Original Article

Pediatric tracheostomy decannulation: post implementation of tracheostomy team and decannulation protocol

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Background: Historically, the Royal Children's Hospital tracheostomy service relied upon senior airway clinician decision-making regarding decannulation. In March 2016 we established a formal Tracheostomy multidisciplinary team (MDT) which now meets on a weekly basis. Simultaneously, we devised a Tracheostomy Decannulation protocol to be used to guide management and treatment decision-making around timing of tracheostomy decannulation.

Methods: The tracheostomy decannulation outcomes at a large tertiary pediatric Hospital were reviewed for the period spanning 2003 until 2018. The primary outcome measure was decannulation success. Secondary outcome measures were timing of failure (early ≤28 days, or late >28 days) and mortality. Decannulation results before and after the tracheostomy MDT were compared, along with other variables which could influence decannulation success including indication for tracheostomy, significant comorbidities, cyanotic heart disease, simple or major airway reconstruction, peri-decannulation steps and timing of decannulation.

Results: Fifty-two children underwent a total of 68 decannulation attempts across the 15-year study period. Involvement of the tracheostomy MDT correlated with improved likelihood of decannulation success (P=0.007). Additional variables which also strongly correlated with decannulation success included indication for tracheostomy (P=0.048), major airway reconstruction (P=0.031), normal overnight oximetry (P=0.003), and timing of the decannulation (P=0.002).

Conclusions: Tracheostomy multidisciplinary teams and protocol-guided decannulation pathways should recognise the need for appropriate pre-attempt multidisciplinary work-up, good oxygen saturations before attempts and well-supported appropriately-timed decannulations. Due to the medical complexity of these patients, protocol-based decision-making is useful as a guide to management, but care should be individualised in order to maximise successful outcomes.

Keywords: Pediatric; tracheostomy; decannulation; success; multidisciplinary

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Introduction

Tracheostomy insertion is a life-saving intervention that has been performed for more than 2000 years (1). The most common indication for adult tracheostomy is to facilitate mechanical ventilation (2). In children, acute upper airway obstruction is a far more common indication. Fortunately, the need for pediatric tracheostomies due to

acute upper airway pathology has dramatically reduced over recent decades, mainly due to widespread specialty airway programs and improvement in anaesthetic skills (3). As a result, tracheostomy is used infrequently in the pediatric population and usually only after significant deliberation and interdisciplinary consultation (4). Correspondingly, the management of the tracheotomised child is a complex and demanding assignment. Various institutional decannulation protocols have been reported, yet there is still no standardised approach to pediatric tracheostomy decannulation.

The American Thoracic Society and American Academy of Otolaryngology Head and Neck Surgery guidelines, as well as other institutions, recommend performing endoscopic evaluation of the pediatric airway prior to decannulation to determine airway patency at all levels (5,6). This also allows identification and treatment of peristomal complications such as stenoses and granulation tissue. Pre-decannulation polysomnography (PSG) is also recommended to identify any residual obstructive component.

Ideally, the decannulation process should proceed once the child no longer requires mechanical ventilation, can manage their own secretions and the underlying pathology has resolved or been reversed (5,7). Unfortunately, this ideal scenario is not always possible, and compromises sometimes need to be made to allow the child the opportunity to live tracheostomy-free. As a result, the decision to decannulate should be made once a set of minimum safety criteria are met in keeping with local institutional guidelines, with the decannulation process occurring in a stepwise manner in a supported environment. This allows the tracheostomy to be reinserted if the process fails. This "safe failure" concept mandates that attempt is undertaken in safe and controlled conditions, thus reducing the risk of permanent adverse outcomes.

Various experienced institutions have published their protocols and decannulation outcomes (8-14). However, variation in reporting methods makes institutional comparisons difficult—some centres report overall success, others list initial success or success for each episode, and some give a breakdown of subgroups outcomes without reporting specific data. Additionally, some studies report failures while others report successes. Published failure rates range from 0% in Wirtz's study (13) to 42% in Beaton's study (14).

The Victorian Royal Children's Hospital implemented a tracheostomy multidisciplinary team (MDT) and adoption of a formal decannulation protocol in March 2016 (*Table S1*). The team was established in order to improve co-ordination and quality of care, to unify the stakeholders and to align with a trend towards multidisciplinary management of complex patients (15). This study aims to determine if these changes affected the rate of success of decannulation in pediatric tracheostomy patients.

Following a review of published decannulation protocols, The Royal Children's Hospital adopted the Great Ormond Street decannulation protocol (11) with modifications to adjust for local variables, namely the substitution of pre-decannulation PSG with overnight oximetry (*Table S1*). The role of PSG in the pre-decannulation assessment is to identify the presence of ongoing obstructive pathology. In Victoria, access to formal PSG is very limited and only performed at a limited number of tertiary centres. There is well-documented correlation between overnight pulse oximetry and PSG in the pediatric population with a recently published article reporting a high positive predictive value between abnormal overnight oximetry and the presence of obstructive sleep apnoea (16).

Prior to the tracheostomy MDT approach, decisions regarding decannulation were made by a senior airway surgeon without access to collaborative support from other units. Decannulations were performed on each day of the week and at variable times throughout the day with wide variation in their work-up. Currently, children assessed in the tracheostomy MDT clinic must meet a set of minimum criteria in order to be suitable for decannulation. The process commences with airway evaluation under anaesthesia using flexible endoscopy or bronchoscopy prior to admission for decannulation. Daytime awake trials of speaking valve use occur at home with occasional trials of short periods of capping. Select patients may also downsize in the community prior to decannulation. Higher risk patients undergo these steps in hospital under monitored conditions. Children are admitted to the ward the night before the planned decannulation where they undergo further downsizing and supervised capping followed by overnight oximetry with a capped tracheostomy and, if safe to proceed, ultimately supervised tracheostomy decannulation. The patient is discharged after 2 to 3 days of observation. Early review in the tracheostomy clinic is then planned for 2 weeks following discharge.

This study aimed to compare decannulation results before and after the tracheostomy MDT was instituted, including the use of the decannulation protocol. It also aimed to identify other variables that affect decannulation success. Previous decannulation outcomes from the studied

institution were published in 2005 (17).

We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/ajo.2020.03.07).

Methods

Prior to commencing data collection, low risk ethics approval was obtained from the RCH ethics committee. A retrospective review was performed of the electronic medical records of all patients who had attempted ward tracheostomy decannulation in the 15-year period between March 2003 and March 2018 at the Royal Children's Hospital, in Victoria. Data was collected about any child who had undergone a tracheostomy insertion and had experienced a decannulation attempt since 2003. Tracheotomised children who had not undergone a decannulation attempt were excluded.

Data points collected across the study population for the 15-year period included demographics, gestational age, indication for tracheostomy, significant comorbidities, cyanotic heart disease, "simple" airway surgery prior to decannulation, major airway reconstruction, duration of tracheostomy and the involvement of an MDT approach to decannulation decision.

The indications for tracheostomy was separated into four groups—prolonged mechanical ventilatory requirement, unstable or obstructive airway (fixed or functional), or mixed pathology. The most common fixed obstructive pathology was subglottic stenosis. The most common functional obstructive pathology was bilateral vocal fold paralysis. Simple airway intervention was defined as microlaryngoscopy with the addition of balloon dilatation, supraglottoplasty or removal of granulation tissue. Major airway reconstruction was defined as laryngotracheoplasty, cricotracheal reconstruction, tracheoplasty, vocal cord suture lateralisation, mandibular advancement or laryngeal cleft repair. If patients had both simple and major procedures during the pre-decannulation episode they were included in both groups.

Extensive data on each child's individual decannulation process was collected, including tracheostomy downsizing, capping, oximetry, decannulation timing, decannulation success, timing of decannulation failure if it occurred (early ≤28 days or late >28 days), and mortality. If a child required tracheostomy reinsertion more than one year after decannulation for a separate or new indication it was considered as a separate episode.

Collated data was grouped categorically and multivariate analysis with a Pearson Chi-squared analysis was performed using SPSS software. Missing data of input variables was excluded from each analysis as intention to treat analysis was considered too likely to skew outcomes.

This review bridges a period of introduction of a standardised protocol and multidisciplinary team decannulation process at this institution. This protocol aimed to standardise overall decision-making, pre-decannulation assessment and the peri-decannulation processes. It also encouraged greater input and support from a multidisciplinary team. Please see *Table S1* for full protocol details. The decannulation pathway is also available for Open Access on the Royal Children's Hospital website: https://www.rch.org.au/rchcpg/hospital_clinical_guideline_index/Tracheostomy_management/#Decannulation.

From March 2016 onwards, the RCH tracheostomy MDT team conducted weekly meetings. The team comprised otolaryngologists, respiratory physicians, respiratory nurses and case managers. Any tracheotomised child who required an episode of care within the preceding week was presented for discussion. Children whose underlying tracheostomy-dependent pathology had resolved were also presented and were assessed for decannulation-appropriateness.

Results

The primary outcome measure explored was decannulation success. Secondary outcomes measures were mortality and early or late decannulation failure. Each of the other variables were compared to determine their influence over the individual outcome measures.

Table 1 shows the cohort frequencies. Fifty-two children underwent a total of 68 decannulation episodes over the fifteen-year study period. There was roughly even male to female distribution (female =48.5%). Obstructive pathology (either fixed or functional) represented 67.6% of the cohort, ventilatory requirements in 20.6% and mixed pathology in 11.8%. It was observed that 53.7% of the group had significant co-morbidities, with a further 14.9% having cyanotic heart disease. Overall 55.2% of patients underwent one or more simple airway interventions, with 31.3% undergoing major airway reconstruction. The mean duration of tracheostomy was 707.8 days (range: 13–3,684 days).

Table 2 addresses the frequency of various factors in the peri-decannulation attempts. We identified that capping

Table 1 Frequency table

Variable	Total (valid %)
Gender: female	33/68 (48.5)
Gestational age: <32/40	14/39 (35.9)
Tracheostomy indication	
Obstructive	
Fixed	29/68 (42.6)
Functional	17/68 (25.0)
Ventilatory	14/68 (20.6)
Mixed	8/68 (11.8)
Significant comorbidities	36/67 (53.7)
Cyanotic heart disease	10/67 (14.9)
Simple airway intervention	37/67 (55.2)
Major airway reconstruction	21/67 (31.3)

Table 2 Frequency of success of decannulation process

Variable	Total (valid %)
Downsizing	38/46 (82.6)
Capping	37/48 (77.1)
Oximetry	
Normal	31/40 (77.5)
Abnormal	2/40 (5.0)
Not recorded	7/40 (17.5)
Decannulation timing	
Standardised timing*	12/62 (19.3)
Other time	47/62 (75.8)
Theatre	3/62 (4.8)
Decannulation success	42/64 (65.6)
Failure	
Early (≤28 days)	17/21 (81.0)
Late (>28 days)	4/21 (19.0)
Tracheostomy MDT involvement	
Pre-trache team	40/65 (61.5)
Post-trache team	25/65 (38.5)
>1 decannulation attempt (range 2–6)	11/52 (22.1)

*, Monday morning (non-Public Holiday).

Table 3 Tracheostomy success rates based on use of the tracheostomy team protocol

Timing	Rate of decannulation success
Pre-protocol	20/39 (51.3%)
Post-protocol	22/25 (88.0%)
Total	42/64 (65.6%)

P=0.007.

occurred in 77.1%, oximetry was recorded in 82.5% and 19% of episodes occurred on a Monday morning. Overall decannulation success was 65.6%, with 81% of all recorded failures occurring early (≤28 days). Of the 52 children in our analysis, there were 11 children who underwent greater than one decannulation attempt (range: 2–6 attempts), for a total of 68 decannulation episodes. The highest number of individual attempts was six. This child had numerous complex comorbidities as well as multifactorial tracheostomy-dependent issues. This child eventually died with their tracheostomy due to acute on chronic respiratory problems. No children died during any of the peri-decannulation periods or as a result of the decannulation process.

Table 3 demonstrates the decannulation outcomes of non-MDT approach compared to tracheostomy MDT approach. The non-MDT approach had a 50% chance of decannulation success, compared with an 88% likelihood of success with the MDT approach (P=0.007).

Table 4 examines the correlation of variables in the decannulation process to decannulation success. These results show that the indication for tracheostomy was associated with decannulation success, reaching statistical significance (P=0.048). Each of the 14 patients who underwent tracheostomy for ventilatory requirements were successfully decannulated on their first attempt without adverse events. In contrast, the patients who were tracheotomised for obstructive or mixed pathology had variable decannulation success. A standardised timing of decannulation was strongly associated with the likelihood of decannulation success (P=0.002). In this instance, this meant all children within the protocol underwent decannulation on Mondays or Tuesdays between 9am and 10am, compared to non-protocol patients, who underwent decannulation at highly variable times and days of the week. The presence of abnormal oxygen saturations in the nights

Table 4 Decannulation success

Variable	Pearson Chi-squared P value
Gender	0.175
Gestational age	0.512
Tracheostomy indication	0.048
Significant comorbidities	0.75
Cyanotic heart disease	0.448
Simple airway intervention	0.181
Major airway reconstruction	0.031
Downsizing	0.394
Capping	0.154
Timing of decannulation	0.002
Tracheostomy team	0.007

Table 5 If failure occurred, was it early (≤28 days) or late (>28 days)

Variable	Pearson Chi-squared P value
Gender	0.091
Gestational age	0.541
Tracheostomy indication	0.605
Significant comorbidities	0.223
Cyanotic heart disease	0.214
Simple airway intervention	0.549
Major airway reconstruction	0.950
Downsizing	0.631
Capping	0.923
Oximetry	0.915
Timing of decannulation	0.622
Tracheostomy team	0.496

prior to decannulation was associated with decannulation failure, without exception, though this was only applicable to 2 patients.

In *Table 5*, we compared the timing of decannulation failures as early failures (≤28 days) *vs.* late failures (>28 days). Where a failure of decannulation did occur, there were no individual variables which correlated with that failure occurring either early or late (*Table 5*). Additionally, we examined mortality as a secondary outcome measure, however, no children died as a result of the decannulation process.

Table 6 Key recommendations

Tracheotomised children benefit from a multidisciplinary tracheostomy care team
Children should have overnight oximetry prior to decannulation. Review decision to decannulate if there are any signs of respiratory compromise, including abnormal oximetry, stridor, increased work of breathing, etc.
Pre-decannulation flexible endoscopic assessment of the airway is vital
Tracheostomy for ventilatory requirements are unique patients who don't follow the same trajectory as those with obstructive pathology
Major airway reconstruction for obstructive pathology should be considered early in the patient journey

Discussion

This study showed there were significantly improved decannulation outcomes following the establishment of the tracheostomy team and implementation of a structured decannulation protocol.

Multidisciplinary collaboration

This improved success rate can be attributed to a multitude of factors and is a model utilised in adult tracheostomy care (15). The ability to collaborate in a clinical setting allows clinicians to share inter-disciplinary experience, learn from evolving best-practice evidence-based medicine, whilst expediting the referral process and creating new avenues for service implementation. This cross-disciplinary assessment of complex patients in a shared clinical setting allows for support for patient care decisions and competence development.

Having the decannulation performed at a standardised time also resulted in improved success rate. This result can be attributed to the additional support service available at this designated time, including medical and nursing services, as well as additional supernumerary staff to ensure the process runs smoothly.

Indication for tracheostomy

Analysis of the data revealed two distinct groups of

tracheostomy patients—those with obstructive airway pathology and those with ventilatory requirements. Each group comprised very different aetiologies and co-morbid profiles, and, as such, conveyed very different decannulation outcomes. Children who underwent tracheostomy for ventilatory requirement had earlier and more reliably successful decannulation once the underlying requirement had passed. This contrasted with those who had obstructive or mixed pathology who were more likely to fail.

Role of intervention

In our study population, we observed that simple airway intervention did not improve the chance of decannulation success, however, major airway reconstructive surgery significantly improved decannulation success rates. This suggests that careful assessment must be made about each child's airway status and that a more conservative surgical option is not always the most appropriate course of action for each child in order to achieve decannulation success. In contrast, major reconstructive surgery including procedures such as laryngotracheoplasty and mandibular advancements, which have traditionally been viewed as more aggressive interventions, could be considered earlier in the pathway, instead of only once all other options have been exhausted. With respect to the greater risks of these interventions, this approach could potentially expedite decannulation and allow children to live a tracheostomy-free life from an earlier age. In our group there was a tendency to perform corrective airway interventions earlier following the advent of the tracheostomy team.

Once there has been a failure, modifiable variables should each be reviewed individually and corrected where possible in order to improve the chances of decannulation success. To simply reattempt decannulation with the identical set of variables is destined to result in the same outcome. Once a failure has occurred, consideration for major reconstructive airway surgery could be made, where indicated.

Role of oximetry

The role of PSG has been extensively reported since the mid-1980s as an indicator of readiness for decannulation (10,18-21). We used overnight oximetry in our assessment algorithm instead of formal PSG due to ease of access to the modality and validated correlation with airway obstruction (16). Despite the small numbers of patients with abnormal oximetry prior to decannulation in this cohort (two patients), the early failure of these attempts all occurred in patients with obstructive pathologies. A child who is unable to maintain normal overnight oxygen saturations prior to decannulation, whether the tracheostomy is capped or not, likely indicates that the underlying pathology is either still present or not fully reversed. Unfortunately, normal oximetry does not ensure decannulation success. Gurbani reports in their study that 26% of those with unfavourable PSGs were still successfully decannulated, which challenges the role of sleep studies as an isolated pre-decannulation assessment tool (22).

There is also discrepancy in the published literature regarding the reliability of a single night recording of pulse oximetry results to predict OSA. Galway *et al.* report that there is significant night-to-night variability in pulse oximetry to suggest that a single night of oximetry may not be sufficient to screen for OSA (23). In contrast, Pavone *et al.* in an earlier publication found that there is strong correlation between a single night pulse oximetry and presence of OSA (24). This needs to be taken into consideration by any institution when designing their tracheostomy care protocols.

Additional data which was not included in this analysis but was collected in the raw dataset, showed that there were an additional four episodes in which patients who were felt to be ready for decannulation experienced desaturations prior to their planned decannulation. This resulted in the decision to abort the planned decannulation. Further interventions in these children prior to their next decannulation episode lead to success on each occasion.

An additional four children who experienced decannulation failures had documented reports from the nursing entries which noted either stridor with capping or increased work of breathing in the night prior to a planned attempt. Each of these children went on to experience decannulation failure. No child who was successfully decannulated had any reports of respiratory concerns prior to decannulation. These qualitative factors illustrate the importance of the pre-decannulation assessment to review and explore any factors which may negatively influence success.

It must be noted that there is a significant variation in patient factors in the pediatric population requiring tracheostomy. As might be expected, the heterogeneity within each condition is great, and that glottic webs, subglottic stenosis, and laryngotracheal clefts can each present a wide range of severities. This means generalisations about the results must be viewed with

caution. Additional limitations of the study were the incomplete patient records due to the transition to electronic medical records which occurred during the study period. This possibly reduced the ability to reach statistical significance in some of the domains examined.

Safe failures

The American Thoracic Society published a consensus statement on the management of the child with a chronic tracheostomy which discussed equipoise in decannulation decision-making. They advised that an excessively conservative approach may lead to inappropriate delay in decannulation, while an overly aggressive approach will result in increased decannulation failure rates (5). A similar analysis performed by the Royal Hospital for Sick Children in Glasgow by Beaton *et al.* discussed the concept of 'safe failures' (14)—where we sometimes need to accept a trade-off to allow treatment progression. This is the concept that sometimes decannulation needs to be attempted, despite all factors not being optimal, in order to give the child the possibility of a tracheostomy-free life. The role of a uniform decannulation approach ensures these potential higher-risk attempts occur in a supportive environment with access to services and resources that reduce the chance of any permanent harm and allow streamlined tracheostomy replacement should the need arise.

Ultimately, despite the promising results with the use of protocol-based decision-making for decannulation, a universal protocol may not be appropriate in every situation, and an algorithm approach may be required (25), as suggested by the persistent lack of agreement across the literature on this topic.

Conclusions

Tracheostomy multidisciplinary teams and protocol-guided decannulation pathways should recognise the need for appropriate pre-attempt multidisciplinary work-up, good oxygen saturations before attempts and well-supported appropriately-timed decannulations. *Table 6* includes a summary of the key recommendations from this study. All of these have significant impact on the ultimate success of decannulation. Given the medical complexity of these patients, protocol-based decision-making is useful as a guide to management, but care should be individualised in the pediatric population to maximise successful outcomes.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at http://dx.doi.org/10.21037/ajo.2020.03.07

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/ajo.2020.03.07). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Prior to commencing data collection, low risk ethics approval was obtained from the RCH ethics committee [QA/60552/RCHM-2019-197477(v1)]. Individual consent for this retrospective analysis was waived.

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Supplementary

Table S1 RCH tracheostomy decannulation protocol

Assessment
Flexible fibreoptic laryngoscopy/bronchoscopy—performed 6 weeks prior to admission—to determine suitability for decannulation
Preparation
Domiciliary daytime/awake speaking valve trial and tracheostomy capping trials with caregiver supervision
Tracheostomy downsizing—performed in tracheostomy clinic
Admission
Pre-decannulation
Afternoon admission
Admitting team review on ward
Tracheostomy downsizing to 3.5 mm tube
Record patient observations including respiration rate, oxygen saturations, work of breathing, heart rate and blood pressure
Overnight pulse oximetry with capped tracheostomy—recorded
Decannulation
Respiratory nurse + admitting team/otolaryngology team review of oximetry + determination of suitability for decannulation
Tracheostomy removed between 9am and 10am—member of medical staff must be present on ward during decannulation
Stoma site care—tracheostomy site to be taped with occlusive dressing
NB: emergency equipment must be available in case of need to emergently reinsert tracheostomy
Post-decannulation
Child to remain on ward for 24 hours following decannulation—only able to leave ward once assessed by medical team as having a "safe airway"
Strict regular observations
15 minutely for the first hour
Half-hourly for the next 4 hours
Hourly for 24 hours
Continuous pulse oximetry (SpO_2) during all periods of sleep (day and night) post decannulation for 24 hours
Observe carefully for any signs of airway obstruction or increased respiratory effort during sleep periods
Consider
Referral to Speech Pathology—if difficulty tolerating diet
Referral to Physiotherapy—if assistance required with secretion management
Discharge from hospital 36–48 h after decannulation, or as required
Following discharge home
Early review in tracheostomy clinic within 2 weeks of decannulation
Surveillance endoscopy as required
Stomal closure as required