




Pediatric Airway Management in Times of COVID-19—a Review of the Evidence and Controversies

Clyde T Matava^{1,3} · James Peyton⁴ · Britta S von Ungern-Sternberg^{2,5,6} 

Accepted: 13 June 2021 / Published online: 24 July 2021
© Crown 2021

Abstract

Purpose of Review This review summarizes and provides a comprehensive narrative synthesis of the current evidence on pediatric airway management during the COVID-19 pandemic.

Recent Findings The safe care of children undergoing airway management is a primary concern for pediatric anesthesiologists. The COVID-19 pandemic has brought challenges related to airway management and the use of personal protective equipment, aerosol barriers, and the need for simulation and intubation teams. The risk of COVID-19 transmission to the health care worker may be lower in children due to the smaller volume of aerosol dispersal. The implementation of vaccinations may further reduce the risk to health care workers. Evidence demonstrating the impact of COVID-19 on airway outcomes in children is necessary to inform their care.

Summary This review shows that pediatric airway management can be a safe procedure for both the patient and provider in the right setting. The use of appropriate personal protective equipment, particularly focusing on protection from aerosolized particles, is paramount to reduce infection risk. However, there are opportunities for future research.

Keywords COVID-19 · Airway · Intubation · Pediatric anesthesia · SARS2-COV2 · Anesthesia

Introduction

The COVID-19 pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) started around November 2019 and has led to significant disruptions in health care provision across the globe with millions of infections and deaths. The incidence of symptomatic COVID-19 among children increases with age (1). As children have been considered silent spreaders of the disease, they pose risk to

health care professionals who may be involved in their care, especially during airway management (2, 3).

Pediatric anesthesia in the context of respiratory tract infection is associated with increased perioperative respiratory adverse events (PRAEs) (4). Airway management during the peri-anesthesia period is an aerosol-generating medical procedure (AGMP) posing an increased risk of transmitting COVID-19 to the anesthesiologist (5). Understanding the impact of AGMPs, personal protection equipment (PPE), and preoperative testing of patients on pediatric airway

This article is part of the Topical Collection on *Pediatric Anesthesia*

✉ Britta S von Ungern-Sternberg
Britta.regli-vonungern@health.wa.gov.au

Clyde T Matava
clyde.matava@sickkids.ca

James Peyton
James.Peyton@childrens.harvard.edu

¹ Department of Anesthesia and Pain Medicine, The Hospital for Sick Children, 555 University Avenue, Toronto, ON M9A 1E9, Canada

² Perioperative Medicine Team, Telethon Kid's Institute, Perth, Western Australia, Australia

³ Department of Anesthesiology and Pain Medicine, Temerty Faculty of Medicine, University of Toronto, Toronto, Canada

⁴ Department of Anesthesiology, Critical Care, and Pain Medicine, Boston Children's Hospital, Harvard School of Medicine, Boston, MA, USA

⁵ Division of Emergency Medicine, Anaesthesia and Pain Medicine, Medical School, The University of Western Australia, Perth, Western Australia, Australia

⁶ Department of Anaesthesia and Pain Management, Perth Children's Hospital, 15 Hospital Avenue, Nedlands, Perth, WA 6009, Australia

management risks is essential for pediatric anesthesiologists, especially as hospitals increase their workload in the context of high community disease prevalence (6). This current review will focus on the latest evidence and the impact of COVID-19 on managing the pediatric airway.

COVID-19 and Transmission Risk from Children

Several million children have undergone anesthesia care since the start of the COVID-19 pandemic. Of greatest concern to health care providers is the risk of disease transmission during AGMPs in children who are asymptomatic and symptomatic with COVID-19. A study reported that children with COVID-19 demonstrate higher SARS-CoV2 RNA in their upper airways than adults admitted to ICU (2). In other studies, the viral load was highest in the first 2 days among most children, even in children without symptoms (2, 7, 8). The high viral load in children's airways raises transmission concerns in health care workers during contact with these patients and particularly so when performing AGMPs, e.g., intubation or mask ventilation. The IntubateCOVID registry reported that 1 in 10 health care workers who intubated COVID-19 positive or suspected patients developed symptoms at 21 days, with three percent becoming seropositive (9). However, the reportedly high risk may have been due to factors that included shortages of PPE at that stage of the pandemic. Modeling data based on the IntubateCOVID registry suggests a risk of 1 in 670 health care workers contracting COVID-19 after performing an AGMP on a patient that is COVID-19 positive. This risk was estimated at 1 in 6.7 million following a single AGMP on a patient that is COVID-19 negative (10••). Mathematical modeling on the volume of dispersion of aerosols during bag-mask ventilation suggests that this volume is significantly smaller in children, especially neonates compared to adults (11). The smaller aerosol dispersal volumes may explain the lower transmission risk rates from infected children (11). However, currently, the actual risk of transmission of SARS-CoV2 from children undergoing AGMPs remains unquantified and maybe underestimated due to the high rates of asymptomatic patients among children. Preoperative COVID-19 testing, adequate PPE, vaccinations, and simulation training to prevent self-contamination will likely reduce this risk.

Recent evidence supports both the airborne and droplet transmission of COVID-19 (12). Active airway management is associated with an increased risk of SARS-CoV2 transmission. Droplets and aerosols can contain SARS-CoV2, which can remain viable in aerosols for at least 3 h. Additionally, not only the aerosol-generating procedure itself but also the potentially sicker patient, particularly in the setting of emergency intubations, with high viral loads in respiratory secretions,

drive the increased transmission risk for health care workers during intubation or manual ventilation (13, 14). While recommended before each use, fit checking of face masks is unreliable to detect a leak and determine an appropriate seal. Standardized annual fit testing is essential to ensure the mask fits the health care worker. However, the use of PPE has been reported to impede communication during pediatric anesthesia care (15•). In a survey of 25 pediatric anesthesiologists, surgeons, nurses, and theater support workers, 100 percent of the respondents reported increased difficulty understanding and being understood by others during pediatric airway surgery (15•). While there were no near-miss events reported in that study, the impact of PPE especially powered air purifying respirators (PAPRs) needs to be evaluated as it relates to communication in the operating room which is a crucial element in the avoidance of critical adverse events (15•).

The risk of airborne transmission can be exponentially reduced by increasing the air turnover in the room as well as the use of negative pressure environments. Both increased air turnover and negative pressure reduce the relative protective contribution of the facemask used by the health care worker (16). Some institutions reported retrofitting operating rooms and other patient care spaces into a negative pressure environment. However, the possibility of false security from asymptomatic patients also exists and underlines the need for PPE (17, 18). In simulation-based studies, Matava et al. highlighted the potential impact of portable HEPA filtration systems as effective for removing aerosols during airway procedures (18). It is important to note that the use of PPE, such as surgical or medical masks, has demonstrated an 85% reduction in risk of transmission of COVID-19 (19••). In particular N95 masks conferred a 96% reduction in risk compared to regular cloth masks (19••). Chu et al. also reported that face shields reduce transmission risk by 76% (19••). An estimated 90% of pediatric anesthesiologists from over 63 institutions across the globe use N95 masks during AGMPs (Soneru et al., personal communication) thus benefitting from the high level of protection conferred by such masks. Pediatric anesthesiologists should continue using PPE as a standard of care when performing AGMPs in children for the duration of this pandemic.

Difficult Airway Management in COVID Times

Within the first few months of the pandemic, several airway management guidelines were produced to attempt to codify best practice (20, 21). These guidelines did not explicitly address the management of the difficult pediatric airway. However, at the time of writing, a multinational expert consensus statement is being prepared to address this issue. The underlying principles of difficult airway management remain. A focus on maintaining oxygenation, limiting attempts at

intubation, and considering advanced airway techniques for the initial attempts at tracheal intubation are still recommended. There is limited data on clinicians' risk from COVID-19-positive patients and airway management or manipulation. What data we do have appears reassuring in that the use of appropriate PPE seems to be effective in preventing cross-infection (22). Given this data, it must be emphasized that all clinicians involved in airway manipulation in this patient group should have access to the correct level of PPE and every guideline should be written with this proviso in place. There is also no contraindication to the use of face-mask ventilation (although a tight seal around the face would be needed to prevent significant air leaks around the mask) or ventilation via a supraglottic device.

Vaccination

At the time of writing, multiple vaccines have been produced to counter COVID-19. Currently it appears that their use dramatically decreases the risk of hospitalization, illness severity, and the likelihood of spreading the virus to others (23, 24). Frontline health care workers have been treated as a priority group for vaccination in most areas. Although the initial data is reassuring, pediatric anesthesiologists should maintain full precautions, including the use of PPE for high-risk procedures, maintaining social distancing, and routine mask-wearing. As a greater proportion of the population is vaccinated, the need for these precautions may diminish; however, we are not yet at that stage of the pandemic.

Intubating Boxes

At the beginning of the pandemic, when little data was available about the virus's infectivity and PPE supplies were limited, many clinicians thought about creating extra physical barriers between a patient's airway and an intubating clinician (25). This led to the creation of a variety of aerosol barriers or intubation boxes, some made from solid plastic, others from more flexible material (26–30). In the USA, the FDA created an Emergency Use Authorisation (EUA) for these devices which came into effect on May 1, 2020. However, there is no evidence that they enhance the safety of the practitioner and limited evidence that they may make tracheal intubation more difficult and as such the FDA withdrew their emergency authorization for use in September 2020 (28, 31). Further the barrier devices may interrupt airflow resulting in less clearance of aerosol from the operating room (32). At this stage, there is no data to recommend the use of passive aerosol barriers; although further research is underway examining the effectiveness of active, negative pressure barriers, it must be

emphasized that aerosol barriers or intubation boxes are not a replacement for PPE.

Intubation Teams

Tracheal intubation was required in approximately 3% of cases reported in Wuhan (33, 34). The overwhelming case numbers seen in China, Europe, and the USA prompted changes to established staffing models. In many hospitals, intubation teams, consisting of senior anesthesia providers, were tasked with performing all tracheal intubations within one institution (35). This precaution was taken to create a system where tracheal intubation was performed by experienced practitioners, increasing the chances of successful first attempts, limiting inexperienced providers exposure to procedures that may place them at high risk for cross-infection, and allowing teams to become familiar with the donning and doffing of PPE to increase their efficiency and decrease the risk of contamination in the setting of unfamiliarity with the procedures. It also allowed groups of practitioners to form bubbles with limited interaction with their colleagues to again reduce the risk of cross-contamination.

Impact of COVID-19 on Respiratory Outcomes

Unpublished reports are highlighting a similar incidence of PRAEs in children with COVID-19 to those with typical upper respiratory infections at the time of writing. There is an ongoing need to generate evidence on the impact of COVID-19 and pediatric airway management. The *Pediatric AirWay complicationS COVID-19* (PAWS-COVID19) Registry, a prospective multi-center study, is assessing the impact of COVID-19 on airway management in children ([ClinicalTrials.gov NCT04449042](https://clinicaltrials.gov/ct2/show/study/NCT04449042)) (36). The results of this study will shed light on the incidence of airway complications associated with COVID-19.

Lessons Learnt for the Future and Areas for Research

The COVID-19 pandemic is the first genuinely global infectious disease health care emergency of the modern era. It has prompted a massive international research effort and caused significant advances in vaccine production technology and provided the opportunity for international collaboration on a previously unseen scale. There remain many areas of controversy, not least the disease's mechanism in the health care setting. It is accepted that both droplets and aerosolized viral particles spread the virus, but there remains some controversy regarding the creation of aerosols during anesthesia and, in

particular, airway management (37). Assuming that the COVID-19 pandemic will be with us for some time yet and that in the future there will be other similar pathogens that appear and have the potential to cause a similar threat, further research is needed to quantify and clarify the risk of infection posed to health care professionals and the public. This cannot be achieved in isolation, and the global nature of the threat has shown the need for close collaboration and the formation of networks across scientific and medical specialties that can bring their own expertise to bear in the fight against such a virulent disease.

The importance of accurate and timely information has also been highlighted. Risks of misinformation and social media's role in spreading false information has been a significant issue seen in all parts of the world (38, 39). As we learn more about the medical management of COVID-19, we are also learning more about information flow and how this influences behavior on a population scale. It is to be hoped that in the future, the scientific approach to managing a pandemic can be separated from the political process to a greater degree than we saw in 2020.

Conclusion

Airway management in patients with a virulent disease spread by respiratory droplets, and aerosolized viral particles will always be a challenging process. The most important aspect for medical professionals to bear in mind is the use of appropriate PPE when caring for these patients. It is incumbent upon hospital administrators and political leaders to ensure clinicians have access to PPE and receive training on using it.

The use of novel equipment to facilitate airway management, such as the intubation box, also highlighted a need to develop systems where innovations can be rapidly assessed before being placed into widespread clinical practice. The traditional peer review process, which relies on unpaid volunteers to assess scientific manuscripts in their spare time, may not keep pace with a rapidly changing, challenging environment, and alternative assessment systems may need to be considered.

Pediatric airway management is usually uncomplicated and straightforward, even in the current pandemic. When the correct PPE is used and care taken to ensure that a face mask or supraglottic device forms a good seal, tracheal intubation is successful with the minimal number of attempts, the risk of harm to others is very likely minimal.

Compliance with Ethical Standards

Conflict of Interest The authors do not have any potential conflicts of interest to disclose.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

1. Leidman E, Duca LM, Omura JD, Proia K, Stephens JW, Sauber-Schatz EK. COVID-19 trends among persons aged 0-24 years - United States, March 1-December 12, 2020. *MMWR Morb Mortal Wkly Rep.* 2021;70(3):88–94.
2. Yonker LM, Neilan AM, Bartsch Y, Patel AB, Regan J, Arya P, et al. Pediatric severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): clinical presentation, infectivity, and immune responses. *J Pediatr.* 2020;227:45–52.e5.
3. Lee-Archer P, von Ungern-Sternberg BS. Pediatric anesthetic implications of COVID-19—a review of current literature. *Paediatr Anaesth.* 2020;30(6):136–41.
4. von Ungern-Sternberg BS, Boda K, Chambers NA, Rebmann C, Johnson C, Sly PD, et al. Risk assessment for respiratory complications in paediatric anaesthesia: a prospective cohort study. *Lancet.* 2010;376(9743):773–83.
5. Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. *PLoS One.* 2012;7(4):e35797.
6. Okonkwo INC, Howie A, Parry C, Shelton CL, Copley S, Craig R, et al. The safety of paediatric surgery between COVID-19 surges: an observational study. *Anaesthesia.* 2020;75(12):1605–13.
7. Kam KQ, Yung CF, Cui L, Lin Tzer Pin R, Mak TM, Maiwald M, et al. A well infant with coronavirus disease 2019 (COVID-19) with high viral load. *Clin Infect Dis.* 2020;71(15):847–849. <https://doi.org/10.1093/cid/ciaa201>.
8. Kam KQ, Thoon KC, Maiwald M, Chong CY, Soong HY, Loo LH, et al. SARS-CoV-2 viral RNA load dynamics in the nasopharynx of infected children. *Epidemiol Infect.* 2021;149:e18.
9. El-Boghdady K, Wong DJN, Owen R, Neuman MD, Pocock S, Carlisle JB, et al. Risks to healthcare workers following tracheal intubation of patients with COVID-19: a prospective international multicentre cohort study. *Anaesthesia.* 2020;75(11):1437–47.
10. Kakodkar PS, Sivia DS, Pandit JJ. Safety of aerosol-generating procedures in COVID-19 negative patients: binomial probability modelling of intubateCOVID registry data. *Anaesthesia.* 2020;75(11):1415–9 **This study presents a mathematical model for risk of developing COVID-19 in anesthesiologist following aerosol generating medical procedures.**
11. Shalish W, Lakshminrusimha S, Manzoni P, Keszler M, Sant Anna GM. COVID-19 and neonatal respiratory care: current evidence and practical approach. *Am J Perinatol.* 2020;37(8):780–91.
12. Centers for Disease Control and Prevention. How coronavirus spreads | CDC: Centers for Disease Control and Prevention; 2021 [updated 2021-01-27T07:18:03Z March 1, 2021]. Available from: <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html>.
13. Regli A, Sommerfield A, von Ungern-Sternberg BS. The role of fit testing N95/FFP2/FFP3 masks: a narrative review. *Anaesthesia.* 2021;76(1):91–100.

14. Regli A, von Ungern-Sternberg BS. Fit testing of N95 or P2 masks to protect health care workers. *Med J Aust.* 2020;213(7):293–5.e1.
15. Hampton T, Sharma S, Dunham M, Okonkwo I. We still cannot hear: Staff perceptions of personal protective equipment impact on speech and communication in the operating theater during pediatric airway surgery. *Pediatric Anesthesia.* <https://doi.org/10.1111/pan.14127>. **This survey study reports the negative impact of personal protective equipment during pediatric airway cases.**
16. Vonci N, De Marco MF, Grasso A, Spataro G, Cevenini G, Messina G. Association between air changes and airborne microbial contamination in operating rooms. *J Infect Public Health.* 2019;12(6):827–30.
17. Wei L, Lin J, Duan X, Huang W, Lu X, Zhou J, et al. Asymptomatic COVID-19 patients can contaminate their surroundings: an environment sampling study. *mSphere.* 2020;5(3):e00442–20. <https://doi.org/10.1128/mSphere.00442-20>.
18. Matava C, Collard V, Siegel J, Denning S, Li T, Du B, et al. Use of a high-flow extractor to reduce aerosol exposure in tracheal intubation. *Br J Anaesth.* 2020;125(4):e363–e6.
19. Chu DK, Akl EA, Duda S, Solo K, Yaacoub S, Schünemann HJ, et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis. *Lancet.* 2020;395(10242):1973–87 **This is a systematic review and meta-analysis demonstrating the protective benefits of personal protective equipment including surgical masks, N95 masks and face shields.**
20. Cook TM, El-Boghdady K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19: guidelines from the Difficult Airway Society, the Association of Anaesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists. *Anaesthesia.* 2020;75:785–99.
21. Matava CT, Kovatsis PG, Summers JL, Castro P, Denning S, Yu J, et al. Pediatric airway management in COVID-19 patients - consensus guidelines from the Society for Pediatric Anesthesia's Pediatric Difficult Intubation Collaborative and the Canadian Pediatric Anesthesia Society. *Anesth Analg.* 2020;131:61–73.
22. Cook TM. Risk to health from COVID-19 for anaesthetists and intensivists - a narrative review. *Anaesthesia.* 2020;75(11):1494–508.
23. Moghadas SM, Vilches TN, Zhang K, Wells CR, Shoukat A, Singer BH, et al. The impact of vaccination on COVID-19 outbreaks in the United States. *Clin Infect Dis.* 2021:ciab079. <https://doi.org/10.1093/cid/ciab079>.
24. Dagan N, Barda N, Kepten E, Miron O, Perchik S, Katz MA, et al. BNT162b2 mRNA Covid-19 vaccine in a nationwide mass vaccination setting. *N Engl J Med.* 2021;384:1412–23.
25. Baker PA, von Ungern-Sternberg BS, Engelhardt T. Desperate times breed desperate measures: about valiance or foolhardiness. *Paediatr Anaesth.* 2020;30(6):634–5.
26. Trujillo A, Arango F. Impact of aerosol box use on orotracheal intubation times in children. *Pediatr Anesth.* 2021;31(2):237–8.
27. Brown H, Preston D, Bhoja R. Thinking outside the box: a low-cost and pragmatic alternative to aerosol boxes for endotracheal intubation of COVID-19 patients. *Anesthesiology.* 2020;133(3):683–4.
28. Tighe NTG, McClain CD, Vlassakova BG, Cravero JP, Peyton JM, Kovatsis PG, et al. Aerosol barriers in pediatric anesthesiology: clinical data supports FDA caution. *Paediatr Anaesth.* 2021;31(4):461–464. <https://doi.org/10.1111/pan.14091>.
29. Matava CT, Yu J, Denning S. Clear plastic drapes may be effective at limiting aerosolization and droplet spray during extubation: implications for COVID-19. *Can J Anaesth.* 2020;67:902–4.
30. Mariano ER, Kou A, Stiegler MA, Matava C. The rise and fall of the COVID-19 aerosol box through the lens of Twitter. *J Clin Anesth.* 2021;69:110145.
31. Baker PA, Peyton J, von Ungern-Sternberg BS. What's inside the box? Or shall we think outside the box? *Pediatr Anesth.* 2020;30(7):734–6.
32. Lee-Archer P, Boyd D, Du T, Elliott R, Graydon C, Paterson N, et al. A comparison of anesthetic protective barriers for the management of COVID-19 pediatric patients. *Paediatr Anaesth.* 2021;31(3):323–9.
33. Meng L, Qiu H, Wan L, Ai Y, Xue Z, Guo Q, et al. Intubation and ventilation amid the COVID-19 outbreak: Wuhan's experience. *Anesthesiology.* 2020;132:1317–32.
34. Patel GP, Collins JS, Sullivan CL, Winters BD, Pustavoitau A, Margulies SS, et al. Management of coronavirus disease 2019 intubation teams. *A A Pract.* 2020;14(8):e01263.
35. Miller L, Luković E, Wagener G. Guiding airway management and personal protective equipment for COVID-19 intubation teams. *Br J Anaesth.* 2020;125(3):e288–e90.
36. Brooks Peterson ML, Fiadjoe JE. In response: Pediatric airway management in COVID-19 patients - Consensus Guidelines from the Society for Pediatric Anesthesia's Pediatric Difficult Intubation Collaborative and the Canadian Pediatric Anesthesia Society. *Anesth Analg.* 2020;131:e45.
37. Center for Disease Control U. Scientific brief: SARS-CoV-2 and potential airborne transmission [Webpage]. 2020 [updated October 2020. CDC webpage].
38. Peyton J, Matava CT, von Ungern-Sternberg BS. The plural of anecdote is not data, please mind the gap between virtual and real life. *Paediatr Anaesth.* 2020;30(7):732–3.
39. Slavik CE, Buttle C, Sturrock SL, Darlington JC, Yiannakoulis N. Examining tweet content and engagement of Canadian public health agencies and decision-makers during COVID-19: mixed methods analysis. *J Med Internet Res.* 2021;23:e24883.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.