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TRACHEOSTOMY IN CHILDREN: THE CHALLENGES OF DECANULATION, REVISION AND WORK PROPOSAL

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ABSTRACT

Tracheostomy (TQT) in pediatrics is a procedure that allows maintaining permeable airways and establishes prolonged mechanical ventilation. Continuous noninvasive ventilatory support (CNVS) along with mechanical insufflation-exsufflation (MIE) can always be used for patients capable of cooperating with it. Despite this, TQT continues to be indicated frequently, limiting home transfer and care, conditioning additional burden of morbidity and risks. In those with upper airway obstruction (UAO), except in <2 years, decannulation follows similar guidelines as in adults. Young children who require ventilation, even if only during sleep, cannot be decannulated to NVS if they cannot be relied on to use it via noninvasive interfaces. So, Children under age 12 should not be decannulated unless they are ventilator weaned. For adolescents and adults, the principle criteria for safe decannulation is MIE-peak exsufflation flows (MIE-EF) over 150 L / m whereas need for tracheotomy occurs when MIE-EF decrease is below 120 L / m, irrespective of the extent of ventilator dependence. The following article is a critical narrative review of different decannulation alternatives to ensure that this process can be safely carried out with effectiveness and efficiency. Patients with different ages and diseases have been considered, knowing that younger children, non-collaborative and those dependent on ventilation significantly increase the challenge.

Keywords: Tracheostomy, pediatric decannulation protocols, non-invasive ventilatory support.

INTRODUCTION

Tracheostomy (TQT) is a procedure that is performed to ensure airway patency in patients undergoing mechanical ventilation, or with upper airway obstruction (UAO), indicated both for hospitalized critical care units and in the follow-up of chronic outpatients. Despite resolving these conditions, it is related to morbidity and risks that increase the demand for the care of these patients in the healthcare network (1). In pediatrics, the main causes for its indication are pathologies such as congenital and acquired UAO, prolonged intubation, weak neuro-muscularity and poor secretion management (1,2).

The confrontation through protocols that consider the integrality of the care of these patients, especially in those

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who have ventilatory insufficiency, can achieve substantial improvements in the quality of life of the patient and their caregivers, optimizing the decannulation process (2,3). Being the first step to take this option, the choice of the ideal time for cannula removal, and the management of the newly decannulated patient with safe support actions (3).

CONTEXT AND PECULIARITIES OF THE PEDIATRIC SCENARIO

In Pediatrics, advances in ENT surgery that allow early approach to UAO, as well as the development of non-invasive ventilatory support (NIVS) and assisted cough strategies, have allowed access to therapeutic alternatives other than tracheotomy. However, it is still a preferred option to resolve airway patency, maintain mucociliary clearance and provide prolonged mechanical ventilation (PMV), indicating in more than 50% of patients, with any of these characteristics (2).

In addition, protocols are lacking to avoid TQT in patients defined as non-extubable, or in patients already with TQT and who fail in a first attempt at extubation. Decannulation is usually performed in spontaneous ventilation, independent of the patient's respiratory pump reserve (3).

The considerations of safety, ambulatory management, costs and effectiveness of a TQT are often ignored, due to decisions made in exacerbations, usually in intensive care units, where it is considered that early TQT can even be an appropriate standard of care, without considering the potential complications and increased morbidity that this entails (2,4). (Table 1).

Once TQT has been decided, there being no other management option, especially non-invasive support in children with ventilatory insufficiency, this should be seen as a temporary support strategy, until the conditions that were the reason for its indication are resolved.

The formation of a multidisciplinary work team and the implementation of a formal decannulation protocol can predict its success (2).

There is a wide variability in the frequency of success in pediatric decannulation protocols in the last 20 years, ranging from 67% to 94% (2).

In the countries with intermediate economies, a weakness is the lack of teams of professionals specialized in respiratory care techniques that minimize the risk of tracheostomizing. Currently in Chile and Paraguay, there are government programs with secured financing to deliver domiciliary PMV, which try to privilege non-invasive ventilatory assistance (5). However, there are no specific follow-up programs for patients with just a tracheostomy.

Table 1. Tracheotomy complications.

Skin and mucous lesions
Hemorrhages
Residual Granulomas
Occlusion due to secretions
Airway colonization and lung infections
Swallowing alterations
Difficulty to speak (in those under 18 months of age, absolute impossibility)
Accidental decannulation

The literature available since the 1980s establishes paradigmatic postulates that have supported the few published pediatric decannulation protocols, generally backed by expert opinion and summarized in Table 2.

The objective of this article is to propose a protocol, prepared by the review team, for the management of the decannulation of TQT in children based on the review of the available literature, including a specific decision tree for <2 years (6).

To simplify the understanding of concepts, the information has been classified into three major instances: Preparation for decannulation, decannulation process and post-decannulation monitoring.

Table 2. Decanulation Protocols.

Author / reference	Patients	Choice criteria	PN	Intervention Pre-decanulation	Decanulation Method	Post-Decanulation Intervention	Observation days	Success
	1 to 17 years / long-term tracheostomy	Resolution of the cause that led to the tracheostomy, without respiratory distress, without the need for ventilation in the last 2 months	35	Laryngoscopy	Direct decannulation	Stoma occlusion and observation with fibrolaringoscopy	2	94%
Faroux (19)	2 to 12 years / long-term tracheostomy	Patients with permeable airway found, who presented obstructive symptoms after cannulation, with decannulation failure with spontaneous ventilation	15	Laryngoscopy	Reduction and Occlusion	NIV		100%
Robinson (8)	Average age 5-9 months	Clinical criteria, without respiratory distress, adequate secretion management	28	Nasopharyngnolaringoscopy	Occlusion + PSG	Observation in critical care with oximetry	3	71,40%
Prickett (28)	Under 18	Good daytime tolerance to TQT occlusion, with good secretion management and no need for ventilatory support	46	Respiratory endoscopy	Reduction and Occlusion + PSG	Oxi-capnography	3	91%
Tunkel (9)	18 or less	Without mechanical ventilation, minimum O2 requirements, without pulmonary infection, resolved the cause that led to Tracheotomy	16	Nasopharyngnolaringoscopy PSG	Reduction and Occlusion PSG	Oxi-capnography at ICU	2	81%

Author / reference	Patients	Choice criteria	PN	Intervention Pre-decanulation	Decanulation Method	Post-Decanulation Intervention	Observation days	Success
Linda (16)	Neurosurgical patients	Stable hemodynamic state, Body temperature <38oC. SpO2> 90%. Inspired oxygen supplement less than 4 L / min. incapacity of voluntary cough through TQT	32	Measurement of tracheal secretions, Measurement of peak flow, with induced cough. Cut-off point 29 L / min	Direct decannulation	Measurement of tracheal secretions, Peak flow measurement after induced cough	3	71%
Cristea (24)	Pediatric patients (includes infants> 6m)	Tolerance of daytime occlusion at home, with no signs of respiratory distress. Good weight progress, minimum O2 requirements. No mechanical ventilation requirements. 189	189	The patient should tolerate stoma occlusion during BCF (approx. 1 min) as the lower airway is evaluated.	Direct decannulation	Nap PSG direct decannulation + oxi-capnography. If tolerated, nocturnal PSG (IAH,% SpO2 record <90%). ETCO2> 45 mmHgz 20% of total sleep time.	2	98%
Waddell (22)	Pediatric patients (0-14 y)	Upper endoscopy without obstructions	84	Laryngoscopy-FBC	Reduction and Occlusion	Clinical observation	9	79%
Morrow (27)	Children with spinal cord and brain lesions	Normal SpO2 with FiO2 <0.3. Aspiration requirement less than 1 every 4 hours. Stable adapted to home ventilation	46	Laryngoscopy-FBC	Reduction and Occlusion	PSG and ETCO2 (HAI← 2 y ETCO2 ← 50 mmHg)	2	83%
Ceriana (17)	Adult tracheotomy patients with prolonged mechanical ventilation with chronic respiratory failure and NMD.	Parameters intended to assess the ability to eliminate secretions,PaCO2 <60 mmHg, swallowing function, absence of psychiatric diseases, possibility of spontaneous breathing	108	The cough was judged if the patient could have spontaneous expectoration and PEM of at least 40 cmH2O.	Direct decannulation	Observation CCU	2	80%

PN: patients number. NIV: non-invasive ventilation. ICU: intensive care unit. ETCO2: Maximum exhaled CO2 per capnography.
NMD: neuromuscular diseases. PSG: Polysomnography. SpO2: oxygen saturation.
MEP: maximum expiratory pressure. TQT: tracheostomy. FBC: Fibrobroncoscopy. HAI: Hypnea apnea index

PREPARATION FOR DECANULATION

Although preparation for decannulation should be addressed considering the individual characteristics of each patient, we can summarize the essential clinical conditions that must be met to potentially be considered to be cannulated (Table 3) (2,7,8). This evaluation is mainly clinical and multidisciplinary. It is essential to emphasize that starting the process leading to decannulation implies the resolution of the original indication of the tracheotomy or the possibility of resorting to a new therapeutic strategy that makes it possible to safely remove the cannula. During preparation for decannulation it is important to differentiate which patients will require rehabilitation or support of specific functions (2,7).

Table 3. Checklist prior to decannulation

The cause that led to tracheostomy is overcome.
Hemodynamically stable patient.
Absence of active infection or sepsis.
Effective ventilation (with or without support).
Adequate secretion management (with or without support).
Effective and safe swallowing evaluated with FEES.
Family interview with Mental Health.

FEES: fiberoptic endoscopic evaluation of swallowing

The oxygen therapy requirement should not exclude a decannulation test as long as the child can tolerate the oxygen administered by the upper airway (9). These patients can present hypoxia by chronic hypoventilation (hypoxemia-hypercapnia), such as neuromuscular patients, in which it is necessary to prioritize the use of a ventilatory strategy, ensuring an adequate minute volume, thus normalizing hypoxemia, by eliminating excess CO2. If we were to treat these patients with oxygen, we would impede the ability to eliminate CO2, by canceling the only stimulating mechanism to resolve alveolar hypoventilation. On the other hand, the requirement of mechanical ventilation should not be an impediment for a patient to be considered potentially apt for decannulation, as long as there is a non-invasive ventilatory strategy that is tolerated by the patient (10). As has been shown, patients with insufficient or no vital capacity, who require ventilatory support 24 hours a day, achieve effective ventilation with NIVS by nasal, or oral route, having even fewer complications and better quality of life than patients with invasive ventilation mechanics by TQT (10).

Some clinical conditions require evaluating the postponement of decannulation, such as the probability of requiring spinal surgery, oral maxillofacial surgery, among others. It is not advisable to attempt a decannulation when the patient has an infectious respiratory condition, atelectasis or unresolved pneumonia and would be contraindicated if the patient is hemodynamically unstable (2). In those patients who meet the clinical conditions described above, it is necessary to evaluate the effective function of a pulmonary ventilatory pump, the proper management of secretions, the possibility of using NIVS, swallowing ability and a psychological evaluation (7,10).

EFFECTIVE VENTILATION FUNCTION

Ventilatory function is maintained by the relations between lungs, rib cage, inspiratory and expiratory muscles and the bulbar musculature that allows the protective glottal closure during swallowing and allows to achieve the period of pre-expulsion compression of the cough thus the clearance of secretions in the airway (10). It is essential to be able to make objective assessments of the effectiveness of cough, lung capacities and muscular strength (inspiratory and expiratory). Although, in children under 4 (11), as in patients with cognitive impairment, it is difficult to achieve coordinated and objective maneuvers, there are some reproducible methods, which should be considered for the diagnosis and monitoring of the patient.
Effective ventilation will depend mainly on the ability to generate a sufficient minute volume, capable of responding to the different requirements of the individual. To assess the failure of the ventilatory pump, the vital capacity (VC), the maximum inspiratory pressure index (PiMax), the nasal inspiratory pressure (Sniff) are measured.

VC: if is less than 60% of the predicted, it would be an indicator of probable respiratory sleep disorder, if it is <40%, it is very likely that there is nocturnal hypoventilation and if it is <25% it presents a high risk of diurnal hypoventilation as well (12).
PiMax: allows to evaluate the strength of the inspiratory muscles, being more sensitive than the VC, since it begins to deteriorate in earlier stages in neuromuscular patients. A value equal to or less than 25 cmH2O is associated with nocturnal alveolar hypoventilation (12).

Sniff: it is a more natural and more reproducible maneuver than the PiMax, with normal values between 80 to 100 cmH2O and can be performed in children under 4 (11).

Inspiratory forces would be an indicator of ventilatory capacity, either nasal or oral, keeping a direct correlation with the VC. A patient without the ability to perform any force will not be able to mobilize sufficient air volumes for proper ventilation. If the weakness is important, it would present a ventilatory disorder that would lead to alveolar hypoventilation (11,12). In this case, we can opt for non-invasive means for support. Tracheotomy being justified, only, in patients with upper motor neuron involvement due to dystonia or hypertonia of the supraglottic muscles or in patients with high, severe and fixed obstruction of the upper airway (3). For this reason, a fibronasolaringoscopy would be of great help, to visualize structural characteristics of the upper airway. Another accessible way to evaluate UAO, anatomically or functionally indirectly, is to measure subglottic pressure with a speaking valve during expiratory closure. If this value is less than 10 cmH2O, it would be a value that would support the decision to decannulate (13).

PROPER MANAGEMENT OF SECRETIONS

For this we will need a force capable of generating an effective cough. Which can be objectively evaluated by measuring the maximum flow or peak cough flow (PCF), of which there are reference values starting at 4 years of age (14) and the maximum expiratory pressure index (PeMax).

PFT> 160 L / min is the minimum acceptable value to ensure a minimally effective cough to produce adequate mucociliary clearance. When the PFT is <at 270 L / min, in patients older than 6, it is likely to fall below 160 L / min against a respiratory infection, so manual or mechanical assistance of cough should be ensured in these circumstances (3,15,16).

The PeMax index: has a greater relation with body weight, proposing a cut-off point equal to or greater than 40 cmH2O, to achieve an adequate expiratory effort that manages to meet basic needs (11,17).

If PFT is <160 L / min or the VC is <20% of the predicted or less than 300 ml (in patients over 30 kg), the patient cannot make sufficient efforts to generate adequate flows to generate an effective cough, presenting poor secretion management, with recurrent respiratory infections. In these cases, opting for non-invasive support could be an alternative, assisting the cough manually (15,16). When manual assisted coughing is not adequate due to the inability to hold a deep breath, whether due to bulbar insufficiency, diaphragmatic asymmetry or excess weight, cough assisted with insufflation and mechanical insufflation may be useful (3.18). Therefore, a tracheotomy would not be necessary for the management of secretions. Since the tracheotomy tube itself produces inflammation and secretions and aspiration through the cannula is not entirely effective, due to its short range, it could also generate traumatic injuries and complications. In patients with TQT it will always be preferable to perform non-invasive assisted cough maneuvers instead of direct aspiration of the tracheostomy (3, 10).

NON-INVASIVE VENTILATORY SUPPORT

Non-invasive ventilatory support (NIVS) can be used to facilitate decannulation in children who no longer need a tracheotomy, even if they present some degree of residual airway obstruction, such as obstructive sleep apnea (OSA), treatable with continuous positive pressure in the airway (Cpap) and in the most severe cases ventilatory support with positive Bilevel Positive Airway Pressure (Bipap) (19).

In turn, it can also ensure adequate ventilation in patients with muscular weakness, alternating the use of NIVS with assisted cough, either manually or with the use of mechanical assisted cough devices (10), to obtain adequate secretion management while achieving to generate exuflated flows, generated through the use of efficient MIE (PFE-MIE), thus preventing the occurrence of lower respiratory infections and atelectasis (10,18). A PFE-MIE above 150-200 LPM has been associated with neuromuscular patients (adolescents and adults) who achieved adequate mucociliary clearance after decannulation, in turn a value below 120 LPM, would be an exclusive indicator of the need of non-invasive ventilation support, being a contraindication to decannulate (10,18).

NIVS can be administered through nasal prongs or mouth masks, CPAP mask, nasal masks, as well as with the use of breathing tubes in older children (10). Patients are managed with non-invasive nocturnal ventilation, after decannulation, being able to receive support 24 hours if necessary (10). It would be according to the needs of the patient, with volumes and pressures that ensure adequate ventilation (10).

NIVS can represent a valuable tool to treat the recurrence of residual symptoms after decannulation, hypoventilation associated with residual obstructive pathology or neuromuscular weakness, as well as ensure adequate mucociliary clearance. It can facilitate the onset of tracheostomy weaning in children who have failed repeated attempts at decannulation (10,18,19).

EFFECTIVE AND SAFE SWALLOWING

For a normal swallowing function, anatomical integrity of the structures involved and appropriate sensory, motor and sequential coordination of all these components are required. The use of TQT prevents air flow through the glottis, decreases the glottic sensitivity, prevents the increase of subglottic pressure during swallowing and limits the laryngeal ascent during it (20). When there are serious disorders of swallowing, do not confuse tracheotomy as a beneficial therapeutic action to said disorder, as is gastrostomy. TQT on the contrary, worsens and hinders the development of oral rehabilitation, without impeding the risk of laryngeal penetration and transglottic aspiration of high secretions (20).

A patient fed by gastric button will continue to aspirate saliva and high secretions, with or without TQT (20). If we consider that saliva, unlike gastric contents, does not have an irritating and inflammatory pH for the larynx and that the usual flora of the mouth with adequate hygiene would not be more dangerous than the germs that would colonize a TQT cannula. Aspiration of high secretions, in a patient fed by gastric button, could be managed

with other non-invasive mechanisms, such as assisted cough (18), postural management, correct trunk-cephalic alignment and oral rehabilitation exercises (21).

Semiological classification of swallowing can be complemented with the administration of stains, which when mixed with water or foods and swallowed, reveal aspiration when stained secretions are seen coming out of the tracheotomy (20). Fiberoptic endoscopic evaluation of swallowing (FEES) allows for a thorough swallowing evaluation (20). We recommend carrying out this study before decannulating, since it includes the anatomical study of the upper airway, performing a fibrorinolaryngoscopy, which allows a direct visualization of the structures involved and a dynamic evaluation of the larynx in addition to the swallowing function with food administration of different volumes and viscosities. Its main disadvantages are that it has a blind moment when the bolus passes through the pharynx, and that it does not allow the evaluation of the esophageal phase (20). The endoscopic evaluation of swallowing with fiber optic and sensory test, fiberoptic endoscopic evaluation of swallowing -sensory testing (FEES-ST), includes the study of laryngeal sensitivity by applying pressurized air on the glottic structures to evaluate the reflex closure of these (20).

PSYCHOLOGICAL EVALUATION

The anxiety or fear of the parents to the failure of the decannulation influences the response of the child. Decannulation panic has been attributed to physiological changes in the airway at the time of decannulation, tachycardia, tachypnea, hyperventilation and choking sensation. In addition, many patients have anxiety, not only when they occlude or remove the cannula, but also when they enter the hospital. It would be advisable to include a psychological evaluation, of parents and children, during admission to decannulation and anticipate each step to follow, as well as presenting the therapeutic team, generating greater stability and tranquility, both in the child and in their caregivers (22).

DECANNULATION PROCESS

The ideal decannulation protocol must be applied by a specialized multidisciplinary team. A proposed algorithm for decannulation is detailed in Figure 1 (2, 22).

In addition, non-invasive ventilation should be available if necessary, to support the cannula removal process or as a therapeutic alternative in hypoventilation or UAO situations. These actions must be adaptable to the needs and capacities of the place (18,19).

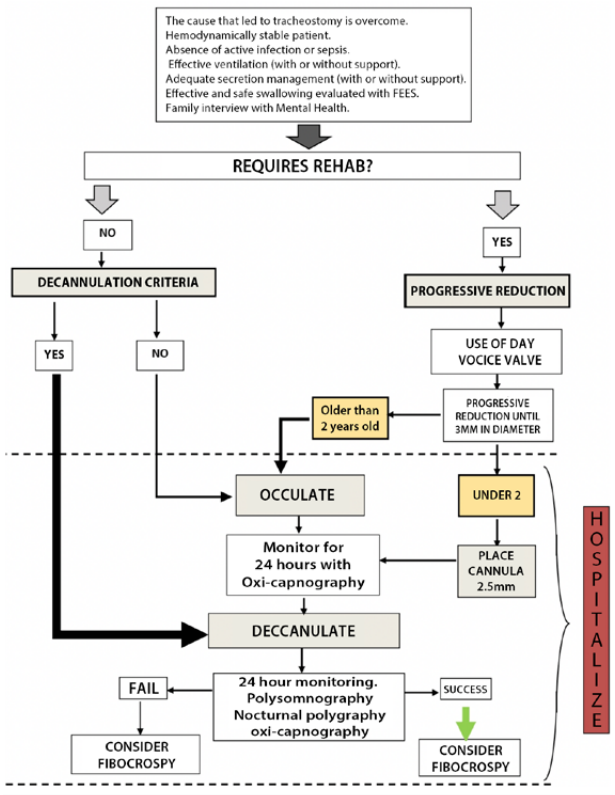
Method Customization

Within the steps to follow in a patient to decannulate, there are several ways of carrying out the process, and must adapt to the needs of each candidate (2,7).

Direct Decannulation (Table 5)

If the patient is without sequelae that hinder their proper respiratory function, if they have had a tracheotomy for a short time, with complete recovery and certainty of tolerance, does not require pressure support, they have anatomical and dynamic permeability of the upper airway (endoscopic evaluation) and subglottic pressure tolerance recording during the use of the appropriate speaking valve, they could be directly decannulated, monitoring their response at the hospital for 24 h (16, 22, 23, 24) (Table 5).

Figure 1. Decannulation protocol.



Decannulation after occlusion

If they do not meet the criteria to directly decannulate, the occlusion method is opted, which consists of complete occlusion of the TQT cannula, finding tolerance. This procedure would predict the chances of success, with an OR up to 4.76 times more than those who do not tolerate it (25). Subsequently, the cannulation is performed by monitoring the patient for another 24 h. If tolerated, follow-up could be continued on an outpatient basis (3.8).

Progressive Decannulation (Table 6)

In some cases, the progressive decrease in the diameter of the TQT is essential, alternating the use of a speaking valve that helps strengthen the supraglottic musculature as a rehabilitation strategy (2). This occurs mainly in patients who have remained long periods in critical care units or cannulated patients. Among the main benefits of reducing the diameter of the TQT is that it helps to sensitize the same structures, collaborating in the reduction of the stoma, adapting to the smaller sizes of

Table 4. Patients who do not require rehabilitation or support.

Patients with short duration in mechanical ventilation (minus 4 weeks)
Patients without muscle weakness.
If the cause of tracheostomy was due to acute obstruction of the airway by foreign body, allergic reaction, edema or infectious cause.
Patient who has had tracheostomy less than 14 days.

Table 5. Direct Decannulation Criteria.

Patient resolved the causality of tracheostomy.
Does not require pressure support.
Adequate secretion management with minimal assistance.
Anatomical and dynamic permeability with rigid fibrobronchoscopy / bronchoscopy.
Tolerance register with occlusion pressure at the subglottic closure of the speaking valve.

Table 6. Patients requiring Rehabilitation and / or Support: Progressive reduction and occlusion.

Patient with long-term mechanical ventilation.
Patient with muscle weakness.
Patient with neurocognitive disorder that affects his respiratory function.
Patient who has had tracheostomy for more than 2 weeks.
Patient under 2 years.

cannulas that allow the glottic flow. These patients require a more cautious approach, rehabilitation and special training, before occluding the cannula and decannulation.

Patients who do not require rehabilitation

This group includes patients who underwent TQT as a short-term therapeutic strategy and still maintain swallowing functions and safe and effective airway protection, without presenting muscle weakness. Children who were tracheostomized due to an acute event, such as foreign body aspiration or preventively assuming prolonged ventilation in intensive care, with complete recovery, who have not had more than 28 days of care in intensive care unit and have adequate muscle tone and strength belong in this group (Table 4) (7.23).

Patients that require rehabilitation or respiratory support

These patients are those with weakness associated with neuromuscular disease, which do not allow for effective ventilation, as well as adequate secretion management. As well as patients with weakness development and diminished muscle tone due to myopathy / polyneuropathy of the critical patient, long-term cannulas, or with long stays in critical care units, accustomed to the permanent use of TQT (7,26,9). These patients, presenting defunctionalization of supraglottic and / or subglottic structures, for long periods, generate, decrease in respiratory muscle strength and low lung volumes, which can lead to multiple complications when deciding to decannulate. As obstructive sleep apnea (OSA) due to a reduction in the tone of the pharynx and pharyngomalacia, due to dysfunction of the bulbar muscles (27). Hypotonia can also combine episodes of central hypoventilation, accompanied or not by events of obstructive hypoventilation, due to low lung volumes and a weakening of the respiratory response to hypercapnia. In addition to a possible alteration of the central impulse in patients with brain lesions (27). These patients, presenting a loss of their supraglottic functions, carry a higher risk of presenting late complications to the cannulation (24,27).

Progressive Reduction and Occlusion Method

This method is characterized by a progressive reduction of the cannula's diameter, Table 6. It is usually reduced every week, or with each cannula replacement, according to the clinical response, being able to implement rehabilitation or non-invasive support in the meantime (2 ,19). Whenever the cannula is reduced, a minimum clinical observation is advised, if possible, by related professionals, either at home or in a hospital setting to confirm tolerance to the new diameter. Complementing, from the beginning, the use of a speaking valve for progressive, diurnal periods, according to tolerance, achieving as main objective the use of the valve throughout the vigil (2). This type of procedure prepares the child for decannulation, as well as activating the functionality of the supraglottic structures, stimulating and rehabilitating complex functions of the upper airway, which require coordination (2,26).

In this period, if necessary, the patient could access therapists that allow him to train specific functions that require deeper rehabilitation. The progressive reduction also allows the adaptation of the stoma to the smallest possible size, facilitating its closure in the case of decannulation. It is recommended to reduce the diameter of the TQT to the smallest possible size

according to the patient's age. In> 2 years, this tube is 3.0 mm internal diameter (2) and once tolerance has been confirmed occlusion would be performed with 24-hour hospital observation with monitoring, if the patient does not have respiratory difficulty, the cannula would be removed evaluating tolerance for 24 h with monitoring and clinical control.

Patients under 2

In children <2 years of age, a TQT cannula would occupy a larger cross-sectional area of the airway than in older children, decreasing the effective radius of the trachea when occluded, increasing breathing resistance, and can be misinterpreted, as a sign of decannulation failure (6).

For this reason, infants under 2 years of age are a risk group with particularities that must be addressed differently.

In these patients, direct decannulation may be chosen as long as it meets the criteria (Table 5). Otherwise we can begin to make the progressive and periodic reduction of the tube diameter, similar to the above. The complex issue in these cases is that the blockage of the tube is not necessarily tolerated, even if the airway is in good condition. Keep in mind that a 3 mm blocked tube will occupy a larger proportion of the airway in younger children than in older children. At the age of 18 months, assuming a normal tracheal diameter of 7 mm, a Shiley Tube of 3 mm internal diameter (outside diameter 4.2 mm), blocked will occupy 36% of the trachea's transverse area, compared to 49% of the cross section in a 6-month-old child, with a tracheal diameter of 6 mm (6). This leads to a large increase in resistance to air flow, so the patient could respond by increasing their respiratory effort, with clinical worsening. We must consider that the ability to tolerate a blocked tube during the decannulation process is in itself a tolerance test for decannulation. If the additional obstruction of the airway caused by the presence of the tube can be tolerated, it is very likely that breathing could be modified without problems, in occasions that the demand increases, such as during exercise or in the presence of respiratory tract infections.

A modified protocol for children <2 years (6) includes a reduction of the progressive cannula of up to 2.5 mm of internal diameter. Although the 2.5 size TQT tube is available, we must consider that its light is so small that it is contraindicated for use outside the hospital, due to the danger of mucous plugging of the tube and the difficulty of suction, which can lead to a fatal complication (2). If it is tolerated for 24 hours, direct decannulation without a plugging test could be performed.

Another alternative is to perform direct decannulation, without going through the step of reducing the diameter of the cannula. This in case of high suspicion that the patient will tolerate the procedure, under the immediate supervision of a health professional who remains with the child checking tolerance for at least half an hour, and available at the hospital for the rest of the day.

FOLLOW-UP AFTER DECANULATION

Monitoring and control

Most of the evidence indicates that the observation time should be between 48 and 72 hours (28), once there is occlusion of the cannula (Table 2).

The TQT tube placed in the airway can permeabilize and stabilize any underlying area of malacia and give false assurance that the airway will not collapse, especially during sleep. The dynamics of airway pressure change following decannulation. The sudden imposition of resistance of the upper airway from the nose, tongue and pharynx can cause significant changes in the collapse of the lower airway (24,27). Unlike wakefulness that improves airway patency, its collapse becomes more pronounced during sleep, and can lead to varying degrees of obstructive hypoventilation.

In recent years, the role of polysomnography (PSG) and all-night polygraph with oxi capnography is increasingly being explored. Correlation between decannulation failure and polysomnographic values has been reported. An AHI (apnea-hypopnea index) of less than 1.7 is correlated with successful decannulation (8). Severe OSA is a contraindication of decannulation (24,27). Many children with mild and moderate OSA can be successfully decannulated (8). Maximum exhaled CO2 (ETCO2) high,> 50 mmHg or better, this tendency, during the complete sleep record> 25% is associated with decannulation failure (24,27).

A less expensive study in the evaluation prior to decannulation is a measurement of continuous expired saturometry and CO2, performed simultaneously with an oxi-capnograph or with a transcutaneous CO2 analyzer (13,30).

In those patients who have a low risk of hypotonia of the pharynx and do not present dynamic disorders to the upper airway, the subsequent controls can be just clinical and outpatient.

Successful Decannulation

Although there is still no clear consensus on the definition of success in these procedures, the literature proposes as a definition of successful decannulation the absence of consequent respiratory symptoms or alveolar hypoventilation for at least 2 weeks, after the cannula is removed (3).

Other publications have defined failure as the need to reopen tracheotomy due to an acute episode or a progressive worsening of alveolar ventilation, not corrected by the application of non-invasive mechanical mechanisms, knowing that non-invasive ventilatory support could correct hypoventilation, even in patients with 0 ml of CV, as long as we achieve a correct adaptation to the devices for use, including appropriate equipment and interfaces (10, 27).

Nevertheless, we must bear in mind that the failure in decannulation is still described in frequencies that vary from 6.5% to 21.4% (3).

Oxi-capnography follow up is necessary during the 2 weeks following the decannulation, avoiding blood gases, which regardless of being painful, may have false negatives due to secondary hyperventilation caused by the puncture. Clinical findings such as noisy breathing, low intensity of the voice and stridor should lead to late complications, unusual if they had not been foreseen with the previous assessment of the airway.

KEY RECOMMENDATIONS

There are conditions in the evolution of a child with TQT that allow for defining moments where decannulation can be raised.

The anatomical and functional permeability of the airway should be considered. The functional ventilatory reserve

and the requirement of prolonged total or only night ventilation. The primary and acquired disorders of swallowing by the same TQT and the existence of efficient cough for an appropriate mucociliary clearance.

• The patient's age, obesity, existence of neurocognitive compromise and integrity of the respiratory pump should be considered at all levels, central, neuromuscular, rib cage, spine and lung.

• Reduction / occlusion protocols in the steps prior to decannulation should be reviewed in the reality of the patient and the functional objective pursued, especially in children under 2.

• Elements of clinical, rigid and flexible endoscopic monitoring plus non-invasive monitoring of SpO2 and CO2 are currently management standards.

• New technological elements for the investigation of respiratory sleep disorders could be a contribution in individualized populations at high risk for OSA or obstructive hypoventilation in the pre-decannulation stage, such as immediate, mediate and late monitoring.

• Non-invasive ventilatory support should be included in patients with NMS, with low functional reserve for UOA, parenchymal and distal airway diseases, minimizing the risk of extubation failure immediately and in the long term.

• Therapeutic strategies should be assessed and agreed with the patients, family members and caregivers in charge, being trained in the management of each of the therapies.

• It is very difficult to think of an experimental study that allows testing different protocols and therefore, it is possible that with observational studies, protocols such as those proposed in this review can analyze different outcome variables that also include assessment of quality of life related to health, caregiver burden and expenses from the perspective of the payer, especially in countries with intermediate economies and low robust health budgets.

• Home care actions and empowerment protocols in the care of patients and their families should also be considered.

CONCLUSION

TQT has been used for years to allow breathing in patients with critical UOA and also to deliver prolonged mechanical ventilation. However, over time and with new surgical alternatives for craniofacial malformations, the use of non-invasive ventilatory support and assisted cough for patients with hypoventilation, preferably due to neuromuscular diseases, have reduced the need to tracheostomize a child and also allowed to accelerate the indication of its decannulation.

We understand that today there are multiple strategies that could replace the use of a tracheotomy, being these justified, only in extremely specific cases, supported by the decision of the patient or his family. Therefore, it is necessary to review each indication, proceeding together with the patient and their caregivers, to look for the most beneficial therapeutic option. Although there are recommendations for decannulation and its follow-up, there is no systematization of actions that can be supported with a good level of evidence, being observational studies of different clinical series those which allow through experience, to build recommendations.

The review carried out and the critical analysis of it have allowed us to make the suggestions synthesized in the proposed algorithm, as a first stage to improve the opportunity and quality of care in this population of children with special health needs and medical complexity.

Conflict of Interests:

The authors declare themselves free of any conflicts of interest, they have done so on their own accord and none of them have received money or any other financing for the realization of this bibliographical review article.

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REFERENCES

1. Charles G Durbin. Tracheostomy: Why, When, and How?. Respiratory Care 2010: 55(8); 1056-1068.
2. Watters K., Tracheostomy in Infants and Children. Respiratory Care 2017; 62 (6); 799-825.
3. Bach JR, Saporito LR. Criteria for extubation and tracheostomy tube removal for patients with ventilatory failure. A different approach to weaning. Chest 1996; 110: 1566–1571.
4. Goldenberg D, Ari EG. Tracheotomy complications: a retrospective study of 1130 cases. Otolaryngol Head Neck Surg 2000;123(4):495-500.
5. Prado F, Salinas P. Non-invasive home ventilatory assistance in children: initial impact of a national program in Chile. (Asistencia ventilatoria no invasiva domiciliaria en niños: impacto inicial de un programa nacional en Chile.) Rev Chil Pediatr 2011; 82 (4): 289-299.
6. Kubba H, Cooke J. Can we develop a protocol for the safe decannulation of tracheostomies in children less than 18 months old? Int J PediatrOtorhinolaryngol 2004; 68(7):935-937.
7. Ratender K, Sai S. The practice of tracheostomy decannulation a systematic review. Journal of Intensive Care (2017) 5:38.
8. Robison JG, Thottam PJ. Role of polysomnography in the development of an algorithm for planning tracheostomy decannulation.Otolaryngol Head Neck Surg 2015;152(1):180-184.
9. Tunkel DE, McColley SA. Polysomnography in the evaluation of readiness for decannulation in children. Arch Otolaryngol Head Neck Surg 1996; 122(7):721-724.
10. Bach JR, MD.Noninvasive Respiratory Management of Patients With Neuromuscular Disease. Ann Rehabil Med 2017;41(4):519-538.
11. Verma R, Chiang J. Maximal Static Respiratory and Sniff Pressures in Healthy Children. A Systematic Review and Meta-Analysis. Ann Am Thorac Soc. 2019 Apr;16(4):478-487.
12. Mellies U, Ragette R, Daytime predictors of sleep disordered breathing in children and adolescents with neuromuscular disorders. NeuromusculDisord. 2003 Feb;13(2):123-8.
13. Utrarachikij J Pongsasnongkul J. Measurement of End-Expiratory Pressure as an Indicator of Airway Patency above

Tracheostomy in Children. J Med Assoc Thai 2005; 88: 928-33.
14. Bianchi C, Baiardi P. Cough Peak Flows: Standard Values for Children and Adolescents. Am J Phys Med Rehabil. 2008 Jun;87(6):461-7
15. Gauld, L. M., & Boynton, A. (2005). Relationship Between Peak Cough Flow and Spirometry in Duchenne Muscular Dystrophy. Pediatric Pulmonology, 457–460.
16. Linda Y. Chan L, Jones A, Chung R, Hung K. Peak flow rate during induced cough: a predictor of successful decannulation of a tracheotomy tube in neurosurgical patients. Am J Crit Care 2010; 19: 278-28.
17. Ceriana P, Carlucci A. Weaning from tracheotomy in long-term mechanically ventilated patients: feasibility of a decisional flowchart and clinical outcome. Intensive Care Med 2003; 29: 845-848.
18. Bach JR, Giménez GC. Mechanical In-exsufflation-Expiratory Flows as Indication for Tracheostomy Tube Decannulation: Case Studies. Am J Phys Med Rehabil. 2019;98(3):e18-e20.
19. Fauroux B, Leboulanger N. Noninvasive positive-pressure ventilation avoids recannulation and facilitates early weaning from tracheotomy in children. PediatrCrit Care Med 2010;11(1): 31-37.
20. Alvo A. Olavarria C. Decannulation and assessment of deglutition in the tracheostomized patient in non-neurocritical intensive care. Acta Otorrinolaringol Esp. 2014;65(2):114-119
21. Kagaya H. Inamoto Y. Body Positions and Functional Training to Reduce Aspiration in Patients with Dysphagia. JMAJ 2011: 54(1): 35–38
22. Waddell et al. The Great Ormond Street protocol for ward decannulation of children with tracheostomy: increasing safety and decreasing cost / Int. J. Pediatr. Otorhinolaryngol. 1997; 11 I- 118.
23. Wirtz N, Tibesar RJ. A pediatric decannulation protocol: outcomes of a 10-year experience. Otolaryngol Head Neck Surg 2016;154(4):731-734.
24. Cristea AI, Jalou HE, Use of polysomnography to assess safe decannulation in children. PediatrPulmonol 2016;51(8):796-802.
25. Stelfox HT, Crimi C,: Determinants of tracheostomy decannulation: an international survey. Crit Care 2008, 12:R26.
26. Kontzoglou G, Petropoulos I, Decannulation in children after long-term tracheostomy, B-ENT. 2006;2(1):13-5.
27. Morrow MD, Tunkel MD. The role of polysomnography in decannulation of children with brain and spinal cord injuries - Pediatric Pulmonology. 2018;1–9.
28. Prickett KK, Sobol SE. Inpatient observation for elective decannulation of pediatric patients with tracheostomy. JAMA Otolaryngol Head NeckSurg 2015;141(2):120-125.
29. Gurbani N, Promyothin U. Using polysomnography and airway evaluation to predict successful decannulation in children. Otolaryngol Head Neck Surg 2015;153(4):649-655.
30. Liptzin DR, Connell EA. Weaning nocturnal ventilation and decannulation in a pediatric ventilator care program. Pediatr Pulmonol. 2016 ;51(8):825-829. doi: 10.1002/ppul.23436. Epub 2016 Apr.