spain and Portugal) and others. For each parent, school education level was categorized into ≥12 and >12 years. Passive smoking was defined as either of the parents smoking more than five cigarettes per day in the presence of the child. Nocturnal dry cough was defined as recurrent cough occurring without any relation with a recent respiratory tract infection. Asthma was defined as clinically diagnosed wheezing in the last 12 months. Allergy was investigated with regard to the presence of a history of cutaneous or food allergy, pollens or animal allergies, eczema, urticarial reaction, previous positive allergic tests. Atopy was defined by the history of hay fever or other allergic rhinitis. Obstructive sleep disorder was determined by the presence or not of snoring during URTI and/or by the presence or not of apnoea syndrome. Induction technique was classified as inhalational (halothane, sevoflurane) or intravenous (thiopental, propofol). Analgesic techniques were classified as for the route of administration: peripheral blocks (penile block, ilioinguinal, axillary, femoral blocks), epidural including caudal blocks and intravenous or intrarectal route. Airway maintenance categories were facial/LMA vs oro/nasotracheal intubation. Tracheal intubation with muscle relaxants was differentiated from that without myorelaxants. Anaesthesiologists could be categorized as specialized paediatric anaesthesiologists and residents: general anesthesiologists with at least 3 years of training.

Results

Among the 800 children eligible for the study, 45 refused to participate, were not operated, or presented incomplete data. The analytical sample comprised 755 children.

Demographic data, surgical and anaesthetic characteristics are shown on Table 1. There was a higher percentage of boys (65%) with 41% of the children being <2 years old and 40% 2–5 years old. Most of the children were European, and the level of the parent education was higher for the fathers than for the mothers. Prevalence of passive smoking in this population was 58%. Prevalence was 5.3% for asthma, 15% for dry nocturnal cough and 2.6% for allergy (data not shown in the table). Almost one-third of the surgical procedures concerned the ear, nose and throat (ENT) area. Induction technique of anaesthesia was equally distributed between inhalation and intravenous. Tracheal intubation was performed in two-thirds of the children, whereas a facial or a laryngeal mask airway (LMA™) was used in the other cases. Analgesia was achieved with various drugs and techniques.

Intraoperative adverse events were reported in 21.3% of the children and 12.8% had a respiratory adverse event postoperatively (Table 2). The most frequently observed PRAE was recurrent cough either intra or postoperatively. The second intraoperative event was airway obstruction (6.9%). Laryngospasm was almost only observed intraoperatively (3.9%), whereas oxygen desaturation was equally noted intra and postoperatively (about 5%). The incidence of bronchospasm was 1.2% overall.

After univariate analysis, young age, absence of a specialist paediatric anaesthesiologist, ENT procedures and tracheal intubation without relaxants were significantly associated with an increased risk of PRAE. Several models of multivariate logistic analysis were performed; Table 3 represents a model

Table 1
Demographic data, surgical and anaesthetic characteristics of children undergoing elective surgery, Geneva, Switzerland, 1999–2000

	n[a]	%
Gender		
Male	487	65
Female	268	35
Age (years)		
<2	147	41
2–5	301	40
≥6	307	19
Origin		
Switzerland	291	40
Italy, Spain, Portugal, France	261	36
Others	168	24
Fathers' education (years)		
≤12	406	59
>12	283	41
Mothers' education		
≤12 years	464	66
>12 years	244	34
Passive smoking		
Yes	429	58
No	314	42
Surgical procedure		
ENT	222	30
Urology	185	25
Others	334	45
Induction technique		
Inhalation	381	51
Intravenous	367	49
Airway		
Facial, LMA	244	33
Tracheal tube	504	67
Analgesic technique		
Peripheral block	142	20
Central block	71	15
Intravenous, intrarectal	498	65

[a]Total may vary because of missing data.
ENT: ear, nose and throat.

including age, gender, type of airway maintenance and anaesthesiologist, adjusted for age and gender. Children not looked after by a specialized paediatric anaesthesiologist had a 1.7-fold increased risk for PRAE (95% CI = 1.12–2.57). The risk of PRAE was significantly lower when the anaesthetic technique included tracheal intubation facilitated by a relaxant (OR = 0.65, 95% CI = 0.44–0.94), compared with airway maintenance by mask. The risk of PRAE decreased by 8% with each increasing year of age (OR = 0.92, 95% CI = 0.87–0.97). The risk of PRAE was not related to gender.

Moreover, when the model includes age, gender, airway maintenance and surgical procedure (Table 4), children admitted for ENT surgery had 1.57 higher risk of PRAE compared with other surgical procedures (95% CI = 1.01–2.44).

Figure 1 shows the interaction between the effect of the anaesthesiologist and that of the surgical procedure for the PRAE risk; among children not anaesthetized by a specialized paediatric anaesthesiologist, the OR of PRAE during non-ENT surgical procedures was 1.43 (95% CI = 0.91–2.24), but increased to 2.74 (95% CI = 0.47–15.82) for ENT surgery. The interaction itself was not statistically significant ($P = 0.44$), but the study had small power to detect such interaction, given the small number of ENT children anaesthetized by a specialized paediatric anaesthesiologist ($n = 10$).

Discussion

Risk factors of PRAE in children without respiratory tract infection, as has been discussed in this study, have not been reported so far. The results of the study show that one in every five children undergoing elective surgery has mild intraoperative respiratory adverse events. One in every 10 has postoperative respiratory adverse events. Factors identified as being predictive of PRAE occurrence are: age of the child, anaesthetic care by a nonpaediatric anaesthesiologist, ENT surgery and tracheal intubation not facilitated by the use of a muscle relaxant.

This incidence is high, but most of the reported PRAE were easily managed with no postoperative sequellae. The incidence of laryngospasm in this survey was twice that reported previously in the literature concerning children without upper respiratory tract infection (7,8). This high incidence was not correlated with the type of surgery. However, 80% of the laryngospasm (23 of 29 cases) as well as 80% of airway obstruction (47 of 58 cases) occurred in the absence of a specialized paediatric anaesthesiologist. Therefore, this high incidence may result in part from our institution being a teaching hospital with a large number of residents compared with paediatric anaesthesiologists. Indeed, PRAE were almost twice as frequent when the anaesthesiologist was a resident. This finding is totally in agreement with previous studies that demonstrated the importance of the presence of a specialized paediatric anaesthesiologist to reduce anaesthesia morbidity in

Table 2
Perioperative respiratory adverse events of children undergoing elective surgery, Geneva, Switzerland, 1999–2000

Adverse events	*Intraoperative*		*Postoperative*		*Perioperative*	
	n	%	n	%	n	%
Laryngospasm						
Yes	29	3.9	1	0.1	30	4.2
No	710	96.1	737	99.9	708	95.8
Bronchospasm						
Yes	9	1.2	3	0.4	12	1.6
No	730	98.8	736	99.6	727	98.4
Airway obstruction						
Yes	51	6.9	18	2.4	69	9.3
No	688	93.1	720	97.6	669	90.7
Oxygen desaturation						
Yes	36	4.9	33	4.5	69	9.3
No	705	95.1	706	95.5	669	90.7
Recurrent cough						
Yes	90	12.1	56	7.6	146	19.8
No	652	87.9	682	92.4	592	80.2
Number of patients						
With adverse events	161	21.3	98	12.8	211	27.9
Without adverse events	603	78.7	659	87.2	546	72.1

Table 3
Determinants of perioperative respiratory complications in children, using a multivariate logistic regression model including: age, anaesthesiologist, airway maintenance and surgical procedure, adjusted for age and gender, Geneva, Switzerland, 2000

Variables	*Perioperative respiratory complications* (n) *Yes*	*No*	*OR*	*95% CI*
Specialized paediatric anaesthesiologist				
Yes	37	141	1.0	
No	173	384	1.70	1.12–2.57
Gender				
Male	132	344	1.0	
Female	79	183	1.18	0.84–1.66
Airway maintenance				
Mask, LMA	74	168	1.0	
Intubation without relaxants	52	87	1.16	0.74–1.82
Intubation with relaxants	82	266	0.65	0.44–0.94
Age[a]	n.a.	n.a.	0.92	0.87–0.97

ENT: ear, nose and throat surgery, OR: odds ratio, CI: confidence interval, n.a.: not applicable.
[a]This variable was included as a continuous variable in the model (mean ± 1.96 SD).

Table 4
Determinants of perioperative respiratory complications in children, using a multivariate logistic regression model including: age, gender, airway maintenance and surgical procedure, adjusted for age and gender, Geneva, 2000

Variables	*Perioperative respiratory complications* (n) *Yes*	*No*	*OR*	*95% CI*
Airway maintenance				
Mask, LMA	74	168	1.0	
Intubation without relaxants	52	87	0.83	0.48–1.44
Intubation with relaxants	82	266	0.59	0.40–0.87
Surgical procedure				
Else	128	388	1.0	
ENT	82	138	1.77	1.15–2.70
Gender				
Male	132	344	1.0	
Female	79	183	1.15	0.82–1.61
Age[a]	n.a.	n.a.	0.93	0.90–0.99

ENT: ear, nose and throat surgery, OR: odds ratio, CI: confidence interval, n.a.: not applicable.
[a]This variable was included as a continuous variable in the model (mean ± 1.96 SD).

children (7,14). Furthermore, a synergistic interaction was observed between high-risk procedures (such as ENT) and the level of experience of the anaesthesiologist. Thus, in the presence of the two risk factors (ENT and nonspecialized paediatric anaesthesiologist), the OR for the occurrence of PRAE (2.7) was higher than the OR obtained by multiplication of each OR taken independently ($1.51 \times 1.57 = 2.37$). In conclusion, the results of the present study indicate that children not anaesthetized by a specialized

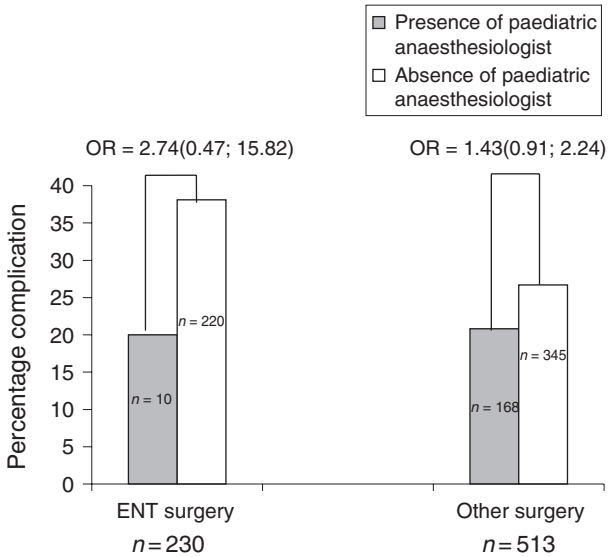

Figure 1
Effect of absence of specialized paediatric anaesthesiologist on PRAE OR by type of surgery (P for interaction = 0.4402).

paediatric anaesthesiologist for ENT procedures present the higher risk of PRAE. This finding points out the importance of admitting children for ENT surgery in hospital facilities where specialized paediatric anaesthesiologists provide perioperative care.

The prevalence of asthma, bronchial hyperreactivity and allergy was lower in this population than expected (15). These diseases were not found to be risk factors of PRAE. In addition, only well-controlled patients and children without acute symptoms of bronchial hyperreactivity were scheduled for surgery and thus a lower risk of bronchospasm was expected. This may explain the very low incidence of bronchospasm observed in this survey. In contrast, oxygen desaturation was frequently reported both peri and postoperatively, but was often a consequence of another concomitant respiratory adverse event.

More than half of the children were exposed to passive smoking. Skolnick *et al*. (10) has reported a high incidence of PRAE in children with respiratory tract infection and high levels of urine cotinine, a marker of passive smoking exposure. Such objective measurements were not performed in the present study, we failed to demonstrate any relation between PRAE and passive smoking among children without respiratory tract infections. We must keep in mind the lack of accuracy of a questionnaire to evaluate real passive smoking exposure. Accordingly, Skolnick *et al*. reported that almost 20% of children whose parents did not report a smoking habit by a questionnaire still exhibited cotinine in the urine. Thus, urinary cotinine should be preferred to a questionnaire to identify the exposed children (16).

Surprisingly, neither the anaesthetic induction technique nor the airway maintenance influenced the occurrence of PRAE. However, the use of a relaxant to facilitate tracheal intubation prevented the occurrence of PRAE. This phenomenon was not reported previously, and its causes can only be hypothesized. Recently, relaxants for tracheal intubation have been less used because of allergic reactions observed during anaesthesia (17). Accordingly, almost one-third of the tracheal intubations were achieved without relaxants. One could argue that the depth of the anaesthesia was not correctly evaluated and therefore the timing of intubation was not appropriate when no relaxant was administered. Howover, the experience of the anaesthesiologist inserting the tracheal tube as well as the use of inhalation or intravenous induction technique did not influence the incidence of PRAE. These PRAE were easily managed with no adverse outcomes, which is in agreement with other studies (18).

Children under 1 year of age were not included in the study, because the ISAAC questionnaire has not yet been validated for infants. However, it has been already widely demonstrated that infants are at higher risk of PRAE (2,3,9). In the present analysis, the fact that age was used as a continuous variable allowed us not only to confirm the importance of age but also to quantify the impact of each year of age on this risk factor. Accordingly, one could expect an 8% decrease risk of occurrence of PRAE with each increasing year of age.

Although the ISAAC questionnaire has been widely used and validated in the literature (12,13), it considers only events that occurred in the last 12 months. Its accuracy greatly depends on the parent's memory. However, a trained interviewer, as in the present study can improve a parent's recall.

In summary, results of the present study show that the age of the children and the experience and the skills of the anaesthesiologist are primary risk factors for perioperative adverse respiratory events. This finding confirms the need for worldwide guidelines on paediatric anaesthesia and young

children should have their anaesthetic management provided by specialized paediatric anaesthesia specialists, especially for high-risk procedures. Furthermore, no matter what the anaesthesia technique, the relevant correlation revealed in the present study between PRAE and tracheal intubation without a relaxant, should be considered during anaesthesia management. Thus, one should ponder the risk of using a relaxant with the occurrence of respiratory adverse events when attempting tracheal intubation. Further investigations are necessary to establish the usefulness and/or the hazard of relaxants when administered for tracheal intubation.

Although one in five children was associated with PRAE, no serious PRAE were identified in our study and were easily managed.

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References

1 Cohen MM, Cameron CB, Duncan PG. Pediatric anesthesia morbidity and mortality in the perioperative period. *Anesth Analg* 1990; **78:** 461–467.
2 Caplan RA, Posner KL, Ward RJ *et al.* Adverse respiratory events in anesthesia: a closed claims analysis. *Anesthesiology* 1990; **72:** 828–833.
3 Morray JP, Geiduschek JM, Caplan RA *et al.* A comparison of pediatric and adult anesthesia closed malpractice claims. *Anesthesiology* 1993; **78:** 461–467.
4 Webb RK, van der Walt JH, Runcimann WB *et al.* The Australian Incident Monitoring Study. Which monitor? An analysis of 2000 incident reports. *Anaesth Intensive care* 1993; **21:** 529–542.
5 Training guidelines in anaesthesia of the European Board of Anaesthesiology Reanimation and Intensive Care. *Eur J Anaesthesiol* 2001; **18:** 563–571.
6 Rosenstock C, Moller J, Hauberg A. Complaints related to respiratory events in anaesthesia and intensive care medicine from 1994 to 1998 in Denmark. *Acta Anaesthesiol Scand* 2001; **45:** 53–58.
7 Tay CLM, Tan GM, Ng SBA. Critical incidents in paediatric anaesthesia: an audit of 10 000 anaesthetics in Singapore. *Paediatr Anaesth* 2001; **11:** 711–718.
8 Olsson GL. Laryngospasm during anaesthesia. A computer incidence study of 136 929 patients. *Acta Anaesth Scand* 1984; **28:** 567–575.
9 Tait AR, Malviya S, Voepel-Lewis T *et al.* Risk factors for perioperative adverse respiratory events in children with upper respiratory tract infection. *Anesthesiology* 2001; **95:** 299–306.
10 Skolnick ET, Vomvolakis MA, Buck KA *et al.* Exposure to environmental tobacco smoke and the risk of adverse respiratory events in children receiving general anesthesia. *Anesthesiology* 1998; **88:** 1141–1142.
11 Parnis SJ, Barker DS, Van der Welt JH. Clinical predictors of anaesthetic complications in children with respiratory tract infections. *Paediatr Anaesth* 2001; **11:** 29–40.
12 Jenkins MA, Clarke JR, Carlin JB *et al.* Validation of questionnaire and bronchial hyperresponsiveness against respiratory physician assessment in the diagnosis of asthma. *Int J Epidemiol* 1996; **25:** 609–616.
13 Pearce N, Weiland S, Keil U *et al.* Self-reported prevalence of asthma symptoms in children in Australia, England, Germany and New Zealand: an international comparison using the ISAAC protocol. *Eur Respir J* 1993; **6:** 1455–1461.
14 Schreiner MS, O'Hara I, Markakis DA *et al.* Do children who experience laryngospasm have an increased risk of upper respiratory tract infection. *Anesthesiology* 1996; **85:** 475–480.
15 Braun-Fahrlander C, Gassner M, Grize L *et al.* Comparison of responses to an asthma symptom questionnaire (ISAAC core questions) completed by adolescents and their parents. SCARPOL-Team. Swiss Study on Childhood Allergy and Respiratory Symptoms with respect to Air Pollution. *Pediatr Pulmonol* 1998; **25:** 159–166.
16 Ehrlich RL. Parental smoking and childhood asthma. *S Afr Med J* 1992; **81:** 443–444.
17 Laxenaire ML. Again and always allergy. *Ann Fr Anesth Reanim* 1999; **18:** 831–833.
18 Rolf N, Cote CJ. Frequency and severity of desaturation events during general anesthesia in children with and without upper respiratory infections. *J Clin Anesth* 1992; **4:** 200–203.

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