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Pediatric tracheotomy

Michele M. Carr, DDS, MD, PhD, FRCSC

From Department of Surgery, Division of Otolaryngology–Head and Neck Surgery, Penn State College of Medicine, Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania.

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Tracheotomy in children is not a particularly complex procedure, but may be associated with a high rate of complication over time. This article reviews the indications for tracheotomy in children, describes a commonly used technique, and lists the more common potential complications.

Tracheotomy is a longstanding subject of debate in medicine. Depicted in Egyptian art as early as 3600 BC, tracheotomy did not become a staple of the medical armamentarium until the 19th century. Chevalier Jackson is credited with making tracheotomy safer by standardizing the procedure and its aftercare in the early 20th century, and subsequently, this procedure has become widely used.[1]

Nomenclature in this article utilizes *tracheotomy* as the procedure by which an opening from the skin to the trachea is made.[2]

Indications

Indications for tracheotomy have evolved, in part related to changes in disease prevalence but also in response to changes in medical materials. Vaccination programs that have eradicated diphtheria are responsible for getting rid of the most common indication for tracheotomy in the 19th century. Advances in material for endotracheal intubation—from rubber and sterling silver to polyvinyl chloride tubes—have reduced the laryngeal damage related to long-term intubation, reducing the frequency of this as an indication for tracheotomy. Also, the availability of fiberoptics to achieve intubations of difficult airways has reduced the need for emergency tracheotomies in these situations.[1]

The 2 main reasons for tracheotomy in a child are to bypass an upper airway obstruction or to provide long-term respiratory support, including pulmonary toilet.[1] Table 1 lists factors that might favor tracheotomy in these children. Over 30% of tracheotomies in children are in infants under 1 year of age, and of these, almost 30% undergo this surgery for pulmonary issues, including prematurity.[3] A second peak occurs in adolescents aged 15 to 18 years, about a third of the total pediatric tracheotomy population, almost 80% of whom require airway stabilization following trauma.[3]

A separate issue is that of prolonged intubation. In adults, it is widely accepted that the risk of laryngeal damage increases after the second week of intubation, but there is no similar process seen in children.[4] The only potential exception to this is in severely burned pediatric patients, in which the incidence of subglottic stenosis after intubation was 15% in children who underwent tracheotomy before 10 days versus 50% in those who had tracheotomy delayed after 10 days.[5] The pathogenesis of laryngeal damage in children with burns who require intubation is not known. Early tracheotomy in these cases should be considered, especially if there is evidence of upper airway inflammation.[1]

Technique

Anesthesia

Most tracheotomies are undertaken using general anesthesia, with the airway secured by either an endotracheal tube or bronchoscope.[2] Local anesthesia can be employed, with attention to maximal dosing (approximately 4 mg/kg for lidocaine). A laryngeal mask should only be used if intubation is impossible. The pediatric trachea is soft, com-

Address reprint requests and correspondence: Michele M. Carr, DDS, MD, PhD, FRCSC, Otolaryngology–Head and Neck Surgery, H091, Penn State Milton S. Hershey Medical Center, 500 University Drive, PO Box 850, Hershey, PA 17033-0850.

E-mail address: mcarr@psu.edu.

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Table 1 Factors favoring tracheotomy in children (modified from Trachsel and Hammer[1])

The child with upper airway obstruction
1. Low chance of definitive resolution within a reasonable time (weeks)
2. Low probability that surgery can definitively correct the cause
3. High risk of critical upper airway obstruction with simple URTIs or minor bleeding (for example, epistaxis)
4. High risk of or previous history of difficulties in airway management in the case of an emergency
5. Difficult to control gastroesophageal reflux
The child requiring long-term ventilation or pulmonary toilet
1. Young age, with a high risk of midfacial deformation from mask pressure
2. Ventilator dependency for more than 12 hours per day
3. Inability to cope with a mask
4. Recurrent aspiration (laryngeal incompetence, gastroesophageal reflux), with benefit from pulmonary toilet

pressible, and laterally mobile, issues that are lessened by a rigid structure in the airway.

Positioning

All esophageal tubing should be removed before positioning. A shoulder roll is placed and the neck extended to bring the trachea superiorly and position it more anteriorly (Figure 1). Plastic perforated tape is secured to the operating table and circles the chin to maintain this position. Sterile prep is placed from chin to nipples, shoulder tip to shoulder tip, and down the sides of the neck to the surface of the bed. Draping the face is most easily accomplished by using a transparent adhesive-edged drape placed under the chin and then using a split sheet to cover the patient. This way, there is some visibility for the team as the anesthesiologist withdraws the endotracheal tube just before placing the tracheotomy tube.

Skin incision and dissection

Landmarks are palpated and marked. First, the cricoid cartilage is located. It is the most prominent structure in the midline. The infant larynx is relatively higher in the neck than in adults. The suprasternal notch is marked. The skin incision is usually horizontal and located midway between the cricoid and the sternal notch in the midline (Figure 2).

Local anesthetic is injected into the planned skin incision, and then a no. 15 blade used to incise the skin. Shallow skin flaps are developed superiorly and inferiorly.

When subcutaneous fat is encountered, it is grasped with an Adson forceps and a segment is excised in the midline with a protected needle-tipped cautery. This usually reveals the fascia overlying the strap muscles. This fascia is grasped on either side of the midline and a vertical incision made with scissors. These flaps are developed, and then Senn retractors are placed on either side of the trachea to expose the dissection and stabilize the trachea.

Dissection is performed to the anterior surface of the trachea, with care taken to stay in the midline, by periodic palpation of the trachea. If the thyroid isthmus is encountered, it can be dissected from the trachea and divided with the cautery.

Tracheal incision

The trachea is well exposed using blunt dissection with a peanut dissector. Exposure is usually sufficient using the 2 Senn retractors laterally (depending on the child's size) and 2 smaller right-angle retractors superiorly and inferiorly. The cricoid cartilage is located and the rings are counted by palpating each one. A cricoid hook is typically not employed. If the anatomy dictates the need to pull the trachea superiorly, a skin hook can be placed under the cricoid cartilage, but care must be taken not to damage the cartilage. The tracheotomy is usually located at rings 3 and 4. Left and right stay sutures are placed a few millimeters away from the midline through both the third and fourth ring cartilage, but not through the airway mucosa (Figure 3). A nonabsorbable suture such as a 3-0 silk is typically used. At the end of the procedure, Steri-strip flags marked "left" and "right" are attached to these stay sutures. They are knotted at intervals to keep them in place and as a further way of differentiating left from right (for example, 3 knots on the right and 2 on the left).

At this point, however, the stay sutures are clamped and used as further stabilizers of the trachea. The anesthesiolo-

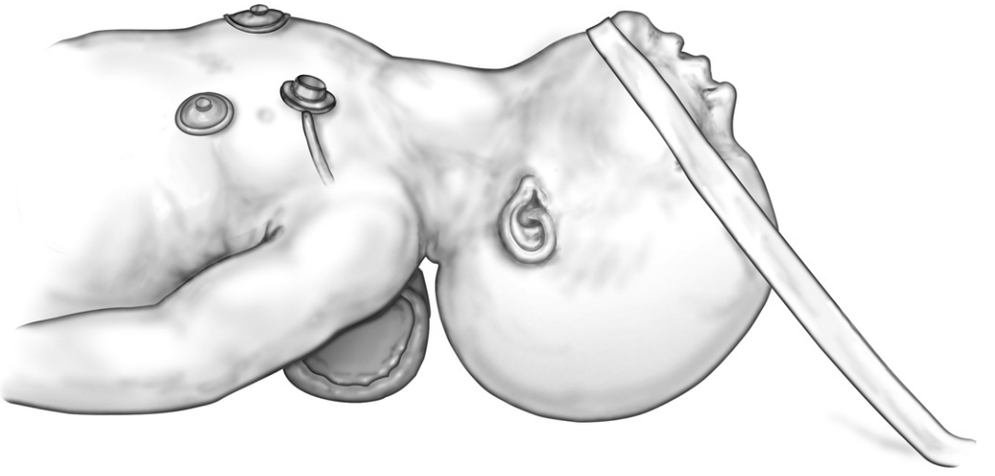

Figure 1 Positioning for pediatric tracheotomy. (Adopted from Bluestone and Rosenfeld.[2])

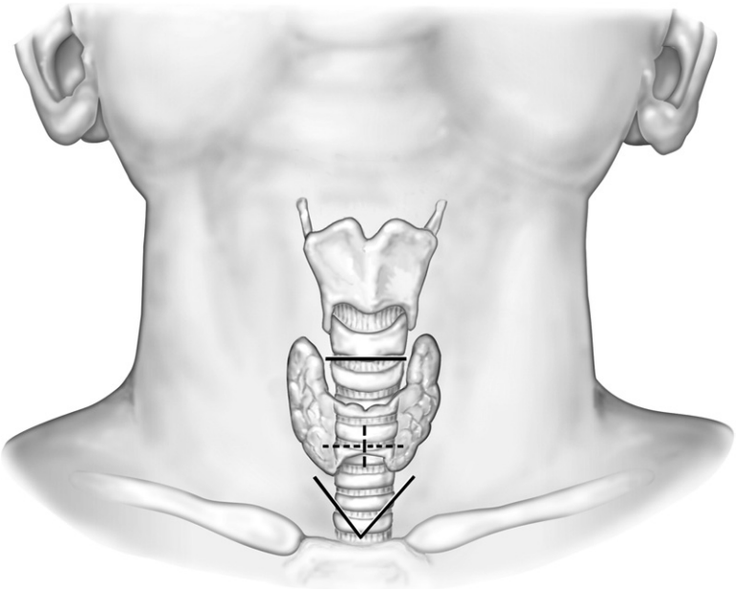

Figure 2 Landmarks and position of incision. Horizontal solid line = cricoid; horizontal dashed line = skin incision; vertical dashed line = tracheal incision; "V" line = sternal notch.

gist is alerted that the surgical team is ready to enter the airway. The tracheotomy tube is checked and the obturator placed. A no. 15 blade is used to make a vertical incision in the anterior midline of the trachea, through the third and fourth rings. The trach tube is visualized and the anesthesiologist asked to slowly withdraw it until the tip is seen at the superior aspect of the tracheal incision. The trach tube is inserted, the obturator removed, and the anesthesia circuit attached. Returned CO_2 is watched for; if a Jolley tube is used, the large dead space may make this step slower or impossible in a small infant. The endotracheal tube is left in the airway until the tracheotomy tube is completely secured.

Securing the tube

The trach tube is usually secured with twill tapes tied around the neck. There are various ways to attach the tape to the trach tube. The method we use involves looping the

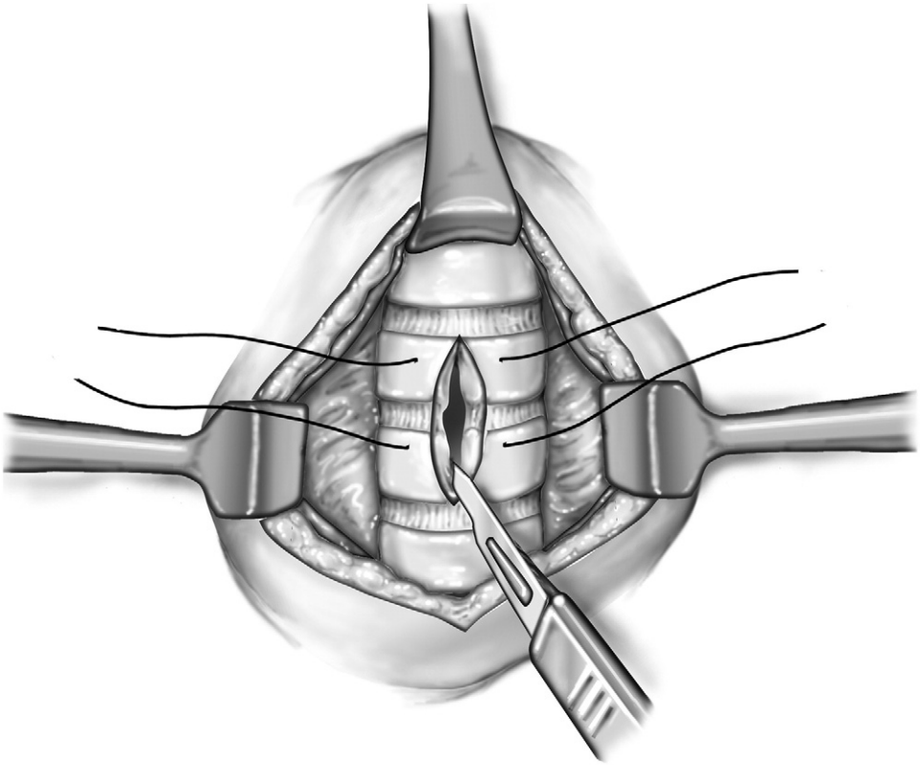

Figure 3 Stay sutures and tracheal incision. (Adapted from Bluestone and Rosenfeld.[2])

Table 2 Sample of tracheotomy tubes that may be used in children of specific age ranges

Age range	Inner diameter (mm)[12]	Outer diameter (mm) (Shiley)	Length (mm) (Shiley)	Tube size (Shiley or Bivona)
Premature <1,000 g	2.5*	4.0*	30 (NEO)*	2.5
Premature, 1,000-2,000 g	3.0	4.5	30 (NEO)	3.0 NEO
Neonate to 6 months	3.0-3.5	4.5-5.2	30-32 (NEO)	3.0-3.5 NEO
6 Months to 1 year	3.5-4.0	5.2-5.9	32-34 (NEO)	3.5-4.0 NEO
1-3 years	4.0-5.0	5.9-7.1	41-44 (PED)	4.0-5.0 PED
>3 years	(Age in years + 16)/4			

*Bivona only.

tape through 1 hole on the trach plate, carrying the 2 lengths behind the neck, feeding 1 length through the opposite trach plate hole, and tying it on the side of the neck. The ties should be fastened with the shoulder roll removed, the neck flexed, and fairly tightly, so that a small finger can still fit between the tape and the neck.

More than a third of practicing pediatric otolaryngologists in the United States also suture the trach plate to the skin, in addition to using trach ties.[6] Any nonabsorbable suture is appropriate. Usually, a keyhole nonadherent dressing is placed between the skin and the trach plate.

Once the trach tube is completely secured, the chest is auscultated to ensure that both lungs are being ventilated.

Choosing the tube

See Table 2 for suggested trach tube sizes for children of specific ages. In general, a neonatal tube is used in children under 1 year of age and a pediatric tube in older children. Endoscopy is useful to monitor tube fit.

Note that tube sizes are their internal diameter, and the external diameter is larger. In general, cuffed tubes are only used for children who require ventilation. For children with congenital anomalies, an adjustable or a custom-made tube may be necessary.

Postoperative care

Early: In hospital

Patients should have a postoperative chest x-ray to check tube positioning and rule out pneumothorax. Humidified oxygen, close monitoring, and frequent suctioning are necessary.

Emergency equipment kept at the bedside should include:

1. second tracheotomy tube, including obturator
2. a spare tracheotomy tube 1 size smaller, including obturator
3. an appropriately sized endotracheal tube
4. laryngoscope
5. scissors
6. trach ties
7. tracheal spreader
8. suction apparatus and sterile suction catheter

The first trach tube change occurs between 5 and 7 days. If the stay sutures are intact, this can be done at the bedside.

Late: At home

Home emergency equipment is similar to that listed above, except for the laryngoscope and endotracheal tube. Home humidified oxygen and a saturation monitor are also necessary.

Caregivers need training in trach care, including responding to emergencies. They should be trained in infant cardiopulmonary resuscitation.

Tracheotomy surveillance is accomplished with serial bronchoscopy at 6-month to 1-year intervals, depending on how stable the patient is and how quickly he or she is growing. The goal of this is to assess readiness for decannulation, monitor tube size, and detect complications.

Decannulation

Before decannulation, pediatric patients undergo bronchoscopy to assess patency of the airway. They have the trach downsized and capped for 24 hours, and if that is successful they are decannulated. They should be monitored for 24 to 48 hours following decannulation, at least the first day in an acute care setting.

Complications

Early complications

Bleeding

Excessive bleeding is rare, although a high innominate artery can be inadvertently damaged, with disastrous results.

Tracheoesophageal fistula

The most likely cause of esophageal damage is a deep tracheal incision in the situation where visualization is not optimal. If this occurs, the opening must be closed primarily in 2 layers. To reduce the chance of this occurring, all esophageal tubes should be removed before the procedure, with care to use the tip of the blade when the trachea is incised.

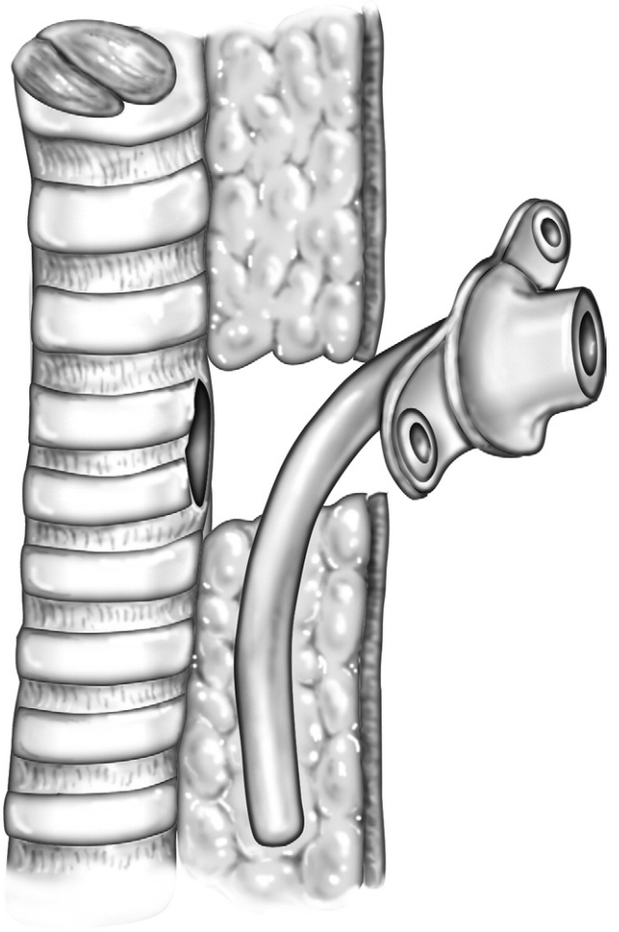

Figure 4 False passage. This shows the tracheotomy tube sitting in the pretracheal subcutaneous tissue.

Anatomic injury

The recurrent laryngeal nerves and the cricoid cartilage can be damaged if landmarks are not kept in sight during the whole procedure.

False passage (Figure 4)

This occurs when the trach tube is placed into the subcutaneous tissues anterior to the trachea and, surprisingly, may not be obvious for minutes. If the tube is allowed to remain, subcutaneous emphysema will develop, with pneumomediastinum and pneumothorax. Care to expose the trachea well before its incision and care to place the tip of the tracheotomy tube into the tracheal opening reduce the chance of development of a false passage intraoperatively. Once the patient is out of the operating room, a short, poorly secured tube, especially in an obese neck, may pop out of the trachea and into the soft tissues of the neck when the patient moves (Figure 4).

Late complications

Accidental decannulation

Accidental decannulation occurs in about 5% of patients[7] but accounts for a high proportion of early tracheotomy-related complications. Preventive measures include securing the tracheotomy tube with sutures and ties and attentive nursing care in the early postoperative period. One-on-one nursing and patient sedation for a variable length of time are employed by many hospitals. Stay sutures allow easier recannulation. Appropriate emergency equipment must be kept at the bedside.

Tracheotomy tube obstruction

This is more common in small tubes and can be avoided by frequent careful suctioning.

Tracheitis

All patients with tracheotomies will become colonized by *Staphylococcus aureus*, *Haemophilus influenzae*, *Pseudomonas aeruginosa*, and other species. Antibiotics are only indicated when the patient has signs of infection. Appropriate immunizations should be used to minimize these infections.[8]

Bleeding

Sources of bleeding include stomal granulomata, tracheal irritation related to the tracheotomy tube, and tracheal wall erosion involving the innominate artery. Preventive measures include appropriate sizing of tracheotomy tubes, humidification, and good tracheotomy hygiene. Bronchoscopy is indicated in any instance of tracheal bleeding.[8]

Tracheoesophageal fistula

This results from posterior tracheal wall erosion by the tracheotomy tube and again can be prevented by proper tube sizing and good tracheotomy hygiene.

Aspiration pneumonia

Tracheotomy can worsen aspiration. Many children who are tracheotomized are already at risk for it. Aspiration pneumonia was diagnosed in 8.5% of our patients at some point during their cannulation.[7]

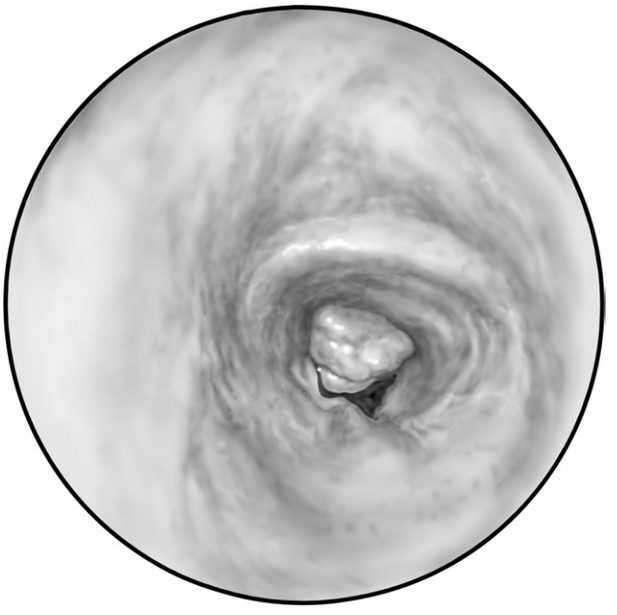

Figure 5 Small suprastomal granuloma.

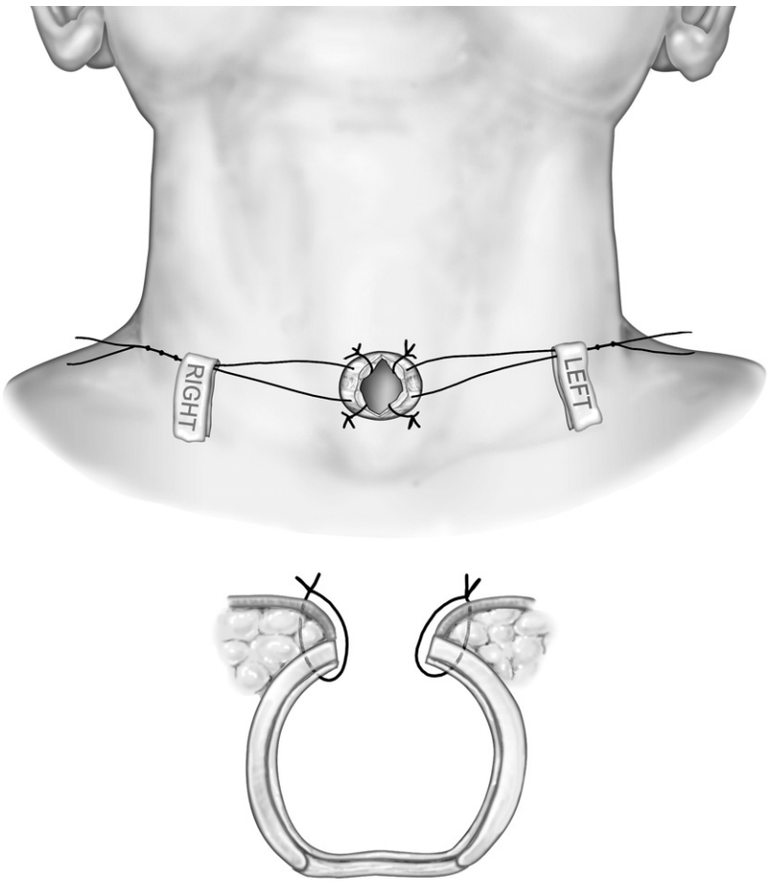

Figure 6 Securing stomal edges to skin: an alternate method. (Adapted from Bluestone and Rosenfeld.[2])

Aspiration of foreign bodies via stoma

This is not a common problem in North America. It has been reported related to tracheotomy tube breakdown (separation of the tube from the neck plate) that can occur with repeated sterilization and very-long-term tube usage.[8]

Granuloma formation (Figure 5)

In our series, this was the most common complication in children with long-term tracheotomies, occurring in about 26% of patients.[7] These are most likely to be found at the superior aspect of the stoma and do not require treatment unless they are symptomatic: bleeding, interfering with phonation, or interfering with tube changes either by blocking the tube itself or obstructing the airway. They can be removed either through a bronchoscope or via the stoma, using sharp dissection, cautery, or laser. Granulation tissue is also frequently found around the external aspect of the stoma and can be treated with silver nitrate cautery (Figure 5).[8]

Suprastomal collapse

This occurs most frequently in infants who have a tracheotomy placed and is related to inflammation and chondritis. This is relatively frequent and can even be severe enough to prevent decannulation.[8]

Subglottic or tracheal stenosis

Subglottic stenosis can occur if the cricoid becomes inflamed in a high tracheotomy or if it is damaged during surgery.[8] Tracheal stenosis is most likely to occur at the level of the tracheotomy tube tip, again related to chronic inflammation. Tracheal stenosis at the site of the stoma is decreased by using a vertical tracheal incision and not removing any cartilage.

Postdecannulation tracheocutaneous fistula

The incidence of this depends on the technique used for the tracheotomy, ranging from 3% to 89% for Koltai's starplasty technique.[9] Other factors related to persistent tracheocutaneous fistula include early age at tracheotomy and a long period of cannulation.[9] Surgery is indicated if the fistula does not close over 6 months, and in this situation an airway obstruction above the stoma must be ruled out.

Discussion

Some of the key differences between adult and pediatric tracheotomy include defatting the neck, using stay sutures to stabilize the trachea and to allow control of the stoma in the event of early accidental postoperative decannulation, and using a vertical incision to open the trachea to prevent tracheal stenosis. These are commonly done; defatting is done routinely or sometimes by 78%, stay sutures placed by 97%, and a vertical incision by 87% of pediatric otolaryngologists who replied to a recent survey.[6]

Since early accidental decannulation can be disastrous, there has been attention in the literature to securing the stoma by suturing tracheal edges to skin. The edges of the vertical tracheal incision can be sutured to the skin (Figure 6), or a Bjork flap can be fashioned. Neither is used widely.[6] Koltai[10] described and has reported on long-term follow-up of a technique he calls starplasty; a cruciate skin incision facilitates the construction of a continuous mucocutaneous suture line via the interposition of skin and tracheal flaps. Koltai's experience with starplasty indicates that the stoma stays patent even in the situation of accidental decannulation, preventing tracheotomy-related deaths, but the rate of persisting tracheocutaneous fistula is high.[11] However, at this point, only 2% of pediatric otolaryngologists who responded to a survey use this method.[6]

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