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Clinical Investigation

CLINICAL INVESTIGATION

Airway management in paediatric anaesthesia in Europe—insights from APRICOT (Anaesthesia Practice In Children Observational Trial): a prospective multicentre observational study in 261 hospitals in Europe

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Abstract

Background: Critical respiratory events are common in children in the peri-anaesthetic period and are caused by airway and ventilation management difficulties. We aimed to analyse current European paediatric airway management practices and identify the incidence and potential consequences of difficult airway management.

Methods: We performed a secondary analysis of airway and ventilation management details of the European multicentre observational trial (Anaesthesia PRactice in Children Observational Trial, APRICOT) of children from birth to 15 yr of age. The primary endpoint was the incidence of difficult airway management. Secondary endpoints were the associations between difficult airway management, known pre-existing respiratory risk factors, and the occurrence of critical respiratory events.

Results: Details for 31 024 anaesthetic procedures were available for analysis. Three or more tracheal intubation attempts were necessary in 120 children (0.9%) and in 40 children (0.4%) for supraglottic airways insertions. The incidence (95% confidence interval) for failed tracheal intubation and failed supraglottic airway insertions was 8/10 000 (0.08%; 0.03–0.13%) and 8.2/10 000 (0.08%; 0.03–0.14%) children, respectively. Difficulties in securing the airway increased the risk for a critical respiratory event for tracheal tube (2.1; 1.3–3.4) and supraglottic airway (4.3; 1.9–9.9) placement. History of pre-existing respiratory risk factors was significantly associated with critical respiratory events independently of the airway device used.

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Conclusions: Airway management practices vary widely across Europe. Multiple airway device insertion attempts and pre-existing respiratory risk factors increase the likelihood of critical respiratory events in children and require further stratification during preoperative assessment and planning. This study highlights areas where education, research, and training may improve perioperative care.
Clinical trial registration: NCT01878760.

Keywords: airway; anaesthesia; children; morbidity

Editor's key points

- Critical respiratory events are common in children in the perianaesthetic period, but the incidence and potential consequences of difficult airway management are not clear.
- Analysis of >31 000 anaesthetic procedures provided the incidence of difficult airway management.
- Multiple airway device insertion attempts and pre-existing respiratory risk factors increase the likelihood of critical respiratory events in children.

Difficulties in airway management in children are frequently encountered and continue to be a leading cause of perioperative morbidity and mortality. These problems are more common in young children who are more prone to hypoxaemia[1,2] because of a decrease in their functional residual capacity.[3] Poor oxygenation and ventilation and failure of tracheal intubation are responsible for up to 25% of perioperative cardiac arrests in children.[4] Even when admitted to specialised hospitals, children with a compromised or impaired airway may suffer severe complications in up to 1:50 patients, with a subsequent mortality exceeding 30%.[5]

Over the past decades, improvements in ventilation in paediatric anaesthesia have been limited by the choice of airway devices and use of ventilators poorly suited to the small child's respiratory physiology.[6] Current evidence-based lung-protective ventilation strategies which are promoted in adult anaesthesia[7,8] may be beneficial in children.[6] However, the impact of ventilation strategies on the occurrence of respiratory critical events remain unclear.

Recently, a large multicentre European observational study, Anaesthesia PRactice in Children Observational Trial (APRICOT), reported a high incidence of critical respiratory events, and identified young age, medical history, presence of airway hypersensitivity, and medical condition (ASA physical status) as independent risk factors for their occurrence.[9] This study provided detailed information on airway management and modes of ventilation across the different age groups, in 33 countries and 261 institutions. Considering that the choice of paediatric airway management remains highly individualised and is dictated by personal preference and local resources,[5,10] characterisation of current practices in Europe is of utmost importance to harmonise clinical practice and potentially improve patient outcome.

Therefore, the aim of the present study is to characterise paediatric airway management strategies across Europe and to analyse the relationship between critical respiratory events, choice of airway technique and equipment, associated comorbidity, existing clinical experience, inpatient or outpatient settings, and urgency of the procedure. The primary endpoint was the incidence of difficult airway management. Secondary endpoints were the potential associations between difficult airway management, presence of known pre-existing respiratory risk factors, and occurrence of critical respiratory events.

Methods

This study is registered with ClinicalTrials.gov, number NCT01878760.

Study design

Detailed study design and data collection for the APRICOT study were previously published.[10] In summary, the APRICOT study prospectively collected perioperative data that described the anaesthesia management of consecutive children aged from birth to age 15 yr during a consecutive 2-week period between April 1, 2014 and January 31, 2015. All participating centres applied for formal ethics approval or a waiver, as appropriate, as ethics requirements varied between centres and countries.

Setting

Before data collection, a local investigator provided details of their hospital's paediatric anaesthesia activity, perioperative care facilities, estimated annual number of procedures, and the number of certified or dedicated paediatric anaesthesiologists.

Participants

All patients undergoing an inpatient or outpatient diagnostic or surgical procedure, whether elective, urgent, or emergency, in-hours or out-of-hours, under sedation or general anaesthesia, with or without regional analgesia were eligible for inclusion. Children who underwent awake regional anaesthesia only were excluded from further analysis. Children were followed for up to 60 min after anaesthesia or sedation in the post anaesthesia recovery unit, and the child's status at discharge or at 30 days was recorded. Children were excluded if they were admitted directly to the operating room with their tracheas already intubated, or anaesthesia procedures were performed in the neonatal or paediatric ICU.

Variables

Details on patient history, type of procedure, and the experience of the anaesthetic team in charge were recorded. The choice of anaesthesia and airway management including

medication, airway devices, the use of cuffed or uncuffed tracheal tubes, and other supraglottic airway (SGA) were considered for detailed analysis. In addition, the ventilation strategy used during the anaesthesia procedure was detailed along with the management of the recovery period and postoperative care (up to 60 min).

All predefined severe critical events and their time of occurrence (during anaesthesia induction, maintenance, or emergence, or in the PACU), the treatment needed, and the immediate outcome were documented. The definitions of the severe critical events were previously reported[9] as requiring immediate intervention that led, or could have led, to major disabilities or death. The potential consequences of those severe critical events and outcome at discharge from the hospital or at 30 days postanaesthesia was also recorded. Severe critical respiratory events available for analysis in this study included all episodes of laryngospasm, bronchospasm, and the occurrence of stridor. The following variables were included in the analysis: difficult laryngoscopy [defined as Cormack–Lehane (CL) grading of 3 or 4]; difficult tracheal tube insertion (three or more attempts); difficult intubation (defined as CL grading of 3 or 4, AND three or more attempts to insert the tracheal tube); difficult SGA insertion (three or more attempts of insertion). Current paediatric anaesthesia practice was considered as: specialist anaesthesiologist with mainly paediatric practice (>80%); specialist anaesthesiologist with frequent paediatric anaesthesia cases (50–80%); specialist anaesthesiologist with occasional paediatric anaesthesia cases (<50%); anaesthesiologist in training; anaesthetic nurse or technician with the years of experience of the most senior practitioner considered. The variables inpatient or outpatient activities and the urgency of the procedure (elective, urgent, or emergency) were considered. The variables 'awake' or 'deep' removal of the airway device was not further defined in terms of minimum alveolar concentration (MAC) value or complete regaining of airway reflexes within the APRICOT dataset. Detailed definitions of patient characteristics, medical history, and parameters related to the general anaesthesia are available in the study protocol (www.esahq.org/apricot).

Data sources

Anonymised data were uploaded onto a secure Internet-based electronic case record form (OpenClinica, Boston, MA, USA).

Bias

An *a priori* statistical analysis plan was defined in the initial protocol, which is accessible online (www.esahq.org/apricot).

Study size

The study size for the APRICOT study was estimated at a minimum of 25 000 patients to provide 95% confidence interval (CI) for the overall incidence of severe critical events with an acceptable confidence width assuming that the lowest incidence of severe critical events is 0.1% (i.e. 95% exact CI is 0.065–0.147).

Statistical methods

Statistical analysis was performed using SPSS version 24 (IBM Corp., Armonk, NY, USA) statistical software. Data are expressed as mean (standard deviation) for continuous variables and percentages for categorical variables. Univariate methods with age and sex adjustment were used to test factors associated with the endpoints. A multivariate relative risk regression model was applied to identify the potential risk factors for the occurrence of any respiratory severe critical events as defined above. These methods were used on all available data and when all risk factors were present. Considering that multiple procedures were done on some of the individuals, a generalised linear model, using binomial distribution for the dependent variable, log-link function, and exchangeable covariance structure for correlated observations was used. Relative risks and 95% CIs were estimated from the model. Two-sided tests were used in all cases.

Role of the funding source

The funding source provided the infrastructure for the trial, identified the national study coordinating investigators, liaised with the local investigators, and monitored the data entry and cleaning. All authors had access to the raw data. The corresponding author had full access to all the data in the study and had the final responsibility for the decision to submit the manuscript for publication.

Results

Participants

The final APRICOT dataset comprising 31 127 anaesthetic procedures in 30 874 patients was available for analysis. As children who underwent awake regional anaesthesia were excluded, a total of 31 024 datasets were interrogated. The median age (inter-quartile range) of the included children in the present analysis was 5.4 (7.2) yr with 356 (1.2%) neonates, 2872 (9.3%) infants (aged 28 days to 1 yr), 13 456 (43.7%) preschool children (1–5 yr), 9215 (29.9%) school children (6–12 yr), and 4873 (15.8%) adolescents (13–15 yr).

Descriptive data

Choice of airway devices

Table 1 illustrates the distribution amongst the different airway devices of the participating centres across Europe during the study period. Overall, tracheal tubes were the most commonly used airway device during anaesthesia in children. Tracheal tubes were used in the majority of children aged <1 yr, during emergency procedures and in inpatient settings. Conversely, SGA were primarily used for outpatient procedures. Years of experience of the most experienced member of the anaesthetic team and anaesthetic practice in the hospital did not influence the choice of airway device.

The choice of the airway device, varied significantly across participating European centres ($P<0.0001$) (Supplementary material, Appendix S1). Tracheal tubes were used commonly for surgical procedures ranging from 37% to 76%. Conversely, face masks and SGA were more commonly used in non-surgical procedures with, however, a practice that varied from <24% to >88% amongst countries.

Uncuffed tracheal tubes were more frequently used in neonates 69.1% (n=203 of 294) and in children aged <1 yr 55.5% (n=884 of 1593). Cuffed tracheal tubes were used in 62.1%, 83%, and 97.7% in 1–6-yr-olds, 6–12-yr-olds, and >12-yr-olds, respectively. Overall, cuffed tracheal tubes were used in 9811 patients, with the cuff pressure monitored in 4667 (47.6%) (Supplementary material, Appendix S2).

Table 1 Distribution of the airway devices according to age, degree of urgency, admission setting, years of experience of the primary anaesthesiologist in charge, and frequency of paediatric practice. Data are presented as absolute numbers and (percentages).

	Facemask	Tracheal tube	Supraglottic airway	Tracheotomy	Sedation only
Age					
<28 days	38 (10.6)	294 (82.1)	14 (3.9)	2 (0.6)	10 (2.8)
<1 yr	507 (17.5)	1593 (55.0)	612 (21.1)	25 (0.9)	160 (5.5)
1–6 yr	2416 (17.8)	5635 (41.5)	4812 (35.4)	72 (0.5)	656 (4.8)
6–12 yr	1427 (15.4)	3829 (41.3)	3660 (39.5)	24 (0.3)	332 (3.6)
>12 yr	582 (11.9)	2320 (47.3)	1820 (37.1)	6 (0.1)	178 (3.6)
Urgency					
Elective	4104 (16.3)	10 617 (42.2)	9153 (36.4)	113 (0.4)	1169 (4.6)
Urgent	786 (15.6)	2508 (49.9)	1587 (31.6)	13 (0.3)	133 (2.6)
Emergency	80 (9.5)	545 (65.0)	177 (21.1)	3 (0.4)	34 (4.1)
Setting					
Outpatient	2504 (20.2)	3248 (26.2)	5992 (48.3)	16 (0.1)	657 (5.3)
Inpatient	2466 (13.3)	10 422 (56.0)	4925 (26.5)	113 (0.6)	679 (3.6)
Experience					
<5 yr	756 (16.4)	2125 (46.0)	1583 (34.2)	12 (0.3)	147 (3.2)
5–10 yr	1101 (14.7)	3244 (43.3)	2752 (36.7)	37 (0.5)	365 (4.9)
>10 yr	3111 (16.5)	8282 (44.0)	6549 (34.8)	79 (0.4)	823 (4.4)
Paediatric practice					
Specialist	3180 (17.4)	8255 (45.1)	5961 (32.6)	105 (0.6)	800 (4.4)
Mixed	639 (14.7)	1873 (43.1)	1598 (36.8)	11 (0.3)	227 (5.2)
Occasional	769 (12.9)	2563 (43.1)	2381 (40.0)	6 (0.1)	231 (3.9)
Training	382 (15.8)	979 (40.4)	979 (40.4)	6 (0.2)	77 (3.2)
Totals	4970 (16.0)	13 671 (44.1)	10 918 (35.2)	129 (0.4)	1336 (4.3)

SGA were used in 35.2% (n=10 915) of all patients with the vast majority first generation devices (n=9457, 85%). Neither years of experience nor current paediatric practice influenced this choice (Supplementary material, Appendix S2).

Ventilation modes

Spontaneous ventilation was used in up to 15% of patients with uncuffed tracheal tubes and in almost half (45.5%) of the children with SGA devices. In addition, spontaneous ventilation was used in 63.1% of all non-surgical procedures compared with 28% of surgical procedures. Conversely, pressure support ventilation was rarely reported, whether it was in presence of a tracheal tube (6.3%) or an SGA device (12.9%) (Supplementary material, Appendix S3).

Positive pressure (mechanical) ventilation was recorded overall in almost 90% of children with tracheal tubes and >40% of those with SGA devices. The modes of positive pressure ventilation varied between children with cuffed and uncuffed tracheal tubes with pressure-controlled ventilation (PCV) being significantly more frequently (P<0.001) used in the latter than volume-controlled ventilation (VCV). However, PCV was the mode of choice in the presence of an SGA device. Pressure-regulated VCV was rarely used, with <7% of children with a tracheal tube and <3% of those with an SGA device being ventilated using this mode. Almost all neonates were mechanically ventilated with PCV being used significantly more than VCV (72% *vs* 17%, respectively; P<0.001) and negligible consideration of pressure-regulated VCV (3.5%) (Supplementary material, Appendix S4). This difference in modes of ventilation was also found when tracheal tubes were used in infants and preschool children, whilst no difference between PCV and VCV was found in children aged >6 yr. There was no evidence for the influence of clinical experience and inpatient or outpatient settings and urgency of the procedure on the choice of airway device and subsequent mode of ventilation (data not shown).

Outcome data

Airway management

Tracheal intubation was successfully achieved using direct laryngoscopy in >98% (n=13 422) of patients, whilst videolaryngoscopy was used in 181 (1.3%) patients and fibreoptic intubation in 37 (0.3%) patients. The proportion of CL grade 3 and 4 was greater in neonates and children aged <1 yr. Tracheal tube insertion aids were not commonly used (7.9% for stylets and 0.8% for bougies, respectively). Patient age, urgency of the procedure, inpatient or outpatient, years of paediatric experience, or current practice did not influence the use of direct or videolaryngoscopy or use of tube insertion aids. The SGA was successfully inserted within two attempts in 10 685 (99.5%) patients with 446 (4.1%) patients under neuromuscular block during insertion.

A wide variability in the removal of the tracheal tube or SGA was observed. The tracheal tube was more frequently removed in awake children whilst almost a third was removed deep. The experience of the anaesthesiologist in charge, the inpatient or outpatient setting and urgency of the procedure did not influence awake or deep removal of the tracheal tube. Similarly, the SGA removal (awake *vs* deep) was not influenced by the urgency of the procedure, inpatient or outpatient setting, previous paediatric experience, or current practice (Supplementary material, Appendix S2).

Difficult airways

Table 2 details the demographic, airway, and anaesthesia characteristics of patients in whom airway management difficulties were reported with either a tracheal tube or an SGA. A

Table 2 Characteristics of procedures requiring three or more attempts to successfully insert either a tracheal tube or a supraglottic airway. Absolute numbers (percentage) given for tracheal tubes and supraglottic airways and per category. CL, Cormack–Lehane grade

	Tracheal tubes n=120		Supraglottic airways n=40			
	CL 1/2 n=82	CL 3/4 n=38	Classic n=23	ProSeal n=1	Flexible n=9	iGel n=7
Age						
<28 days	6 (5.0)	3 (2.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
<1 yr	41 (34.2)	18 (15.0)	3 (7.5)	0 (0.0)	0 (0.0)	1 (2.5)
1–6 yr	20 (16.7)	9 (7.5)	10 (25.0)	0 (0.0)	6 (15.0)	2 (5.0)
6–12 yr	9 (7.5)	5 (4.2)	6 (15.0)	1 (2.5)	2 (5.0)	3 (7.5)
>12 yr	6 (5.0)	3 (2.5)	4 (10.0)	0 (0.0)	1 (2.5)	1 (2.5)
Urgency						
Elective	58 (48.3)	29 (24.2)	23 (57.5)	0 (0.0)	9 (22.5)	4 (10.0)
Urgent	23 (19.2)	6 (5.0)	0 (0.0)	1 (2.5)	0 (0.0)	3 (7.5)
Emergency	1 (0.8)	3 (2.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Setting						
Outpatient	15 (12.5)	6 (5.0)	10 (25.0)	0 (0.0)	9 (22.5)	4 (10.0)
Inpatient	67 (55.8)	32 (26.7)	13 (32.5)	1 (2.5)	0 (0.0)	3 (7.5)
Paediatric practice						
Specialist	57 (47.5)	27 (22.5)	15 (37.5)	1 (2.5)	2 (5.0)	5 (12.5)
Mixed	12 (10.0)	6 (5.0)	2 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
Occasional	9 (7.5)	3 (2.5)	2 (5.0)	0 (0.0)	6 (15.0)	1 (2.5)
Training	4 (3.3)	2 (1.7)	4 (10.0)	0 (0.0)	1 (2.5)	1 (2.5)
Type of procedure						
Surgical	67 (55.8)	32 (26.7)	18 (45.0)	1 (2.5)	7 (17.5)	7 (17.5)
Non-surgical	15 (12.5)	6 (5.0)	5 (12.5)	0 (0.0)	2 (5.0)	0 (0.0)
Neuromuscular blocking agent						
Yes	49 (40.8)	24 (20.0)	2 (5.0)	0 (0.0)	0 (0.0)	1 (2.5)
No	33 (27.5)	14 (11.7)	21 (52.5)	1 (2.5)	9 (22.5)	6 (15.0)
Anaesthesia management						
Inhalation only	29 (24.2)	15 (12.5)	5 (12.5)	0 (0.0)	3 (7.5)	1 (2.5)
Propofol TIVA only	2 (1.7)	2 (1.7)	4 (10.0)	0 (0.0)	0 (0.0)	1 (2.5)
Other	51 (42.4)	21 (17.5)	14 (35.0)	1 (2.5)	6 (15.0)	5 (12.5)

total of 120 patients (0.88%), required three or more attempts for tracheal intubation. Of these, 82 patients (68.4%), had a CL grade 1 or 2; tracheal intubation was attempted without a neuromuscular blocking agent in 47 of them (39.1%). Direct laryngoscopy was used in 85% (n=102) of these patients, videolaryngoscopy in 10.8% (n=13), fibreoptic intubation in 2.5% (n=3) and an intubating LMA in 1.7% (n=2). A stylet or a bougie was used during intubation attempts in 41 (34.2%) and 12 (10%) of these patients, respectively.

Difficult intubation was reported in 38 (0.28%) patients. The estimated incidence for difficult intubation was significantly higher in neonates (1%, 95% CI: 0–2.2%) and children aged <1 yr (1.1%, 95% CI: 0.6–1·6%) than any other age groups (1–5 yr: 0.2%, 95% CI: 0.1–0.3%; 6–12 yr: 0.1%, 95% CI: 0.0–0.2%; and >12 yr: 0.1%, 95% CI: 0.0–0.3%; $P \leq 0.0001$). There was no evidence for an effect of years of experience and seniority of the team on the incidence of difficult intubation. No neuromuscular blocking agent was administered in 14 patients (36.8%) and inhalation anaesthesia was performed in 26 (68.4%) patients. An alternative technique to direct laryngoscopy (videolaryngoscopy n=6, intubating laryngeal mask airway, n=2, or fibreoptic n=2) was used in 10 patients with a difficult intubation. A stylet was used in 20 (52.6%) and a bougie in four (10.5%) patients. Difficult intubation during rapid sequence induction was reported in three of 1372 (0.2%) patients.

Failed tracheal intubation was reported in 11 patients (8/10 000; 0.08%, 95% CI: 0.03–0.13% tracheal intubation attempts). The characteristics of these patients are reported in Table 3. Only direct laryngoscopy was used for tracheal intubation attempts in these patients. No neuromuscular blocking agent was used in seven of 11 patients at induction. An SGA device was used for surgery in one patient; the surgical procedure was abandoned in another.

A total of 40 patients (0.36%) required three or more attempts for successful insertion of SGA with the highest number in preschool children (n=18, 45%). Three of these patients received a neuromuscular blocking agent at induction. A total of nine SGA insertions were reported to be unsuccessful (six Classic, three iGel, and one other SGA; 8.2/10 000; 0.08%, 95% CI: 0.03–0.14%; Table 3).

Airway management difficulties resulted in a number of critical respiratory and also critical cardiovascular events (Table 4). There was a significant increase in the risk for critical respiratory events when using more than two attempts to secure the airway with a tracheal tube or an SGA (P=0.001). A difficult or unsuccessful attempt to insert an SGA was also associated with a significant increase in the incidence of cardiovascular instability (P=0.013).

Critical respiratory events

The incidence of severe critical respiratory events was: laryngospasm 1.2% (95% CI: 1.1–1.3); bronchospasm 1.2% (1.1–1.3); overall postanaesthetic stridor 0.7% (0.6–0.8); and 1.1% (0.9–1.3) in children who had a tracheal tube inserted.

Table 3 Details of failed tracheal intubation and failure to insert a supraglottic airway. Team: S, specialist anaesthesiologist with mainly paediatric practice (>80%); SF, specialist anaesthesiologist with frequent paediatric anaesthesia cases (50–80%); SO, specialist anaesthesiologist with occasional paediatric anaesthesia cases (<50%); T, anaesthesiologist in training, anaesthetic nurse or technician/years of experience of most senior practitioner). *CL (Cormack–Lehane) grade applies to tracheal tube and SGA type applies to supraglottic airway. †After unsuccessful intubation SGA (iGel) was inserted

ID	Age (yr)	Sex	Urgency	ASA physical status	Comorbidities	Team (experience years)	CL grade/ SGA type*	Procedure type	Induction drugs	Neuromuscular blocking agents	Complications	Location after anaesthesia	Status at 30 days
Tracheal tube													
1	7.70	Male	Elective	1	No	S (18)	1	Urological/kidney	Propofol Opiate	Succinylcholine	No	Recovery room	Discharged home
2	4.50	Male	Elective	2	Yes	S (20)	3	Ear-nose-throat	Sevoflurane Propofol Opiate	None	Cardiac Arrest	Recovery room	Still in hospital on day 30
3	1.63	Male	Urgent	1	No	S (11)	1	Orthopaedic	Sevoflurane Propofol	None	No	Recovery room	Discharged home
4†	1.34	Male	Elective	1	No	S (8)	1	Urological/kidney	Sevoflurane Propofol Opiate	None	Bronchospasm Laryngospasm	Recovery room	Discharged home
5	10.34	Female	Urgent	3	No	S (25)	4	Venous access	Sevoflurane	None	No	Intensive Care	Still in hospital on day 30
6	1.27	Male	Elective	2	No	S (11)	1	Urological/kidney/ ear–nose–throat	Sevoflurane Propofol Opiate	None	No	Recovery room	Discharged home
7	1.39	Male	Elective	1	No	SO (15)	1	Gastro/abdominal	Propofol	Atracurium	No	Recovery room	Discharged home
8	10.25	Male	Elective	3	Yes	S (12)	N/A	Gastro/abdominal	Propofol	None	No	Recovery room	N/A
9	2.52	Male	Elective	2	No	S (3)	1	Gastroenterology	Sevoflurane Propofol Opiate Atropine	Succinylcholine	No	Recovery room	Discharged home
10	1.60	Female	Urgent	4	No	S (11)	2	Gastroenterology	Propofol Opiate	Succinylcholine	No	Recovery room	Discharged home
11	5.97	Male	Elective	1	No	SO (23)	1	Ear–nose–throat	Sevoflurane	None	No	Recovery room	Discharged home
Supraglottic airway													
1	0.12	Male	Elective	3	Yes	SF (22)	Classic	Thoracic	Propofol Opiate	None	Cardiovascular instability	Intensive Care	Discharged to acute centre
2	0.86	Male	Emergency	2	No	S (2)	iGel	Orthopaedic	Sevoflurane Propofol Opiate	None	No	Recovery room	Discharged home
3	2.27	Male	Elective	1	No	S (26)	iGel	Ophthalmological examination	Sevoflurane	None	No	Recovery room	Discharged home
4	2.52	Male	Elective	1	No	S (6)	Classic	Gastro/abdominal	Sevoflurane Opiate	Rocuronium	No	Recovery room	Discharged home
5	5.51	Female	Elective	1	No	S (7)	Other	Dental	Sevoflurane	None	No	Recovery room	Discharged home
6	9.37	Male	Elective	1	No	S (14)	Classic	Urological/kidney	Propofol	None	Laryngospasm	Recovery room	Discharged home
7	2.11	Female	Elective	3	Yes	S (14)	Classic	Ophthalmology	Propofol Opiate	Atracurium	No	Recovery room	Discharged home
8	0.60	Female	Elective	3	Yes	SO (10)	Classic	Gastro/abdominal	Sevoflurane	None	No	Recovery room	Discharged home
9	0.28	Female	Elective	1	No	T (1)	Classic	Orthopaedic	Sevoflurane	None	Laryngospasm	Intensive Care	Discharged home

Table 4 Absolute numbers (percent) and relative risk (95% CI) for critical respiratory and cardiovascular events in children with difficult or failed tracheal intubation (n=131) and children with difficult or failed insertion of supraglottic airways (n=49). *P=0.001, **P=0.013

	Difficult/ failed	Successful	Relative risk
Critical respiratory event			
Tracheal intubation	16 (12.2)	539 (4.0)	2.1 (1.3–3.4)*
Supraglottic airway	5 (10.2)	217 (2.0)	4.3 (1.9–9.9)*
Critical cardiovascular event			
Tacheal intubation	8 (6.1)	477 (3.5)	1.6 (0.8–3.2)
Supraglottic airway	2 (4.1)	80 (0.7)	5.7 (1.4–22.3)**

Table 5 summarises the relative risk and 95% CIs for the occurrence of critical respiratory events with face mask as a reference value.

The presence of one of the main risk factors for perioperative respiratory events (asthma, wheezing, upper respiratory tract infection, snoring and passive smoking) revealed an increased risk for bronchospasm for tracheal tubes and SGA and stridor for tracheal tubes (data not shown). Applying a multivariate relative risk regression model confirmed the significant association between the occurrence of severe respiratory critical events with preoperative respiratory risk factors, experience of the anaesthesiologist, the presence of difficult airways, and the airway device used (Table 6). The choice of ventilation mode for each airway device did not influence the incidence or the relative risk for the occurrence of critical respiratory events. However, the use of uncuffed tracheal tube was associated with a higher risk for bronchospasm in preschool children (relative risk: 1.8; 95% CI: 1.2–2.7, $P \leq 0.005$).

Discussion

The present study provides information on the wide variation of airway management strategies in 261 participating European centres. The incidence of the reported difficult airway management was low but led in more than half of them to a severe critical event with one cardiac arrest. In addition, there was a strong association between severe respiratory critical events and the number of attempts to secure the airways, the airway management device and the presence of preoperative respiratory risk factors.

The APRICOT study was designed to establish the incidence of severe critical events (laryngospasm, bronchospasm, pulmonary aspiration, drug error, anaphylaxis, cardiovascular instability, neurological damage, cardiac arrest, and post-extubation stridor) occurring during and up to 60 min after

Table 5 Critical respiratory events. Relative risk and 95% confidence intervals of respiratory critical events of tracheal intubation and supraglottic airways when compared with face mask ventilation as reference value. *P<0.05 and **P<0.01

	Bronchospasm	Laryngospasm	Stridor
Endotracheal intubation			
Urgency			
Elective (n=23 874)	4.7 (2.9–7.6)**	2.9 (1.9–4.5)**	4.0 (2.2–7.2)**
Non-elective (n=5683)	3 (1.3–6.7)**	3.4 (1.1–11)*	4.7 (1.1–19.6)*
ASA physical status			
1–2 (n=26 340)	3.8 (2.5–5.9)**	3.4 (2.2–5.3)**	4.6 (2.5–8.6)**
3–5 (n=3211)	14.4 (2.0–97)**	1.2 (0.4–3.3)	2.4 (0.7–7.9)
Experience			
<5 yr (n=4464)	2.6 (1.1–6.1)*	5.0 (1.6–16.1)**	7.6 (1–56.5)*
5–10 yr (n=7097)	7.9 (2.9–21.4)**	4.7 (1.7–13.2)**	4.3 (1.3–13.9)**
>10 yr (n=17 942)	3.9 (2.2–6.7)**	2.3 (1.4–3.6)**	3.7 (1.9–7.1)**
Paediatric practice			
Specialist (n=17 395)	4.6 (2.6–8.1)**	3.4 (1.9–6.0)**	6.1 (2.5–15.1)**
Mixed (n=4110)	3.9 (1.6–9.6)**	1.2 (0.6–2.4)	2.5 (0.8–8.2)
Occasional (n=5713)	5.5 (1.7–17.6)**	7.4 (1.8–31)**	3.3 (1.2–9.1)*
Trainees/nurses (n=2340)	2.5 (0.7–8.4)	6.2 (0.8–48.0)	3.4 (0.7–15.1)
Supraglottic airway			
Urgency			
Elective (n=23 874)	1.5 (0.9–2.6)	2.1 (1.4–3.3)**	1.4 (0.7–2.7)**
Non-elective (n=5683)	1.5 (0.6–3.7)	4.6 (1.4–15)**	1.1 (0.2–5.8)
ASA physical status			
1–2 (n=26 340)	1.35 (0.8–2.2)	2.5 (1.6–3.9)**	1.4 (0.7–2.8)
3–5 (n=3211)	6.1 (0.8–47)	2.2 (0.8–6.3)	1.6 (0.4–6.9)
Experience			
<5 yr (n=4464)	1.0 (0.4–2.8)	4.4 (1.3–14.6)*	2.3 (0.2–20.8)
5–10 yr (n=7097)	2.6 (0.9–7.4)	4.5 (1.6–12.8)**	1.8 (0.5–6.3)
>10 yr (n=17 942)	1.4 (0.7–2.7)	1.6 (1.0–2.7)	1.1 (0.5–2.4)
Paediatric practice			
Specialist (n=17 395)	1.9 (1–3.5)*	2.9 (1.6–5.2)**	2.2 (0.8–6)
Mixed (n=4110)	0.7 (0.2–2.1)	0.8 (0.4–1.6)	0.6 (0.1–2.7)
Occasional (n=5713)	2.2 (0.6–7.5)	5.3 (1.2–22.7)*	1.0 (0.3–3.3)
Trainees/nurses (n=2340)	0.8 (0.2–3.2)	6.2 (0.8–47.5)	0.9 (0.2–5.2)

Table 6 Risk factors associated with severe respiratory critical events. Results of univariate and multivariate analysis adjusted for age and sex. RR, relative risk; URTI, upper respiratory tract infection; TT, tracheal tube; SGA, supraglottic airway

Risk factors	Categories	Univariate		Multivariate	
		RR (95% CI)	P-value	RR (95% CI)	P-value
Respiratory comorbidities: asthma/wheezing/recent URTI/snoring/passive smoking	≥3	4.6 (3.5–6.0)	<0.0001	3.8 (2.8–5.1)	<0.0001
	2	3.4 (2.8–4.2)	<0.0001	3.1 (2.4–3.9)	<0.0001
	1	1.8 (1.5–2.3)	<0.0001	1.8 (1.5–2.2)	<0.0001
Experience of the anaesthesiologist	Years	0.99 (0.98–1.00)	0.001	0.99 (0.98–1.00)	0.008
Securing the airway	≥3 insertion attempts	2.7 (1.8–4.0)	<0.0001	2.1 (1.2–3.8)	0.014
Interface for airway management	Face mask *vs* TT	0.3 (0.2–0.4)	<0.0001	–	–
	SGA *vs* TT	0.5 (0.5–0.6)	<0.0001	0.7 (0.6–0.9)	0.002

anaesthesia or sedation. Whilst the APRICOT study was not designed primarily to investigate airway management, this large observational cohort study provided detailed information on airway and ventilation strategies for children undergoing sedation or general anaesthesia in Europe.

The incidence for difficult intubation in this current study is comparable with previous reports.[1,11] Surprisingly, multiple tracheal intubation attempts were reported in the presence of CL grades of 1 and 2, which may reflect the need to improve teaching of the direct laryngoscopy technique particularly in neonates and infants in specialised paediatric centres. The use of videolaryngoscopy in this study was surprisingly low and was almost not reported in patients with difficult airway management. This indicates either a poor general availability of these devices or a principle use as a rescue tool/alternative during unexpected difficult tracheal intubations. Both multiple tracheal intubation attempts despite CL grades of 1 and 2, and the low use of videolaryngoscopy are in stark contrast to the findings of the PeDI study.[5] Although a recent study demonstrated that the use of a videolaryngoscope was associated with a higher success rate for tracheal intubation in children when compared with direct laryngoscopy[12] there is currently no single one type of videolaryngoscope shown to be superior to others for children in terms of value or clinical use in all situations.[12,13] It is also of note that intubation aids with bougies and stylets, which are recommended for indirect laryngoscopy, were rarely used in clinical practice in line with a recent trend.[14]

To our knowledge, this is the first report on the incidence of failure of securing the paediatric airway using either a tracheal tube or an SGA in Europe. The incidence of severe critical respiratory and cardiovascular events increases with multiple insertion attempts of tracheal tubes and SGA. This is consistent with the findings of the PeDI registry[5] and underlines the importance to limit instrumentation airway attempts in children. The current analyses revealed that no neuromuscular blocking agent was administered for airway management to almost two-thirds of these patients. Whilst it is not possible to ascertain the exact causes for the lack of administration of a neuromuscular blocking agent in this study it is important to recognise that neuromuscular block overcomes functional airway obstructions and prevents unnecessary invasive airway procedures.[15] It is of note that the use of neuromuscular blocking agents was previously associated with a significant decrease in severe respiratory critical events.[9]

Surprisingly, only one single patient with failed tracheal intubation had an SGA device inserted despite a 99.5% of SGA success rate within two insertion attempts. The successful and easy insertion of SGA confirms the place of these devices in paediatric difficult airway algorithms ensuring oxygenation and ventilation.[16,17] Importantly, this finding also requires incorporation of future updates of current paediatric airway rescue algorithms for anaesthesia, intensive care, and emergency medicine.[18,19]

The choice of the airway device needs to be considered in the context of patient's respiratory risk factors and planned surgical procedures. In line with previous reports, the use of tracheal intubation was associated with higher incidence of critical respiratory events when compared with the use of face masks.[20,21] Bronchospasm and stridor were more common in healthy and elective patients undergoing tracheal intubation, with this association again consistent with recent reports.[21]

A lack of evidence-based clinical practice in paediatric anaesthesia recommendations may contribute to the large variability in airway management, such as the use of cuffed tracheal tubes, the extubation and SGA removal techniques, and ventilation strategies. This study confirms the increasing use of cuffed tracheal tubes. No comments, however, can be made regarding the design and type of cuffed tracheal tube used, which may have influenced the incidence of severe critical events.[22,23] The strong recommendation that the use of a cuffed tracheal tube necessitates cuff pressure monitoring,[24,25] was not universally followed in this study. The lack of cuff pressure monitoring did not lead to an increased incidence of stridor in this study acknowledging that stridor is not a valid outcome measure to assess airway injury.[26]

The reported extubation practices of tracheal tubes were in line with traditional teaching with more than two-thirds of tracheal tubes being removed awake. The definition of 'awake extubation' was, however, not precisely defined in the APRICOT case report form and differences in practice may lead to unexpectedly high incidences of postoperative respiratory complications.[27] Conversely, the optimal timing as to when best to remove the SGA remains open for debate.[28–30] This latter may explain the current findings that the technique for removal of SGA was not influenced by urgency, inpatient or outpatient setting, experience, or paediatric practice, but only by age.

In the present study, there was no evidence for an association between the paediatric practice of the anaesthesia provider, the patient's characteristics, the ventilation strategy, and the occurrence of serious critical event after the use of a tracheal tube or an SGA. This result is probably a result of the low incidence of serious critical events and thus

underpowered to examine such risk factors. However, the multivariate analysis confirmed that the presence of respiratory risk factors was significantly associated with critical respiratory events independently of the airway device used. This finding is in line with previous investigations[9,23,29] highlighting the relevance of preoperative respiratory assessment in children for the planning of anaesthesia management. As already highlighted in the original report of the results of APRICOT,[9] there was also statistical evidence that the experience of the anaesthesiologists decreased the risk for a critical respiratory critical event by 1% for every year of experience.

In summary, the current analysis provides a snapshot of the current clinical practices in Europe for airway management strategies. The nature of voluntary participation, however, may miss unusual and potentially dangerous practices and introduces a positive selection bias. The wide variation observed in practice amongst participating European centres is testimony to a lack of evidence-based guidelines, a lack of adherence to good clinical practice, or both. Priority should be given to the implementation of a European guideline for difficult airway management and good clinical practice recommendation for management of tracheal intubation, SGA devices, and subsequent intraoperative ventilation. The present study identifies areas where research, education, and training may improve quality of care in paediatric anaesthesia.

Authors' contributions

Literature search: T.E., F.V., W.H.
Data analysis: all authors.
Data interpretation: all authors.
Manuscript writing: all authors.
Statistics: K.V.
Coordinating investigators, coordination of the team: F.V., W.H.
Study design, data cleaning: F.V., W.H.

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Declaration of interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.bja.2018.04.013.

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