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EDUCATIONAL REVIEW

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Developing an Extubation strategy for the difficult pediatric airway—Who, when, why, where, and how?

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Abstract

Comprehensive airway management of the pediatric patient with a difficult airway requires a plan for the transition back to a patent and protected airway. Multiple techniques are available to manage the periextubation period. Equally important is performing a comprehensive risk assessment and developing a strategy that optimizes the likelihood of safe extubation. This includes team-focused communication of the desired goals, critical steps in the process, and potential responses in the case of failed extubation. This review summarizes extubation of pediatric patients with difficult airways along with one suggested framework to manage this challenging period.

KEYWORDS
airway extubation, airway management, pediatrics

> *Great is the art of beginning, but greater is the art of ending.*
>
> Henry Wadsworth Longfellow

The clinician managing the pediatric airway must be proficient in airway assessment, basic airway maneuvers, the use of airway adjuncts, laryngoscopy, and endotracheal intubation. Just as important is the ability to safely manage extubation and optimize conditions for the patient to maintain their own airway thereafter. An airway management plan that does not consider extubation is missing a major part of the story. A key goal should be a comprehensive and defined strategy that brings techniques together as part of a coherent whole.

The literature on pediatric airway management does not reflect the clinician's understanding that extubation is as vital as other phases of care. Descriptions of difficult airway management often focus on the challenges of assessment, basic airway management techniques, a range of supraglottic airway devices, variants of direct or videolaryngoscopy, advanced airway techniques such as fiberoptic intubation, and debates over emergency procedures such as front of neck access. The literature addressing the topic of extubation is far more limited in scope and scale.

Consideration of an extubation strategy has more robustly entered the adult literature. The Difficult Airway Society (DAS) guidelines for tracheal extubation in adult patients stress the importance of planning, preparation, performance, and postextubation care.[1] Recently, the Canadian Airway Focus Group also published guidelines that included considerations for an extubation strategy.[2]

In view of limited extubation-related literature in pediatric patients, this review will focus on extubation strategies in the context of pediatric airway management. We propose a scheme

similar to the DAS guidelines that can be applied in pediatric patients. Veckyemans recently published an excellent review of the critical steps in the extubation process and specific extubation techniques in pediatric patients.[3] The aim of this review is to build upon that knowledge base to emphasize the importance of a planned and safe extubation strategy in pediatric patients with a difficult airway.

1 | DEFINING DIFFICULT EXTUBATION

There is no consensus on the definition of difficult extubation. The relevant American Society of Anesthesiologists practice guidelines note the value of an extubation strategy in the management of the difficult airway but do not otherwise define difficult extubation itself.[4] The DAS guidelines are directed at planning for any extubation rather than focusing specifically on difficult extubation.[1]

The recent Canadian Airway Focus Group guidelines offer the most comprehensive definition.[2] The "at-risk tracheal extubation is defined by the patient anticipated to be intolerant of tracheal extubation or who might be difficult to reintubate." For the purposes of this review, we suggest a slight tweak to this definition:

A difficult extubation should be anticipated when the airway clinician assesses that it is likely that additional techniques, oxygenation methods, or ventilatory support will be required to support the patient after extubation, or when reintubation is likely to be difficult.

This definition encapsulates a need to consider the patient's condition, the skillset of the clinician, and the challenges of safe reintubation. Both this definition and that of the Canadian Airway Focus Group hint at an additional key truth: A patient may present no difficulty with endotracheal intubation, but still require careful care through the extubation phase.

2 | PEDIATRIC EXTUBATION IN THE LITERATURE

The majority of the literature on extubation of pediatric patients focuses on cases of failed extubation particularly in the pediatric intensive care unit (PICU) setting. There is good reason to avoid extubation failure in that context because it has been associated with longer durations of mechanical ventilation, intensive care admission, and increased mortality.[5] Overall, extubation failure in the critical care population varies widely in reports. Baisch et al. reported a failure rate of 4.1%, Gaies et al. reported a 5.8% failure rate, while Laudato et al. reported rates as high as 17.5%.[5-7] These rates include patients who have been intubated for several days.

In anesthesia literature relating to extubation and reintubation work published in 2004 by Murat et al. noted a reintubation rate, either intraoperatively or in the postanesthetic care unit (PACU), of 26 per 10 000 general anesthetics in children under 16 years of age (0.0026%).[8] This study excluded patients undergoing open-heart surgeries and neurosurgical procedures. It is also not clear whether the 37 episodes of intraoperative reintubation were related to accidental extubation or some other form of difficulty.

A retrospective review of reintubation in pediatric patients over 3 years by Ing et al. found an incidence of 27 out of 28 208 anesthetics (0.096%).[9] They defined reintubation as occurring intraoperatively, in the PACU, or within 2 h of transfer from the care of anesthetists. Twenty-five of those 27 reintubations occurred in the operating theater, with the other two split between PACU and PICU. This study incorporated both those having planned extubations (19 of the 27 reintubations) and those reintubated after inadvertent extubation. Of note, 15 of the 27 reintubations were associated with serious adverse outcomes, including a need for resuscitation medications, chest compressions, unanticipated ICU admission, and unplanned prolonged intubation. Ten of the 27 patients experienced significant desaturation.

Extubation of pediatric patients with known difficult airways was explored by Jagannathan et al.[10] Patients were defined as having a difficult airway if direct laryngoscopy revealed a Cormack and Lehane grade 3 view or greater, tracheal intubation required three or more attempts, mask ventilation was difficult (further defined as needing a two-handed method to maintain airway seal and ventilation, or impossible mask ventilation), and/or needing an alternate device for successful tracheal intubation. Of the 99 712 patients studied over 78 months in a tertiary pediatric facility, 137 patients met all inclusion criteria. Across the whole difficult airway patient cohort, 29 episodes of adverse outcomes after extubation were reported, with some patients having more than one adverse outcome. There were 12 (9%) cases of significant hypoxemia with oxygen desaturation below 85%.

Extubation failure occurred in only seven out of 137 (5%) of cases, with most patients extubated directly to anesthesia face mask with no adjuncts (121 of 137 cases; 88%). Of the patients who failed extubation, four had decreased oxygen saturation, and one of these was associated with hypoxemic cardiac arrest, reintubation, and later death. The other three patients had evidence of airway obstruction or hypoventilation and required reintubation. Two of the patients required multiple attempts at reintubation before the airway was secured. One patient who failed extubation later died in the context of progression of spinal muscular atrophy and a decision to transition to a palliative approach to management.

It is evident that extubation failure is associated with significant morbidity. With a very low rate of extubation failure in the unselected pediatric anesthetic population, there is little justification for specific planning in every case. Therefore, a critical step is to identify patients at high risk of extubation failure so that a plan to maximize success can be developed.

3 | DEFINING RISK FACTORS

Risk factors associated with failed extubation track across multiple settings. In a neonatal cardiac setting, Gaies et al. noted that procedure complexity, new vocal cord dysfunction, and duration of ventilation were all significantly associated with failed extubation.[7] Baisch et al. noted patient age less than 6.5 months and duration

of ventilation as significant risk factors.[6] In a general intensive care population, age under 24 months, duration of ventilation, and syndromes associated with dysmorphic facial features were all associated with extubation failure.[11] Any acute medical condition affecting the airway was a risk factor, as was an admission for airway surgery. Chronic medical conditions also increased the likelihood of extubation failure. Jagannathan et al. reported that an age less than 18.5 months and a weight under 10 kg were associated with an increased risk of failed extubation.[10]

4 | REASONS FOR EXTUBATION FAILURE

Again, with limited literature available in the pediatric population and low absolute numbers, attempts to define reasons for extubation failure must be approached with caution. Ing et al. described laryngospasm and airway obstruction as significant factors.[9] In their cohort, children with laryngospasm accounted for half of the cases requiring resuscitation medications and chest compressions. While they could not define the cause for airway obstruction accurately, they note the likelihood of airway edema in their postextubation group. Half of their cases included surgeries involving the airway, and two of their 27 reintubations included patients who were originally easy to intubate but who proved difficult at reintubation. Jagannathan et al. reported that seven patients displayed signs of upper airway obstruction shortly after extubation.[10]

This noted association with upper airway obstruction is also evident in the intensive care literature. Green et al. demonstrated a prevalence of upper airway obstruction of 16% of pediatric patients having cardiac surgery.[12] Newth et al. also reported high rates of upper airway obstruction but felt this was unrelated to duration of intubation.[13] Other epidemiologic factors associated with extubation failure include the length of mechanical ventilation, patient age, and a low periextubation arterial oxygen partial pressure or high need for inotropic support.[6,7,14,15] In neonates after cardiac surgery, Gaies et al. identified co-existent genetic conditions, a background of hypoplastic left heart syndrome, and postoperative infection as risk factors for failed extubation.[6] Laudato et al. also identified the duration of mechanical ventilation as a key risk factor.[7] These epidemiological factors do not allow the clinician to identify the location of airway obstruction.

5 | THE SPACE FOR BETTER PLANNING

The DAS adult guidelines suggest a simple approach with four steps that could easily be adapted to pediatric practice.[1] While these guidelines utilize the prompts of "Plan, Prepare, Perform and Postextubation Care," we propose a slightly different approach to emphasize the initial prioritization of risk assessment:

- Risk
- Ready
- Do
- Discharge

Or,

R2D2.

Each of these steps serves as a prompt to consider some simple clinical questions important in formulating a safe and comprehensive extubation strategy for pediatric patients with the difficult airways.

[Figure 1A and B; Table 1].

5.1 | Risk

Assessing the risk of extubation failure is the first key step in planning for the potentially difficult extubation. While the anesthetist might have a standardized approach for extubation, the planning phase for difficult extubation requires identification of potential risk factors which would then prompt the practitioner to undertake more extensive preparation. Evaluating risk factors involves considering four simple questions:

- Were there known risk factors for a difficult airway prior to this admission?
- Have any new risk factors become evident during this admission?
- Is there more information that would aid planning?
- Are there any reversible factors?

5.1.1 | Known preexisting risk factors

Table 2 summarizes several known preexisting risk factors for difficult tracheal extubation across the areas of difficult face mask ventilation, difficult intubation, prior failed extubation, and preexisting ventilatory issues.

5.1.2 | New risk factors

New risk factors are summarized in Table 3 and include any new airway pathology, any new changes to respiratory pathology or changed respiratory mechanics and any changes that result in compromised access to the airway with resultant challenges in airway maneuvers.

It should be noted that difficulty in airway management for the first time during the current admission should be considered a new risk factor. The extension of this is that if a clinician has difficulty managing the airway during an anesthetic, this should immediately prompt planning for extubation. Assessment may well lead to the clinician concluding that minimal additional steps are required, as not all cases of difficult airway management will automatically imply that extubation will be challenging.

5.1.3 | The value of more information

The relevance of obtaining more information is heavily determined by the patient's individual history and clinical status. Prior records

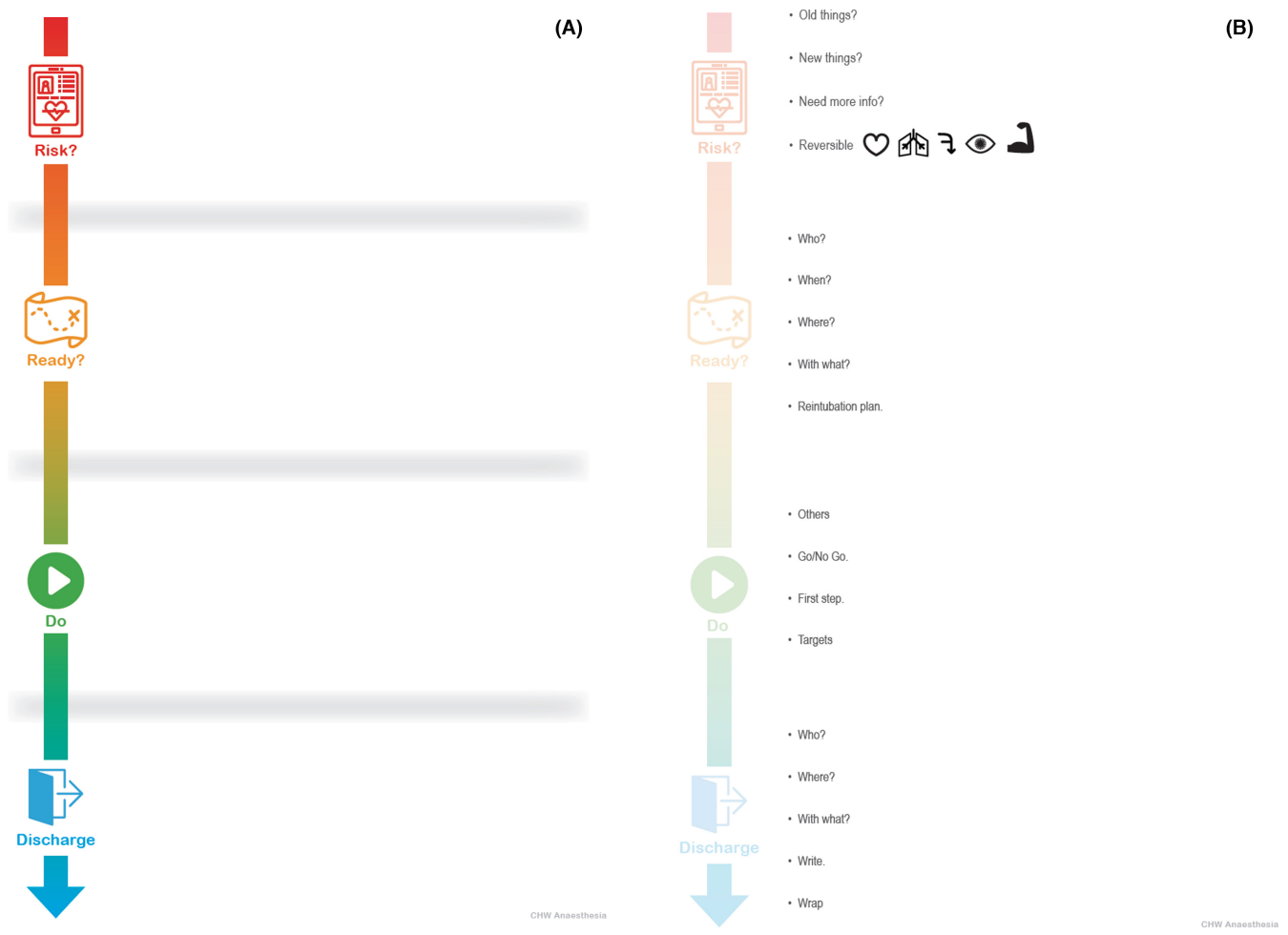

FIGURE 1 (A) Cognitive aid for R2D2 extubation planner (front). (B) Cognitive aid for R2D2 extubation planner (rear with prompts)

relating to the airway or respiratory system should be obtained wherever practical. Other clinicians familiar with the patient are excellent sources of information, and difficult airway alerts in hospital records should be encouraged as an efficient way to transfer this information. In some patients, particularly those who have previously failed extubation, additional information regarding the airway may be valuable in the form of airway endoscopy or bronchoscopy, potentially as part of the extubation process. For patients with upper airway issues, the anesthetist may glean useful information by performing a direct laryngoscopy, or flexible nasendoscopy. Other imaging modalities might provide relevant information in specific circumstances such as with cervical spine or soft tissue pathology.

5.1.4 | Reversible factors

Planning for success following extubation also requires consideration of whether there are any acutely reversible changes that will influence outcomes. Any residual neuromuscular blockade must be reversed. The importance of this step is highlighted by the mnemonic "Reverse" chosen by the Canadian Airway Focus Group, which emphasizes the consideration of reversible factors to accompany the broader reminder to optimize patient factors.[2] Cardiac and respiratory status should likewise be optimized. The patient's level of consciousness must not be impaired by sedative agents in such a way that respiratory control will be compromised after extubation. The approach to sedation management may also be influenced by whether the extubation plan involves further assessment of the airway in the form of airway endoscopy requiring general anesthesia.

The airway leak test was initially developed in the setting of viral croup and airway trauma when uncuffed tubes were the standard of care. Assessment of whether there is a leak around the endotracheal tube at a threshold airway pressure has previously shown highly variable sensitivity for predicting postextubation stridor or other complications[16–18] It is worth noting that not all investigators have stratified airway leak in the same manner. Thresholds vary between a focus on a leak at a pressure at <20 cmH_2O, >20 cmH_2O, or >30 cmH_2O.

There is limited literature on differing approaches for patients with a cuffed endotracheal tube in situ. At The Children's Hospital at Westmead, it is common practice to fully deflate the endotracheal tube cuff and then assess whether there is a difference between inspired and expired tidal volumes at standard patient ventilation pressures. This aims to confirm a leak at relatively low pressures rather than only providing assessment at a higher, forced pressure.

The role of steroids in pediatric extubation preparation is also uncertain. Unlike in adults, systematic reviews in neonatal and

pediatric settings have suggested that there is not enough evidence to make strong recommendations regarding their efficacy in reducing postextubation complications.[19,20] A more recent study suggests there may be some reduction in postextubation issues if steroids are administered for 24 h prior to extubation, rather than only 6 h.[21] In this publication, the authors suggested particular utility in high-risk children intubated for over 48 h. In the setting of ventilation for over 48 h, prior treatment with corticosteroids is a reasonable measure if there are no contraindications to steroid administration. Optimal dosing also remains uncertain, with at least one study suggesting noninferiority of a dose of 0.25 mg/kg administered fourth hourly for 24 h prior to extubation when compared to 0.5 mg/kg.[22]

TABLE 1 Expanded prompt questions for R2D2

Risk
What risk factors were already present?
What risk factors are new on this admission?
Would more information help?
Are there any reversible factors?
Cardiovascular, Respiratory, Airway, Sedation Level, Strength.
Ready
Who is needed?
When should it happen?
Where should it happen?
With what equipment?
Reintubation plan.
Do
Any other procedures as part of the extubation?
What are the Go/No Go points?
Is the first step in respiratory support ready?
What are your targets after extubation?
Discharge
Who will be looking after the patient?
Where will the patient be?
With what ongoing respiratory support?
Is the plan documented and directly handed over?
Are other parts of the plan wrapped up (e.g., analgesia)?

5.2 | Ready

After assessing the potential risks and optimizing patient-related factors, final steps to proceed with extubation should be undertaken. This involves getting things ready for extubation and asking the following questions:

- What **people** are required?
- What **location** should the extubation occur in?
- What **time** should it take place?
- What **equipment** is required?
- What is the **reintubation** plan?

5.2.1 | People

Extubation of the patient with a difficult airway should involve experienced airway clinicians. There is no evidence to confirm that more experienced clinicians are more likely to successfully extubate pediatric patients with difficult airways. There is, however, evidence that senior clinicians have more success with intubation of patients with difficult airways, and reintubation planning is a requirement for adequate preparation.[23]

At a minimum, the team involved in extubation must include at least one experienced practitioner to manage the airway after extubation and potentially undertake reintubation, and a qualified assistant who can help as needed. This may also include having an ear, nose, and throat (ENT) surgeon on standby. The ENT surgeon will also need a dedicated assistant.

5.2.2 | Location

The location for extubation is primarily determined by the clinical scenario. If a difficult extubation is part of a single operative procedure, by default, it is undertaken in the operating theater. For patients in the intensive care unit, a decision should be made collaboratively between the intensivist, anesthetist, and ENT surgeon, as to whether the risk profile supports extubation in the intensive care unit or warrants transfer to the operating theater.

TABLE 2 Preexisting risk factors for difficult extubation[a]

Face mask ventilation (FMV) factors	Intubation factors	Extubation factors	Ventilation factors
Significant CPAP to maintain FMV	Cormack and Lehane laryngoscopic view 3/4	Prior failed extubation	Background need for noninvasive respiratory support
Airway adjuncts necessary	3/4		
Two-person technique required	Videolaryngoscopy view < 50% of vocal cords		Known neuromuscular condition causing weakness
High oxygen need during FMV	3+ attempts at intubation		

[a]Adapted from Valois-Gomez et al and Jagannathan et al.

TABLE 3 New risk factors relevant to extubation planning

New airway risk factors	New respiratory risk factors	Airway access factors
Newly noted difficult intubation	Acute respiratory pathology impairing oxygenation or ventilation	E.g., mandibular fixation, halo traction.
Iatrogenic trauma to the airway		
Airway edema	Acute respiratory muscle weakness	

TABLE 4 Equipment Considerations for Planned Extubation

Minimum Equipment Considerations for Extubation
Suction.
Working intravenous access.
Face mask + breathing circuit for a clinician to provide positive pressure mask ventilation.
Airway adjuncts (oropharyngeal airway and nasopharyngeal airway)
Equipment for induction of anesthesia and reintubation
Nebulizer mask with adrenaline ready in preparation for postextubation stridor requiring treatment
Chosen postextubation respiratory support equipment where planned (humidified high-flow nasal cannula circuit or noninvasive ventilatory support)

5.2.3 | Timing

Reintubation or other complications after extubation may occur several hours after the event. Therefore planning for a known difficult case should ideally aim for extubation prior to midday to maximize the chance that if reintubation is required it still occurs during normal business hours when staffing and support are optimal.

5.2.4 | Equipment

For an anticipated difficult airway situation, it is important that the required equipment is obtained in advance and easily identifiable to support optimal team functioning.[24] There are some minimum requirements that should be available at extubation (see Table 4).

A plan for noninvasive ventilation after extubation should be considered. There is evidence supporting its use in the pediatric setting to prevent extubation failure.[25] Additionally, there is a growing body of literature showing the usefulness of humidified high-flow nasal cannulae as a means of delivering oxygen at a positive airway pressure in pediatric patients.[26–28]

In the anesthetic setting, the majority of literature on humidified high-flow nasal oxygen has focused on apneic oxygenation.[29–31] Since humidified high-flow nasal oxygen is useful in periextubation care in both infants and adults, it is reasonable to include this as an option for difficult extubation in pediatric patients, though other noninvasive support options should also be available. A recent retrospective review of 427 patients extubated in the pediatric intensive care setting noted that the majority of patients were extubated to room air or nasal cannulae.[32] One hundred thirty-two patients (30.9%) were extubated to high-flow nasal cannulae (HFNC), and 23 patients received non-invasive positive pressrue ventilation (NIPPV) (5.8%) immediately after extubation. Intubation for longer than 7 days was associated with a higher rate of use of both HFNC and NIPPV. There is a need for further research to establish the best indications for each respiratory support option.

Although the use of airway exchange catheters is popular in adults, there is little evidence regarding their utility in pediatric patients. There are case reports and small series suggesting that they are useful and may be tolerated by pediatric patients, but there is not enough literature to make any concrete recommendations.[33,34]

5.2.5 | Reintubation plan

A comprehensive plan for reintubation should be in place before extubating a patient with a difficult airway. This includes gathering all the necessary equipment and appropriately briefing the team regarding the plans for reintubation. To maximize the chance of success on the first attempt, reintubation should be undertaken by the most experienced airway practitioner, utilizing a technique with which they are confident.[23]

5.3 | Do

While this step is essentially about executing the plan, it is worth emphasizing the importance of a detailed briefing. The briefing should involve all team members and include:

- Planning for appropriate personal protective equipment for the team, as highlighted by the COVID-19 pandemic.
- The plan for any procedures prior to extubation (e.g., airway endoscopy or other examination).
- Criteria the patient must meet to attempt extubation (or "Go/No Go" criteria), which may include specific oxygenation targets or other criteria associated with successful extubation (see Table 5).
- Clarification of whether extubation will be undertaken with the patient awake or as an alternate while deeply anesthetized as may be the case where extubation is part of ENT surgeon airway endoscopy.
- Primary airway support plan after extubation:
  - Face mask held by a clinician with chosen circuit vs. humidified HFNC vs. noninvasive ventilation.
  - Considerations for the use of airway adjuncts.
- Criteria for assessing patient as having been successfully extubated in the short term.

TABLE 5 Clinical Signs Associated with Successful Extubation after General Anesthesia (adapted from Templeton et al)

Clinical Sign
Facial grimace
Purposeful movement
Eye opening
Conjugate gaze
Tidal volume > 5 mL/kg

- What clinical findings are expected after extubation?
- What signs and symptoms might prompt reintubation?

- The plan for reintubation, including back-up plans and rescue options.

As the extubation sequence proceeds the whole team can then confirm that each "Go/No Go" point has been reached before progressing to the next stage.

5.4 | Discharge

Given the risk that complications related to extubation, including the need for reintubation, may not occur immediately, it is important to select an appropriate setting for postprocedure observation. Planning adequate postextubation care requires a collaborative approach to confirm the following:

- The **location** allows an adequate level of direct patient supervision, supplemented by appropriate monitoring, and frequency of observation.
- **Safe transfer** of the patient to that location is feasible.
- A **plan for ongoing oxygenation** and airway management is in place.
- Adequate **documentation** of the extubation process and the patient's background airway challenges has been completed.
- A direct **peer-to-peer handover** has occurred between both medical and nursing staff. This handover should include names and contact information of key personnel who would potentially be involved in any airway management over the next few hours if the patient deteriorated. It should also involve clarification of a reintubation plan.
- Any **ongoing need** for analgesia and/or sedation has been assessed, and a plan prepared that will minimize the potential for sedation to impede airway care.

6 | CONCLUSIONS

Extubation of the pediatric patient with a difficult airway is a critical step in airway management. Failed extubation is associated with a range of complications that result in morbidity for patients and costs to the health system. Discussions such as this with a focus on the challenges of extubation will hopefully be one extra step to prompt much needed work to develop more research on which to base practice. The evidence that is available may be excellent but the volume is small compared with other areas of airway research. This leaves obvious gaps in knowledge across a range of areas such as the best options for postextubation support and the utility of airway exchange devices in the context of extubation. The future of research in periextubation care will require collaborative work, such as initial surveys of current practice and a focus of existing multicenter airway registries on periextubation care. This twin approach can help more comprehensively describe both what clinicians currently do in the real world and highlight areas that would benefit from both retrospective and prospective observational studies to evaluate specific techniques and develop collaborative research projects targeting very specific and answerable questions. The outlines are there. We now need research to provide the color and detail.

6.1 | Reflective questions

- How do you determine if the management of extubation may be difficult?
- Does your institution have a standardized approach for teams planning a difficult extubation?
- How do you choose the right form of postextubation support after extubating a patient with a challenging airway?

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CONFLICT OF INTEREST

Dr Andrew Weatherall is the Social Media Editor for Pediatric Anesthesia.

DATA AVAILABILITY STATEMENT

As an education review article, this clause is not applicable.

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