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Review

Planned tracheotomy in children: indications, contraindications and preoperative assessment

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Abstract

Pediatric tracheotomy became established as a valuable procedure when Galloway reported its successful use to assist breathing in polio patients during the polio pandemic of the 1950s. Examination of the history of the procedure from its inception to the present day reveals a significant change in the indications for its execution. This is due to the achievements of neonatal and pediatric intensive care medicine, which in recent years have been able to shift the emphasis from performing it as an emergency procedure to solve an acute asphyxia problem to performing it in children, representing a complex group of patients with permanent dependence on tracheostomy and medical technologies for long-term survival related to it.

These undisputed successes have created new groups of small patients in need of tracheotomy – children with diseases requiring a multidisciplinary approach to treatment, in whom, until not so long ago, performing a tracheotomy for the purpose of maintaining life was considered pointless.

The main difference in the modern planned pediatric tracheotomy is noticeable in the reasons for its performance – congenital or acquired upper respiratory tract stenosis, neurological, cardiological and other conditions bilateral insufficiency of the vocal cords and infections of the upper respiratory tract. The indications for its implementation, on the other hand, remain unchanged – overcoming obstruction of the upper respiratory tract, need for long-term mechanical ventilation, performing a tracheobronchial lavage. Most of the children who require tracheostomy are under 1 year of age, with a higher incidence in males compared to females.

Keywords

indications for tracheotomy, pediatric tracheotomy, preoperative assessment for tracheotomy

Introduction

Although there is evidence that it originated in ancient Egypt 3600 years ago BC[1], historical records show that Asclepius performed the first documented instance of tracheotomy in ancient Rome during the second century BC. In the second century AD, Antilles again documented the technique of tracheotomy, emphasizing that the trachea should be opened at the third or fourth tracheal ring.[2] Despite these scraps of information, which are evidence of early steps in the field of tracheotomy as far back as antiquity, the first documented successful pediatric tracheotomy was performed by the Italian physician Antonio Musa Barsolva in the 16th century (1546), in order to overcome the obstruction of the upper respiratory tract caused by tonsillar hypertrophy. In 1620, Nicolas Habicot

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described four successful tracheostomies, one of which was performed on a 14-year-old boy. In 1766, Caron documented a tracheostomy performed on a seven-year-old child to remove a foreign body. Andre's reports of successfully performed tracheotomies on children in 1782 follow. In the 19th century, the procedure was often used to treat children with diphtheria – in 1825, Bretoneau performed a successful tracheotomy, saving the life of a 5-year-old girl suffering from diphtheria and taught Trousseau to perform the procedure. In 1833, Trousseau reported saving 47 children with diphtheria by performing a tracheostomy. In later years, pediatric tracheotomy was frequently used in cases with diphtheria, acute laryngitis, and laryngeal edema. Chevalier Jackson, an otolaryngologist, standardised it at the start of the twentieth century (1865–1958).[3]

There is a significant difference between the reasons and indications for performing a pediatric tracheotomy. The reasons answer the question of which disease necessitates its implementation, and the indications include the pathological condition leading to the need for it.

Nowadays, the indications for elective pediatric tracheostomy are usually related to the expectation of a long-term cardiorespiratory risk for the patient due to chronic respiratory and, in rarer cases, cardiac failure, or the presence of an upper airway obstruction that is unlikely to be resolved over a long period of time.[4,5] There are an increasing number of children with complex therapy for whom tracheostomy care and mechanical ventilation, including in the home environment, are part of their lives.

The most common reasons for placement of a tracheostomy tube in childhood are congenital or acquired airway stenosis, neurological conditions requiring long-term intubation and bronchial toilet, bilateral vocal cord insufficiency, and upper airway infections.

The decision to perform a planned tracheotomy on a child is not one that is taken lightly. A large number of children who need this surgery represent clinical cases further complicated by reasons of an ethical, financial, socioeconomic, or other nature, necessitating the application of a multidisciplinary approach to them. Unfortunately, even in cases where the onset of cardio-respiratory failure is completely predictable or the child is expected to be on long-term (lifelong) mechanical ventilation, the additional factors accompanying the need for tracheostomy often remain unappreciated until the time when the condition already requires urgent measures and decisions to be made.

It should also be noted that although it is performed in the same way in children and adults, tracheotomy is technically more difficult in children (especially in children under 1 year of age) because they have a smaller and softer trachea, the anatomical structures of the neck are located closer and are far more vulnerable, and the surgical field is smaller.

Reasons for tracheotomy in childhood

In recent years, there have been a lot of discussions about changing the indications for performing pediatric tracheotomy.[6] A reduction in the number of children tracheotomized due to acute conditions as well as an increased number of young patients tracheotomized due to reasons (diseases) necessitating the provision of an alternative airway for a prolonged period and even for life has also been noticed.

It is imperative to clarify the difference between the reasons and indications for performing tracheotomy in childhood. The reasons for its performance answer the question which disease requires it, and the indications include the pathological condition leading to its need. Strictly speaking, the main difference in modern elective pediatric tracheotomy is seen in the reasons for performing it.

In neonatology and children's intensive care units, tracheotomies are performed increasingly often in patients with anomalies of the upper respiratory tract – congenital or more often acquired because of prolonged intubation.

In recent years, there has been a worldwide increase in the number of children surviving complex medical interventions for whom tracheostomy and/or mechanical ventilation at home become part of their disease management.[5] The tracheotomy nowadays is also increasingly performed in children with chronically progressive diseases, including neurological impairment, congenital heart and lung diseases.

In childhood, the reasons for performing a tracheotomy are divided into two large and clearly distinguishable groups – congenital and acquired. The classification can also be done according to the system in which the damage leading to its need is located – respiratory, nervous, cardiovascular, trauma and burns, sepsis.

Indications for tracheotomy in childhood

Pediatric tracheotomy, as an invasive procedure, is performed to ensure an effective supply of air to the lungs. In recent years, the reasons for its performance have drastically changed and expanded, from an emergency surgery in acute respiratory distress to a planned intervention performed to ensure the patients' airway flow for the long-term. However, the indications for its performance remain unchanged – it is performed either to overcome obstruction of the upper airway, or due to the need for long-term mechanical ventilation and/or tracheobronchial toilet[1,3] **(Table 1)**. The only new and rare indication is its use as covering procedure for head and neck surgery.[7]

The main indications for performing a tracheotomy in children are:

1. Overcoming acute or chronic upper airway obstruction;

Table 1. Conditions requiring tracheotomy in childhood. (Adapted from Daniel Trachsel and Jurg Hammer; Indications for tracheostomy in children; Pediatric Respiratory Reviews 2006; 7:162–8; amended and supplemented by the authors)

Reasons and indications for tracheotomy in children, as well as examples of concomitant diseases (without conditions requiring emergent tracheotomy)	
Indications for tracheostomy	**Examples**
Upper airway obstruction	
Nasopharyngeal obstruction	Congenital bilateral choanal atresia
Subglottic stenosis	Congenital/acquired
Laryngomalacia / Tracheomalacia	Congenital/acquired
Tracheal stenosis	Congenital/acquired
Craniofacial syndromes	Pierre-Robin sequence CHARGE syndrome Goldenhar syndrome Treacher–Collins syndrome Beckwith-Wiedemann syndrome
Others	Retrognathia Glossoptosis Pharyngeal musculature collapse Epiglottitis
Craniofacial and laryngeal tumors	Cystic hygroma Hemangioma of the base of the tongue Subglottic hemangioma
Bilateral vocal cord paralysis	Hydrocephalus internus Moebius syndrome
Obstructive sleep apnea (OSA)	
Laryngeal obstruction	Laryngeal papillomatosis Laryngeal granuloma
Laryngeal trauma	Burn, fracture
Corrosive substances ingestion	Bases
Oncohematological diseases	Leukemias and lympholeukemias
Long-term ventilation/pulmonary toilet	
Pulmonary diseases	Bronchopulmonary dysplasia Scoliosis with restrictive pneumopathy Pneumonia
Congenital conditions leading to chest dysfunction	Thoracic dystrophy Giant omphalocele Idiopathic scoliosis /severe form/
Heart diseases – congenital and acquired	Postoperative diaphragmatic paresis Ventricular septal defect with aortal coarctation Atrioventricular septal defect Double right ventricular output Tetralogy of Fallot with missing valve Truncus arteriosus Ebstein's anomaly Myopathies Down syndrome Ellis Van Creveld syndrome Charge syndrome DiGeorge syndrome

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Neurological/neuromuscular diseases	Duchenne neuromuscular dystrophy
	Spinal muscular atrophy type I
	Congenital central hypoventilation syndrome
	Cerebral palsy
	Trisomy 21
	Basilar artery thrombosis
	Traumatic brain and spinal cord injury
	Spina bifida
	Guillain Barre syndrome
	Werdnig-Hoffmann syndrome
	Arnold-Chiari syndrome
	Brain tumors
	Epileptic West-undefined syndrome
	Spinal cord injury/tumor
	Meningoencephalitis
	Botulinum intoxication
Trauma and traumatic consequences	Head trauma
	Post-traumatic tetraplegia
	Tracheal rupture

2. Facilitate the care of patients requiring long-term mechanical ventilation;

3. Protection from aspiration in patients with impaired swallowing reflexes;

4. Providing access to perform a tracheobronchial toilet;

5. Prevention of laryngotracheal stenosis in patients requiring prolonged intubation;

6. Procedure accompanying surgeries of the head and neck, as well as some cardiac surgical interventions;

7. To facilitate weaning the patient from mechanical ventilation by eliminating dead space[8];

For classification of indications for tracheotomy in childhood, usually the specific cause (disease) leading to its need refers to the two large groups of indications – obstruction of the upper airway or long-term mechanical ventilation and/or performance of tracheobronchial toilet **(Tables 1, 2)**.

A global decrease in the number of tracheotomized children due to upper airway obstruction has been documented on a global scale.[5] Nowadays, the most common indication for tracheostomy is to facilitate long-term mechanical ventilation (in 82.3% of cases).

Contraindications for tracheotomy in children

There are no absolute contraindications to performing a tracheotomy on children. The most frequently mentioned relative contraindications are rather difficulties in performing the intervention. Rare relative contraindications listed in the literature are:

1. Local skin infections
2. Persistent eczemas
3. Presence of enlarged pretracheal venous plexus in patients with advanced vena cava syndrome
4. Its performance in children with mental impairment and a tendency to self-harm.

None of these reasons is a sufficient cause not to perform a tracheotomy.

Preoperative assessment for performing planned tracheotomy in children

Performing a tracheotomy in an emergency situation – to solve the problem of acute respiratory failure – is beyond question. It is performed in all patients of any age, as quickly as possible by the most experienced surgeon.

On the other hand, when we talk about planned pediatric tracheotomy, a number of additional factors must be taken into account, such as the fact that as it is increasingly often performed in children with complex chronic progressive diseases, the majority of them may need to remain with the tracheostomy for several years, if not for life, with a constant need for long-term, complex, and persistent domestic care. These aspects and their impact on the child's family should also be taken into account before tracheotomy is performed.[9] Guidance and counseling for families of such children with severe chronic conditions about what to expect long-term after tracheostomy remains a challenge.

Due to the complexity of the problems created by tracheotomy in children, the decision to perform it becomes an interdisciplinary process involving a pediatric pulmonologist, pediatric surgeon, otorhinolaryngologist, pediatric anesthesiologist-resuscitator, social worker, nurses, and last but not least, the parents (relatives) of the child whose con-

Table 2. Conditions in childhood for which tracheotomy has been advocated. (Pediatric Otorhinolaryngology, Vol. 2)

	Allergy	**Metabolic**	**Prophylactic**	**Degenerative; idiopathic**	**Sleep Disorders**
Upper airway obstruction	Angioneurotic edema, Anaphylaxis		Head and neck surgery, Neurosurgery, Cardiac surgery, Prolonged endotracheal tube placement	Vocal cord paralysis	Pharyngeal musculature collapse, Tonsilloadenoid hypertrophy
Pulmonary Toilet, Assisted ventilation	Asthma	Cystic fibrosis, coma due to diabetes, Reye syndrome, uremia, etc. Respiratory distress syndrome		Central nervous system or neuromuscular failure as in Guillain-Barré syndrome, Polymyositis, Myasthenia gravis, Botulism, Cardiac arrest, Respiratory arrest	
	Congenital	**Trauma**	**Toxic**	**Infection**	**Neoplastic**
Upper airway obstruction	Choanal atresia, Macroglossia, Cleft palate, Pierre Robin anomaly, Laryngomalacia, Laryngeal stenosis, Vocal cord paralysis, Laryngeal webs, cysts, Subglottic stenosis, Vascular ring, Tracheal hypoplasia	Facial injury, Oral injury, Foreign body, Burns (steam, smoke, thermal), Laryngeal edema, Recurrent laryngeal nerve injury, Laryngeal fracture	Corrosives	Epiglottitis, Laryngotracheitis (croup), Gingivostomatitis, Diphtheria, Retropharyngeal abscess, Ludwig angina, Neck cellulitis, Tetanus, Rabies, Plague	Laryngeal tumors, Tracheal tumors Tumors of pharynx and tongue: papilloma, hemangioma, lymphangioma, sarcoma
Pulmonary toilet, Assisted ventilation	Congenital heart disease, Congenital heart failure, Esophageal atresia due to tracheoesophageal fistula, Hypoplastic lung due to diaphragmatic hernia, Adjunct to craniofacial surgery	Head trauma, Crushed chest, Shock lung, Intrapulmonary Hemorrhage, Pneumothorax after lung bypass	Coma due to toxins (e.g.. phenobarbital), Hydrocarbon lung, Aspiration syndromes such as from meconium	Meningitis, Encephalitis, Brain abscess, Pneumonia, Bronchiolitis, Poliomyelitis, Pulmonary aspiration necessitating laryngeal closure	Brain tumors, Spinal cord tumors

sent must be obtained to perform it and who bear the main burden of caring for the tracheotomized child at home.

The role of the preoperative assessment of the child's condition is to confirm the need for tracheotomy[8], as well as to predict intraoperative and postoperative complications. It is done by an interdisciplinary team, and includes the condition of the respiratory tract – from the oral and nasal cavities to the distal bronchi, as well as assessment of the child's general condition. The preoperative evaluation of the child is important, and a prediction for the future development of its disease must be made because the type of the tracheostoma depends on that—if the condition is expected only to get worse, a permanent tracheostoma should be performed during surgery with the idea of easing the caregivers; if there is any chance for future decannulation, classical tracheotomy must be done.

The general status of the child should be assessed by the relevant specialists of the team in order to ensure optimal medical preparation of the patient for the surgical intervention.[2] Particular attention is paid to the condition of the child's neck to identify problems in advance during the tracheotomy – the short neck, the inability to palpate anatomical landmarks, the presence of scars from previous surgical interventions, the palpation of arterial pulsations in the area of the upcoming operation are indications of intraoperative difficulties that may arise.

Detailed examination of the child's airway may reveal such an obstruction, the removal of which may obviate the need for a tracheotomy. It is also performed to ensure that the tracheotomy will bypass the obstructed airway in cases where the obstruction is the cause of the respiratory problem.[8,10]

There are a number of criteria that help make this decision, and they must be considered individually in each case.

In children with diseases leading to the occurrence of a respiratory problem, it is indicated to discuss performing a planned tracheotomy if:

1. patients have little or no chance of spontaneous resolution of the breathing problem within the next few weeks.

2. the operative intervention necessitated by the underlying disease is unlikely to definitively resolve the cause leading to the respiratory problem.

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3. there is a high risk of sudden onset of severe obstruction of the upper respiratory tract during a simple respiratory tract infection or scanty bleeding.

4. there is a risk of difficulty in providing a free airway in emergency situations or there is uncontrollable gastroesophageal reflux.

In children requiring long-term mechanical ventilation and/or a tracheobronchial toilet, tracheostomy may be discussed if:

1. the patient needs mechanical ventilation for most of the day (more than 12 hours a day).

2. the patient is unable to cope/adapt to the face mask or there is an increased risk of midface deformity from the mask.

3. conditions necessitating frequent aspiration, in which the performance of a tracheobronchial toilet is of great benefit.

The decision regarding the performance of an elective tracheotomy in a child is often accompanied by a degree of ambiguity. A number of ethical problems must be considered before discussing the indications for performing a planned tracheotomy or placing the child on long-term mechanical ventilation. Physicians in many cases underestimate the change in the patient's quality of life that the performance of tracheotomy and cannulation for a long period of time or for life may lead. The doctor's vision for the patient's future treatment is often put in the foreground.

When the decision is made to perform a tracheotomy in children, its purpose should be clearly defined and explained to the parents before the operation. Sometimes this is very difficult, as often the need to perform a pediatric tracheostomy, even in children with chronic and progressive disease, is motivated by the development of an acute respiratory crisis, which does not allow for consideration of the possibility that the child may remain on continuous mechanical ventilation or with a tracheostomy for life. In such cases, the young patient and his family have no choice but to face and deal with the problems associated with the tracheostomy.

Unfortunately, even when the need for prolonged respiratory support can be foreseen, for example in children with chronic diseases that impair breathing, prolonged mechanical ventilation and the performance of a planned tracheotomy before a critical point in the child's ventilation occurs, as well as their duration – the possibility of being for life – are rarely discussed with the relatives (parents) and the child (in cases where the child is old enough for such a conversation). In many Western countries, it is routine practice not only to discuss the possibility of tracheostomy with the parents and often with the child, but also to meet other patients and families who have encountered this intervention and are coping with the challenges associated with it at home. Perhaps this is the best way, along with a visual introduction to what lies ahead, for the family to receive guidance and advice from people for whom caring for a child's tracheostomy is an everyday occurrence.

The decision to perform a planned tracheotomy in childhood must definitely be made by the parents. The role of everyone else is to help them reach a point of making that decision before the child's condition deteriorates, requiring urgent life-saving measures. Of course, parents can never be completely ready for such a challenge, but still, being aware of the upcoming changes is extremely important. Tracheotomy decision making is not usually a one-time discussion, but rather an iterative process over a course of days to weeks.[11]

From a medical perspective, obtaining informed consent from parents for performing a planned tracheotomy in childhood is essential.

The paramount significance of the decision to perform or not perform a tracheotomy in a child on mechanical ventilation, particularly in a pediatric intensive care unit, is evident from the following global statistics: more than 7% of children do not survive the hospitalization when a tracheostomy is performed, with mortality increasing to 9%–15% by the next 10 years after tracheostomy. It is important to note that less than 3% of this mortality is directly attributable to tracheostomy-related adverse events. The majority of deaths are due to complications related to the child's chronic underlying disease. According to international data sources, 15%-19% of children develop tracheostomy tube-related complication during the first 2 years. According to recent clinical studies, this percentage can reach up to 38.8%.

Discussion

In our study, we described the indications and contraindications for elective tracheotomy in childhood, and the conclusion we drew from all the data collected is that, to a large extent, these topics are clear and not difficult to follow, so that the question of whether a child in a certain condition has an indication for this operation has a clear answer in most cases. This is because the indications have been commented on for so many years that every little detail surrounding them is now well understood. They are all the same since the dawn of the medicine – it is performed to overcome obstruction of the upper airway, or due to the need for long-term mechanical ventilation and/or tracheobronchial toilet. The great change in modern times are the reasons for planned pediatric tracheotomy – a great number of diseases and conditions in which the young patients survived due to the achievements of neonatal and pediatric intensive care medicine.

The difficulty in all cases is to determine the right time to perform the operation, especially when the child has been intubated for a long time – in adults it is said that to avoid complications, the tracheotomy should be done no later than the 14th day after intubation if there is no clear idea of recent extubation, but according to the literature, children can tolerate the intubation tube for much longer – up to 90 days without severe complications, which is why in most

pediatric cases the decision of when to proceed with the operation (to insert a tracheostomy tube) is strictly individual (most studies report that the mean periods of mechanical ventilation before tracheostomy are 26 to 65 days).[8,10,11] This long period allows for a good assessment of the child's condition, especially the condition of his or her airway – conventional investigations, imaging studies (CT and/or MRI), bronchoscopic examination are all necessary steps to assess before surgery is performed and sometimes, if they are done correctly, there is an opportunity to detect and resolve a problem that will lead to the elimination of the need for a tracheotomy.

Every effort should be made to assess all problems – preoperative, intraoperative, and postoperative. A multidisciplinary team should be set up to deal with them. The team should work actively during the preparatory period with both the child who needs tracheotomy and the parents of the young patient.

Nowadays, it is an important matter, the quality of life of the patients to be evaluated too (in most cases, it is improved after tracheotomy). All the people around the child indicated for tracheotomy must be aware to the fact that their life will change – sometimes dramatically, because the care for tracheostomized child is 24/7 commitment.

Conclusions

Although the number of tracheostomies performed in childhood is increasing (compared to the adult population), it is still one of the least commonly performed procedures (less than 2%) in pediatric intensive care units.[12] Therefore, on many of the aspects related to it, a common consensus has not yet been accepted.

Even today, there are no clear international protocols for managing the need for tracheotomy in childhood and most decisions are made individually, at the bedside.

Advances in neonatal and pediatric intensive care medicine and pediatric surgery have shifted the emphasis on its use from an emergency procedure performed to resolve an acute asphyxia problem, to its performance in children with chronic progressive illness or who have undergone major surgical procedures.

The exact timing of elective tracheotomy in childhood is determined individually for each patient. Unfortunately, even when the need for long-term respiratory support can be anticipated, for example in children with chronic diseases that impair breathing, both parents and physicians usually wait until a respiratory crisis occurs and the indications for performing an elective pediatric tracheotomy change to emergency (to resolve acute respiratory distress).

During the preoperative evaluation of the child prediction for the future development of its disease must be made, and the type of the future tracheostoma must be chosen[4] – if the condition that necessitates that surgery is expected only to get worse, a permanent tracheostoma should be performed with the idea of easing the caregivers especially at home, if there are chances for future decannulation, classical tracheotomy must be done. Preoperative workup should also include precise physical examination to assess neck mobility preparing for the hyperextension necessary for the surgery. Coagulation and blood cell count studies should also be done previously. Further testing depends on each patient's comorbidities.[13]

The decision to perform a planned tracheotomy in childhood must be made by the parents, and they have to sign informed consent form to declare that.

Author contributions

Conceptualization: Stoyan Markov; methodology: Stoyan Markov; software: Stoyan Markov; validation: Stoyan Markov and Petya Markova; investigation: Stoyan Markov; resources: Petya Markova; data curation: Petya Markova; writing—original draft preparation: Stoyan Markov; writing—review and editing: Stoyan Markov and Petya Markova.

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Competing interests

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