

Role of Polysomnography in the Development of an Algorithm for Planning Tracheostomy Decannulation

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Abstract

Objective. To examine the role of polysomnography (PSG) in helping determine readiness of tracheostomized patients for decannulation.

Study Design. Case series with chart review of pediatric patients who underwent PSG with tracheostomy tube in place with the goal of decannulation.

Setting. Tertiary care pediatric center.

Subjects and Methods. Twenty-eight tracheostomized patients who underwent PSG from January 2006 to March 2012 were included. Outcome measures were successful decannulation, PSG results, surgical procedures, and medical comorbidities.

Results. Of the 28 patients, 20 (71.4%) were decannulated and 8 (28.6%) were not. One (3.6%) patient failed long-term decannulation. The average apnea-hypopnea index (AHI) with a capped tracheostomy for those successfully decannulated was 2.75 (range, 0.6–7.6), while the AHI for those not decannulated was 15.99 (range, 3.2–62). Factors associated with success or failure to decannulate were assessed, and an algorithm was developed to plan for successful decannulation. Laryngotracheal reconstruction was a significant factor in those successfully decannulated. Those who were not decannulated had multiple medical comorbidities, multilevel airway obstruction, need for additional surgery, or chronic need for pulmonary toilet.

Conclusions. Polysomnography may be a useful adjunctive study in the process of determining a patient's readiness for decannulation. Our current algorithm for decannulation includes upper airway endoscopy with identification of levels of obstruction, followed by surgical correction of those obstructions; capped PSG to determine patency of the airway and help assess lung function; and overnight intensive care unit admission for capping trial, with decannulation the following day if well tolerated.

Keywords

pediatric airway, tracheostomy, decannulation, polysomnogram

The most common indication for tracheostomy is prolonged ventilation secondary to either (1) anticipated long-term cardiorespiratory compromise resulting from chronic ventilatory insufficiency or (2) the presence of a fixed upper airway obstruction that is unlikely to resolve for a significant period of time.^{1,2,3} Despite tracheostomy being a life-saving procedure, tracheostomy-related mortality rates range from 0.5% to 3.6% and are associated with significant morbidity.⁴ Complications can include catastrophic plugging, accidental decannulation, stomal granuloma formation, and minor to fatal bleeding.⁵ In addition, the social stigma as well as financial costs of care and equipment can be burdensome. It is for the above reasons and many others that decannulation is frequently desired by both family and physicians alike. However, it is paramount that decannulation occur only after being determined safe and appropriate, as premature removal can prove to be fatal.

To date, the literature is devoid of well-established guidelines of determining the readiness for decannulation. Although agreement does exist among authors that prior to decannulation, upper airway endoscopic examination should be performed, different proposals have been formed for care after this key portion.^{6,7} In 1996, Tunkel et al⁷ published a study looking at the utility of polysomnography (PSG) in the evaluation of readiness for decannulation. The authors reasoned that PSG provides objective data measuring for dynamic factors influencing upper airway patency during a

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time when pharyngeal muscle tone is maximally decreased and airway obstruction is at greatest risk. They concluded that sleep study data near the PSG range of normal values correlate with successful decannulation outcome.

The goal of our current study was to examine pre-decannulation, capped PSG study findings, and clinical information to develop an algorithm for safe and successful tracheostomy decannulation.

Methods

An electronic database search of patients who underwent PSG with a concomitant diagnosis of tracheostomy at the Children's Hospital of Pittsburgh of the University of Pittsburgh Medical Center, from January 2006 to March 2012, was conducted. This study included all patients with a tracheostomy tube in place who were deemed clinically stable prior to PSG for possible tracheostomy decannulation. Those patients who were tracheostomy dependent and underwent PSG for reasons not related to possible decannulation were excluded from the study.

Demographic data, medical comorbidities, surgical interventions, age at tracheostomy, and age at decannulation (if achieved) were collected from our patients' medical records. The following data were collected from PSG with capped tracheostomy tubes: apnea-hypopnea index (AHI), central apneas, obstructive apneas, mixed apneas, hypopneas, total sleep time, O₂ nadir, arousal index, percentage of total sleep time with O₂ saturations <89%, severity of snoring, and presence of hypoventilation, periodic breathing, or stridor/stertor. While reported criteria for grading severity of pediatric obstructive sleep apnea (OSA) are variable, we used the following grading system based on AHI: AHI <1.5, normal; 1.5 to 4.9, mild; 5.0 to 9.9, moderate; and ≥10, severe.^{8,9} We also considered an arousal index ≥12 and oxygen desaturations <89% for ≥2% of total sleep time as abnormal.^{10,11}

Polysomnograms were performed with a computerized system (Somnostar, San Diego, California). The standard electroencephalogram (EEG) montage (C3/A2, C4/A1, F3/A2, F4/A1, O1/A2, O2/A1) included right and left electrooculogram, submental electromyogram, tibial electromyography (EMG), snoring (piezo sensor), heart rate with electrocardiogram (lead II), arterial oxygen saturation by pulse oximetry (Nonin Medical, Plymouth, Minnesota), respiratory effort pattern by inductance plethysmography (including rib cage, abdominal, sum, and dvt channels), expired ETCO₂ (Novamatrix COSMO, Wallingford, Connecticut), nasal airflow (including thermistor and nasal pressure transducer), and body position. Video and technical observations were also recorded.

The studies were manually scored by registered technologists and reviewed by a physician board-certified in sleep medicine. The 2-breath rule was used for scoring obstructive events. Obstructive apneas were defined as reduction of airflow >90% from baseline amplitude with continuing effort to breathe. Hypopneas were defined as reduction in airflow >50% from the baseline associated with desaturation >3%, arousal, or awakening. The AHI was defined as the number of apneas and hypopneas occurring per hour of sleep time.

Table 1. Average Polysomnography Apnea-Hypopnea Index (AHI) Values Based on Decannulation Status.

	Total No.	Average AHI	AHI Range
All patients	28	6.05	0.6-62
Decannulated patients	20	2.75	0.6-7.6
Patients not decannulated	8	15.99	3.2-62

Electroencephalogram arousal was defined as an abrupt shift in EEG frequency of at least a 3-second duration. Rapid eye movement (REM) arousal required a concurrent increase in chin EMG. Arousal index was defined as the number of arousals per hour of sleep.

The protocol summary for this study was reviewed by the University of Pittsburgh Medical Center and University of Pittsburgh Human Investigation Committee, and full approval for the collection and reporting of data was granted.

Results

Of the 59 tracheotomized patients who underwent PSG, 28 underwent capped PSG for the consideration of future decannulation, and 31 underwent PSG by pulmonology for ventilator setting monitoring. Of the 28 who were evaluated for possible decannulation, 20 patients were successfully decannulated. Eight patients did not undergo any attempt for decannulation. The average age at time of tracheostomy was 25.9 months, with an average age of decannulation of 58.8 months.

The average AHIs for all patients, those who were decannulated, and those who were not decannulated are depicted in **Table 1**. The average AHI for those decannulated was 2.75 (range, 0.6-7.6). For those not decannulated, the average AHI was 15.99 (range, 3.2-62).

When evaluating the severity of OSA during PSG, there was a difference in distribution of patients between those who were decannulated and those who were not. For the decannulated patients, 18 (90%) had either normal or mild OSA, 2 patients (10%) had moderate OSA, and none were categorized as having severe OSA. In contrast, 1 patient (12.5%) with mild OSA, 3 (37.5%) with moderate OSA, and 4 (50%) with severe OSA were not decannulated (see **Table 2** for results arranged by severity of OSA). Contributing factors for why the 4 patients with mild to moderate OSA were not decannulated include the following: need for multiple additional surgeries (1 patient), progressive neuromuscular disease (Duchenne muscular dystrophy, 1 patient), and the need for prolonged pulmonary toilet with underlying neuromuscular symptoms (2 patients) (see **Table 3**). One patient who was originally decannulated failed prolonged decannulation secondary to progressive obstructive symptoms, necessitating repeat tracheostomy 15 months after original decannulation. This child had underlying Down syndrome, as well as a left vocal fold paralysis, and could not tolerate nasal/

Table 2. Severity of OSA Based on Decannulation Status.

	Severity of OSA, No. (%)			
	Normal (AHI <1.5)	Mild (AHI 1.5-4.9)	Moderate (AHI 5.0-9.9)	Severe (AHI ≥10)
Decannulated	1 (5.0)	17 (85.0)	2 (10.0)	0
Not decannulated	0	1 (12.5)	3 (37.5)	4 (50.0)
Total	1 (3.6)	18 (64.3)	5 (17.9)	4 (14.3)

Abbreviations: AHI, apnea-hypopnea index; OSA, obstructive sleep apnea.

Table 3. Patient-Specific Factors for Those Not Decannulated Despite Mild or Moderate OSA on PSG.

AHI	Grade	Comorbidities, Reason for Not Decannulating
Patients with mild to moderate OSA who were not decannulated		
3.2	Mild	Costello's syndrome, tracheobronchomalacia, chronic aspiration, and need for continued pulmonary toilet
7.1	Moderate	CHARGE syndrome, Duchenne muscular dystrophy, chromosome 11 duplication with progressive neuromuscular disease
8.2	Moderate	Lymphatic malformation of the neck and need for additional surgery
8.5	Moderate	Cerebral palsy, holoprosencephaly, and need for continued pulmonary toilet
Patient who failed decannulation		
3.5	Mild	Retracted 15 months after decannulation. Progressive worsening OSA symptoms, history of Down syndrome, left vocal fold paralysis, chronic renal failure

Abbreviations: CHARGE, coloboma of the eye, heart defect, atresia of the choanae, retardation of growth or development, genital abnormalities, ear abnormalities; OSA, obstructive sleep apnea; PSG, polysomnography.

oral continuous positive airway pressure (CPAP) at night (**Table 3**).

A total of 5 patients underwent post-decannulation PSG. The results of the post-decannulation PSG were very similar to pre-decannulation studies in 4 of the 5 patients. One patient on pre-decannulation PSG had a normal AHI (0.8) and, on post-decannulation PSG, had AHI values ranging from 0.8 to 3.0, with the longest term follow-up PSG done at 75 months after decannulation with an AHI of 1.2. Multiple studies were conducted due to persistent parental concerns of obstruction. Four patients with initial mild OSA (AHI values of 2.1-4.0) had post-decannulation studies. For 3 of the 4 patients, the post-decannulation AHI was very similar to the pre-decannulation AHI. The pre-decannulation AHIs and post-decannulation AHIs are as follows: patient 1, 2.1 to 1.8 (6 months post-decannulation); patient 2, 3.4 to 3.5 (5 months post-decannulation); and patient 3, 4.0 to 4.2 (1 month post-decannulation) and then 1.7 (37 months post-decannulation). One patient had worsening of his AHI post-decannulation, with a pre-decannulation AHI of 3.5 and post-decannulation AHI of 32.8 at 1 month and 25.9 at 5 months. Due to the severe OSA and multiple comorbidities, he was treated with CPAP and eventually underwent repeat tracheostomy (**Table 3**).

Discussion

Determination of tracheostomy decannulation readiness is challenging. Etiology for the tracheostomy, overall health of the patient, underlying medical comorbidities, functional status, and need for long-term pulmonary toilet all play a critical role in this determination. The decision for decannulation is not to be taken lightly, and the appropriate timing is very important. In this study, those patients who underwent capped PSG prior to successful decannulation demonstrated normal, mild, or moderate levels of OSA. No attempt was made to decannulate patients with severe OSA. The decision to not proceed with decannulation was made after reviewing the underlying health of the patient, medical comorbidities, clinic presentation, and objective measures of the PSG. Of those patients who had mild to moderate OSA but were not decannulated, each had a specific etiology or underlying condition that made them poor candidates for decannulation despite having an unobstructed airway (**Table 3**).

Through experiences illustrated in the above study, we developed an algorithm to assist in candidate selection for decannulation (**Figure 1**). Once the underlying etiology for tracheostomy has been resolved and the child has not been requiring ventilator support for at least 3 months, he or she

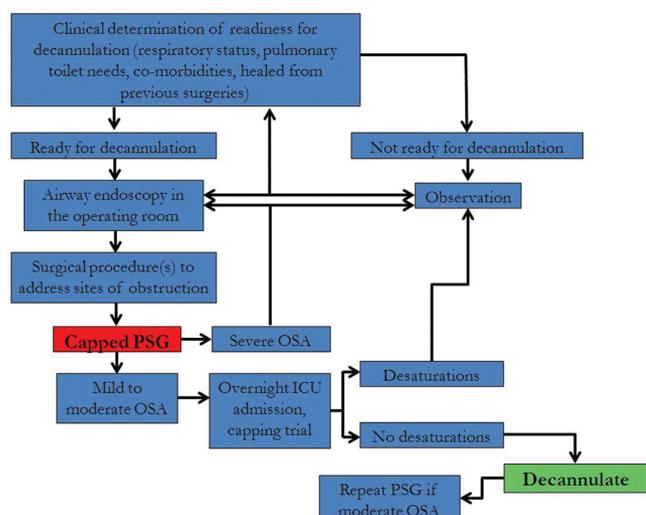


Figure 1. Algorithm for tracheostomy decannulation. Dashed lines represent possible pathways as determined by results of previous steps. ICU, intensive care unit; OSA, obstructive sleep apnea; PSG, polysomnography.

is ready to be considered for decannulation. An upper airway endoscopic evaluation is performed in the operating room, including flexible fiberoptic naso-pharyngo-laryngoscopy to assess upper airway obstruction as well as palatal and vocal fold movement. A direct laryngoscopy and bronchoscopy are also performed, looking for airway abnormalities, peristomal collapse, granulation tissue, or other airway abnormalities. If there are identified levels of obstruction, these are addressed by the determined appropriate surgical procedures. If no obstructive components are identified, or once the patient has healed from surgery (usually a minimum of 6 weeks) and outfitted with an age-appropriate tracheostomy tube that allows for decannulation attempts, daytime tracheostomy tube capping at home is attempted. If the patient tolerates capping during the day, a capped polysomnogram is performed. If this demonstrates normal, mild, or moderate OSA, the patient is admitted to the intensive care unit (ICU) for possible decannulation monitoring. The ICU admission is for 2 nights. The first night is a tracheostomy capping trial. If no desaturations or respiratory events occur, the patient is then decannulated and observed in the ICU for an additional 23 hours the following day. As further illustrated in **Figure 1**, if the pre-decannulation PSG shows moderate OSA, or if there are any concerns about possible obstruction after decannulation, a post-decannulation PSG should be obtained. If the pre-decannulation PSG shows severe sleep apnea, the patient is not ready for decannulation. Continued evaluation to determine site of obstruction is necessary. This patient may not be ready for decannulation, and observation may be the best option. This entire process is dynamic, as demonstrated in **Table 3**, and the results of a 1-night PSG are not sufficient evidence for decannulation when multiple other airway comorbidities are present. Clinical evaluation and assessment continue to play a key role in determining decannulation candidates.

This study is not without limitation. During this time frame, additional patients with tracheostomy tubes were decannulated without undergoing a prior PSG. The decision to use pre-decannulation PSG was attending surgeon specific and not always used. With time, the use of pre-decannulation PSG has become more common at our institution due to increased availability, subjective usefulness of the PSG data, and the desire to develop a more unified approach to tracheostomy decannulation. We also do not know if any of the patients with severe OSA could have been decannulated successfully. It is possible that they could have done well or even been decannulated with future use of CPAP or other positive pressure ventilation at night to treat the OSA. It also may have been useful to obtain PSG on patients after decannulation as a comparison point to pre-decannulation PSG to investigate the role of capped tracheostomy tubes in increasing obstruction. Since this has not been the practice within our institution, we are unable to provide any data on decannulation of patients with severe OSA noted on the capped or post-decannulated PSG. Last, this study was retrospective in nature, and therefore both clinical and intraoperative findings as well as decision making cannot be controlled for or addressed in our data and associated algorithm.

Conclusion

The determination of when a previous tracheostomy-dependent pediatric patient meets criteria for decannulation is not an easy task for even the most experienced otolaryngologist. These children often have comorbidities and require specialized care more than just airway-related issues. In the above study, we demonstrate how PSG findings can be used on capped/pre-decannulated patients to determine the appropriateness of decannulation while providing an algorithm on how to manage these complex patients.

Author Contributions

Jacob G. Robison, primary author, concept and design, intellectual development; **Prasad John Thottam**, editing of paper, reevaluation of study design, critical revisions; **Laura L. Greenberg**, acquisition of data, drafting work; **Raymond C. Maguire**, editing, revisions, concept; **Jeffrey P. Simons**, editing, revisions, concept; **Deepak K. Mehta**, intellectual development, analysis, drafting, redesign.

Disclosures

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