

Original Article

Complications associated with paediatric airway management during the COVID-19 pandemic: an international, multicentre, observational study

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Summary

Respiratory adverse events in adults with COVID-19 undergoing general anaesthesia can be life-threatening. However, there remains a knowledge gap about respiratory adverse events in children with COVID-19. We created an international observational registry to collect airway management outcomes in children with COVID-19 who were having a general anaesthetic. We hypothesised that children with confirmed or suspected COVID-19 would experience more hypoxaemia and complications than those without. Between 3 April 2020 and 1 November 2020, 78 international centres participated. In phase 1, centres collected outcomes on all children (age ≤ 18 y) having a general anaesthetic for 2 consecutive weeks. In phase 2, centres recorded outcomes for children with test-confirmed or suspected COVID-19 (based on symptoms) having a general anaesthetic. We did not study children whose tracheas were already intubated. The primary outcome was the incidence of hypoxaemia during airway management. Secondary outcomes included: incidence of other complications; and first-pass success rate for tracheal intubation. In total, 7896 children were analysed (7567 COVID-19 negative and 329 confirmed or presumed COVID-19 positive). The incidence of hypoxaemia during airway management was greater in children who were COVID-19 positive (24 out of 329 (7%) vs. 214 out of 7567 (3%); OR 2.70 (95%CI 1.70–4.10)). Children who had symptoms of COVID-19 had a higher incidence of hypoxaemia compared with those who were asymptomatic (9 out of 51 (19%) vs. 14 out of 258 (5%), respectively; OR 3.7 (95%CI 1.5–9.1)). Children with confirmed or presumed COVID-19 have an increased risk of hypoxaemia during airway management in conjunction with general anaesthesia.

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The COVID-19 pandemic caused by the SARS-CoV-2 virus has transformed healthcare and anaesthetic practice globally. However, early in the pandemic, children were thought to be unaffected by the SARS-CoV-2 virus and few studies focused on children [1, 2]. Given the paucity of paediatric data, clinicians have relied on expert opinion to guide airway management.

A review of children with COVID-19 who had a general anaesthetic reported one peri-operative death in nine symptomatic cases [3]. Studies have reported anaesthesia-related complications in adults with COVID-19 [3–5]. One such study found that pulmonary complications occurred in 50% of adults having a general anaesthetic and identified male sex, age ≥ 70 y, ASA physical status ≥ 3 and emergency/major surgery as risk-factors for complications [5]. Children with COVID-19 may have more airway-related complications due to the pulmonary effects of the illness or the use of novel personal protective equipment (PPE) such as barriers during airway management [6]. On the other hand, the mild symptoms experienced by many children may mean that general anaesthesia might not be associated with more adverse events.

During the early stage of the pandemic, anecdotal data suggested barriers such as plastic drapes or boxes could protect clinicians from droplets containing SARS-CoV-2 [7–9]. Recent literature has challenged the efficacy of this practice; however, there are few data about the impact of using barriers on outcomes in children. Videolaryngoscopy is recommended in people with COVID-19 to increase the distance from the patient's airway to the clinician ('mouth-to-mouth' distance) [10, 11] and probability of successful tracheal intubation on the first attempt [12].

The Pediatric Difficult Intubation Collaborative is an international multicentre group that focuses on research, quality improvement and difficult airway management education. Members of the collaborative created the Pediatric AirWay complicationS during COVID-19 (PAWS-COVID-19) registry to capture data about anaesthesia-related airway management of children during the COVID-19 pandemic [13]. The collaborative aimed to determine whether children with confirmed or suspected COVID-19 having a general anaesthetic had a higher incidence of complications such as hypoxaemia during airway management.

Methods

After obtaining institutional review board approval, we recruited centres to participate using web announcements through the Society for Pediatric Anesthesia, European

Society for Paediatric Anaesthesiology and Pediatric Difficult Intubation Collaborative network. We collected baseline characteristics of patients, details of anaesthetic and airway management, clinician type, PPE used and occurrence of hypoxaemia and other complications during anaesthetic care. We used Research Electronic Data Capture (REDCap) software hosted at the Children's Hospital of Philadelphia to collect and manage the study data. We included patients aged ≤ 18 y who were under the care of an anaesthetist. We did not study children whose tracheas were intubated before their anaesthetic care or who required tracheal intubation for life-threatening conditions outside the operating theatre.

Institutions entered anonymised data into the registry in two phases during the study period. In phase 1, sites recorded all anaesthetic cases performed during a self-determined, consecutive 2-week time frame. This provided a census of airway management practice at each participating institution during the pandemic, creating a comparison group for the patients with suspected or laboratory-confirmed COVID-19. In phase 2, sites recorded only patients with suspected or confirmed COVID-19, defined as a positive test within 48 h of the procedure, or who were 'presumed to have COVID-19'. We defined presumed COVID-19 as patients who had not undergone COVID-19 testing but whose symptoms, history, physical examination, laboratory or imaging findings were consistent with the disease.

Our primary aim was to compare the incidence of hypoxaemia in children with proven or suspected COVID-19 (COVID-19 group) with those who were COVID-19 negative. This was defined as mild (oxygen saturation (S_pO_2) $< 90\%$ or 10% decrease from baseline), moderate ($S_pO_2 < 80\%$ or 20% decrease from baseline) or severe ($S_pO_2 < 50\%$ or 50% decrease from baseline). Secondary outcomes included: incidence of airway management complications; first-attempt success rate of tracheal intubation; and incidence of failed tracheal intubation. In addition, we aimed to describe the airway devices, induction techniques used, determine risk-factors associated with complications and the impact of having COVID-19 symptoms (dyspnoea, headache, sore throat, cough, myalgia, fever, anosmia and/or diarrhoea) on outcome.

We analysed non-normally distributed variables using Wilcoxon rank-sum tests and the incidence of hypoxaemia and other complications using Chi-square and Fisher's exact tests. Based on a previous study [12], we assumed that the incidence of hypoxaemia during tracheal intubation for children without COVID-19 was 3% (SD 3). We estimated the incidence of hypoxaemia in children with COVID-19 to be

33% higher, that is, an incidence of 4%. Using a t-test for two independent groups and assuming equal variance in the incidence of hypoxaemia during airway management for both groups, a sample size of 191 participants per group (382 total) was required ($\alpha = 0.05$, $\beta = 0.90$). We performed a post-hoc sub-group analysis of patients who underwent tracheal intubation in conjunction with a protective barrier. We compared complications by barrier use at tracheal intubation and extubation using Chi-square and Fisher's exact tests. Where applicable, multiple comparisons were performed for outcomes and complications, and we adjusted p-values for false discovery rate correction. All analyses were conducted in SAS (version 9.4; SAS Institute, Cary, NC, USA).

Results

From 3 April 2020 to 1 November 2020, the PAWS-COVID-19 registry enrolled 14,834 cases from 78 sites in 16 countries, of which 7896 cases were included in the final analysis (Fig. 1). In total, 7567 children were COVID-19 negative and 329 were suspected or confirmed as having COVID-19 (COVID-19 group).

Baseline characteristics of patients are summarised in Table 1. Participating institutions came from across the globe, with most patients enrolled in North America and Europe. There was a higher proportion of emergency cases in the COVID-19 group (146 out of 329 (44%) vs. 734 out of 7567 (10%); $p < 0.001$). Most children had airway management and anaesthetic care in positive-pressure rooms (Table 2). However, a greater proportion of children in the COVID-19 group were cared for in negative-pressure

rooms (70 out of 329 (21%) vs. 265 out of 7567 (4%), Table 2).

Anaesthetic induction technique differed significantly in children in the COVID-19 group, with most having intravenous inductions (143 out of 329 (44%)), rapid sequence induction (RSI) (46 out of 329 (14%)) or modified RSI (18 out of 329 (6%)). Children in the COVID-19 group were less likely to be induced with an inhalational anaesthetic agent (121 out of 329 (37%) vs. 4160 out of 7567 (55%)). Additionally, there was a significant difference in the primary airway management approach, with children in the COVID-19 group more likely to have their airway secured with a tracheal tube (232 out of 329 (71%) vs. 4241 out of 7567 (56%); $p < 0.001$) and less often with a supraglottic airway device (SAD) (66 out of 329 (20%) vs. 2432 out of 7567 (32%); $p < 0.001$) (Table 3). Anaesthetists were less likely to facemask ventilate children in the COVID-19 group (218 out of 329 (66%) vs. 6190 out of 7567 (82%); $p < 0.001$); however, nearly two-thirds of children in the COVID-19 group were facemask ventilated. Videolaryngoscopy was used in 96 of 329 (29%) children in the COVID-19 group compared with 422 out of 7567 (6%) of the COVID-19-negative children ($p < 0.001$). The seniority of the clinician making the first attempt at securing the airway was significantly different between the two groups. An attending or consultant anaesthetist was more likely to perform the first attempt at securing the airway compared with a trainee in the COVID-19 group (117 out of 329 (36%) vs. 1937 out of 7567 (26%); $p < 0.001$).

More children in the COVID-19 group became hypoxaemic during airway management (24 out of 329 (7%)

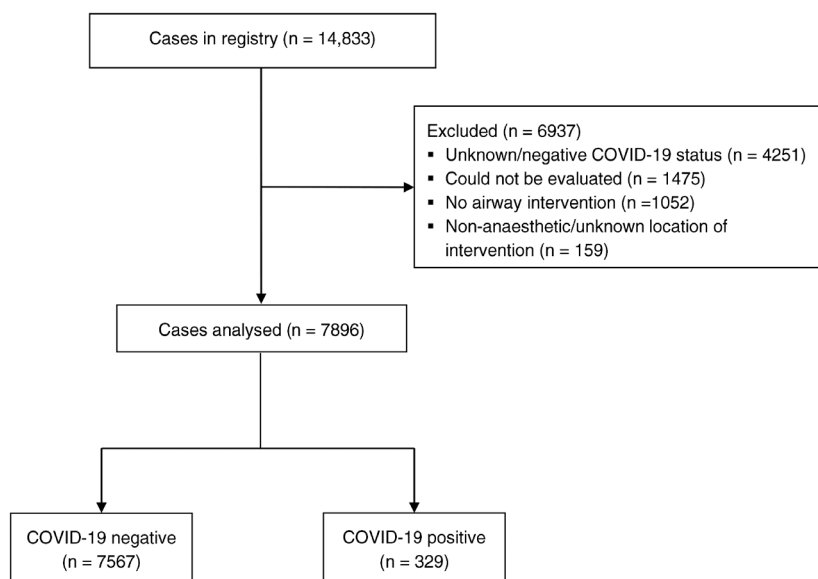


Figure 1 Flow chart of study participants.

Table 1 Characteristics of children with and without COVID-19 undergoing general anaesthesia. Values are number (proportion) or median (IQR [range]).

	No COVID-19 n = 7567	COVID-19 n = 329
Age		
Neonate (0–30 d)	142 (2%)	9 (3%)
Infant (1–12 mo)	1036 (14%)	23 (7.0%)
Toddler (1–4 y)	2285 (30%)	103 (31%)
Child (5–12 y)	490 (7%)	12 (4%)
Teenager (13–18 y)	3612 (48%)	181 (55%)
Missing	2 (<1%)	1 (<1%)
Sex; male	4429 (59%)	185 (56%)
Missing	50 (<1%)	1 (<1%)
Weight; kg	20 (12–40 [1–164])	25 (14–48 [3–124])
ASA physical status		
1	2843 (38%)	110 (33%)
2	2718 (36%)	118 (36%)
3	1761 (23%)	93 (28%)
4	243 (3%)	8 (2%)
5	2 (<1%)	-
Emergency surgery	734 (10%)	146 (44%)
History of difficult airway	167 (2%)	11 (3%)
Baseline oxygen saturation > 95% on air	7123 (94%)	304 (92%)
Location of anaesthetic induction		
Operating theatre	6606 (87%)	268 (82%)
Other	961 (13%)	61 (18%)
Country of origin		
North America	3969 (53%)	148 (45%)
South/Latin America	234 (3%)	45 (14%)
Europe	2734 (36%)	98 (30%)
Other	630 (8%)	38 (12%)

vs. 214 out of 7567 (3%); OR 2.70 (95%CI 1.70–4.10); Table 4). The difference between the two groups was most notable for mild and moderate hypoxaemia during airway device removal. A post-hoc sub-group analysis of children whose tracheas were intubated showed that the risk of hypoxaemia at extubation was significantly higher in the COVID-19 group (19 out of 232 (8%) vs. 162 out of 4241 (4%), OR 2.25 (95%CI 1.33–3.59); Table 4).

The occurrence of any complication was more common in the COVID-19 group (39 out of 329 (12%) vs. 463 out of 7567 (6%), OR 2.06 (95%CI 1.44–2.88); Table 5). The complications which occurred are detailed in Table 6. The increased risk of complications was significant at every phase of airway management and most pronounced during airway device removal (24 out of 329 (7%) vs. 267 out of 7567 (4%) OR 2.15 (95%CI 1.36–3.25); Table 5). In the COVID-19 group, 17% (51 out of 309) of children had

COVID-19 symptoms. Symptomatic children had a higher incidence of complications (13 out of 51 (25%) vs. 22 out of 258 (9%), OR 3.67 (95%CI 1.67–7.83)) and hypoxaemia (9 out of 51 (18%) vs. 14 of 258 (5.4%), OR 3.73 (95%CI 1.47–9.08)) compared with children who were asymptomatic.

Clinicians were more likely to use a barrier during induction/tracheal intubation of children in the COVID-19 group (81 out of 329 (25%) vs. 352 out of 7567 (5%); $p < 0.001$), with the most common barrier being a plastic drape over the child or a transparent shield (Table 3). Clinicians used a barrier more often at tracheal extubation for children in the COVID-19 group (100 out of 329 (30%) vs. 418 out of 7567 (6%); $p < 0.001$). The most common barriers used during extubation of the trachea were a plastic drape over the child or a transparent shield, alone or in combination (Table 3). The use of a barrier during tracheal

Table 2 Induction of anaesthesia in children with and without COVID-19 undergoing general anaesthesia. Values are number (proportion).

	No COVID-19 n = 7567	COVID-19 n = 329
Type of room		
Negative-pressure	265 (4%)	70 (21%)
Neutral-pressure	1463 (19%)	74 (22%)
Positive-pressure	5251 (70%)	167 (51%)
Positive-pressure with negative-pressure antechamber	56 (1%)	2 (1%)
Unknown/missing	532 (7%)	16 (5%)
Induction technique		
Inhalational	4160 (55%)	121 (37%)
Intravenous	3226 (43%)	143 (43%)
Rapid sequence induction	125 (2%)	46 (14%)
Modified rapid sequence induction	54 (1%)	18 (6%)
Intramuscular	2 (1%)	-
Induction drugs		
Fentanyl	3593 (47%)	195 (59%)
Midazolam	1000 (13%)	51 (15%)
Propofol	5197 (69%)	249 (75%)
Etomidate	21 (<1%)	1 (<1%)
Ketamine	286 (4%)	10 (3%)
Neuromuscular blocker drugs		
Vecuronium	85 (1%)	-
Rocuronium	1886 (25%)	105 (32%)
Other	487 (6%)	30 (9%)
Succinylcholine	163 (2%)	41 (12%)
Other drugs		
Lidocaine, intravenous	889 (12%)	72 (22%)
Lidocaine, topical	98 (1%)	7 (2%)
Dexmedetomidine	485 (6%)	12 (4%)
Gases used		
Sevoflurane	4433 (59%)	175 (53%)
Air	1704 (23%)	107 (32%)
Oxygen	5279 (70%)	249 (75%)
Nitrous oxide	2143 (28%)	61 (18%)
Other	783 (10%)	14 (4%)

intubation and SAD placement was not associated with an increase in the first-attempt success rate (Table 7). However, using a barrier when removing the tracheal device or SAD was associated with an increased occurrence of complications (35 out of 515 (7%) vs. 254 out of 6456 (5%), OR 1.78 (95%CI 1.22–2.53)), with more children experiencing more than one complication during emergence/tracheal extubation (12 out of 515 (2%) vs. 52 out of 6456 (1%), OR 2.98 (95%CI 1.51–5.43)). The most common complication was mild hypoxaemia during tracheal extubation/emergence (16 out of 515 (3%) vs. 55 out of 6457 (1%), OR 3.73 (95%CI 2.06–6.40)). To explore

the impact of barriers, we looked at barrier use in the COVID-19 group in isolation. We found more attempts at tracheal intubation in children when a barrier was not used (Table 7). Using a barrier in the COVID-19 group was associated with similar complications at induction (1 out of 78 (1%) vs. 12 out of 220 (5%), OR 0.23 (95%CI 0.01–1.17)) and emergence (10 out of 99 (10%) vs. 14 out of 199 (7%), OR 1.48 (95%CI 0.62–3.45)) (Table 7). As with the overall cohort, using a barrier was associated with a greater incidence of mild hypoxaemia in children in the COVID-19 group (6 out of 99 (6%) vs. 2 out of 199 (1%), OR 6.35 (95%CI 1.43–43.9)).

Table 3 Airway management in children with and without COVID-19 undergoing general anaesthesia. Values are number (proportion) or median (IQR [range]).

	No COVID-19 n = 7567	COVID-19 n = 329	p-value
Primary airway device			
Tracheal tube	4241 (56%)	232 (70%)	<0.001
Supraglottic airway device	2432 (32%)	66 (20%)	<0.001
Anaesthetic facemask	894 (12%)	31 (9%)	0.18
Adjuncts used			
Facemask or assisted ventilation	6190 (82%)	218 (66%)	<0.001
Nasal cannulae	29 (<1%)	1 (<1%)	0.65
Nasal trumpet/airway	21 (<1%)	1 (<1%)	>0.99
None	83 (1%)	46 (14%)	<0.001
Missing	1244 (16%)	63 (19%)	
Airway device used for first airway attempt			
Direct laryngoscopy	3797 (51%)	133 (41%)	<0.001
Standard videolaryngoscopy	331 (4%)	53 (16%)	
Hyper-angulated blade videolaryngoscopy	91 (1%)	43 (13%)	
Freehand fiberoptic	32 (<1%)	-	
Fiberoptic through supraglottic airway device	6 (<1%)	-	
Facemask	754 (10%)	30 (9%)	
Supraglottic airway device	2441 (33%)	64 (20%)	
Other	56 (<1%)	4 (1%)	
Missing	59 (<1%)	2 (<1%)	
Clinician making first airway attempt			
Attending/consultant	1937 (26%)	117 (36%)	<0.001
Trainee	3513 (48%)	149 (46%)	
Nurse anaesthetist/anaesthesia assistant	1797 (24%)	57 (17%)	
Other	186 (3%)	4 (1%)	
Missing	134 (2%)	2 (<1%)	
First-attempt tracheal intubation success (n = 4473)	3899 (92%)	219 (94%)	0.18
Number of tracheal intubation attempts (n = 4473)	1 (1-1 [1-10])	1 (1-1 [1-3])	0.17
Tracheal intubation barrier used			
Plastic barrier over patient	352 (5%)	81 (25%)	<0.001
Plastic barrier under patient	308 (4%)	59 (18%)	
Transparent box	4 (<1%)	-	
Transparent shield	15 (<1%)	8 (2%)	
Transparent shield	158 (2%)	33 (10%)	
Other	10 (<1%)	-	
Tracheal extubation barrier used			
Plastic barrier over patient	418 (6%)	100 (30%)	<0.001
Plastic barrier under patient	360 (5%)	80 (24%)	
Plastic barrier under patient	2 (<1%)	-	
Transparent box	16 (<1%)	6 (1.8%)	
Transparent shield	131 (2%)	24 (7%)	
Other	25 (<1%)	7 (2%)	

Discussion

Our prospective, international, multicentre observational study showed that children with COVID-19 had a higher

incidence of hypoxaemia and overall complications during airway management for general anaesthesia. Children with COVID-19 were 2.7 times more likely to

Table 4 Incidence of hypoxaemia during airway management in children with and without COVID-19 undergoing general anaesthesia. Values are number (proportion).

	All patients			Airway managed with tracheal tube			Airway managed with SAD		
	No COVID-19 n = 7567	COVID-19 n = 329	Odds ratio (95%CI)	No COVID-19 n = 4241	COVID-19 n = 232	Odds ratio (95%CI)	No COVID-19 n = 2432	COVID-19 n = 66	Odds ratio (95%CI)
Any hypoxaemia	214 (3%)	24 (7%)	2.70 (1.7–4.1)	162 (4%)	19 (8%)	2.25 (1.33–3.59)	40 (2%)	1 (2%)	0.92 (0.05–4.34)
Mild	121 (2%)	13 (4%)	2.53 (1.35–4.37)	87 (2%)	12 (5%)	2.60 (1.34–4.65)	28 (1%)	1 (2%)	1.32 (0.07–6.34)
Moderate	66 (1%)	9 (3%)	3.20 (1.47–6.14)	54 (1%)	5 (2%)	1.71 (0.59–3.92)	8 (<1%)	-	-
Severe	27 (<1%)	2 (1%)	1.71 (0.27–5.73)	21 (<1%)	2 (1%)	1.75 (0.28–6.00)	4 (<1%)	-	-
Hypoxaemia during airway insertion									
Mild	70 (1%)	6 (2%)	1.99 (0.77–4.25)	52 (1%)	5 (2%)	1.77 (0.61–4.08)	12 (<1%)	1 (2%)	3.10 (0.17–16.1)
Moderate	47 (1%)	6 (2%)	2.97 (1.13–6.48)	37 (1%)	2 (1%)	0.99 (0.16–3.25)	6 (<1%)	-	-
Severe	13 (<1%)	1 (<1%)	1.77 (0.10–8.93)	10 (<1%)	1 (<1%)	1.83 (0.10–9.62)	1 (<1%)	-	-
Hypoxaemia during airway removal									
Mild	63 (1%)	8 (2%)	2.97 (1.30–5.89)	46 (1%)	8 (3.4%)	3.26 (1.41–6.61)	17 (1%)	-	-
Moderate	22 (<1%)	3 (1%)	3.16 (0.74–9.17)	17 (<1%)	3 (1.3%)	3.26 (0.76–9.77)	5 (<1%)	-	-
Severe	15 (<1%)	1 (<1%)	1.53 (0.08–7.61)	12 (<1%)	1 (0.4%)	1.53 (0.08–7.79)	3 (<1%)	-	-

Mild hypoxaemia: oxygen saturation < 90% (or 10% decline from baseline); moderate hypoxaemia: oxygen saturation < 80% (or 20% decline from baseline); severe hypoxaemia: oxygen saturation < 50% (or 50% decline from baseline). SAD, supraglottic airway device.

Table 5 Complications during airway management in children with and without COVID-19 undergoing general anaesthesia. Values are number (proportion).

	All patients			Airway managed with tracheal tube			Airway managed with SAD		
	No COVID-19 n = 7567	COVID-19 n = 329	Odds ratio (95%CI)	No COVID-19 n = 4241	COVID-19 n = 232	Odds ratio (95%CI)	No COVID-19 n = 2432	COVID-19 n = 66	Odds ratio (95%CI)
Any complication	463 (6%)	39 (12%)	2.06 (1.44–2.88)	339 (8%)	33 (14%)	1.91 (1.28–2.77)	99 (4%)	2 (3%)	0.74 (0.12–2.40)
Complications on device insertion	232 (3%)	17 (5%)	1.72 (1.00–2.77)	163 (4%)	12 (5%)	1.36 (0.71–2.39)	46 (2%)	1 (2%)	0.80 (0.04–3.74)
1	194 (3%)	12 (4%)	1.45 (0.76–2.52)	139 (3%)	10 (4%)	1.33 (0.65–2.44)	37 (1%)	1 (2%)	0.99 (0.06–4.69)
≥2	38 (<1%)	5 (2%)	3.09 (1.06–7.22)	24 (1%)	2 (1%)	1.54 (0.25–5.24)	9 (<1%)	-	-
Complications on device removal	267 (4%)	24 (7%)	2.15 (1.36–3.25)	205 (5%)	23 (10%)	2.17 (1.34–3.34)	60 (2%)	1 (2%)	0.61 (0.03–2.83)
1	209 (3%)	18 (6%)	2.06 (1.21–3.29)	162 (4%)	17 (7%)	2.03 (1.17–3.31)	45 (2%)	1 (2%)	0.81 (0.05–3.80)
≥2	58 (1%)	6 (2%)	2.48 (0.95–5.34)	43 (1%)	6 (3%)	2.69 (1.02–5.94)	15 (0.6%)	-	-

SAD, supraglottic airway device.

experience hypoxaemia during tracheal intubation or extubation. Furthermore, the severity of hypoxaemia was greater, and complications such as laryngospasm occurred more frequently in children with COVID-19. These results challenge the belief that the implications of COVID-19 in children are insignificant, and clinicians should consider this when general anaesthesia is required.

We showed that emergence from anaesthesia and tracheal extubation are associated with more adverse

events in children with COVID-19, although these were not severe. One could argue that these findings are not dissimilar from those seen in children with other respiratory tract infections. Given the recency of the pandemic, few studies have examined peri-operative outcomes in children with COVID-19. A recent study by Saynalath et al. found that respiratory adverse events in children with non-severe SARS-CoV-2 infection were higher than in matched controls, irrespective of upper respiratory infection symptoms [14].

Table 6 Complications seen during airway management in children with and without COVID-19 undergoing general anaesthesia. Values are number (proportion).

	Airway device insertion		Airway device removal	
	No COVID-19 n = 232	COVID-19 n = 17	No COVID-19 n = 267	COVID-19 n = 24
Coughing/bucking	38 (16%)	4 (24%)	134 (50%)	10 (42%)
Laryngospasm	24 (10%)	2 (12%)	59 (22%)	4 (17%)
Oesophageal intubation	14 (6%)	3 (18%)	-	-
Airway trauma	13 (6%)	1 (6%)	5 (2%)	-
Bronchospasm	9 (4%)	-	9 (3%)	-
Bradycardia requiring treatment	7 (3%)	-	3 (1%)	-
Vomiting without aspiration	5 (2%)	-	14 (5%)	2 (8%)
Vomiting with aspiration	-	-	-	1 (4%)
Cardiac arrest	3 (1%)	-	2 (1%)	1 (4%)
Arrhythmia	2 (1%)	-	-	-
Pneumothorax	1 (<1%)	-	-	-
Death	1 (<1%)	-	-	-
Other	25 (11%)	1 (6%)	17 (6%)	1 (4%)

Table 7 Impact of protective barrier use on complications during airway device (tracheal tube or supraglottic airway device) insertion and removal in children with and without COVID-19 undergoing general anaesthesia. Values are median (IQR [range]) or number (proportion).

	All		COVID-19			
	No barrier n = 6548	Barrier n = 423	Odds ratio (95%CI)	No barrier n = 220	Barrier n = 78	Odds ratio (95%CI)
Attempts at device insertion; n	1 (1-1 [1-10])	1 (1-1 [1-5])	1.00 (0.73-1.28)	1 (1-1 [1,3])	1 (1-1 [1-1])	-
1	6142 (94%)	398 (94%)	n/a	205 (93%)	78 (100%)	-
2	332 (5%)	20 (5%)	0.93 (0.57-1.44)	13 (6%)	-	-
≥3	73 (1%)	5 (1%)	1.06 (0.37-2.38)	2 (1%)	-	-
Missing	1	-				
Complications on device insertion	209 (3%)	13 (3%)	0.96 (0.52-1.63)	12 (6%)	1 (1%)	0.23 (0.01-1.17)
1	175 (3%)	12 (3%)	1.06 (0.55-1.84)	10 (4%)	1 (1%)	0.27 (0.01-1.45)
≥2	34 (<1%)	1 (<1%)	0.45 (0.03-2.11)	2 (1%)	-	-
Hypoxaemia during airway insertion						
Mild	66 (1%)	4 (1%)	0.94 (0.28-2.28)	6 (3%)	-	-
Moderate	40 (1%)	5 (1%)	1.95 (0.67-4.52)	1 (<1%)	1 (1%)	2.84 (0.11-72.5)
Severe	11 (<1%)	1 (<1%)	1.41 (0.08-7.26)	1 (<1%)	-	-
	No barrier n = 6456	Barrier n = 515		No barrier n = 199	Barrier n = 99	
Complications on device removal	254 (4%)	35 (7%)	1.78 (1.22-2.53)	14 (7%)	10 (10%)	1.48 (0.62-3.45)
1	202 (3%)	23 (4%)	1.47 (0.92-2.24)	13 (6%)	5 (5%)	0.80 (0.25-2.19)
≥2	52 (1%)	12 (2%)	2.98 (1.51-5.43)	1 (1%)	5 (5%)	10.4 (1.65-201)
Hypoxaemia during airway removal						
Mild	55 (1%)	16 (3%)	3.73 (2.06-6.41)	2 (1%)	6 (6%)	6.39 (1.43-43.9)
Moderate	24 (<1%)	1 (<1%)	0.52 (0.03-2.47)	3 (1%)	-	-
Severe	15 (<1%)	1 (<1%)	0.84 (0.05-4.13)	-	1 (1%)	-

Mild hypoxaemia: oxygen saturation < 90% (or 10% decline from baseline); moderate hypoxaemia: oxygen saturation < 80% (or 20% decline from baseline); severe hypoxaemia: oxygen saturation < 50% (or 50% decline from baseline).

However, in that study, no child suffered complications such as postoperative pneumonia, acute respiratory distress syndrome or death. Our study did not quantify the severity of illness in the children with COVID-19, so we remain unable to assess the morbidity or mortality of children with more severe symptoms. The impact of disease severity on outcomes is a question for future studies, given the emergence of new variants like the delta and omicron variants of SARS-CoV-2.

Because airway management techniques are considered high risk for generating aerosols and droplets [15], many clinicians use physical barriers, in addition to traditional PPE, for protection during airway management. These barriers are highly controversial, with some clinicians decrying their use and others believing they are helpful [9, 16, 17]. Our study found that using a barrier did not change first-attempt success rates of tracheal intubation or SAD placement. However, using a barrier during tracheal extubation was associated with higher incidence of complications and risk of mild hypoxaemia. This may have been because the barriers made airway management more difficult during critical periods such as emergence and tracheal extubation. To explore this further, we examined the impact of using a barrier in children with COVID-19. Surprisingly, we showed that using a barrier was associated with fewer tracheal intubation attempts. Additionally, there was no increase in the incidence of complications in the COVID-19 group when clinicians used a barrier. However, consistent with the overall study population, using a barrier was associated with mild hypoxaemia at emergence in children with COVID-19. Taken together, our results suggest using a barrier is associated with a greater incidence of mild hypoxaemia at emergence in children who have COVID-19.

Determining the risk of aerosol generation during airway management is a work in progress, and several studies have tried to quantify the magnitude of aerosol generation of various procedures [18–20]. We found that clinicians were less likely to perform inhalational inductions in children with COVID-19, using traditional and modified RSI instead. Rapid sequence inductions have been associated with more airway adverse events in infants [21] and could have contributed to the complications we discovered. However, most of our cases were performed in older children, and most of the observed differences in complications occurred during emergence. Clinicians performed inhalational inductions more frequently in patients who were COVID-19 negative. However, surprisingly, 60% of patients in the COVID-19 group had inhalational inductions. This is contrary to some consensus guidelines and highlights the comfort level paediatric

anaesthetists have with inhalational induction and a downplaying of the risks of aerosol spread. It may also be that the clinicians using inhalational techniques wore respirators and were confident in their level of PPE. The adoption of videolaryngoscopy for tracheal intubation in the COVID-19 group was surprisingly low at 29%. This could have been due to the lack of videolaryngoscopes or may reflect the greater experience level of the clinicians intubating the trachea.

There are limitations to our study. First, although we analysed close to 8000 anaesthetics, we had only a small number of COVID-19 cases (4.4%), limiting our ability to detect differences in outcomes. In addition, the low rate of adverse events prevented us from analysing risk factors associated with complications, one of our a priori goals. Second, there is potential for under-reporting of the magnitude of effects because we included patients who were COVID-19 positive and presumed (but not test-proven) positive in the COVID-19 group. Fourth, potential confounders may remain, such as whether neuromuscular blockade was antagonised. This may have contributed to adverse respiratory events in the postoperative period. Finally, as we wanted to collect data quickly, we collected anonymised data and did not collect personal health information. We, therefore, could not assess patient outcomes beyond the immediate peri-operative period. Additionally, under-reporting of complications and adverse events is likely in this type of self-reporting registry. There were more emergency cases in the COVID-19 group, potentially confounding our results; however, the ASA physical status was similar in the two groups.

In summary, our study found that children with COVID-19 have a greater incidence of mild hypoxaemia and more complications during airway management than children without the disease; however, these were not life-threatening adverse events.

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Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1. List of study collaborators.