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Review

SPECIAL CONSIDERATIONS IN PEDIATRIC TRACHEOSTOMY – A NARRATIVE REVIEW

Ana Kvolik Pavić[1,2], Luka Tabak[1,2], Ana-Maria Lazar[1,2], Josip Butković[1,2], Ivan Mumlek[1,2], Silva Gulјaš[2,3] and Vedran Zubčić[1,2]

[1]Department of Maxillofacial and Oral Surgery, Osijek University Hospital, Osijek, Croatia;
[2]Faculty of Medicine, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia;
[3]Department of Diagnostic and Interventional Radiology, Osijek University Hospital, Osijek, Croatia

SUMMARY – Surgical tracheostomy is a life-saving procedure performed for emergent or expectant airway compromise. Morbidity in the pediatric population is higher than in adults due to smaller operating field, immaturity of tissues, anatomic specificities of the child's neck, or the presence of craniofacial dysmorphism. The procedure varies among surgeons regarding the position of the skin incision (vertical or horizontal), resection of the subcutaneous adipose tissue and isthmus of the thyroid gland, use of tracheal flaps, and use of maturation or stay sutures. Both early and late complications can be life-threatening, and include accidental decannulation, stomal plugging, bleeding, and difficult ventilating. Consistent tracheostomal care is crucial in avoiding complications. Primary caregivers must be included and educated about proper stomal care. Decannulation failures are common. Prerequisites for safe decannulation include non-dependence on mechanical ventilation and no recent aspiration events, positive endoscopic airway assessment, and successful daytime capping. The role of polysomnography in decannulation protocols is debated. Although seldom performed, tracheostomy is the procedure of choice in a selected group of pediatric patients. The risks and benefits of the procedure must be weighed for each patient. The education of medical personnel and caregivers is key to reducing serious complications.

Key words: *Pediatrics; Tracheotomy; Tracheostomy, postoperative complications; Airway management*

Introduction

Adult tracheotomy is one of the most common procedures done in an intensive care unit (ICU) setting[1]. It can be performed as an elective or urgent procedure, surgically in an operating room, or percutaneously as a bedside procedure. In the pediatric population, tracheotomy is done in less than 3% of ICU patients[2].

It carries a risk of life-threatening short-term complications, as well as long-term sequels such as decannulation failure and speech impairment[3]. Indications and timing vary among institutions, and the procedure varies among surgeons on several key points[4]. Pediatric candidates for tracheotomy are few and often burdened by their primary diseases. Because of this, decision to perform tracheotomy in infants and children must be carefully weighed and made on a case-by-case basis.

In this narrative review, we will summarize available data on patients and populations, variations in procedure, most common complications, key points for tracheostomy care, and decannulation principles.

Correspondence to: *Ana Kvolik Pavić, MD,* Department of Maxillofacial and Oral Surgery, Osijek University Hospital, Huttlerova 4, HR-31000 Osijek, Croatia
E-mail: kvolik.ana@gmail.com

We will use the term tracheotomy to denote the procedure while tracheostomy stands for stoma created by the procedure.

A search of available literature was conducted on the PubMed database using a combination of the following keywords: "pediatric", "children", "infant", "tracheotomy", "tracheostomy", "complication", and "decannulation".

Population and Indications

Tracheotomy used to be performed primarily due to infectious diseases, so decannulation was an expected outcome of treatment. Because of effective vaccination protocols and the widespread use of antibiotics, infectious diseases have become less and less of a concern[5,6]. Instead, tracheotomy is now performed at a younger age because of congenital anomalies of the respiratory tract (such as in craniofacial dysmorphic syndromes), prolonged mechanical ventilation and intubation, and airway toilette[7,8].

With better pediatric ICU care, preterm infants and younger patients that may not have survived now live on prolonged ventilatory support[7,9,10]. Many of these patients are candidates for tracheotomy. This has resulted in lowering the age at which pediatric tracheotomy is performed, sometimes in infants as young as a few days. In some cases, tracheostomy is a permanent solution for airway management. Half of the pediatric tracheotomies are performed in children under one year of age, and one-third in children under one month of age[11].

Timing of tracheotomy is also debated. For adults, it is generally accepted that tracheotomy should be considered in patients after two weeks of intubation that have a reasonable chance for recovery[12]. In pediatric patients, timing of tracheotomy varies among institutions and opinions of healthcare providers. Long-term sequels of tracheostomy are not limited to tracheostomy complications (such as suprastomal collapse, granuloma formation, and decannulation failure, etc.). Tracheostomy can also impair social interactions and speech development[13]. Pediatric patients tolerate intubation better than adults, so the procedure is sometimes delayed as much as three months after intubation. However, tracheostomy can improve airway toilette[10,14], and tracheostomy is sometimes helpful in weaning pediatric patients from ventilatory support[15]. It eliminates upper airway 'dead space', thus decreasing breathing effort and making final wean safer[16].

The second peak in age is in late adolescence, mostly for patients requiring tracheotomy airway management due to cervical spine instability and trauma[5].

Surgical Features of Pediatric Tracheotomy

Surgical airway management in children is more complex than in adults. Tracheotomy is a procedure that proves that children, especially infants, are not small adults. Their tracheas are much smaller, more mobile, and pliable. Tracheal cartilage is partially covered by the hyoid bone, so palpation of anatomic landmarks cannot be accurate (Fig. 1). The narrowest part of the airway is the cricoid, which is at the C4 level (Fig. 1), as compared to C6 in adults[17]. Naturally, the airway is narrowest in neonates, measuring only 5 mm in diameter, and continues to grow linearly until late adolescence[18].

Numerous variations regarding the orientation of skin incision, excision of subcutaneous fat, resection of the isthmus of the thyroid, orientation of tracheal incision, use of tracheal flaps, stay sutures and maturation

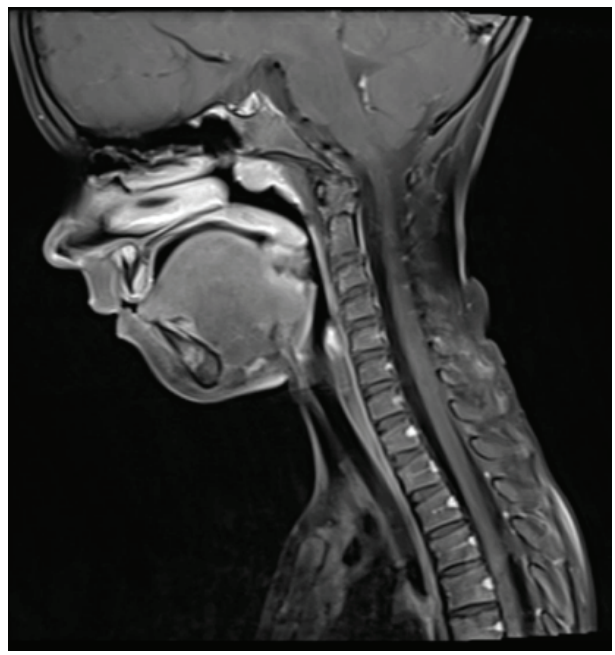

Fig. 1. Sagittal midline MRI scan of a child's neck showing position of the airway. The neck is short, the tongue is larger compared to an adult, and the larynx is located more anteriorly.

sutures exist, implying that no procedure is appropriate in every situation and universally accepted[19].

Skin incision can be oriented vertically or horizontally. Literature favors vertical incision because it allows for movement of the cannula during breathing and swallowing[20]. Some authors argue against vertical incision, as it is not esthetically pleasing[16]. Horizontal incision creates skin redundancy, especially in smaller children with copious subcutaneous fat that rests on top of the cannula and displaces its tip towards the posterior wall, which could lead to ulcerations and tracheoesophageal fistula formation[7]. Horizontal skin incision also makes changing of cannula and recannulation in case of accidental decannulation difficult.

Tracheal incision can also be vertical, horizontal, or use a flap. Vertical incision is most frequently used, but it can cause significant tracheal stenosis. The pressure of the cannula on cut edges of tracheal rings can inhibit normal healing, as seen on microscopic specimens[21]. Horizontal incision causes less tracheal stenosis, but it can be difficult to achieve in very small airways[21]. Bjork flap is also described in pediatric patients; two vertical incisions in the trachea are made and connected by a horizontal one creating a trapdoor flap that is sutured to the skin[19].

Since accidental decannulation is the most common complication in the pediatric population, most surgeons employ stay sutures that are marked 'left' and 'right' and taped to the skin[4]. They remain *in situ* until the first cannula change when they are used to bring up the trachea and slightly spread the incision site to facilitate recannulation. Maturation sutures are also sometimes used. They suture the trachea directly to the skin and 'mature' the stoma, facilitating recannulation and preventing false route insertion[19].

Koltai has described a starplasty design of tracheostoma that uses two Z-plasties to create a 3D stoma. A cross-shaped incision to the skin creates four flaps which are interdigitated with four such flaps from the trachea. This immediately creates a funnel-shaped stoma that is easy to cannulate and prevents leakage of tracheal secretion to the surrounding tissues, decreasing the chance of infection. Starplasty design is well suited for cases where the stoma is expected to be permanent but leads to persistent tracheocutaneous fistula after decannulation[22].

In adults, the percutaneous tracheotomy technique is considered safe and appropriate for a bedside procedure, replacing surgical tracheotomy in many cases. In the pediatric population, the percutaneous technique is reported only anecdotally and never routinely performed[7]. The softness of tracheal tissues predisposes this procedure to perforation of the anterior wall of the esophagus. All previous reports stress the need to perform this procedure in the operating room under bronchoscopic guidance in young children, using the same precautions as for operative tracheotomy[23]. The percutaneous technique can therefore only be considered feasible in older children.

Complications and Tracheostomy Care

The rates of complications range between 15% and 19%, while some reports claim as high as 51%[8,24,25], which is mostly due to heterogeneity of pediatric population. Mortality is highest in children under 1 year of age, while the likelihood of complication is highest in children with complex chronic conditions[26]. Hebbar *et al*. report tracheostomy accidents as a cause of one-quarter of all deaths of their study population[27]. It is important to note that most infants and children who undergo tracheotomy are burdened with other medical conditions and that reported complications are dependent upon the type of population treated in each study.

The most serious complications that immediately obstruct the airway are accidental decannulation and mucous plugging. Both can occur early postoperatively or in a mature stoma. Other early complications include subcutaneous emphysema, pneumothorax, hemorrhage, and incorrect tube placement. Late complications are hemorrhage, granuloma formation, suprastomal collapse, subglottic stenosis, failure to decannulate, skin breakdown, dysphagia, and speech problems[3].

Previously, only cuffless pediatric tracheostomy tubes were available. Air leaks from the tracheostomy site can occur in 3% to 9% of patients leading to subcutaneous emphysema, pneumothorax, and pneumomediastinum[25]. Cuffed pediatric tubes are now available as small as 2.5 mm, and offer better control of pressure and volume during mechanical ventilation[7].

Accidental decannulation can occur as early as during patient transfer from the operative room. Small tracheostomy wounds with vertical tracheal incisions are difficult to decannulate, especially in the early postoperative period when anatomic landmarks are

lost due to edema and tissue manipulation. During the first cannula change, false route tube placement can occur, so stay sutures are crucial in correct cannula replacement[7]. Mucus plugging and crusting are most common in the early postoperative period but can occur anytime, especially during a respiratory infection. Infant trachea and tracheostomy cannulas have a small diameter that is plugged more easily than the adult one. Pediatric tracheostomy cannulas also do not have an inner cannula that can be removed and cleaned when plugged. Constant irritation of the skin and airway can result in granulations that are prone to bleeding, can obstruct airways and make tube changes more dangerous.

The patient must always be closely monitored. Leaving the cannula sutured to the skin is not advised as accidental decannulation can occur without anyone noticing[28]. Stay sutures are crucial for correct cannula replacement during the first cannula change, which usually occurs around day 5. Humidifiers and air filters can prevent cannula crusting and plugging, but also make suctioning more difficult[7]. Almost one-third of pediatric patients develop some sort of skin complication in the stoma site[29]. Children's skin is softer and more susceptible to breakdown under prolonged pressure from cannula flanges and neck straps and mucosal secretion[4]. Stoma site should be monitored daily as early recognition of skin complications can reduce the number of serious adverse events. Protective skin dressing and Velcro neck straps should be used to minimize pressure-related injuries[30]. In case of stoma site infection, proper hygiene, frequent dressing changes, and topical antibiotic ointment can usually resolve the issue[31].

A key point when dealing with children is education and compliance of primary caretakers[28]. Some centers have specialized educational modules that caretakers are required to pass before patient discharge. Also, having a tracheotomy 'go-bag' (which includes everything needed for tracheostomy care such as replacement tracheostomy cannula, neck straps, and skin dressings, soft suctioning tube, etc.) improves compliance and reduces the number of tracheostomy-related adverse events[32].

Decannulation in Infants and Children

In some cases, tracheostomy is a permanent airway management solution. In others, tracheostomy is a bridge between intubation and unassisted breathing. Decannulation should be considered as soon as the underlying condition for which tracheostomy was performed is resolved[7]. The decision to decannulate a pediatric patient is complex and should not be taken lightly, as failure rates are high, varying from 6.5% to 21.4% in published literature[28].

The American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) has published recommendations for three criteria that need to be met before attempting decannulation, i.e., non-dependence on mechanical ventilation and no recent aspiration events, positive endoscopic airway assessment, and successful daytime capping of the tracheostomy tube[28].

Before attempting decannulation, the patient must be free of mechanical ventilation for three months. This could be prolonged to four months during winter when respiratory infections are common. Endoscopic airway assessment includes bronchoscopy which should show a patent airway, and flexible laryngoscopy that shows at least one mobile vocal fold or a patent glottis. If any lesions such as suprastomal granulations, enlarged tonsils, and adenoid tissue are found during airway assessment, they should be treated before decannulation[33]. A favorable finding of the patient's airway prior to the decannulation attempt increases its success rate[9]. While AAO-HNS recommends daytime capping prior to decannulation, it is not universally applied. Some authors doubt the ability of capping to truly represent the physiology of the decannulated child and highlight the possibility of stenting the malacic airway or diminishing the lumen of the trachea with a capped cannula[28,34]. Others argue that tracheostomy tube be progressively downsized to the smallest tolerable size before attempting decannulation[35,36].

Recently, polysomnography (PSG) has emerged as an alternative evaluation tool before decannulation. It evaluates various dynamic factors that influence the upper airway, such as sleep apnea, tracheomalacia, pharyngeal hypotonia and associated neuromuscular disorders, which are better evaluated during sleep when muscle tone is lower. An unfavorable PSG, evaluated through the obstructive index, apnea-hypopnea index and maximal end-tidal CO2, may predict an unfavorable outcome and prevent it[37,38]. The advantage of PSG is its noninvasive character, but the method is not widely available, and its use has not entered the mainstream.

While tracheostomy placement can be used to wean pediatric patients from mechanical ventilatory support, so can noninvasive ventilation be used to facilitate decannulation, especially in children with structural upper airway obstruction and severe sleep apnea[39].

Conclusion

Tracheostomy in the pediatric population is a procedure that can be both life-saving and improve the quality of care. It is, perhaps, underused because of the risk of serious and long-term complications that make healthcare providers cautious. Since it is seldom performed, there is no consensus regarding timing, surgical approach, aftercare, and decannulation procedure. With proper indications and with adequate preparations, the procedure is safe and effective in managing the airway of pediatric patients. Education of medical personnel and caretakers is key to early recognition and dealing with complications.

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Sažetak

SPECIFIČNA OBILJEŽJA U PEDIJATRIJSKOJ TRAHEOSTOMIJI – PREGLEDNI RAD

A. Kvolik Pavić, L. Tabak, A-M. Lazar, J. Butković, I. Mumlek, S. Guljaš i *V. Zubčić*

Kirurška traheotomija je postupak kojim se osigurava dišni put kompromitiran uslijed infektivnih bolesti, traume, tumora ili anomalija dišnih putova. Pobol je veći u pedijatrijskoj populaciji zbog malog operativnog polja, nezrelosti tkiva, anatomskih specifičnosti ili prisutnosti kraniofacijalnih dismorfizama. Procedura varira između kirurga. Ne postoji usuglašeni stav oko pozicije kožne incizije, resekcije supkutanog masnog tkiva i istmusa štitnjače, upotrebe trahealnih režnjeva ili maturacijskih šava. I rane i kasne komplikacije mogu biti životno ugrožavajuće. Najčešće su nenamjerna dekanulacija, začepljenje traheostome sluznim čepovima, krvarenje ili otežana ventilacija. Stalna briga o traheostomi je ključna u sprječavanju komplikacija. Skrbnici moraju biti uključeni i obrazovani o pravilnoj njezi stome. Neuspjele dekanilacije su česte. Preduvjeti za pokušaj dekanilacije su neovisnost o mehaničkoj ventilaciji, endoskopski pregled dišnih putova i toleriranje začepljene kanile tijekom dana. Upotreba polisomnografije u dekanilacijskom protokolu nije ušla u široku primjenu. Iako se rijetko izvodi, traheostomija je postupak izbora za zbrinjavanje dišnog puta u određenim skupinama pedijatrijskih bolesnika. Prednosti i nedostatci moraju se razmotriti za svaki pojedini slučaj. Izobrazba medicinskog osoblja i skrbnika je ključna za smanjenje broja ozbiljnih komplikacija.

Ključne riječi: *Pedijatrijska populacija; Traheostomija; Traheotomija, zbrinjavanje dišnog puta; Komplikacije*