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Tracheostomy decision making: From placement to decannulation

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ABSTRACT

Over the last few decades, greater numbers of tracheostomies have been performed in medically complex and fragile children to manage upper airway obstruction, progressive neuromuscular disorders, abnormal ventilatory drive and to facilitate airway clearance. The optimal timing of tracheostomy tube placement and methods to determine suitable patients for the procedure remain unclear. Caring for children with tracheostomies can have a considerable financial and psychosocial impact on a family. Pediatric patients with tracheostomies have a 2–3 fold greater morbidity and mortality compared to adult patients. Clinicians should provide as much clarity as possible for families on the positive and negative aspects of pediatric tracheotomies and long term mechanical ventilation prior to tracheostomy placement. Tracheostomies are often placed as a bridge, whilst time for healing, growth and other therapies are needed to help overcome the indication for tracheostomy. Suitable investigations used to determine the optimal timing of decannulation remain physician and institution dependent.

1. Introduction

Tracheostomy was not commonly performed in children until the nineteenth century, when it was used at times of infectious epidemics including Poliomyelitis and Diphtheria [1]. With the introduction of vaccines and antibiotics, the main indication for tracheostomy has changed from infection to upper airway obstruction, progressive or irreversible neuromuscular disorders, abnormal ventilatory drive and to allow adequate airway clearance [2]. Tracheostomy is a common procedure in the adult intensive care unit (ICU), but is less common in the pediatric population, occurring in < 3% of pediatric ICU patients [3]. More children are surviving with chronic medical conditions, largely due to advances in technology including tracheostomy care with the majority of these children now cared for in their own home. Although a surgical tracheostomy provides a safe and protected airway, all procedures present potential risks and complications. Morbidity and mortality rates reported with tracheostomy insertion in pediatric patients are 2–3 times higher than in adults [4]. Therefore, the pros and cons of tracheostomy placement should be carefully considered for each individual patient and their family.

2. Considerations pre tracheostomy insertion

Many factors should be carefully considered by the medical team prior to tracheostomy placement including; a thorough preoperative history and examination with the aim to identify factors which if addressed could avoid tracheostomy placement, optimal timing of the tracheostomy, caregiver education and ability to manage the patient in the home setting and the expected outcome of tracheostomy placement (whether a bridge to recovery and decannulation or long term tracheostomy).

2.1. Timing of tracheostomy placement

In the adult population, tracheostomies are considered if mechanical ventilation is required for more than 72 h, with a median occurring at day 9 of intubation & ventilation [3]. Early tracheostomy in the adult population was shown to reduce the risk of hospital acquired pneumonia, duration of mechanical ventilation, length of stay in the ICU and mortality rate [5]. There is no consensus on the optimal timing of tracheostomy insertion in the pediatric and neonatal population. Some preterm infants remain intubated for > 3 months prior to tracheostomy consideration [3]. A recent meta-analysis reported that early tracheostomy (performed within the first 7 days of endotracheal intubation) was associated with decreased duration of mechanical ventilation and length of stay in the ICU [5]. However, the pediatric populations included in the studies analyzed were not inclusive of all pediatric patients requiring a tracheostomy with some studies excluding neonatal

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ICU patients [6]. Prolonged periods of intubation can interfere with normal development and may result in laryngotracheal damage [7,8]. Neonates often undergo many failed extubation trials prior to tracheostomy placement. Despite this, tracheostomies in the pediatric population are most frequently performed in the first year of life due to the increasing survival of preterm infants requiring long term ventilation [2].

The age at time of tracheostomy insertion differs based on the pathophysiology of the underlying disorder. Patients with airway obstruction, cardiopulmonary or craniofacial anomalies are typically younger at time of tracheostomy placement than those with traumatic injury or neurological impairment [2,9].

2.2. Indications for tracheostomy insertion

The development of immunizations and advances in neonatal care have led to a change in the primary indications for pediatric tracheostomy. Current common indications include facilitating long term ventilation, overcoming craniofacial abnormalities causing airway obstruction, subglottic stenosis, neurological impairment and providing access for airway clearance [10]. Neonates and infants are increasingly surviving with complex medical needs for whom tracheostomy and/or home mechanical ventilation is an integral part of their overall care [11,12]. The most common indication differs amongst institutions and countries, likely related to the availability of medical care and local infrastructure [13]. Gergin et al. described the changes in indication of tracheostomies over time in their institution with increasing numbers performed for cardiopulmonary reasons [2] (Fig. 1).

Traditionally, tracheostomy was viewed as a negative neonatal outcome, due to an assumed increased risk of death and impaired neurodevelopmental outcome in the preterm population [14]. However, causality is difficult to prove and bronchopulmonary dysplasia (BPD) and prolonged mechanical ventilation are themselves associated with neurodevelopmental impairment [15,16]. Luo et al. reported improved outcomes in short term changes in growth, respiratory support needs, tolerance of developmental therapy and daily sedation requirements after tracheostomy in infants with severe BPD [8]. They suggested that these benefits should be taken into consideration in infants requiring prolonged high-level respiratory support and balanced against the risks and caregiver burden of tracheostomy [8].

In some cases, a tracheostomy may be a temporary procedure to permit further treatment e.g. to facilitate mandibular distraction surgery in cases of micrognathia or retrognathia. Bannink described 4 patients with syndromic craniosynostosis who were successfully decannulated after midface advancement surgery [17]. In other cases, tracheostomy is considered a long term intervention with no expectations that developmental changes or growth will allow decannulation in the future. This group typically includes children with permanent neurological or pulmonary conditions that require mechanical ventilation for survival. Clinicians should provide as much clarity as possible for families about the distinction between tracheostomy as a *bridge* or *destination* to avoid unrealistic expectations [18].

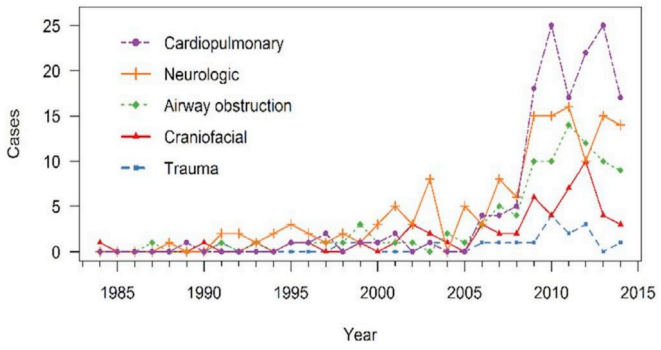

Fig. 1. Distribution of pediatric tracheostomy indications by year. (Reprinted from Int J Pediatr Otorhinolaryngol, 2016; 87:144-7. Gergin O, Adil EA, Kawai K, Watters K, Moritz E, Rahbar R. Indications of pediatric tracheostomy over the last 30 years: Has anything changed? Pages 144-7, Copyright 2016, with permission from Elsevier).

A detailed airway examination should be performed from the nares to the distal bronchi to ensure there are no areas of obstruction that if treated may negate the need for a tracheostomy e.g. subglottic cysts or posterior glottis synechiae [7,10]. Other potential surgical interventions should be considered where appropriate e.g. epiglottoplasty for laryngomalacia.

2.3. Co-morbidities

Increasingly, tracheostomies are performed in children with multiple complex medical problems. Determining appropriate candidates for tracheostomy placement is often challenging. In some complicated cases, the risks of the procedure include cardiac arrest and death [19,20]. In a study by Watters et al., 62% of children had a complex chronic medical condition, 43% had ≥ 3 chronic conditions and 29% had other medical technology needs in addition to their tracheostomy [21]. A systematic review on the use of tracheostomy in pediatric obstructive sleep apnea (OSA) did not identify any mild or moderate case of OSA requiring tracheostomy without significant co-morbidities or syndromes e.g. cerebral palsy, neuromuscular disease and craniofacial abnormalities [17,22–24]. This was likely because most cases of OSA in children without co-morbidities can be managed with traditional interventions such as adenotonsillectomy [22]. Strang et al. reported that the presence of congenital heart disease was associated with increased mortality rates in infants who were ≤ 12 months old at time of tracheostomy [23].

Oral communication and feeding with a tracheostomy become more of a challenge in children with pre-existing neurological conditions [7]. Caregivers and families should be counselled on what potential changes this could pose for the child. Infants with severe cognitive deficits also deserve special consideration by the clinical team. The decision to provide chronic invasive ventilation in this group often raises ethical discussions within medical teams with some perceiving this a futile use of resources or prolonging the suffering of the child [18]. Clinicians must address their ethical obligations to each individual child and their family with patience, foresight and teamwork [18]. Understanding the values and goals of the family is critical in the decision-making process. Involving clinicians who care for children with tracheostomies and/or home ventilators in the discussion can be helpful. Additionally, facilitating the family access to other families whom have had positive as well as challenging experiences may assist with the decision-making process [25].

2.4. Caregiver education

The education needs of the caregivers should be reviewed frequently including prior to tracheostomy insertion, during the hospital stay and at discharge [26]. Due to the significant medical burden of a tracheostomy and long term mechanical ventilation, the psychological impact on the child and their family can weigh heavily [27,28]. Anticipatory guidance on long term considerations and potential complications during the informed consent discussion prior to tracheostomy insertion, is of paramount importance [7,27]. However, it is often difficult to counsel families on what to expect and the hardships involved [3,21]. Home-care teaching should begin before tracheostomy insertion to provide some insight for caregivers [29]. This should be individualized to the cultural needs of the family and conveyed at an unhurried pace. Education should include clinical decision-making skills including identifying and treating tracheostomy complications as well as technical skills of routine tracheostomy care [7,29]. Caregivers should be assessed for competencies in these skills in the hospital prior

to discharge [26]. Any limitations or difficulties should be identified and addressed as appropriate. Hettige et al. demonstrated that the expectation, knowledge and confidence in delivering this type of care can remain a challenge for parents [30].

2.5. Economic considerations

Tracheostomies come at a high economic cost to the family and healthcare system when one considers both the initial hospitalization and tube placement and more so the post-operative care, which in children is 24-h care. Children with tracheostomies require skilled nursing care and this is particularly important during the initial period upon discharge home. The duration and extent of supplemental specialized home-care required should be decided by the tertiary care team on an individual basis with periodic reassessment [29]. In the absence of clear scientific evidence, financial issues including local and national insurance coverage may influence the home-care packages available to patients and families [31]. Health care teams must be familiar with local policies to develop care strategies that remain within these constraints but in the best interests of the patient [31].

2.6. Type of tracheostomy tube

Identifying the appropriate size (diameter and length) of a tracheostomy tube is paramount to the overall success of this intervention. Ideally the smallest diameter tube capable of providing adequate air exchange should be used to avoid tracheal mucosal injury [3,26]. At times a larger tube may be indicated in ventilated patients to prevent a significant air leak. A tube which is too long may cause obstruction or migrate into the right main bronchus leading to left lung collapse.

In general, uncuffed tracheostomy tubes are preferred over cuffed tracheostomy tubes in the pediatric population. Uncuffed tubes will avoid excessive mucosal injury potentially induced by the cuff and facilitate phonation around the tracheostomy tube. Sometimes, cuffed tracheostomy tubes are indicated in patients requiring ventilation with high pressures, nocturnal ventilation only (speaking around the deflated cuffed tracheostomy tube during the day) and patients with chronic translaryngeal penetration [29]. Custom tracheostomy tubes are also available and are used increasingly in the patient population with complex upper airway, tracheoesophageal and craniofacial anomalies. There are no specific recommendations on the optimal tracheostomy type for specific patient populations and hence physician and institutional preferences often play a major role in tracheostomy tube selection [31].

3. Post tracheostomy care

Pediatric tracheostomy placement is associated with a relatively high morbidity and mortality and every endeavour should be made to ensure optimal medical care and development of the child [4,32]. Post-operative care is often individualized to the patient's needs and physician's preference as there is limited data on the optimal frequency of routine surveillance and tube changes, home monitoring and speaking valve use.

3.1. Tracheostomy surveillance

After initial tracheostomy placement, the patient should be closely monitored in an ICU, often until the initial tube change. Stomal maturation is usually complete within 3–7 days and the first tube change generally occurs at this stage [26].

There are no clear guidelines regarding the ideal frequency of tracheostomy tube changes after the initial tube change. It is often driven by local practice and can range from daily to monthly [31]. Advantages of frequent tracheostomy tube changes include ensuring continued caregiver comfort with tube changes, whilst also possibly reducing the risk of infection and tube occlusion due to inspissated secretions. However, frequent tracheostomy changes can also lead to stomal stretch and damage [29]. The American Thoracic Society (ATS) guidelines on tracheostomy care did not reach consensus on optimal frequency of tracheostomy change [29].

Post tracheostomy surveillance with endoscopy differs amongst centers, but in general is dependent on the indication for initial tracheostomy, in addition to the age of the child. For patients with rapidly evolving airway lesions, tracheoscopy with or without intervention e.g., tissue excision or dilation, may be required as often as every 2 weeks. Young infants who are growing rapidly may require tracheoscopy every 2–3 months to assess appropriate tube size, in contrast to teenage patients who may only require annual endoscopies. Most institutions also perform a formal airway evaluation prior to decannulation [33].

3.2. Humidification and suctioning

Humidification and suctioning are required to reduce the risk of tube obstruction, crusting and mucus plugs, as the normal functions of the upper respiratory tract have been bypassed by the tracheostomy. Various devices exist which assist in humidification including ventilators with built in humidifiers, saline nebulizers, saline drops and heat moisture exchangers (HME) often referred to as “Swedish or artificial noses”. These are filter devices in which moisture and heat are deposited during exhalation and returned during inhalation. HMEs can increase the work of breathing by increasing airway resistance and dead space and are not tolerated by all patients [34]. Patients may also have difficulty clearing secretions with a HME in situ and those with a large secretion burden may not tolerate it. A tracheostomy collar may be used in patients who do not tolerate a HME. Aerosol tubing is connected to a collar mask with the other end of the tubing attached to a nebulizer bottle and air compressor. Oxygen if required can be delivered through both a HME and tracheostomy collar.

Endotracheal suctioning to ensure airway patency and manage secretions is one of the most common procedures performed in patients with artificial airways [31,35]. There are two methods of endotracheal suctioning: open and closed. The open method requires a patient to be disconnected from a ventilator, whilst the closed method involves attachment of a sterile, closed in-line suction catheter to the ventilator circuit allowing the patient to stay connected to the ventilator throughout [35]. The depth at which to insert the suction catheter is of upmost importance to avoid tracheal epithelia damage and therefore the use of pre-marked catheters is strongly recommended [29]. The ATS consensus document on tracheostomy care states that suctioning should be performed on the basis of clinical assessment rather than specific time intervals, though a minimum of twice daily suctioning is recommended to ensure airway patency [29].

3.3. Speaking valves

One way speaking valves have proven successful in the adult population to enable patients to vocalize after tracheostomy tube placement. To promote the success of speaking valves in the adult population various criteria are recommended including tracheostomy tube size less than two-thirds of the tracheal lumen, medical stability, tolerance of having the tracheostomy tube cuff deflated and an ability to control secretions [29]. Unfortunately, there is a dearth of research on the use and benefit of speaking valves in the pediatric population. Most pediatric studies focus on tolerance of speaking valves rather than the impact on verbal communication [36]. Speaking valve trials are often started for a brief period e.g., 10 min under direct observation and gradually increased. As communication is an integral part of pediatric development more research is required in this area [36]. The ATS recommend that all patients regardless of diagnosis, age or expected duration of tracheostomy be referred to speech and language teams for assessment and appropriate follow-up [26,29].

Table 1
Perioperative complications of tracheostomy insertion.

Intraoperative	Early post-operative	Late post-operative
Hemorrhage	Hemorrhage	Granuloma formation
Air dissection	Tracheostomy malposition	Suprastomal collapse (tracheal ring compression, weakening and displacement)
Trauma to surrounding tissue	Tracheostomy obstruction	
Tracheostomy malposition	Wound infection	Tracheoesophageal fistula
Tracheostomy obstruction	Dysphagia	Tracheal & subglottic stenosis
Post obstructive pulmonary edema	Accidental decannulation	Tracheo-innominate artery fistula

3.4. Monitoring

The goal of home monitoring devices for children requiring chronic invasive mechanical ventilation is to provide early warning of any airway compromise. Options include pulse oximeters, end-tidal carbon dioxide monitors and apnea monitors, however, standards of care are lacking on both the type and frequency of such monitoring. The ATS suggests factors to be considered by the medical team when deliberating what type of home monitoring to use including patient age, tracheostomy size, degree of airway obstruction, underlying pathology, other medical conditions present, social environment and the behavior of the child [29].

Once prescribed by the medical team, home monitors should be reliable and maintained by the home care company. Appropriate training should be provided for families and caregivers. Ideally the monitors chosen should have a backup battery for portability in case of an emergency. Clinicians also find it useful to employ monitors with remote download capabilities facilitating medical assessment both in clinic and from the home.

Most portable ventilators also have monitoring and alarm capabilities to detect high or low pressure, apnea, high or low minute ventilation, low battery or power failure. Many ventilators can be equipped with a downloadable smart card to help the physician identify issues such as ventilator dyssynchrony, air leaks or inappropriate ventilator settings. Kun et al. described how the high tube resistance in small uncuffed tracheostomy tubes may prevent low pressure alarms from detecting accidental decannulation [37]. Low pressure and low minute ventilation alarms should be set appropriately to help detect ventilator leaks in children with smaller tracheostomy tubes along with additional monitoring e.g. pulse oximetry. Physicians may choose a combination of patient monitoring devices in the home to minimize the risk of a single monitor failing unpredictably e.g. pulse oximetry and ventilator alarms.

3.5. Inhaled medications

There is a paucity of recommendations regarding specific aerosol devices and techniques to use when administering inhaled medications via tracheostomy and the choice is often patient, physician and institution dependent. Differences in devices and techniques can result in a variable amount of drug delivered. A review by Berlinski concluded that aerosol delivery through pediatric tracheostomy tubes is impaired by small internal diameters and breathing patterns with low tidal volumes [38]. However, adult data comparing drug delivery between endotracheal tubes and tracheostomy tubes has shown that the latter delivers 50% more drug than the former due to the shorter length of the tracheostomy tube [39].

Vibrating mesh nebulizers are more efficient than jet nebulizers but are also more expensive [38]. Either device can be used with a tracheostomy however, high bias flows should be avoided as they can reduce aerosol delivery and interfere with ventilation [39,40]. Piccuito and Hess demonstrated that turning off high-flow oxygen before administration of aerosolized drugs to patients with tracheostomies via a jet nebulizer resulted in an increase in drug delivery of up to 3-fold [39].

In patients with tracheostomies who tolerate disconnection from a ventilator, pressurized metered-dose inhalers (pMDI) can be used to administer medications using a holding chamber designed for use with tracheostomies. However, if the patient cannot tolerate ventilator disconnection then the timing of the actuation is crucial. Failure to synchronize the pMDI actuation with an inhalation reduces aerosol delivery by 35% [38].

The use of assisted technique to administer aerosols either by nebulizer or pMDI varies amongst institutions [41]. Some reports suggest that assisted technique decreases lung delivery of pMDIs but results in increased tracheal deposition when nebulizers are used [40,41]. Berlinski and Chavez reported that the use of assisted technique with pMDI administration via tracheostomy resulted in a reduction in drug delivery ranging from 18 to 54% [40]. The difference between pMDIs and nebulizers regarding the effect of assistance on aerosol deposition could in part be explained by the continuous flow which a nebulizer provides.

4. Complications

Tracheostomy is a lifesaving operation for many however, it is also associated with potential serious complications. Nageswaren et al. highlighted the importance of discussion of both the positive and negative aspects of tracheostomy with families prior to tracheostomy placement including potential complications [27]. Mortality rates with pediatric tracheostomy are higher than the adult population, with highest rates in children receiving a tracheostomy under 1 year of age [32].

Medical teams must be vigilant for complications of tracheostomies which can be classified temporally as occurring intraoperatively, in the early post-operative period (first 7 days) and in the late post-operative period (after 7 days or after the first tracheostomy tube change) [7] (Table 1).

Fifty percent of deaths in tracheostomy patients are, however, due to progression of the patient's underlying disease rather than a complication of the tracheostomy [46]. In an emergency situation, carers and medical staff should be wary of complications related to both the tracheostomy itself and invasive mechanical ventilation but also cognizant of potential complications of the child's primary medical or surgical condition.

5. Decannulation

Decannulation is often the ultimate shared goal for the patient, their family and their multidisciplinary team [31]. Reported rates for successful decannulation in the pediatric population vary, ranging from 29 to 98% and are hugely impacted by the patient population in each case series reported [32]. Most recent studies show a successful decannulation rate of 29–37% [13,20]. Decannulation rates are higher in patients without neurological impairment [42].

Decannulation failure is defined as the need to replace the tracheostomy tube after decannulation. The incidence of decannulation failure varies from 9 to 45%, partially due to the lack of consensus on the length of time considered for failure determination with some studies reporting days and others months [43]. Various risk factors leading

Table 2
Risk factors for decannulation failure.

Physical risk factors	Functional risk factors
Granulomas	Insufficient deglutition reflexes
Tissue overgrowth	Suboptimal secretion management
Sub/Supraglottic stenosis	Intermittent apnea
Tracheomalacia	

to decannulation failure have been identified, which can be broadly divided into physical and functional categories (Table 2).

Mitchell et al. recommend that no mechanical ventilation support should be required for 2–4 months prior to decannulation [26]. Additionally, there should be no signs or symptoms of ongoing aspiration that would preclude decannulation [26].

5.1. Tracheostomy downsizing and capping trials

Most decannulation protocols begin with downsizing the tracheostomy to promote gradual closure of the stoma and to train the patient to breathe around the tracheostomy [10]. A trial of daytime capping is typically performed under direct observation, to ensure tolerance. If tolerated, the patient is then usually admitted overnight for a 24-h capping trial. If successful, the tracheostomy tube is removed and the stoma is occluded with an occlusive dressing to promote closure. Primary closure is not advised, due to the increased risk of infection and wound dehiscence [10].

The procedure of capping and tracheostomy downsizing is not universally employed in the decannulation process, due to concern for increased risk of mucus plugging and decreasing the cross-sectional area of the trachea to the degree that those who do not tolerate capping may still actually tolerate decannulation [33]. However, other authors contend that reduction and occlusion of the tube diameter can predict success of decannulation in addition to acclimatizing the child to changing airway physiology [44].

5.2. Polysomnogram

The role of polysomnography in decannulation protocols remains debatable, as many patients with mild or moderate OSA may still progress to successful decannulation. Gurbani et al. demonstrated the superiority of combining a polysomnogram and bronchoscopy to determine eligibility for decannulation [45]. Similar reports from Tunkel et al. and Robinson et al., highlighted the benefits of polysomnography in determining the appropriateness of decannulation [46,47]. Unfortunately, these studies are resource intensive and frequently not available for inclusion in decannulation protocols [33].

5.3. Bronchoscopy

Most institutions agree that a formal airway evaluation is essential prior to decannulation to ensure that there are no airway lesions that may prevent a safe decannulation such as vocal cord insufficiency, stomal granulation, suprastomal collapse, distal tracheal granulation or airway malacia [3,10]. Bronchoscopy is one of the most undisputed components of decannulation protocols as it not only provides diagnostic evaluation but also the opportunity for therapeutic airway treatments [33]. The importance of spontaneous breathing during bronchoscopy has been emphasized in many studies, to identify any dynamic collapse or obstruction [48].

6. Conclusions

Increasing numbers of neonates are surviving with complex medical conditions involving airway obstruction and/or cardiopulmonary disease. Improvements in available technology and home-care resources allow greater numbers of these pediatric patients requiring chronic invasive ventilation to be cared for in the home. Medical practitioners caring for patients requiring long term tracheostomy placement face many challenging decisions often with limited or no clinical consensus guidance available. The success of chronic invasive ventilation in pediatric patients is determined by the capacity of the medical teams involved to ensure patient safety (e.g., appropriate home monitoring, adequate care giver education) and patient comfort (e.g., humidification, speech and swallow support).

Practice points

- Decisions regarding tracheostomy placement must be carefully considered by medical teams including assessment of the underlying medical condition as well as the psychological, social and economic impact on the patient and their family.
- Once a child is successfully discharged home on chronic invasive ventilation, there must be regular contact with the clinical teams involved to maintain high-quality tracheostomy care e.g., appropriate management of humidification, suction, inhaled medications and speaking valves.
- Decannulation practices vary between institutions but bronchoscopy, tracheostomy downsizing and capping trials are common. Polysomnography is useful but not always readily available.

Research directions

- Optimal timing of infant and pediatric tracheostomy insertion, particularly in the BPD population.
- Decannulation strategies for pediatric patients.
- Device development for the administration of aerosolized medications in children requiring tracheostomies with or without mechanical ventilation.
- Home monitoring protocols for pediatric patients requiring chronic invasive ventilation.

Declaration of competing interest

Frances Flanagan has no conflicts of interest and no funding sources.

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