An overview of complications associated with open and percutaneous tracheostomy procedures

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ABSTRACT
Tracheostomy, whether open or percutaneous, is a commonly performed procedure and is intended to provide long-term surgical airway for patients who are dependent on mechanical ventilatory support or require (for various reasons) an alternative airway conduit. Due to its invasive and physiologically critical nature, tracheostomy placement can be associated with significant morbidity and even mortality. This article provides a comprehensive overview of commonly encountered complications that may occur during and after the tracheal airway placement, including both short- and long-term postoperative morbidity.

Key Words: Complications, open tracheostomy, percutaneous tracheostomy, review, tracheostomy

INTRODUCTION
Tracheostomy (stoma, Greek for “mouth”), denotes the formation of an artificial opening in the body’s dedicated conduit for air transit between the external atmospheric air and the lung parenchyma. It is one of the oldest surgical procedures on record, dating back as far as 3600 B.C.E. in Egypt.1 Today, tracheostomy is one of the most frequently performed procedures in the critically-ill patients, and is one of the cornerstones (in addition to surgically-placed enteral feeding tubes) that help improve the lives of patients who are ventilator-dependent or have lost their native airway (e.g., post-laryngectomy patients).2-4

As with any invasive procedure, there are numerous potential complications of tracheostomy. In general, these complications can be categorized as perioperative, postoperative, procedural, those that occur or are identified after decannulation, as well as those that are temporally considered to be early (e.g., immediate) or late.5-11 In this review, we primarily organize tracheostomy complications as procedural-related, maintenance-related, and those that occur after decannulation. We also briefly describe the technique of open surgical tracheostomy and percutaneous tracheostomy. While surgical tracheostomy complications are the focus of this review, the percutaneous tracheostomy shares many of the same risks, as well as some of its own unique complications.12,13

PREOPERATIVE CONSIDERATIONS
Indications
A surgical tracheostomy is one of the types of truly “secure” artificial airways along with endotracheal intubation. As with all artificial airways, regardless of the patient’s presenting diagnosis, there are four indications for placement: (a) Relieving airway obstruction or circumventing the loss of native airway conduit; (b) providing mechanical ventilation; (c) preventing...
Despite being a secure airway, tracheostomy should still be considered an elective/semi-elective procedure that is performed after the airway is secured initially by way of endotracheal intubation, as the mortality rate is higher for emergency tracheostomy when compared to endotracheal intubation (1−2% versus 0.05%). Although there are no absolute contraindications to tracheostomy, strong relative contraindications to elective tracheostomy include uncorrected coagulopathy, inability to tolerate the procedure (from medical perspective), certain anatomic considerations (e.g., the presence of aberrant vasculature, airway stenosis/obstruction, or tracheal fistula), recent instrumentation of the cervical spine, as well as active local inflammation or infection. In addition, some authors advocate an individualized approach to tracheostomy, taking into consideration patient-specific and technique-specific factors for different surgical approaches. Of note, the placement of cricothyrotomy, although technically similar to tracheal airway procedures, is characterized by a different (and somewhat unique) set of indications and complications. Consequently, cricothyrotomy will not be discussed in this manuscript. General types of tracheostomy devices and specially modified derivatives (e.g., for patients with neck obesity) are outlined in Tables 1 and 2.

**Procedural timing**

The question of when to perform tracheostomy on a patient with an endotracheal tube is a matter of debate in the literature. Sometimes the decision is straightforward, as in the case of permanent airway loss (e.g., total laryngectomy). However, such situations are not the norm and the decision is left upon the biases, institutional standards of care, and personal preferences of the treating practitioner. One reason that the decision for when to perform tracheostomy may be difficult to make is that there are few randomized, prospective, controlled trials comparing outcomes between early (defined as anywhere from 3 to 10 days) to late (7 to 28 days) tracheostomies. One study in the critical care setting showed that patients undergoing early tracheostomy (defined as tracheostomy within 48 h) spent less time in the intensive care unit (ICU), had shorter duration of mechanical ventilation, experienced less ventilator-associated pneumonia, and were noted to have lower mortality compared with late tracheostomy (defined as 14–16 days). Other studies provide a relatively wide array of outcomes, ranging from “no difference” to significant benefits of early tracheostomy.[20–23] Although there is no universal consensus regarding timing of tracheostomy, the most important consideration appears to be the expected length of mechanical ventilatory support. How some physicians or centers define “prolonged” or “late” is variable, but the general agreement remains regarding the recommendation that tracheostomy should be performed as early as possible in those patients who are expected to survive beyond the initial period of their acute illness and will require long-term airway access.

**OVERVIEW OF SURGICAL TECHNIQUES**

**Open tracheostomy**

Prior to beginning the procedure, it is critical to position the patient with optimal neck extension to aid in adequate exposure. A shoulder roll may be placed underneath the patient’s shoulders to accomplish this. Appropriate sterile technique is used, whether the procedure is performed in the operating room or at the bedside. The tracheostomy device should be tested prior to starting the procedure to ensure that the cuff is functional and has no air leak. The choice of a horizontal versus vertical skin incision depends upon surgeon preference. While a horizontal incision allows for improved healing and cosmesis, a vertical incision allows for extension of the incision and avoidance of the anterior jugular veins. If a horizontal incision is preferred, it is made approximately half-way between the cricoid cartilage and sternal notch (e.g., commonly two fingerbreadths above the sternal notch). Dissection is carried down through the subcutaneous tissues and the platysma muscles. Smaller vessels are cauterized, while larger vessels are ligated and divided. Once the strap muscles are encountered, they are separated in the midline and retracted laterally. Throughout this entire dissection, one should continue to

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**Table 1: Characteristics of tracheostomy tubes**

| Types of tracheostomy tubes | Special considerations |
|-----------------------------|------------------------|
| Cannula                     | Single No inner cannula |
|                             | Can be used in patients where secretions are not a major concern |
|                             | Used for airway protection and positive pressure ventilation |
|                             | Narrowing outer diameter than dual cannulas |
|                             | Dual Has inner cannula |
|                             | Used in patients with secretions |
|                             | Used for airway protection and positive pressure ventilation |
| Cuffed                      | Can be single or dual cannula |
|                             | Used in ventilated patients to create a seal |
|                             | Most commonly used in acute or short-term intubation situations |
| Cuffless                    | Can be single or dual cannula |
|                             | Used in nonventilated patients |
|                             | Long-term Patients able to swallow |
|                             | Patients able to speak |
|                             | Patients have no aspiration risk |
|                             | Used in the pediatric population |
| Fenestrated                 | Opening in back of outer cannula |
|                             | Patients breath and speak normally |
|                             | Used as a trial prior to tracheostomy removal |
| Special length              | Extra-long Considered for tracheomalacia, unusual anatomy, morbid obesity, thick necks, and copious secretions |
Cipriano, et al.: Complications of tracheostomy

Palpate the trachea below to ensure midline orientation is being maintained. A self-retaining retractor or an assistant aids in keeping the strap muscles retracted to expose the thyroid gland. Because anatomy of the thyroid varies, the next steps may involve blunt dissection of the thyroid gland superiorly or inferiorly, or may require division of the thyroid isthmus with ligation of its edges. Once the thyroid has been dissected off the trachea, the pretracheal fascia is cleared off and the trachea is now exposed.²⁴

There are many different methods of performing the tracheal incision. A cruciate incision or an inverted “U” both leave tracheal flaps, which may or may not be secured with stay sutures. Another option is to excise a portion of the tracheal ring in the shape of a square so there are no tracheal flaps. Regardless of the type of incision, the level of the tracheostomy should be at the second or third tracheal ring. The tracheal incision is made sharply with a scalpel and may be completed with the scalpel or heavy scissors as the tracheal rings may be quite calcified. An outline of potential approaches is provided in Figure 1.

Under direct visualization through tracheostomy, the anesthesiologist slowly withdraws the indwelling endotracheal tube. Once the endotracheal tube is just proximal to the newly created stoma, a tracheal spreader can be inserted to dilate the opening. The tracheostomy tube is then inserted, initially perpendicular to the trachea and then rotated 90° as it is slid down into proper position. Once the cuff is inflated, it is then connected to the ventilator and the presence of end-tidal CO₂ and bilateral breath sounds are assessed. A larger skin incision may require additional subcutaneous sutures to close the defect around the tracheostomy. The tracheostomy is secured in place with nonabsorbable sutures laterally, which may be removed in 1–2 weeks.²⁴ Step-by-step representation of the open tracheostomy placement procedure is provided in Figure 2.

### Table 2: Different extra-long tracheostomy tubes

| Type                | Manufacturer                                      | Material                        | Special features                                      |
|---------------------|---------------------------------------------------|---------------------------------|-------------------------------------------------------|
| Bivona® Hyperflex   | Smiths Medical, Dublin, OH, USA                   | Flexible silicone               | Cuffed, Single cannula, Adjustable neck flange, Wire reinforcement prevents kinking, Conformable shaft |
| Arcadia Air Cuff Adjustable | Arcadia Medical Corporation, Crown Point, IN, USA | Flexible silicone               | Cuffed, Single cannula, Adjustable neck flange, Wire reinforcement prevents kinking, Conformable shaft |
| Shiley™ TracheoSoft XLT | Covidien, Minneapolis, MN, USA                      | Semisoft polyvinyl chloride     | Cuffed, Dual cannula, Extra distal or extra proximal length |
| Tracoe Vario        | Boston Medical Products, Inc., Westborough, MA, USA | Spiral reinforced polyvinyl chloride, clear polyvinyl chloride | Cuffed or cuffless, Adjustable wings on neck flange, Wire reinforcement prevents kinking, Can have suction port above cuff |

Pericranial tracheostomy

Percutaneous tracheostomy is becoming the method of choice in many ICUs. The benefits include performance at the bedside, reduction of operating room (OR) costs, limiting patient travel, and improved healing. There are different kits available to perform a percutaneous tracheostomy, but the general steps remain consistent. First, a small incision is made about 1 cm below the cricoid cartilage and dissection is carried down bluntly with a hemostat (of note, this step is sometimes performed after the placement of the guidewire and prior to serial tract dilatations – see below). An assistant at the head of the bed then performs the bronchoscopy. The bronchoscope is advanced to the tip of the endotracheal tube, which is then slowly withdrawn as a single unit until just proximal to the level of the first or second tracheal ring. From here on, all steps of the procedure should proceed under direct bronchoscopic visualization. The introducer needle is advanced through the incision and into the trachea. Once proper placement is confirmed, a guide wire is advanced. The needle is then removed while leaving the guide wire in place. A series of dilatations are performed over the guide wire. Once dilatation is deemed satisfactory, the tracheostomy is then inserted over the guide wire or the dilator.²⁴ The tracheostomy is then connected to the ventilator and placement is confirmed. Similar to an open...
tracheostomy, it is then secured in place with sutures. There is an option to perform the procedure without the use of bronchoscopic visualization, however, this requires more thorough dissection in order to directly palpate the trachea. Step-by-step pictorial representation of percutaneous tracheostomy is shown in Figure 3. Finally, proper tracheostomy positioning is schematically represented in Figure 4.

**PROCEDURE-RELATED COMPLICATIONS**

A general overview of all commonly encountered tracheostomy complications is provided in Table 3. We will begin this portion of the manuscript with the enumeration of procedure-related morbidity.

**Pneumothorax**

Pneumothorax after tracheostomy is one of the most described complications, with an incidence as high as 17% in some reports. Higher incidence of this complication is seen in children, presumably due to their pleural domes often being located in a relatively higher position.[25] There are several proposed mechanisms explaining the pathophysiology of this complication: Direct pleural injury, air dissecting through a plane within the deep cervical fascia and into the mediastinum, or rupture of an alveolar bleb.[26] In rare cases, an inappropriately used guide wire may lead to this complication during percutaneous tracheostomy. For this reason, postoperative chest radiography is routinely ordered to ensure proper tracheostomy placement and to rule out a pneumothorax. This practice of obtaining routine chest X-rays has been called into question in adults, with the underlying premise that a pneumothorax requiring intervention will likely be clinically evident. A recent study revealed that out of 255 patients who underwent a tracheostomy, four patients (1.6%) had a new pneumothorax found on postoperative chest radiography. Only two of these patients required intervention (e.g., placement of a chest tube). It was concluded that avoidance of routine chest radiography after tracheostomy placement would help reduce costs, while not altering clinical management.[26]

**Hemorrhage**

Bleeding remains one of the most common intraoperative complications during a tracheostomy, although major hemorrhage remains rare. Typically, the source of bleeding is from the anterior jugular venous system, which if encountered is ligated and divided. Small venous branches must be controlled diligently as they can be a continued source of intraoperative and postoperative bleeding. Additionally, vessels feeding the thyroid and/or the thyroid itself may cause bleeding. Although rare,
injury to the carotid arteries or internal jugular veins may occur if one courses off midline during the dissection.[27]

**Tube/cannula misplacement**

One of the most feared complications during tracheostomy insertion is tube misplacement, resulting in loss of airway (e.g., false passage) and/or injury to surrounding structures (e.g., esophagus). During a difficult tracheostomy insertion, multiple attempts may be needed to get the tube in place. This may lead to prolonged periods of desaturation. Morbidly obese patients are at greater risk for this complication due to the increased distance from skin to trachea, which decreases visualization and allows for more subcutaneous tissue to serve as a tract for a false passage.[28] In a review published in 2005, it was noted that cannula misplacement and creation of a false passage were more common with percutaneous tracheostomies than their open equivalents.[7]

**Posterior tracheal perforation**

Laceration of the posterior tracheal wall can be a catastrophic event. Fortunately, it occurs infrequently. The membranous portion of the posterior tracheal wall may be susceptible to injury in the elderly, short-statured individuals, or patients with COPD. As it relates to tracheostomy placement, overinflation of the cuff or direct trauma from insertion of the tracheostomy with the obturator in place may cause injury to an already

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Figure 3: Percutaneous tracheostomy procedure. (a) Top row (left to right): After patient positioning with extended neck, sterile prep is applied, followed by sterile drapes and injection of local anesthetic. Bronchoscopy is then performed to visualize the airway and to appropriately (partially) withdraw the existing tracheal tube to the point at which it is above the intended anatomic level (indicated by the finger), but still sufficiently below the vocal cords. (b) Second row from top (left to right): The wire introducer needle/sheath are placed into the trachea under endoscopic visualization, followed by removal of the needle and introduction via the sheath of the introducer wire. This is followed by the performance of a small skin incision around the wire and the initial dilation with a small caliber dilator. (c) Third row from top (left to right): The large dilator is then firmly, but carefully introduced in order to prepare the tracheostomy site for the placement of the intended tracheostomy device. (d) Fourth row from the bottom (left to right): The tracheostomy device, after being tested for balloon integrity, is then introduced into the trachea under endoscopic guidance. Once in the airway, the introducer and the wire are both removed from the inner tracheostomy device lumen and replaced by the inner tracheostomy cannula. Finally, the ventilator is connected to the newly placed device. (e) Bottom row (left to right): Endoscopic verification of airway placement is at times performed, followed by the removal of the endotracheal tube and securing of the new tracheostomy device with sutures and Velcro strap.

Figure 4: Schematic representation of properly placed tracheostomy positioning.
Table 3: Summary of tracheostomy complications

| Procedure-related                                      |
|------------------------------------------------------|
| Pneumothorax                                         |
| Incidence up to 17%                                   |
| Obtain routine chest X-ray (CXR) postoperatively      |
| Hemorrhage                                            |
| Typical source of bleeding in anterior jugular veins  |
| Tube/cannula misplacement                             |
| Misplacement into false passage results in loss of airway |
| Morbidly obese patients at increased risk             |
| Potential for esophageal injury and tracheoesophageal fistula |
| Posterior tracheal perforation                        |
| Catastrophic event                                    |
| Thyroid injury                                       |
| Okay to ligate isthmus during open procedure          |
| Recurrent laryngeal nerve injury                      |
| Rare complication                                     |
| Subcutaneous emphysema                                |
| May signify underlying complication, that is, pneumothorax or tracheal injury |
| Cardiopulmonary arrest/mortality                      |
| Low incidence                                         |
| Airway fire                                           |
| Nonspecific to tracheostomy procedure itself          |
| Maintenance-related                                   |
| Cannula/tube displacement                             |
| Life-threatening complication                         |
| More worrisome of percutaneous tracheostomy because of lack of formal stomal creation and narrow tract |
| Infection                                             |
| Stomal: Usually occurs within first 24 h              |
| Necrotizing infection: Uncommon                       |
| Mediastinitis: Rare, but life-threatening             |
| Pneumonia: More susceptible to bacterial colonization of tracheobronchial tree |
| Tracheitis: infection of mucous membranes of trachea |
| Strenoclavicular osteomyelitis: Rare                  |
| Tracheoesophageal fistula                             |
| Rare, but can develop after posterior tracheal wall injury |
| Bleeding                                              |
| Delayed hemorrhage: Tracheoinnominate fistula         |
| After decannulation                                   |
| Tracheal stenosis                                     |
| Strictures in three areas: Subglottic, stoma site, or cuff site |
| Delayed closure of tracheostomy wound                 |
| Negative pressure wound therapy or vascularized flaps for aggressive treatment options |
| Cosmesis                                              |
| Tracheomalacia and tracheal granuloma                 |
| Weaking of the tracheal wall                          |
| Voice change                                          |

| Intraoperative mortality associates with tracheostomy remains relatively low. The true incidence is difficult to elucidate as this complication is often classified into a “perioperative” category and may be underreported in the literature. In a national survey published in 2012, the intraoperative mortality rate of tracheostomy was 0.4%. This was attributed to cardiopulmonary arrest and in one case, a preexisting tracheal injury. A large meta-analysis from 1999 demonstrated a significant decrease in perioperative mortality with open tracheostomy from 1985 to 1996 (3 per 10,000) compared to 1960–1984 (38 per 10,000). Recent literature has shown low perioperative mortality rates of 0.16% associated with percutaneous tracheostomies. Airway fire caused by electrocautery Although not specific to tracheostomy itself, there are vulnerabilities posterior wall. Also, while creating the anterior tracheotomy, one must take caution as to not accidentally “back-wall” the posterior side and cause an inadvertent laceration. Clinical signs and symptoms include pneumomediastinum, pneumothorax, extensive subcutaneous emphysema, and respiratory distress. If the perforation is identified at the time of the tracheostomy, it is recommended to surgically repair the injury at the index procedure. An associated esophageal injury may result as well.

Thyroid injury
Due to the anatomic location of the thyroid directly anterior to the trachea, the gland is at risk of injury during both open and percutaneous tracheostomy procedures. An open tracheostomy offers the advantage of direct visualization and ability to cauterize, divide, and/or ligate the thyroid isthmus as necessary for exposure of the trachea. Insufficient hemostasis at the time of the procedure may cause significant postoperative bleeding. However, with a percutaneous tracheostomy, there is no visualization of the thyroid gland. A study on blind placement of percutaneous tracheostomies on cadavers demonstrated that about one in three punctured the thyroid. Having said that, clinical consequences of such puncture are not universally of significance.

Recurrent laryngeal nerve proximity
The recurrent laryngeal nerves lie in the tracheoesophageal grooves. If midline is properly maintained during dissection, the nerves should not be encountered, except for cases where significant misplacement of the tracheostomy device has occurred (see earlier sections). However, tracheostomy itself may be needed when bilateral recurrent laryngeal nerve injury has occurred during another procedure (e. g., total thyroidectomy).

Subcutaneous emphysema
Subcutaneous emphysema is a complication that presents along a wide clinical spectrum (e. g., from trivial to life-threatening). Its presence may signify another underlying complication such as a pneumothorax or tracheal injury. Subcutaneous emphysema occur secondary to a disruption in the respiratory tract allowing air to freely leak into the contiguous subcutaneous spaces. This disruption may occur along the anterior or posterior tracheal wall. As it relates to percutaneous tracheostomies, the rate of subcutaneous emphysema has been reported to be approximately 1.4%. Common causes of subcutaneous emphysema during percutaneous tracheostomies include multiple punctures of the anterior trachea, excessive dilatation of the trachea, posterior tracheal lacerations, and use of a fenestrated cannula. At times, air can also dissect into the mediastinum following tracheostomy.
several reports of airway fires caused by either laser or electrocautery during tracheostomy procedures.\textsuperscript{[38-41]} Since prevention is the primary goal of eliminating the “never event” of fire in the operating theater;\textsuperscript{[42]} the focus should be on the following steps to reduce the risk of this serious complication: (a) Reducing inspired oxygen concentration during all parts of the procedure that involve direct access to the airway; (b) eliminating the use of electrocautery during any work involving directly the trachea and/or the open airway; (c) removing any other potentially flammable materials from the surgical field during the critical parts of the operation; and (d) reducing the direct exposure of the surgical field to high oxygen concentrations by limiting the duration of the airway access and exchange parts of the operation.

**TRACHEOSTOMY MAINTENANCE-RELATED COMPLICATIONS**

**Cannula/tube displacement**

Tracheostomy tube displacement is a life-threatening complication that may occur at any time during the course of the patient’s life with a tracheostomy. The reported incidence of tube displacement varies in the literature, but generally falls in the range of 0.35–2.6%.\textsuperscript{[5,43-48]} However, there have been reports of rates as high as 15%.\textsuperscript{[49]} Although the rate of tube displacement is low, inadvertent displacement carries one of the highest mortalities of any tracheostomy complication and is reported as high as 25–100%.\textsuperscript{[46,47,50]} Displacement is even more worrisome in the immediate period following percutaneous tracheostomy because of the lack of formal stoma creation and a narrower tracheocutaneous tract.\textsuperscript{[51]} Risk factors for accidental decannulation include altered mental status/delirium, increased secretions, patient turning, lack of clinically indicated restraints, a poorly secured tracheostomy tube, short neck, obese patient, large goiter obscuring normal anatomy, positive pressure ventilation with noncompliant lungs, excessive coughing, low/off midline tracheostomies, and traction on the tubing.\textsuperscript{[52,53]}

**Infectious complications**

Tracheostomy wound is considered to be clean-contaminated. The tracheostomy site is constantly exposed to contaminated oral/pulmonary secretions, making it an ideal site for bacteria to initiate an infection. Infections can be local and minor, or much more widespread and life-threatening. Several different types of infections related to tracheostomy are reported in the literature, some are much more common, while others are unique and rare.\textsuperscript{[54-56]}

**Stomal infection**

Stomal infection, including cellulitis, usually occurs after the first 24 h and is a common complication. It occurs in approximately 5% of tracheotomies.\textsuperscript{[54]} These minor infections can be the beginning of more severe and aggressive infections such as necrotizing infections and osteomyelitis. Prevention begins with aggressive and timely wound care, frequent dressing changes, regular tube changes, and humidification of inspired air.\textsuperscript{[58]}

**Necrotizing infections**

Although relatively uncommon; necrotizing fasciitis, necrotizing tracheostomy infections, and necrotizing mediastinitis have been reported.\textsuperscript{[47,55]} Snow et al., reported three cases of post-tracheostomy necrotizing infections that lead to dissolution of major portions of the trachea.\textsuperscript{[56]} Patients in that particular series were treated with oral intubation, hourly 1% neomycin dressing changes, tracheal stenting, and eventual dedicated reconstructive procedure.

**Mediastinitis**

Mediastinitis is a rare and potentially fatal result of an infected stoma site. Infection at the stoma can track down through the neck’s fascial planes (carotid space, prevertebral space, and retropharyngeal space) into the mediastinum, resulting in an infection with a high mortality rate. Chew and Cantrell have reported two instances of mediastinitis secondary to tracheostomy with one case resulting in a mortality.\textsuperscript{[57]} Tracheostomy after coronary artery bypass grafting (CABG) or median sternotomies has been shown to be associated with an increased incidence of mediastinitis;\textsuperscript{[58]} however, this is contested in the literature.\textsuperscript{[59]}

**Pneumonia**

Patients with a tracheostomy inherently have some degree of bacterial colonization of the tracheobronchial tree, making them more susceptible to nosocomial respiratory infections. Ibrahim et al., prospectively studied 3,171 medical and surgical ICU patients, showing that tracheostomy was an independent risk factor for ventilator-associated pneumonia (odds ratio of 6.71).\textsuperscript{[60]} Georges, et al. looked at the incidence of nosocomial pneumonia after tracheostomy in a single-center ICU population that included 135 patients requiring tracheostomy, finding that 26% of patients developed nosocomial pneumonia after tracheostomy and >50% of these pneumonias occurred within 5 days of the procedure.\textsuperscript{[61]} However, in the critically-ill patient who will require prolonged endotracheal intubation, it is clear that tracheostomy should be pursued and several studies support early tracheostomy (days 0–3 of mechanical ventilation) versus late tracheostomy in terms of reducing pneumonia in the ICU.\textsuperscript{[62,63]}

**Tracheitis**

Tracheitis is an inflammation or infection of the mucous membrane of the trachea. McClelland, in a large retrospective review, found 35 instances of tracheitis in
389 tracheotomies performed. These infections ranged from mild inflammation to multiple shallow necrotic ulcers. A 1999 meta-analysis of tracheostomies revealed an incidence of tracheitis that ranged from 23 to 480 per 10,000 procedures performed.

**Sternoclavicular osteomyelitis**

Osteomyelitis of the clavicle represents <3% of osteomyelitis cases, and tracheostomy is a rare etiology. Limited case reports of such events exist in the literature. In one, a misplaced tracheostomy tube that remained in the pretracheal space for 10 days caused right-sided sternoclavicular osteomyelitis and an anterior mediastinal abscess. In another report, a 64-year-old male developed a right clavicular osteomyelitis 3 weeks after tracheostomy secondary to an infected tracheostomy site.

**Tracheoesophageal fistula (TEF)**

A TEF is the development of an abnormal connection between the trachea and esophagus. It may occur secondary to injury to the posterior tracheal wall during tracheostomy creation, injury to the esophagus from gastric tubing, or erosion of the tracheostomy cuff secondary to excessive cuff pressures. It is a relatively unusual and rare complication occurring in < 1% of patients undergoing tracheostomy and is manifested by copious secretions, aspirations of food, persistent cuff leaks, or severe gastric distension. In one review of 1,130 tracheotomies, the incidence of TEF was 0.08% and was universally fatal.

**Bleeding**

Post-procedural or in situ bleeding can be classified anywhere on a spectrum from minimal oozing to massive bleeding from tracheostomy tube erosion into a major artery. The incidence of minimal oozing is surely underestimated because there is undoubtedly many instances of mild oozing that resolve spontaneously or with local pressure and not sufficiently documented. Ciaglia and Graniero reported three instances of “minimal ooze” in 165 patients undergoing percutaneous dilatational tracheostomy. A meta-analysis by Dulguerov et al., reported the rate of “minor, external hemorrhage” to be 193–253 per 10,000 patients undergoing tracheostomy. A review of the literature shows numerous ways to control external hemorrhage including local pressure, light packing with adrenaline, tranexamic acid-soaked gauze packs, suture ligation, and gelfoam packing.

Delayed tracheal hemorrhage from tube erosion into a major artery is a feared complication of tracheostomy, and the classic type described is that of a tracheointiminate fistula. The innominate artery crosses the anterolateral surface of the trachea at the level of the ninth tracheal ring and the upper sternum. If the tracheostomy tube is placed below the third tracheal ring, the inferior portion of the cannula may damage the tracheal mucosa and eventually erode into the artery. This complication occurs in less than 1–2% of patients and as much as 50% of all tracheal bleeding occurring > 48 h after surgery are caused by tracheoinnominate fistula. Even with appropriate management, only 25% of patients survive this dreaded complication. The majority of tracheoinnominate bleeds (75%) will occur within 3–4 weeks of tracheostomy placement. Although tracheoinnominate fistula bleeds are the most widely feared and taught, fistulas developing between other major arteries such as the inferior thyroid artery or an anomalous carotid artery have also been described.

**COMPLICATIONS SEEN AFTER DECANNULATION**

**Tracheal stenosis**

Perhaps the most clinically significant complication seen following decannulation is tracheal stenosis, or an abnormal narrowing of the tracheal lumen. Strictures can develop in three main regions of the airway: Subglottic, at the stoma site, or at the cuff site. Stomal stenosis develops secondary to bacterial infection and local inflammation and is very common. Stomal narrowing can be found in up to 31–85% patients after tracheostomy, however, only 3–12% demonstrate clinically important stenosis that ultimately requires intervention. Risk factors for development of tracheal stenosis at the stoma site are sepsis, stomal infection, hypotension, advanced age, male gender, steroids, tight fitting or oversized cannula, excessive tube motion, prolonged placement, and disproportionate excision of anterior tracheal cartilage during tracheostomy creation. A multi-institutional review by Halum et al., interestingly found obesity to be a significant risk factor for stenosis increasing the rate from 0.4% in nonobese patients to 9.9% in patients with a body mass index >30.

Stenosis at the cuff site is related to pressure necrosis secondary to the associated ischemic changes. This occurs when cuff pressure exceeds perfusion pressure of the capillaries of the tracheal wall. Stenosis at the cuff site was a major complication of tracheostomy in the 1960s when small volume, high pressure cuffs were used. The introduction of high-volume, low-pressure cuffs has decreased the incidence by about 10-fold. Risk factors for the development of cuff-site stenosis include female sex, older age, prolonged tube placement, and excess cuff pressure.

**Delayed closure of tracheostomy wound after decannulation**

A meta-analysis of 17 studies performed between 1960 and 1984 showed the rate of delayed cutaneous closure
to be 38 per 10,000 procedures performed. Due to the potentially severe consequences of the failure of the tracheostomy wound to heal, aggressive treatment approaches have been advocated, including negative pressure wound therapy and even vascularized tissue flaps in refractory cases.

Cosmetic deformities

While it may seem to be a minor complication to the surgeon, cosmetic deformities can be very distressing to the patient. A meta-analysis performed by Dulguerov et al. demonstrated the rate of keloid scars to be as high as 22 per 10,000 tracheostomies, and the rate of “unesthetic scars” of up to 36 per 10,000 procedures.

Tracheomalacia and tracheal granuloma

Tracheomalacia and tracheal granulomas represent obstructive tracheal lesions that form in the presence of long-term tracheostomies. Granulomas occur with frictional trauma from the tube, secondary infections, or stasis of secretions at the entry site of the tube. Tracheomalacia is a weakening of the tracheal wall due to ischemic injury and destruction of tracheal cartilage. This weakening causes a collapse of the trachea during expiration, resulting in air trapping and corresponding expiratory flow limitations. In prospective studies, these obstructive lesions are found in 20–64% of subjects with long-term tracheostomies.

Voice changes

Ambesh et al., reported three instances of voice change 8 weeks after decannulation among 30 patients undergoing percutaneous tracheostomy. The change in voice quality may be distressing to the patient and/or those who interact with the patient. Consequently, this likely underreported complication should be given more consideration by surgical specialists who perform tracheostomy procedures.

CONCLUSION

Tracheostomy is one of the most frequently performed operations in the critically-ill, and sound knowledge of its indications, operative techniques, risks, and complications is crucial for the performing surgeon. The procedure is associated with a number of potential morbidities, which can classically be divided into immediate, maintenance-related, and post-decannulation complications. The list of complications may appear formidable, but this should not prevent the surgeon from performing a tracheostomy in a patient who clearly stands to benefit from one. This review provided a comprehensive examination of tracheostomy complications, placing particular emphasis on prompt identification and preventive strategies.

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Conflicts of interest
There are no conflicts of interest.

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