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Techniques of surgical tracheostomy

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Tracheostomy, from the Greek *tracheo* plus *stoma* (mouth), strictly defined as the creation of a opening in the trachea by suturing the skin of the neck to the tracheal mucosa, has come to describe the placement of a tube through the anterior neck into a tracheotomy, or incision in the trachea. Though there is evidence supporting the possibility that tracheostomies date back to 3000 years BC [1], Asclepiades in the first century BC clearly described their use for the relief of upper airway obstruction, the principal indication for the next 2000 years [2]. A surge in the performance of tracheostomy in the eighteenth and nineteenth centuries during the diphtheria epidemic resulted in improvements in the technique, but mortality in this setting was 73% [3]. Jackson, with his description of the technique in 1909, is credited with the establishment of the modern tracheostomy as a safe and important part of the surgeon's armamentarium [4].

The advent of mechanical ventilators and intensive care units in the 1950s drove a shift in the primary indication for tracheostomy from emergent relief of obstruction to elective support for prolonged ventilator dependence. These innovations also prompted a dramatic increase in the use of tracheostomies [5]. Such increased use of the procedure in the critically ill patient, and the evaluation of associated complications, forced refinement of surgical technique and tracheostomy tube design, and served as the impetuses for the development of new, simpler approaches. Toy and Weinstein introduced the percutaneous tracheostomy in 1969 [6]. Their technique was modified by Ciaglia in 1985 into the modern percutaneous dilational tracheostomy [7], the preferred method of bypassing the upper airway in some centers.

This article focuses on surgical tracheostomy: the indications, techniques and complications of one of the most commonly performed procedures in contemporary critical care medicine.

Indications and timing

Despite its long history and frequent use, the indications and timing for tracheostomy remain controversial. As with all surgical procedures, the potential benefits to the patient must be carefully weighted against the risks. The comorbidities and variability of presentation of patients requiring prolonged ventilatory support make establishing a set of rules governing the use of tracheostomies difficult. Aside from those patients requiring permanent tracheostomy following laryngectomy, tracheostomy is indicated for relief of upper airway obstruction, for management of uncontrolled tracheobronchial secretions, and most commonly for prolonged mechanical support due to respiratory insufficiency [8]. The development of fiberoptic bronchoscopy, laryngeal mask airways, and translaryngeal endotracheal intubation allowed for development of the elective tracheostomy. Creation of an emergent surgical airway is now usually precipitated only by severe maxillofacial or laryngeal trauma or significant inhalation injury. Other causes of airway obstruction which may require a tracheostomy include oropharyngeal tumors, severe angioneurotic edema, bilateral vocal cord paralysis, short segment tracheomalacia, edema of the airway from infection or surgery, foreign bodies, and sleep apnea or the Pickwickian syndrome in the morbidly obese [8]. In patients with an ineffective cough or excessive

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secretions related to bronchiectasis, chronic pneumonia, or neurologic or laryngeal dysfunction, tracheostomy allows for effective pulmonary toilet [5].

The most common yet least clearly defined indication for tracheostomy is the requirement for prolonged mechanical ventilatory support due to respiratory failure. The potential advantages of tracheostomy in this setting include provision of a more stable airway, protection against laryngeal injury, improved pulmonary toilet and oral hygiene, a decreased requirement for sedation or restraints, facilitated ventilator weaning, potential for a shorter intensive care unit stay, improved patient comfort, and the potential for speech and oral feeding [9].

Although it is generally agreed upon that conversion of an endotracheal tube to a tracheostomy is indicated at some point during a critical illness, opinions regarding the optimal timing and technique for the procedure vary widely. Despite the large body of literature addressing these issues, problems with study design, the complexity and heterogeneity of the patient population, differing practice patterns, and differing operative techniques and complication rates have confounded the search for an answer to the question of timing [10]. Analysis of available information allows one to draw some conclusions. It is known that intubation, whether translaryngeal or via tracheostomy, results in ischemia, ulceration, and subsequent stenosis at pressure points between the tube, its cuff, and the tracheal mucosa. The introduction of high-volume, low-pressure cuffs in both tracheostomy and endotracheal tube design has decreased the incidence of cuff-related airway stenosis, but laryngeal injury and subglottic and tracheal stenosis remain significant clinical problems [11]. In a prospective study of 200 patients, Whited found a linear correlation between duration of intubation and not only incidence, but also severity, of laryngeal injury. In those patients intubated less than 5 days there were no long-term complications. After 6 to 10 days there was a 5% incidence of chronic stenosis, and those intubated for longer than 11 days had a 12% incidence of chronic stenosis that was consistently more extensive [12]. Although a number of studies in which the incidence of postintubation airway stenosis was extremely low have refuted this correlation, differences in patient population and the etiology for respiratory failure may account for some of these differences [10,13–15]. Interestingly, a second pattern of non–time-related, postintubation laryngeal injuries such as hoarseness, arytenoid dislocation, vocal cord paralysis, and glottic incompetence was uncovered at an incidence of 19% by Colice et al [13]. These data argue against the role of tracheostomy in preventing some forms of laryngeal injury.

Almost by definition, stenosis will occur to some degree at the tracheal stoma; however, the incidence of symptomatic tracheal stenosis is low, and compared with laryngeal stenosis, much easier to treat. In the patient meeting other criteria for conversion from translaryngeal intubation to a tracheostomy, the risk of stomal stenosis should not factor into the equation.

The primary argument against tracheostomy revolves around the incidence of surgical complications, which again vary widely in the literature. Stauffer reported a 66% complication rate with tracheostomy in contrast to a generally accepted 5% to 6% [5,16]. Although his study is flawed by the wide variability in surgeons' experience and biased by not accounting for the length of intubation before tracheostomy, Stauffer correctly emphasizes the meticulous technique and attention to detail required to achieve good outcome in tracheostomy construction [16].

The optimal timing of elective tracheostomy remains nebulous, and universal selection criteria cannot be broadly applied. The choice to convert to tracheostomy must be individualized based on a number of factors. The approach that we encourage sets a horizon some 7 to 10 days after intubation as the first point in the decision tree. If a patient remains intubated at this point and clearly is not going to be extubatable in the next week, a tracheostomy should be done, assuming an acceptable surgical risk and that the patient is hemodynamically stable. Waiting this initial week also will minimize the number of unnecessary tracheostomies. Beyond this point, the risk of severe laryngeal injury, the need for a stable airway, effective pulmonary toilet, and improved patient comfort begin to shift the risk-benefit ratio in favor of tracheostomy. If the prognosis for recovery is uncertain, careful daily reassessment of the patient's progress over the next few days will allow accurate prediction of the likelihood for extubation. We advocate setting a limit between 10 and 14 days, at which time a definitive decision is made. Though traditionally the bias has been to try to avoid tracheostomy, our bias is that the benefits of early tracheostomy far outweigh the risks of prolonged translaryngeal intubation, which also include the risk of self-extubation or reintubation for failed planned extubation.

Anatomy

Depending on the person's size, the adult trachea ranges from 10 cm to 13 cm in length from the larynx to the carina. With the neck slightly extended, about half the length is above the thoracic inlet; however, the trachea slides easily in the cephalo-caudal direction and there is tremendous variability in tracheal orientation, depending on the position of the neck and the patients body habitus. This becomes important when attempting tracheostomy in the obese patient with a short neck, or in the elderly patient with kyphosis. In these cases the trachea may reside almost entirely within the bony thorax [17]. The shape of the trachea is dictated by incomplete cartilaginous rings that extend laterally and anteriorly, accounting for two thirds of its circumference and leaving a flat posterior membranous wall in close relation to the esophagus as they descend together through the neck [17]. At the level of the thoracic inlet the trachea dives from anterior to posterior, passing behind the thymus, innominate vein, and innominate artery; this further complicates tracheostomy in the elderly, in whom this angle can approach 90 degrees [18].

Approaching the trachea anteriorly in the midline beneath the platysma muscle, one encounters a superficial cervical fascia, crossing branches of the anterior jugular veins, the sternohyoid and sternothyroid muscles, the thyroid isthmus, which crosses the trachea at the level of the second ring, and a pretracheal fat pad through which wander the inferior thyroid veins and occasionally a thyroid ima artery [18]. Dissection of the trachea laterally is unnecessary during tracheostomy, and fraught with danger. The blood supply to the cervical trachea is derived from branches of the inferior thyroid artery that approach the trachea laterally and form a longitudinal plexus running alongside the trachea, near the cartilaginous-membranous junction [18]. Lying in the tracheoesophageal groove as they ascend to the larynx are the recurrent laryngeal nerves.

Standard open tracheostomy technique

Surgical tracheostomy is routinely done under general anesthesia in the operating room. The optimum position is supine with maximal neck extension, facilitated by placement of a towel roll beneath or between the patient's scapulae. History of an unstable cervical spine, spinal stenosis, kyphosis, or severe cervical osteophyte disease may preclude extension of the neck. Appropriate head and neck support must be given and access to the trachea may require division of the thyroid isthmus. In the absence of any obvious contraindication, however, hyperextension of the neck can elevate up to half the trachea into the operative field.

The anesthesia team is asked to facilitate eventual removal of the existing endotracheal tube by partially undoing the circumferential wrap used to secure the tube. This avoids a struggle in the case when the patient is draped and access to the face is obscured. After a standard sterile surgical preparation, a 2 cm to 3 cm transverse incision is made crossing the midline, about 2 cm above the suprasternal notch (Fig. 1). The specific location and length of the incision will vary according to patient factors such as location of the cricoid cartilage, obesity, prior neck surgery, or recent median sternotomy. In this not infrequent scenario, the incision is made slightly higher to distance the tracheostomy from the sternal incision, decreasing the risk of contaminating the recently dissected mediastinal tissues. The subcutaneous tissue and platysma muscle are divided transversely entering the subplatysmal plane (Fig. 2). The remainder of the dissection is done longitudinally. Division of the superficial cervical fascia reveals the midline between the strap muscles. Communicating venous branches may need to be divided, but anterior jugular veins should be lateral to the dissection and rarely require ligation. Gentle lateral retraction of the sternohyoid and sternothyroid muscles helps to develop the midline and brings the thyroid gland into view (Fig. 3). The pretracheal fascia and fibrofatty tissue are incised inferior to the thyroid isthmus, and retractors moved inferiorly, exposing the anterior surface of the trachea.

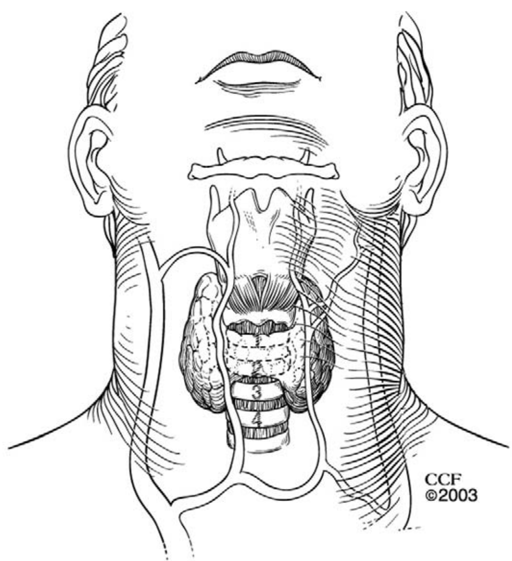

Fig. 1. The patient is positioned supine with the neck extended. A transverse incision is fashioned about 2cm above the suprasternal notch and below the cricoid cartilage.

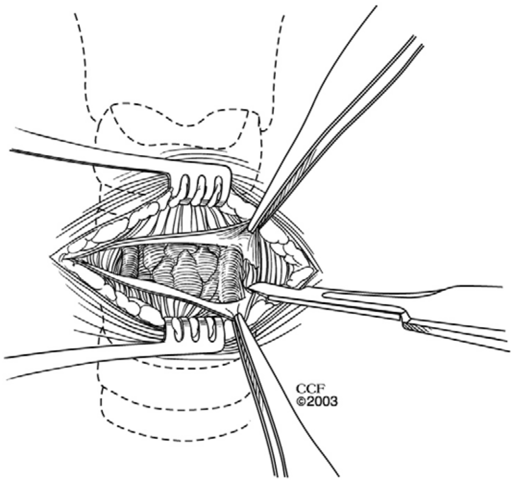

Fig. 2. The subcutaneous tissue and platysma muscle are divided transversly entering the subplatysmal plane.

It is very rarely necessary to divide the thyroid isthmus, which in most cases can be elevated. Skilled superolateral retraction by the assistant with the lips of the retractor beneath the strap muscles, catching the edge of the isthmus or the under surface of the thyroid lobes, provides excellent exposure of the underlying tracheal rings. Care must be taken to avoid avulsing small veins that may drain directly into the innominate vein, and if present, the thyroid ima artery needs to be ligated.

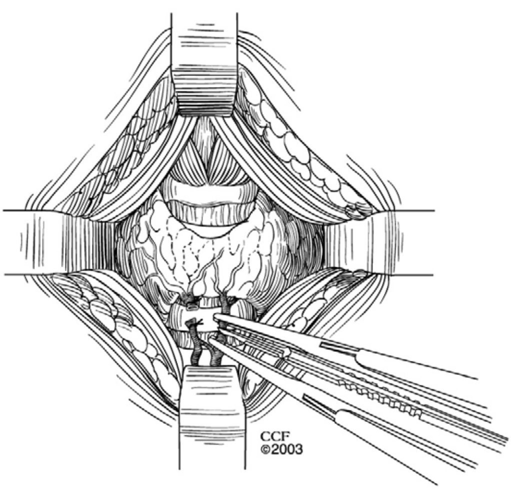

Fig. 3. Gentle lateral retraction of the strap muscles helps develop the midline and expose the underlying thyroid gland and trachea. Rarely it is necessary to ligate anterior jugular veins.

Complete homeostasis is mandatory at this time, as visualization of the wound after insertion of the tracheostomy tube is limited. Before creating a tracheotomy, a systematic check is made of the instruments and the selected appliance. A range of tracheostomy tubes should be immediately available and the size of tube chosen depending on the size of the patients trachea. The cuff is inflated, checked for leaks and deflated. Care should be taken to fully deflate and lubricate the cuff to avoid its getting caught and torn by the cut edge of a calcified tracheal ring. A #15 knife blade, tracheal hook, and tracheal dilators should be readily available. The midline is identified, the tracheal rings carefully counted, and lateral traction sutures are placed around the second or third tracheal ring (Fig. 4). Frequently adequate exposure can be maintained by gentle retraction on these sutures. If necessary, the trachea can be further elevated using the tracheal hook under the cricoid cartilage. A vertical linear tracheotomy is created in the midline, ideally between rings 2 and 4, and gently dilated. The use of electrocautery is avoided to prevent airway ignition. Position of the tracheotomy is important, as injury to the first ring or cricoid cartilage may increase the risk of subglottic stenosis and placement of the tracheotomy too low may pull the tracheostomy tube or its balloon against the innominate artery. The laterally placed sutures provide enough distraction to have the endotracheal tube withdrawn under direct vision to a point just proximal to the tracheotomy, allowing for unobstructed passage of the tracheostomy tube distally and easy reinsertion of the endotracheal tube if necessary. The use of a cruciate

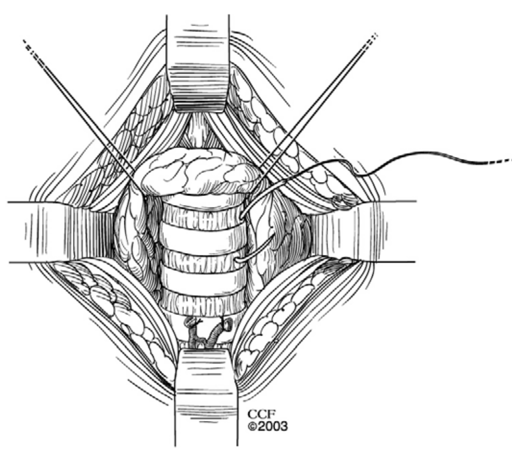

Fig. 4. The thyroid isthmus is retracted cephalad and lateral traction sutures placed around the 2nd or 3rd tracheal ring.

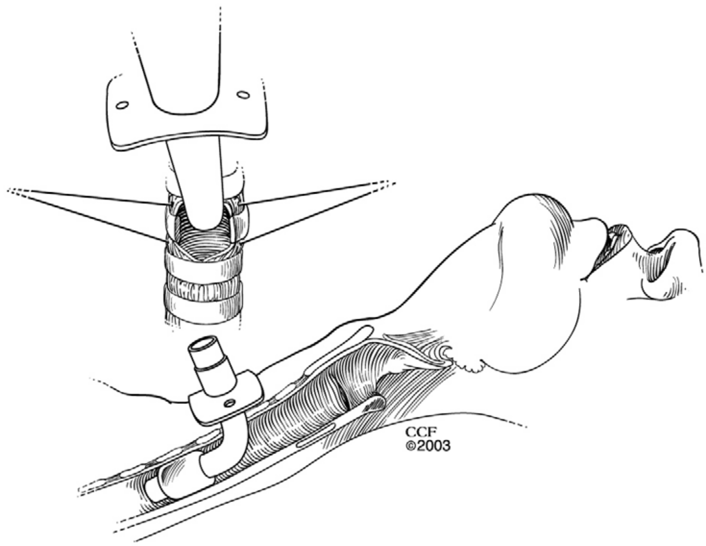

Fig. 5. #15 blade scapel is used to create longitudinal tracheostomy. The laterally placed traction sutures provide enough distraction to allow for tracheostomy tube placement without excessive dilation. After confirming tube placement the traction sutures are removed.

incision or resection of any portion of the anterior tracheal wall is avoided to minimize the size of the tracheotomy in hopes of decreasing the subsequent stomal stenosis. For this reason aggressive dilation of the tracheotomy should also be avoided, though often some degree of laterally oriented dilation is required (Fig. 5). The tracheostomy tube is passed into the airway, the cuff inflated, and ventilation resumed, directly across the operative field. Ease of oxygenation, return of CO_2, confirmed by the mass spectometer and direct inspection with auscultation, confirms proper tube placement. Only then may the orotracheal tube be completely removed. The skin is sutured loosely around the tube with absorbable suture and the flange of the tracheostomy secured to the skin in all four quadrants. Finally the apparatus is further secured by the passage of a tracheal tie around the neck. We do not advocate retaining the traction sutures placed to facilitate tube placement. Although they are helpful in the operating room with optimal patient positioning and superior lighting, they are not helpful in replacing a dislodged fresh tracheostomy tube. This urgent situation is best handled by oral reintubation followed by elective tracheostomy revision in the operating room. Use of traction sutures to blindly replace a fresh tracheostomy tube can easily lead to misplacement of the tube into the mediastinum.

Special circumstances

Although it has become popular in some centers, performing tracheostomy in the intensive care unit (ICU) involves some degree of compromise. The patient's bed is softer and wider than the operating table, limiting exposure and increasing the reach for the surgical team. Additionally, the lighting is almost always inadequate unless a headlight is worn. Bedside tracheostomy is recommended only when the risk of transporting the patient outweighs the risk of operating in a compromised environment.

A number of circumstances may arise that require modification of technique. Unfavorable anatomy is encountered in patients with obese and stout necks, goiters, cervical stenosis, kyphosis, or previous neck operations (Fig. 6). In the morbidly obese patient, excessive soft tissue and a short neck hampers identification of landmarks and challenge exposure. Maneuvers such as caudal distraction of the shoulders, taping of the submental skin, and elevating the head of the bed 30° to 45° improve access to the neck. The use of a longer incision provides valuable additional exposure, and a cricoid hook is helpful in pulling the buried trachea anteriorly and superiorly. Because the final distance of the airway from the skin is greater than usual and difficult to predict, it is wise to use a fiberoptic bronchoscope to confirm

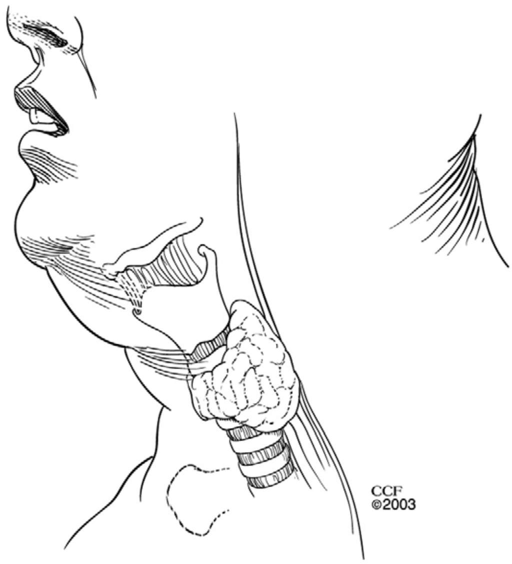

Fig. 6. In the obese or a kyphotic neck, the distance from trachea to skin will be increased. Inthis case a cricoid hook can be used to pull the trachea anteriorly. Use of a longer tube is often necessary and fiberoptic bronchoscopy to confirm proper endoluminal placement is recommended.

proper placement, with the tube orifice centered in the distal trachea. Too short a tube leads to malposition of the orifice that often abuts the membranous airways. Use of a longer tube, such as the Rusch product (Willy-Rusch AG, Kemen, Germany) with an adjustable flange that allows alteration of the

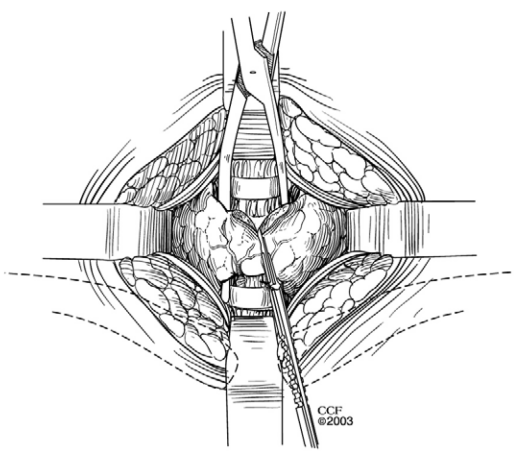

Fig. 7. If the neck cannot be extended ligation, division of the thyroid isthmus will expose a greater length of the underlying trachea.

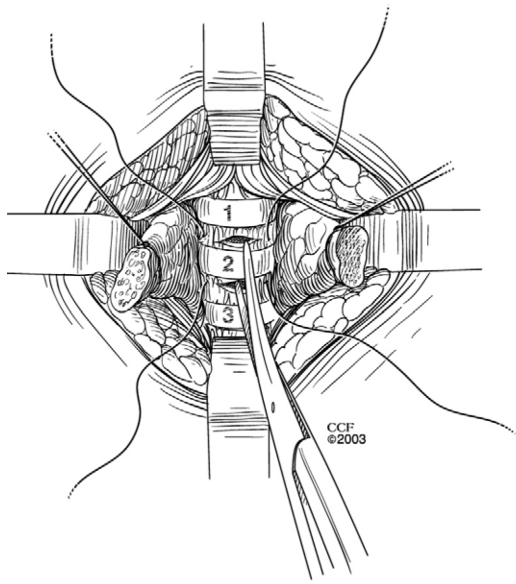

Fig. 8. Heavy scissors are used to create the tracheotomy if the tracheal rings are thickly calcified.

shaft length to prevent a catastrophic accidental decannulation, is recommended.

The elderly can also provide unique challenges. It may not be possible to extend an arthritic, kyphotic neck, significantly decreasing the length of available cervical trachea. Furthermore, calcification of the tracheal rings is seen with advancing age or previous irradiation; this can make incision with a knife blade impossible. These patients will often require division and ligation of the thyroid isthmus for tracheal exposure (Fig. 7). The cricoid hook is used for stabilization, and to deliver the proximal trachea into the field. Heavy scissors are necessary to create the tracheotomy, and if needed, a small window in the anterior trachea to allow for tube placement without cracking the airway from excessive blunt dilation (Fig. 8).

Cricothyroidotomy

Though thought by some to be safe in the elective setting [19], cricothyroidotomy is generally reserved for emergency situations when standard means of translaryngeal intubation are impossible or have failed. Cricothyroidotomy is associated with a historically high rate of difficult-to-manage subglottic stenosis [20]. When forced to obtain a surgical airway in an emergency, a cricothyroidotomy is preferable because of the procedure’s relative speed and simplicity. It is important, especially in this setting, to maintain a calm, systematic approach. A sterile field should be prepared if at all possible, and a roll placed beneath the shoulders unless there is some concern for cervical spine stability. The laryngeal prominence is the most reliable landmark. Using this as a guide, palpation along the midline inferiorly toward the sternal notch allows identification of a small depression, the cricothyroid membrane, immediately above the cricoid cartilage. In the emergency setting a vertical incision is preferable, as it avoids injury to the anterior jugular veins minimizing bleeding and allows for some leeway in placement. The incision should be carried through the skin and subcutaneous tissue to the thyroid cartilage. The cricothyroid membrane is identified and incised along its inferior border transversely, and a tracheal hook is inserted under the thyroid cartilage. Gentle vertical dilation is needed, enough to allow passage of a 6 mm or 7 mm tube, but care should be taken to avoid damage to the inferior edge of thyroid cartilage, thus reducing the risk of subglottic stenosis. The tube can then be inserted and secured in the usual fashion. Though there is some debate about the safety of cricothyroidotomy in regards to the incidence of subglottic stenosis, it is our practice to convert these patients to a standard elective tracheostomy in the next 24 to 48 hours to negate this risk [21].

Percutaneous tracheostomies

Since its introduction by Toy and Weinstein in 1969 [6] and subsequent modification by Ciaglia [7], percutaneous tracheostomies have enjoyed rapidly increasing popularity. Advocates cite the ease of the familiar technique, and the ability to perform the procedure at the bedside, often by nonsurgical practitioners [22]. Briefly, using a modified Seldinger technique with progressive dilation over a guide wire under bronchoscopic guidance, a stoma, preferably between the first and second, or second and third trachea rings, is created large enough to accept a tracheostomy tube [22]. The need for an emergent airway, inability to palpate landmarks, coagulopathy, an enlarged thyroid, and thickly calcified tracheal rings are all relative contraindications for the procedure [5]. The reported complication rates for both percutaneous and open tracheostomy range widely [23]. It is most likely that with an appropriate level of experience and in the appropriate setting, both can be done with equivalent morbidity.

A natural extension of the percutaneous dilational tracheostomy is the minitracheostomy introduced by Matthews and Hopkinson in 1984, for the management of excessive pulmonary secretions in patients without the need for mechanical ventilation [24]. This procedure can also be done with proven effectiveness and safety at the bedside using a commercially available kit and a small-gauge catheter introduced through the anterior tracheal wall [24].

Tube-free tracheostomy

To avoid the morbidity associated with an indwelling tracheostomy tube expected to remain for months to years, Eliachar developed the long-term, tube-free tracheostomy. Common indications for the procedure include obstructive sleep apnea, bilateral vocal cord paralysis, neuromuscular disorders, irreparable laryngotracheal stenosis, and severe chronic pulmonary disease [25]. The procedure begins with a horizontal omega-shaped skin incision extending beyond the lateral margins of the sternocleidomastoid muscles and arching to the level of the cricoid cartilage. Subplatysmal flaps are elevated inferiorly to the level of the manubrium, laterally beyond the sternocleidomastoid muscles, and superiorly to the level of the hyoid bone. The thyroid isthmus is divided and the two lobes mobilized enough to allow them to be sutured gathering the accompanying strap muscles, to the ipsilateral sternal tendon of the sternocleidomastoid muscle. Excessive adipose tissue is removed to provide adequate space for the flaps without obstruction of the stoma. A superiorly based anterior tracheal flap is created by elevating the second and third tracheal rings, the margins of which are then sutured to the edge of the superior skin flap. The remaining exposed tracheal edges are sutured to the corresponding skin flaps until a circumferential noncollapsing mucocutaneous anastomosis is completed. The stoma is intubated until the patient is stable and breathing spontaneously, at which time the majority of patients may be decannulated. Careful, in-hospital, local wound care for the ensuing week allows for tube-free healing.

Since its original description, the tube-free tracheostomy has been further modified for selected patients in a second stage procedure by passing a muscular sling around the stoma, using the clavicular head of the sternocleidomastoid muscle. Although the majority of patients are able to develop fluent unaided speech and physiologic clearance of secretions by voluntary constriction of the stoma, the sling procedure provides the ability to do the same, with minimal detectable morbidity, for those who were previously unable [25,26].

Tracheostomy selection

When selecting among the many available tracheostomy tubes, there are several factors to consider. Important issues include tube diameter and length, cuff design, use of an inner cannula, and the presence or absence of a fenestration (Fig. 9). The size of the tracheostomy can refer to its inner diameter, outer diameter, or length. In general the smallest outer diameter tracheostomy that satisfies the requirement for intubation should be used. This principle will minimize the risk of subsequent tracheal stenosis. In the obese or kyphotic patient whose anatomy does not lend itself to the use of a standard semirigid tracheostomy tube, the adjustable length, flexible wire-reinforced Rusch (Willy-Rusch AG, Kemen, Germany) tube is an excellent option (see Fig. 9B). This tube can be tailored to fit the neck size by movement of the flange, and should be used whenever there is doubt about the security or position of a standard fixed-length tube.

The smaller the tube diameter, the greater will be the resistance to airflow through the tube, but the less the obstruction of flow around the tube. If the indication for tracheostomy is control of excessive tracheobronchial secretions, the smallest tube that allows for adequate pulmonary toilet is appropriate so as not to impede spontaneous respiration. Even a cuffless tube may suffice for this indication. If prolonged mechanical ventilatory support is the indication for tracheostomy, a cuffed tube that completely seals the airway, preventing the loss of tidal volume, is required. A cuff design which provides this seal at an inflated pressure less than 25 mm Hg is optimal [27]. The use of an appliance with an inner cannula provides a safe and simple mechanism for cleaning the tracheostomy; however, these designs decrease the internal diameter of the tube by 1 mm to 2 mm and may therefore require selection of a larger outer diameter tube (see Fig. 9C,D) [27].

Cuff design has evolved from the original low-volume, high-pressure cuffs to high-volume, low-pressure balloons to minimize the risk of pressure necrosis of the tracheal wall and subsequent tracheal stenosis or trachea-esophageal fistula [28,29]. Anticipating the patient's requirement for ventilatory support can influence the choice of cuff design. In the patient with multiorgan failure and a long-term need for

Fig. 9. Examples of available appliances: (*A*) Bivona TTS, Bivona Medical Technologies, Gary, IN. Note the deflated cuff is flush with the tracheostomy tube (tight to shaft). (*B*) Flexible wire-reinforced, adjustable-length tube, Willy-Rusch AG, Kemen, Germany. The mobile flange is not included in the picture. (*C*) Fenestrated Shiley, Mallincrodt Inc., St. Louis, MO. Passage of air through the fenestration allows for phonation with the tube capped. (*D*) Shiley XLT, proximal extension. Note the extended length of the proximal portion from elbow to flange.

positive pressure ventilation, one might chose a Shiley (Mallincrodt, Inc., St. Louis, MO) with a large-volume, low-pressure, air-filled balloon. Considering the substantial additional resistance to airflow around these larger outside diameter tubes with the deflated cuff occupying the airway, this choice can make spontaneous respiration around the tube or speech very difficult [30]. As the patient recovers and is ready to wean, conversion to a different tube is often advisable. In the patient expected to require only intermittent support, tube and cuff selection can be addressed in two ways. One may choose to use a tight-to-shaft Bivona tube (Bivona Medical Technologies, Gary, IN), in which case the balloon is high pressure, saline filled, but when deflated is flush with the tube, which has no inner cannula (see Fig. 9A). Alternatively, a fenestrated tube may be used, which markedly reduces resistance by permitting the flow of air through the lumen of the tube when the appropriate fenestrated inner cannula is inserted [30] (see Fig. 9C).

The fenestrated tube is ideal in the spontaneously breathing patient, as it allows for easy phonation with the tube capped, and can be blocked with an inner cannula to prevent leak of delivered tidal volume in the patient requiring mechanical support. Fenestrated tubes may, however, complicate patient care. The fenestration must be centered in the tracheal lumen to function properly. If the tube is too short the fenestration will be displaced anteriorly into the pretracheal space, resulting in subcutaneous emphysema or obstruction to spontaneous respiration. Additionally, the fenestration is a nidus for the formation of granulation tissue that may cause bleeding or obstruction of the tube, complicating its removal [27]. Problems with position of the tube are not uncommon and the fenestrated tubes require vigilant surveillance and frequent changing.

Complications

Tracheostomy, often considered to be a simple procedure relegated to the most junior members of the surgical team is, in fact, fraught with potential complications. Though covered at length in another article, a review of surgical complications is pertinent to a discussion of technique. Intraoperative complications are technical in nature and as such are avoidable. Bleeding during the procedure is rare and usually easily controlled by judicious use of electrocautery or suture ligation when necessary. Known coagulopathy should be corrected preoperatively. Problems arise when dissection strays from the midline, as their proximity puts the carotid arteries and internal jugular veins at risk if dissection is lateral, or the innominate artery at risk if dissection is too inferior [32]. Similarly, due to their position in the tracheoesophageal groove, overly vigorous lateral retraction or dissection along the side of the airway risks injury to the recurrent laryngeal nerves [32]. The pleura may extend above the level of the clavicles medially, especially in the presence of emphysema or in children; this leads to a reported 0.9% to 5% incidence of post-tracheostomy pneumothorax [31]. Failure to adequately expose and control the trachea increases the likelihood of creating a false passage into the surrounding soft tissue, which, if followed by positive pressure ventilation, creates pneumomediastinum and may lead to pneumothorax. Furthermore, disruption of the surrounding tissues creates potential space in which paratracheal abscess may arise. These complications require prompt drainage and broad-spectrum antibiotics. Benign subcutaneous emphysema may develop as the patient coughs if the dressing surrounding the tracheostomy is occlusive, or the cuff is not fully inflated [32].

Acute tracheoesophageal fistula is the result of inadvertent puncture of the posterior tracheal membrane into the esophagus, usually when performing the tracheotomy. This is protected against to some degree by the underlying endotracheal tube, but one must be cognizant of the risk and avoid excessive force when incising the anterior tracheal cartilage. When confronted with the calcified trachea, use of heavy scissors to divide the rings affords greater control (see Fig. 8). If recognized intraoperatively, the injury should be repaired at the time of the tracheostomy.

The combination of nitrous oxide or concentrated oxygen and electrocautery creates the potential for fire in an airway, as has been reported a number of times in the literature [33,34]. This dramatic complication can be avoided by minimizing the concentration of inspired oxygen, avoiding nitrous altogether, and by not using cautery at all with the airway opened. Hemostasis should be complete before the tracheotomy, not only to avoid the urge to use cautery but for optimal visualization.

Summary

Tracheostomy has become one of the most commonly performed procedures in the critically ill patient. Variations in technique and expertise have led to a wide range of reported procedural related morbidity and rarely mortality. The lack of prospective, controlled trials, physician bias and patient comorbidities further confound the decisions regarding the timing of tracheostomy. With careful attention to anatomy and technique, the operative complication rate should be less than 1%. In such a setting, the risk-benefit ratio of prolonged translaryngeal intubation versus tracheostomy begins to weigh heavily in favor of surgical tracheostomy. At exactly what point this occurs remains undefined, but certainly by the tenth day of intubation, if extubation is not imminent, arrangements should be made for surgical tracheostomy by a team experienced with the chosen technique.

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