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Role of polysomnography in tracheostomy decannulation in the paediatric patient

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Abstract
Tracheostomy in infants and children has been the subject of controversy in the medical literature, but decannulation in the paediatric patient is even more controversial. Various approaches and techniques have been used for decannulation, however in spite of all efforts it continues to be a problem. The objective of our study was to assess the role of polysomnography (PSG) in predicting readiness for decannulation. All subjects (n = 31) of the study were less than 12 years of age, and tracheostomized for periods of at least six months to ensure a minimum period of dependence on the tube. All had clinical, radiological and endoscopic clearance before PSG was performed. Twenty-one out of 22 patients with favourable PSG data were successfully decannulated. Attempts to decannulate all the nine patients with unfavourable PSG failed. The conclusion of the study was that PSG is a useful adjunct to the many methods of evaluating readiness for decannulation in children with long-term tracheostomy tubes.

Key words: Polysomnography; Tracheostomy; Child

Introduction

Tracheostomy decannulation in children is a cause of great anxiety to the patient, parent and physician. Various approaches have been used, mainly centering around clinical, endoscopic and radiographical studies of static upper airway anatomy (MacLachlan, 1969; Bennie and Samuel, 1986). However, we feel that although anatomical and pathological considerations cannot be ignored because of the absence of effective testing methods physiological considerations have largely been overlooked leading to difficulties in decannulation. Mallory *et al.* (1985) have reported on the use of tidal flow measurements in any decision to decannulate the paediatric patient. They evaluated readiness using pulmonary function testing, including flow and volume pattern analysis during tidal breathing. PSG to assess readiness has been used before (Tunkel *et al.*, 1996). They suggested that PSG is very useful prior to decannulation as dynamic factors that influence upper airway patency are most apparent during sleep, when pharyngeal muscle tone is decreased, hence assessment of respiratory function during sleep is important.

Materials and methods

The study was carried out in the PSG laboratory of the Otorhinolaryngology Department of Sucheta Kripalani Hospital. All data was recorded on the Oxford Medilog solid state multiparameter recorder and then analyzed by the Oxford MPA-S sleep analysis software.

The patients were carefully selected from all those who had undergone tracheostomies in our department. They numbered a total of 31 and were cases referred to us from the Kalawati Saran Children's Hospital. All cases were below 12 years of age and had undergone tracheostomy at least six months before to ensure a minimum period of dependence. In all patients decannulation was being attempted for the first time and our study did not include any patient in whom decannulation had failed prior to the study.

Preparation for PSG was performed after a thorough clinical, radiological and endoscopic assessment. The cases were free from pulmonary ailments, were cured of the pathology for which the alternative airway was installed, and did not have any feeding problems. In those who could speak the patient had to have had adequate phonation with tube occluded, free from ventilator support for at least six months and freedom from an oxygen requirement. Radiological clearance was followed by endoscopy i.e. microlaryngoscopy and bronchoscopy and study of cord movements. Anterior tracheal wall collapse posteriorly and suprastomal granulations were specifically addressed.

Preparation for plugging was made by downsizing the tube by at least two sizes. Plugging of the tube was performed in a monitored setting. The tube was

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plugged during the daytime when the patient was awake. The patient was connected to a pulse oximeter while in bed. The tube remained plugged until the patient showed signs of any respiratory distress and the oxygen saturation remained within 10 per cent of the child's baseline. The baseline was decided on the basis of an unplugged pulse oximetry before downsizing of the tracheostomy tube started. Once the child tolerated daytime tube plugging for 48 hrs we began our study.

PSG was started during nocturnal sleep with an open tube for several sleep cycles for establishing a baseline, and then complete plugging was performed. The parameters assessed were electroencephalograph (EEG), electro-oculograph (EOG), submental electromyograph (EMG), tracheal sounds with microphone, nasal-oral airflow with sensors over nostrils and mouth, electrocardiograph (ECG), body position, thoraco-abdominal movements with inductance respiration bands, arterial oxygen saturation was monitored with pulse oximetry, limb position with sensors placed over right and left shin and end tidal carbon dioxide, measured continuously via a nasal cannula. All data was recorded in a multiparameter recorder.

Criteria for quantifying obstructive apnoea were cessation of nasal-oral airflow, with continued respiratory effort, lasting for at least 10 seconds and associated with a decrease in arterial oxygen saturation of at least four per cent. Obstructive hypoventilation was partial upper-airway obstruction associated with nadir arterial oxygen saturation of 95 per cent or less and/or peak end tidal CO_2 of 50 mmHg or more. Obstructive index was defined as the number of obstructive apnoeas and hypoventilation events divided by sleep time in hours. Sleep architecture was scored according to the Questar analysis which stands for 'quantification of EEG and sleep technologies, analysis and review'. **Questar** is a piece of software that uses a neural network (Roberts, 1991) to quantify sleep and wakefulness on a second by second basis, using a single channel of recorded EEG.

Results

All 31 subjects of the study underwent PSG analysis as part of the study protocol but in none of them did we have a pretracheostomized PSG study, hence no predetermined PSG values were available. Neither were there any normal data available to rely upon before proceeding to decannulation.

TABLE I
INDICATIONS FOR TRACHEOSTOMY

Ventilator dependence (9)
Tetanic laryngospasm (2)
Trauma (2)
Vocal fold palsy; unilateral (3), bilateral (4)
Laryngomalacia (4)
Multiple congenital anomalies (2)
Obstructive sleep apnoea (2), vallecular and tongue base cyst (2)
Subglottic stenosis (1)

All the patients were under the age of 12 with a median age of 27 months (range 14 months to 11 years) and the mean duration of cannulation was 19 months (range six months 15 days to 11 years).

We recorded all those with favourable data according to the data for the PSG study on children by Marcus *et al.* (1992). Twenty-two patients had PSG records that suggested the possibility of a successful outcome. Twenty-one were decannulated successfully, a single patient failed decannulation and continues to be cannulated. The cause of the failure of decannulation remains unknown. Each of these patients had an obstructive index of less than two events per hour. The number of central events was less than 2.1 events per hour in all patients. Desaturation indices i.e. no. of desaturation events per hour was fewer than three per hour of study. The mean arterial oxygen saturation during sleep was greater than 96 per cent for 12 out of 22 patients. None of the other 10 patients had a desaturation event showing less than 89 per cent saturation. End tidal CO_2 measurements during sleep were normal for each of these 22 patients (the range of mean end tidal CO_2 values was 36–42 mmHg; the range of maximum end tidal CO_2 values, 42–48 mmHg).

Unfavourable PSG recordings were found in nine patients (results seen in Table II). The abnormal findings included a high obstructive apnoea index, high oxygen desaturation index with oxygen saturation going down to 48 per cent in one patient, excessive tracheal sounds, ECG abnormalities including tachycardia, bradycardia episodes, ectopics in two patients, and end tidal CO_2 measurements approaching 70 mmHg. All patients remain cannulated. In our study patients with unfavourable findings tended to be of a younger age group (30 months vs 54 months), and those with longer periods of cannulation (42 months vs 21 months). It was possible to carry out the whole PSG analysis in only six out of the nine patients as the others could not tolerate the plugged tube for the whole duration of the test.

We cannot assign a predictive value to PSG data with regard to successful decannulation as all children could not be decannulated (Tunkel *et al.*, 1996).

We think, however, that polysomnography should be done while contemplating decannulation in children in order to improve the success rate and avoid the morbidity associated with the whole process of decannulating children.

Discussion

A review of the literature shows paediatric tracheostomy to be a surgical procedure with significant morbidity and mortality (Wind, 1971; Tucker and Silbesman, 1972; Hawkins and Williams, 1976; Perrota and Sehley, 1978; Rogers, 1980; Gerson and Tucker, 1982; Wetmore *et al.*, 1982; Carter and Benjamin, 1983). Complication rates are greater in children than in adults and when it comes to closing the alternate airway the problems are even greater.

Children require tracheostomies for a variety of reasons. Potential aetiologies include upper airway

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TABLE II
POLYSOMNOGRAPHIC FINDINGS (IN A GROUP OF PATIENTS DEEMED UNFIT FOR DECANNULATION BY PSG SCORES

Patient number	1	9	11	17	19	22	26	29	30
Apnoea index*	21	26	40	19	45	112	28	30	68
Obstructive events	19	17	34	12	41	80	18	22	46
Central events	2	7	2	3	1	28	4	4	16
Mixed events	0	2	4	4	3	4	6	4	6
Hypopnoea index**	47	53	68	40	56	204	44	41	72
Obstructive events	40	38	56	37	40	82	40	32	64
Central events	4	13	12	1	6	20	2	3	6
Mixed events	3	2	0	2	10	2	2	6	2
Oxygen desaturation index***	112	107	124	102	164	208	110	94	164
Minimum oxygen saturation	66	56	48	72	58	64	62	68	72
Tracheal sounds	+	+	+	−	+	+	−	−	−
ECG abnormalities									
Bradycardia (<40 beats/min)	14	12	28	7	5	21	0	2	2
Tachycardia (>120 beats/min)	0	4	2	12	4	7	4	8	8
Rhythm abnormality****	−	−	+	−	+	−	−	−	−
Mean end tidal (CO_2	48	46	42	42	50	48	46	44	50
Maximum end tidal CO_2	58	54	50	48	70	64	62	56	68

*Apnoea index: No. of apnoeic spells per hour of study.
**Hypopnoea index: No of hypopnoeic spells per hour of study.
***Oxygen desaturation index: Number of times per hour of study oxygen saturation went below 96%.
****Rhythm abnormality: Multiple ectopics were recorded.
Patients 11, 26, 29 could not undergo the full study because of inability to tolerate a full tube closure.

obstruction, respiratory failure, and the need for pulmonary toilet. Once the problem that created the need for the tracheostomy has resolved or been corrected, the decannulation process may begin.

The timing of the decannulation procedure depended on the initial indication for tracheostomy, the general health of the child, pulmonary function at time of decannulation, ability to phonate (in those children who could) around the tracheostomy cannula, and independence from the ventilator for at least six months. Radiological assessment (Scott and Kramer, 1978a,b) has been advocated to evaluate the presence of tracheal narrowing and intratracheal masses, especially granulomas. Xeroradiography can be especially helpful for outlining the exact location of a lesion within the upper airway (Scott and Kramer, 1978a,b), fluoroscopy may also be helpful to evaluate the extent of tracheomalacia.

Prior to performing PSG we evaluated all the cases for adequacy of the airway from the nasal and oral cavities to the carina. Vocal fold mobility was assessed following microlaryngoscopy and bronchoscopy. Endoscopy is routinely used to evaluate the entire airway once the decision to attempt decannulation has been made (Sasaki *et al.*, 1978; Willis *et al.*, 1987). If subglottic stenosis, tracheal granuloma or fused vocal folds are found at endoscopy, decannulation may be contra-indicated (Sasaki *et al.*, 1978). Anterior tracheal wall displacement and mucosal flaps have been mentioned as reasons for unsuccessful decannulation (Rogers, 1980). All our cases were hence taken only after complete clinical, radiological and endoscopic clearance.

In our opinion the commonest causes for failure of decannulation in children are suprastomal granulation tissue and collapse of the anterior tracheal wall. We took special care in our patients to assess and treat these two causes. In cases where a collapse was found, we worked through the tracheostomy site while visualizing and ventilating through the bronchoscope. The route was denuded of all granulation tissue and haemostasis was ensured through electrocautery. In case of collapse, the collapsed portion was grasped by a hook and sutured anteriorly. The above ensured a check on the adequacy of the lumen and the firmness of collapsed tissue. In all such cases we proceeded for downsizing only when we were satisfied with the surgical repair and a favourable airway was ensured.

Assessment of physiological readiness was reported by Mallory *et al.* (1985). In a prospective, non-randomized study, 40 children with tracheostomies, who were thought clinically ready for decannulation, were evaluated using pulmonary function testing, with flow and volume pattern analysis during awake tidal breathing. They found that successful decannulation outcome was predicted by a ratio of oral peak inspiratory flow to tracheostomal peak inspiratory flow greater than 1.4. Since they made the measurements in awake children they might have underestimated the dynamic airway obstruction created during sleep.

Tunkel and co-workers (Tunkel *et al.*, 1996) reported that they could successfully decannulate 13 out of 16 patients with favourable PSG data as compared to continuing of cannulation of seven out of eight patients with unfavourable PSG data. Patients with unfavourable PSG tended to be older than the children with favourable studies (44 vs 33 months; $p = 0.06$, non-paired student t test), and they tended to have had longer periods of cannulation (36 vs 24 months; $p = 0.06$, nonpaired student t test). We found more unfavourable results in our younger patients and those with longer periods of cannulation. Tunkel *et al.* (1996) state that PSG is useful in several ways; it provides a continuous hardcopy record of multiple physiological variables during sleep and allows a more thorough review of data than that provided by standard intensive care unit monitoring. It was also helpful to predict the efficacy of intervention, after decannulation, of nasal cannula

oxygen or applying nasal continuous positive airway pressure during the study.

In some children, despite a favourable clinical and endoscopic evaluation, decannulation fails. Earlier this was attributed to 'decannulation panic' that was said to occur because of psychological dependence on the tube. This was thought to be due to: 1) increased dead space and airway resistance, 2) tracheal collapse, 3) reduced laryngeal abductor ability (Black *et al.*, 1984). The decrease in laryngeal abductor activity when ventilatory activity is decreased and its return when its resistance is re-established has been demonstrated on a canine model (Sasaki *et al.*, 1973). When the tracheostomy cannula is removed, the dead space doubles and the airway resistance increases 300 per cent. These authors noted the loss of abduction when the airway resistance is abruptly increased, which may lead to stridor and panic. Gradual decrease in the size of the cannula allows for return of abductor function (Sasaki *et al.*, 1973). Contrary to the above reports Benjamin and Curley (1990) have found no evidence of unexplained dependence on the tube in any of the 73 infants in their series. The importance of physiology can be understood from the fact that stomal or tracheal granulations, if actively sought may exist in nearly all tracheostomies, although they may be entirely asymptomatic and require no treatment. Likewise, significant symptomatic tracheal stenosis after decannulation has been noted to occur in fewer than 25 per cent of cases (Rogers *et al.*, 1979).

We are unable to explain why the one patient who had favourable PSG data and the nine patients who had unfavourable data failed decannulation. All these patients were absolutely fit as far as protocol for readiness of decannulation was concerned, that is the airway was adequate and there was no evidence of stomal granulation tissue or tracheal wall collapse as commonly observed. Due to the above observation we are even more certain that altered physiological properties induced by the alternative airway are much more important than thought previously and the inherent weakness of muscles of the paediatric hypopharynx and larynx are compounded after tracheostomy, becoming more apparent during sleep hence PSG analysis can be a good adjunct in prognosticating the possibility of a successful paediatric decannulation.

Conclusion

Our polysomnographic analysis indicated that physiological variables are very important and addition of physiological testing of respiratory function, especially during sleep adds to the predictability of successful paediatric decannulation. A favourable result on PSG with a plugged tracheostomy tube not only complements clinical judgement, radiological clearance and endoscopic evaluation, but is the most important of all the above because of its ability to study multiple variables during sleep. With the advent of comprehensive and easily operable software PSG studies according to us should always be done, whenever paediatric decannulation is being considered.

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