An updated review in percutaneous tracheostomy

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Abstract: The practice of tracheostomy dates to ancient Egyptian times and has undergone a significant evolution in both its popularity and techniques. In its contemporary form, tracheostomy encompasses both surgical and percutaneous approaches. The primary indications for tracheostomy are centered around ensuring a secure airway in the case of airway compromise or the need for prolonged airway support. While there are only a few absolute contraindications for percutaneous dilation tracheostomies (PDTs), the list of relative contraindications is continually being reevaluated as new data emerges. This review article provides an updated review of percutaneous tracheostomy with more recent literature including studies from the pandemic which saw increased use of percutaneous tracheostomies as well as complications from them. Here we additionally reviewed the most recent literature surrounding of optimal timing and continued lack real world data favoring mortality for early intubation despite further randomized controlled trial testing, including neuro-intensive care unit (ICU) patients. Both surgical and percutaneous methods continue to have their roles, but the percutaneous approach is increasingly favored in the right setting due to factors such as smaller incisions, reduced infection risk, and improved bedside convenience and safety data. Over time the PDT technique has undergone various refinements. One widely utilized method involves employing a single dilator. In this review, practical evidence based guidance is included for the performance of the procedure as well as the aftercare.

Keywords: Technique; percutaneous dilation tracheostomy (PDT); timing; surgical tracheostomy (ST); post care

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Introduction to tracheostomy

The term that has come to represent tracheostomy has undergone an evolution over time including laryngotomy, bronchotomy, laryngo-bronchotomy and more. In its purest form tracheostomy means the formation of an opening into the trachea and suturing the inside edges to the outer skin. This is compared to the term tracheotomy which indicates the surgical opening of anterior tracheal wall to create an airway. Due to the subtle nuance, the terms have been used interchangeably throughout history (1).

History of tracheostomy

The first tracheostomy was controversially illustrated on Egyptian tablets with a seated man directing a knife towards the base of the neck of another seated man around 3500 BC (2,3). Little was subsequently documented until the Rig Veda Hindu in 2000 BC, followed by accounts of Alexander the Great making an opening in the trachea of one of his soldiers to save him from suffocation around 300 BC (4). The first recorded successful surgical tracheostomy (ST) was performed in 1546 by Antonio

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Brasalova, who performed the procedure in a patient with tonsillar obstruction (5). In the early 1900's, Chevalier Jackson was the first physician to standardize the practice of ST and is credited with reducing the operative mortality associated with tracheostomy at that time from 25% to 1% (6).

The first percutaneous dilatational tracheostomy (PDT) was reported by in 1955 by Shelden *et al.* (7). This technique underwent several revisions until Dr. Ciaglia published the technique of using serial dilators over a J-wire in 1985 (8). Subsequently other derivations of the technique were developed in an attempt to improve the procedure by using a Howard Kelly forceps, a retrogradely passed wire as a track for the dilator, and a single-step screw-type dilator (9-11). Subsequent iterations of the Ciaglia technique evolved to using balloon dilation over a guidewire, and then finally combined the serial dilations into the single conical design "blue rhino" dilation technique used today.

Indications and benefits

The main indications for tracheostomy center around the establishment and maintenance of a safe airway in situations of airway compromise. These include: upper airway obstruction from tumor, surgery, trauma foreign body or infection, prevention of laryngeal and upper airway damage to prolonged mechanical ventilation, long-term airway protection after head injury, or stroke, and maintenance of easy or frequent access to the lower airway for pulmonary toilette (12,13). One notable caveat to these situations involves emergency airway securement, which requires invasive techniques such as cricothyrotomy, or emergent ST. This circumstance notably excludes a conventional percutaneous approach i.e. not involving the cricothyroid membrane (14).

Benefits are also afforded after tracheostomy is performed through alterations in the work of breathing (WOB) the patient experiences. A study by Deihl and colleagues measured the WOB in eight patients before and after tracheotomy during breathing at three identical levels of pressure support and found that tracheotomy can substantially reduce the mechanical workload of the ventilator-dependent patients (15). Literature further supports additional advantages of tracheostomy when compared to endotracheal tubes including fewer oral-labial ulcerations, improved oral hygiene, improved airway security and improved patient comfort (16).

Contra-indications and risks

Absolute contraindications include cervical instability, uncontrolled coagulopathy, and infection at the planned insertion site. Relative contraindications include concerning anatomy in the form of short necks, limited neck extension, and severe respiratory disease requiring high ventilator settings resulting in the inability of the patient to tolerate periods of apneas or deviation from their current settings (17).

Morbid obesity is a significant relative contraindication that has been more challenged in the recent literature. It has traditionally been thought that increased neck adiposity may complicate identification of tissue landmarks and lead to increased adverse events during placement. Recent studies note that while there may be a higher risk for complications in obese individuals, they are only slightly higher than their non-obese counterparts (18,19). However, it is important to note that standard length tracheostomy tubes are often too short in this patient population, and carry their own risks including excessive pressure on the anterior wall and posterior membrane causing tissue damage, accidental decannulation, difficult suctioning, increased patient discomfort and subcutaneous emphysema (if a fenestrated tube used) (20). Therefore, in order to minimize these risks, the selection of an appropriately sized length tracheostomy tube is imperative in obese patients.

Timing

A lack of consensus exists regarding the most appropriate timing for tracheostomy placement, partly stemming from the diverse definitions of "early" and "late" utilized in the trials aimed at addressing this question. Among the pioneering randomized controlled trials is the work of Terragni *et al.*, published in 2010. Their investigation aimed to discern the impact of early versus late tracheostomy on the incidence of pneumonia in adults undergoing mechanical ventilation within the intensive care unit (ICU). A total of 419 patients, without pulmonary infection as the cause of respiratory failure, were randomly assigned to receive early tracheostomy (after 6–8 days) or late tracheostomy (after 13–15 days). The results revealed no statistically significant difference in ventilator-associated pneumonia or mortality. Nonetheless, the study did highlight that early tracheostomy led to quicker liberation from mechanical ventilation and earlier discharge from the ICU (21). However, concerns regarding generalizability arose due to the exclusion of specific patient populations, including those with chronic obstructive pulmonary disease and pneumonia.

In a subsequent prospective, randomized, controlled, single-center trial, Trouillet *et al.* sought to determine the benefits of early tracheostomy in terms of duration of mechanical ventilation and overall mortality. This study focused on post-heart surgery patients requiring mechanical ventilation beyond 4 days (with an anticipated duration of at least >7 days). Patients were randomized into immediate tracheostomy or prolonged intubation (with tracheostomy after 15 days if intubated). The findings showed no significant disparity in ventilator-free days at the 60-day mark or mortality. However, early tracheostomy correlated with reduced IV sedation, shorter periods of heavy sedation, decreased use of haloperidol, fewer unscheduled extubations, improved comfort and ease of care, and earlier resumption of oral nutrition.

For this study, patients who had undergone heart surgery and still required mechanical ventilation after 4 days (anticipating >7 days at least) were randomized to immediate tracheostomy versus prolonged intubation (and tracheostomy 15 days after randomization if still intubated). Results failed to demonstrate a significant difference in ventilator-free days 60 days after randomization, or mortality. However, early tracheostomy was associated with less IV sedation, less time of heavy sedation, less haloperidol use, fewer unscheduled extubations, better comfort and ease of care, and earlier resumption of oral nutrition (22).

Likewise, the TracMan study aimed to determine if early tracheostomy (within 4 days) versus late tracheostomy (after 10 days if still indicated) would yield improvements in 30-day all-cause mortality. This randomized study encompassed 909 patients from 72 ICUs (70 medical, 2 cardiothoracic) across university and community settings. The study did not unveil any substantial differences in all-cause 30-day mortality, 2-year mortality, or ICU length of stay, but it did exhibit a notable reduction in sedation days favoring the early tracheostomy group by 3 days. However, it is important to note that 45% of the group randomized to receive a late tracheostomy ultimately did not undergo the procedure (23).

Despite these comprehensive, randomized investigations consistently showcasing limited improvement in short-term mortality across diverse populations and contexts, apprehensions persist that a 4-day cutoff might be too brief to define as “early”. Population-based data reveal an average mechanical ventilation duration of around 4.1 days, with interquartile ranges spanning 2.1 to 9.0 days (24). Such a truncated timeframe suggests that patients who typically wouldn’t require prolonged mechanical ventilation might undergo a procedure that lacks overall benefit. Moreover, as underscored in the TracMan study, critical variables like long-term complications from translaryngeal intubation and laryngeal stenosis were not thoroughly examined, potentially leading to enduring repercussions (23).

Recent data from the COVID-19 pandemic illustrated that delayed tracheostomy is associated with an increase in subglottic stenosis (25). These data reinforce findings from prior studies that linked the duration of endotracheal intubation with increasing rates of laryngeal stenosis and vocal cord immobility (26,27).

One unique patient population that bears discussion includes patients with stroke requiring mechanical ventilation, where the duration of mechanical ventilation is more reliably anticipated to be prolonged. One of the first large studies to analyze this patient population was the SETPOINT2 trial. In this study comparisons were made between early (first 3 days) tracheotomy to late (7–10 days). Results noted no significant difference in those without severe disability at 6 months (28). This was further supported through a meta-analysis by Premraj and colleagues (29).

In summary, while there is some debate regarding the optimal timing, evidence is lacking to support a mortality benefit in placing a tracheostomy prior to 7 days of ventilator support. However, there is evidence suggesting that waiting beyond 10–14 days to place a tracheostomy can lead to increased rate of complications (tracheal stenosis, vocal cord injury, pneumonias) which may ultimately impact outcomes farther out than have been measured to date.

ST *vs.* PDT

Once the decision to perform a tracheostomy has been made, the clinical team must determine the most suitable approach for establishing the airway. This can be achieved either surgically or percutaneously, assuming there are no contraindications. Several institutional factors need to be considered to determine the optimal approach. These factors include the presence of appropriately trained support staff, equipment availability, operating room availability, and the patient’s stability.

Assuming both methods are available, the question that many have sought to answer revolves around the comparison between safety and patient centered outcomes.

Early prospective randomized trial with a double-blind evaluation comparing the two methods was carried out by Gysin *et al.* in 1999 found no significant difference in rate of major complications (death, pneumomediastinum, cardiopulmonary arrest, pneumothorax, cannula misplacement, posterior tracheal wall lesion, aspiration, hypotension/desaturation). However, they did find statistical differences favoring PDT in respect to a smaller size of the incision. With respect to minor perioperative complications (difficult tube placement) and difficult cannula changes prior to 7 days greater in ST were favored (30). Subsequent studies that were culminated in a Cochrane review found that when comparing the two methods, PDT significantly reduced the rate of wound infection, and unfavorable scarring. There was also some signaling, albeit with low quality evidence with non-significant positive effects, favoring PDT for mortality, and rate of serious adverse events (31).

In another systematic review and meta-analysis by Delaney *et al.*, sub-group analysis noted a significant reduction in incidence of bleeding [odds ratio (OR) =0.29], mortality (OR =0.71), and trend toward shorter duration of translaryngeal intubation when comparing PDT to ST when ST were performed in the operating room (32). While patient selection bias resulting in sicker, more complex cases being taken to the operating room for ST could be the reason for these results. The act of an intrahospital transfer is known to carry with it significant risks for physiologic alterations, and equipment failure, placing patients at an increased risk for adverse events and prolonged hospitalizations (33-36). In addition to safety, PDT has been demonstrated to also reduce cost in comparison to ST. This can largely be attributed to operating room fees, and anesthesia fees (37).

Complications

Risks are inherent to every procedure and should be included as part of preoperative counseling. Generally the risks for tracheostomy a broken up into immediate, early or late stages according to when they occur following completion of the procedure. Immediate complications occur during the procedure and include hemorrhage, damage to the trachea and surrounding structures, air embolism, hypoxemia, hypercapnia, loss of airway and death. Early complications occur within days of the procedure and include tube displacement, stomal ulceration, stomal infection, obstruction and accidental decannulation. Late complications generally occur weeks to months after the procedure and include tracheal stenosis, tracheoarterial fistula, tracheoesophageal fistula, obstruction and accidental decannulation (38-40). Each of these complications can range in severity from mild to life threatening, and the proceduralist along with the rest of the medical team should take care to maintain a high degree of vigilance at all times (41).

Technique

There are multiple methods for achieving a successful percutaneous tracheostomy. While there is lack of sufficient evidence to confidently assess the best technique, data from meta-analysis suggest the Ciaglia single-step dilation technique was associated with fewer failures and complications than other techniques (42). Here we will discuss the Ciaglia single-step dilation technique.

Pre-procedure

After a thorough review of the patient's clinical history including indications and contraindications, available imaging to examine for concerning blood vessels (high riding aorta, ectatic innominate artery, or aberrant thyroid vessels), informed consent should be obtained. Procedural personnel must then be identified. In addition to the proceduralist, it is common to have a bronchoscopist who will be able to provide direct endotracheal visualization throughout the procedure, a respiratory therapist to retract and hold the endotracheal tube as well as be able to assist with ventilator management, and a nurse to administer medications and monitor the patient's vital signs. Medications for sedation and paralysis should be available. Once all team members are ready, the patient should be appropriately positioned with the head and neck extended. This is most often achieved by placing a towel roll underneath the patient's shoulders. The patient's oxygenation should be optimized and monitored with continuous pulse oximetry. Generally, optimization is achieved with a fraction of inspired oxygen (FiO2) of 1.0 and a positive end-expiratory pressure (PEEP) of 5–10 cmH_2O.

Procedural steps:

(I) Identify the desired location of planned tracheostomy through anatomical palpation, and ultrasound if

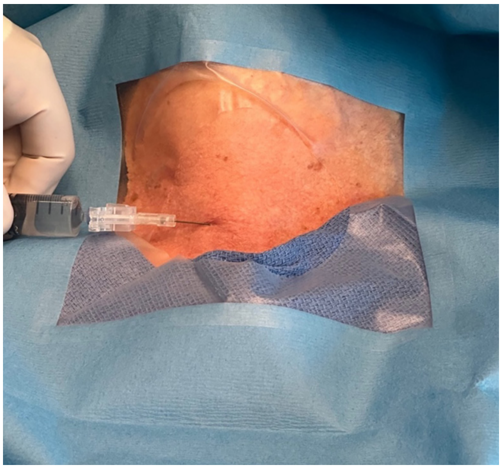

Figure 1 Injection of anesthetic into the subcutaneous tissues at the planned insertion site.

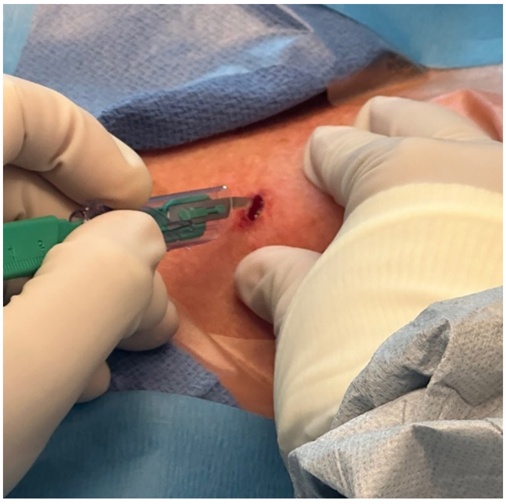

Figure 2 Incision performed using a scalpel.

desired. Ideally this is located between tracheal rings 1&2, or 2&3.

(II) Clean and drape the site per standard sterile protocol.

(III) Palpate the location of the cricoid cartilage. Apply mild pressure below the cricoid cartilage and slowly retract the endotracheal tube. Use the bronchoscope to visualize when you have reached the desired location.

(IV) Infiltrate the target area with 1% lidocaine with epinephrine (generally 10 cc) (*Figure 1*).

(V) Make a 1.5 cm skin incision (we suggest horizontal)

Figure 3 Blunt dissection through the incision.

at the target site (*Figure 2*).

(VI) Gently perform a blunt dissection using a curved Kelly hemostat. Using a fingertip, ensure the tissue anterior to the trachea is free of pulsatile masses (*Figure 3*).

(VII) Using a syringe attached to the introducer needle, advance the needle in the midline position, posteriorly into the trachea. Using simultaneous bronchoscopy, monitor the needle as it tents the anterior trachea and passes through into the tracheal lumen, being careful not to injure the posterior tracheal membrane (*Figure 4A,4B*).

(VIII) Introduce the J-tipped wire guide through the needle or sheath and extend into the trachea until gentle resistance is met, indicated extension into a lower lobe (*Figure 5A,5B*).

(IX) Remove the sheath (or needle if still in place) while maintaining guide wire position within the tracheal lumen.

(X) Dilate the site with the initial tracheal dilator over the wire. This is most commonly a 14 French punch dilator. Remove the dilator over the wire while maintaining wire positioning (*Figure 6A,6B*).

(XI) Advance the conical dilator over the wire to the appropriate depth as indicated per specific device being used (*Figure 7A,7B*).

(XII) Remove the conical dilator over the wire while maintaining wire positioning.

(XIII) Advance the tracheostomy tube with the loaded dilator over the wire to sit flush with the skin against the flange. Remove the dilator and

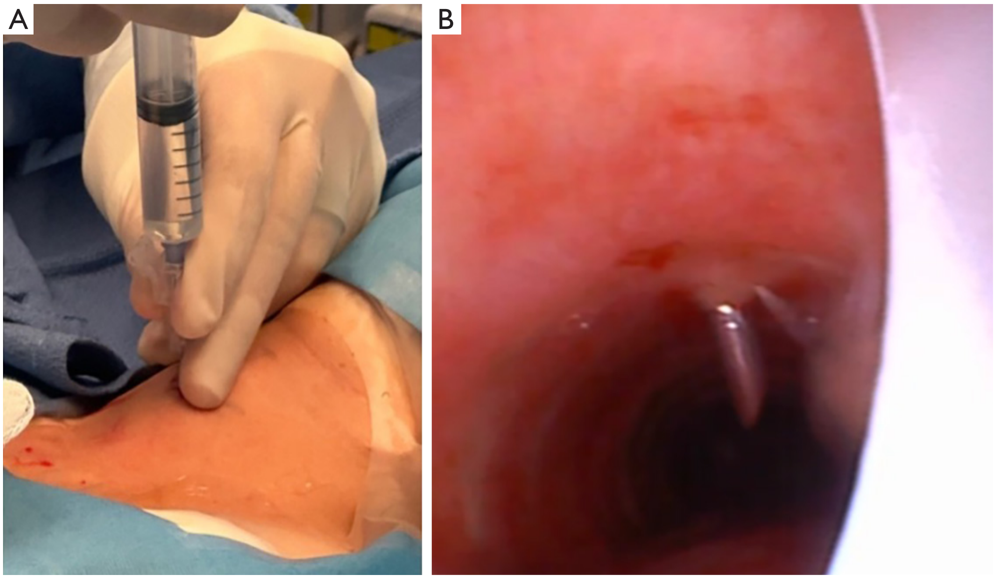

Figure 4 Needle inserted through the desired tracheal ring interspace. (A) External view; (B) bronchoscopic view.

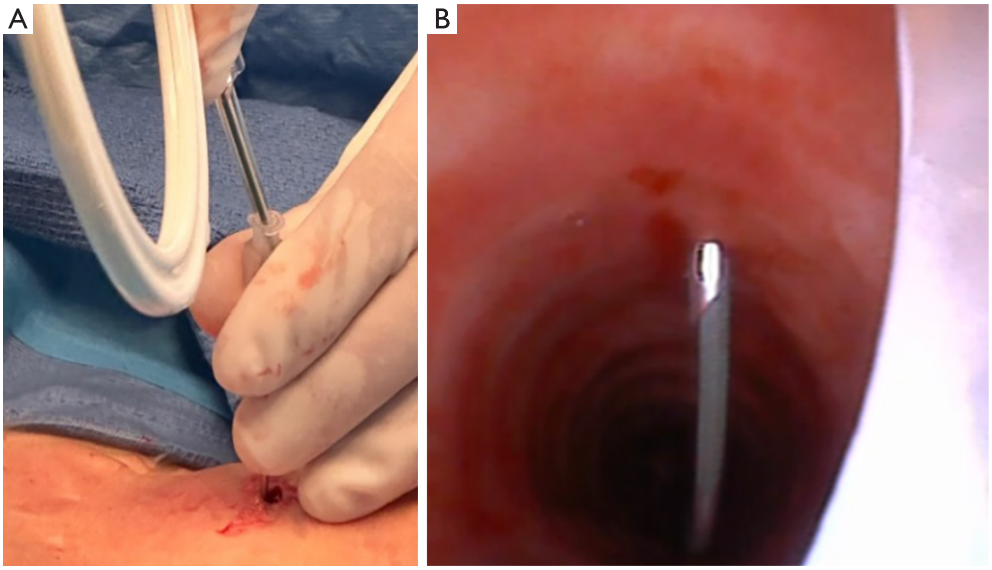

Figure 5 Insertion of the J-tipped wire through needle. (A) External viewview; (B) bronchoscopic view.

guidewire en-bloc. If using bronchoscopy, insert the bronchoscope into the tracheostomy tube to confirm correct placement following removal of the dilator and guidewire (*Figure 8*).

(XIV) Place the inner canula of the tracheostomy tube, if applicable.

(XV) Attach the tracheostomy tube to the ventilator.

(XVI) Remove the endotracheal tube.

(XVII) Suture the tracheostomy tube in place if desired and apply a Velcro tracheostomy tie so that the tie is tight and snug but still permits 1 finger breadth of slack around the neck (*Figure 9*).

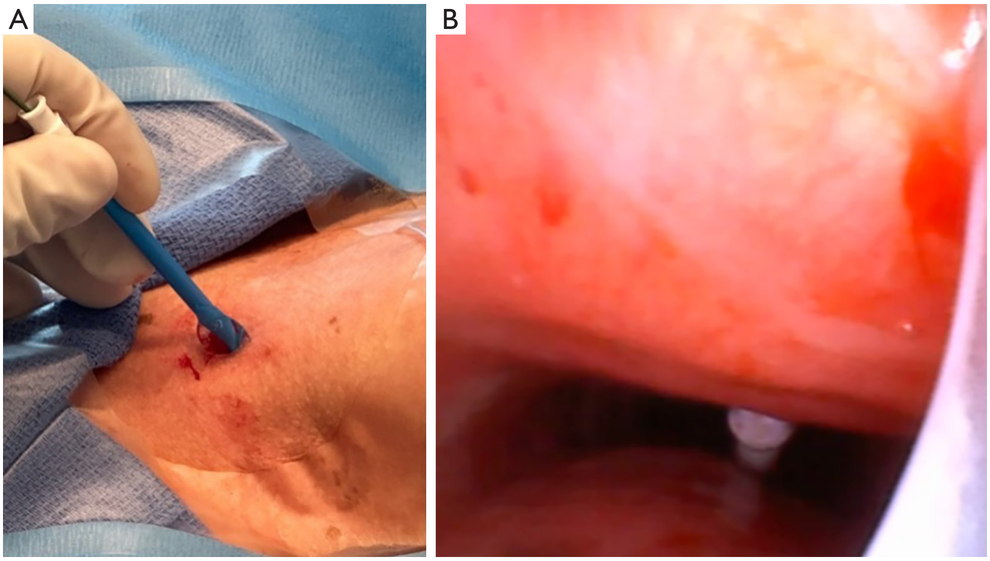

Figure 6 Insertion of the punch dilator over the J-tipped wire. (A) External view; (B) bronchoscopic view.

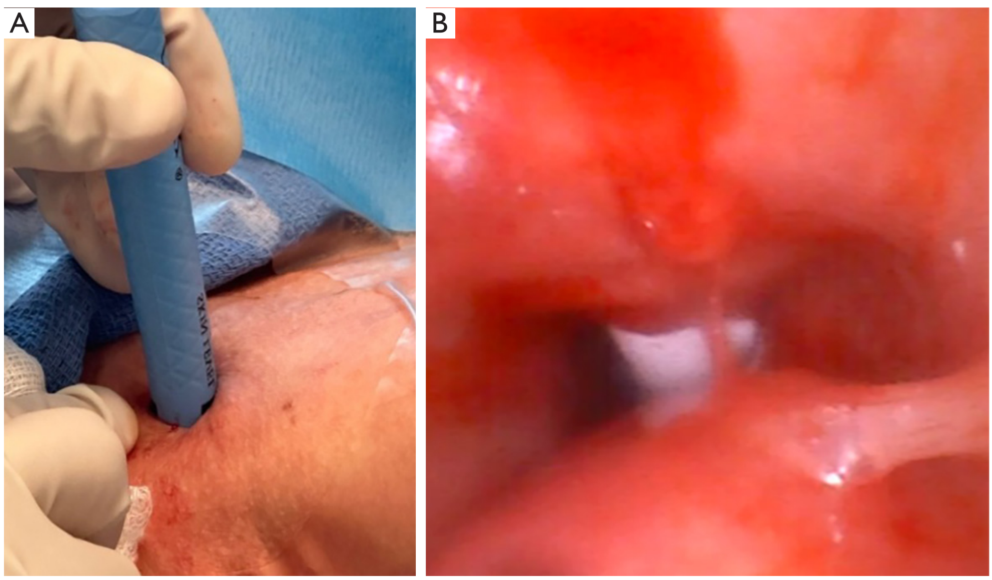

Figure 7 Insertion of the conical dilator over the J-tipped wire. (A) External view; (B) bronchoscopic view.

Post care

Initial placement of a percutaneous tracheostomy tube is undertaken with a cuffed device. This allows for easy management of secretions, some protection from aspiration and ongoing positive-pressure ventilation. The cuff usually inflated to keep the pressure no higher than 30 cmH_2O (or 22 mmHg) as the normal tracheal capillary perfusion pressure runs between 25–35 mmHg (43). If pressures in the cuff are higher than tissue perfusion pressure, the tracheal mucosa is at increased risk of pressure necrosis. Additionally, increased pressure in the cuff causes progressive difficulty in a patient's ability to elicit a swallowing reflex (44). In contrast, pressures (<15 mmHg) are associated with silent aspiration, so it is recommended that cuff pressures be maintained between 20–30 cmH_2O (15–22 mmHg) (43).

Following tracheostomy, the tube may become occluded

Figure 8 Insertion of the tracheostomy tube with the loaded dilator over the wire.

Figure 9 Securing the tracheostomy tube with suture.

by thick secretions. If the tube has an inner cannula, it can be removed and cleaned. Frequent suctioning to manage increased volume of secretions is also prudent and can improve overall tolerance. The optimal frequency to perform tracheostomy tube exchange is not well defined, though general considerations should include tube fracture, pilot balloon rupture, inspissation of secretions, or other indication by the product manufacturer (45).

Decannulation

After the patient has been weaned from mechanical ventilation for 34–48 hours, planning for decannulation may begin. While there are variable patterns between institutions, the first septs for decannulation can be undertaken when the following criteria are met: (I) clinical stability, (II) absence of delirium/intact sensorium, (III) effective cough, (IV) effective swallowing function, (V) patent airway (VI) patient's consent (46,47). The process generally begins with downsizing to an uncuffed tracheostomy tube and speaking valve trial. At our institution this is done for 24 hours, and if no complications occur, the patient is advanced to a capping trial. During capping trial, patients are required to tolerate capping for 24 hours prior to decannulation. This approach is admittedly conservative, and the results from REDECAP study suggest that by basing decannulation on suctioning needs less than 2 times every 8 hours for a 24-hour period, patient's may undergo decannulation at a faster rate without significant differences in complications (48).

Conclusions

The practice of tracheostomy has been around for millennia and has undergone significant evolution. In its contemporary form, tracheostomy encompasses both surgical and percutaneous approaches. The primary indications for tracheostomy are centered around ensuring a secure airway in the case of airway compromise or the need for prolonged airway support. Despite several randomized trials, the optimal timing of performing tracheostomy remains a subject of ongoing scientific debate. Both surgical and percutaneous methods continue to have their roles, but the percutaneous approach is increasingly favored in the right setting due to factors such as smaller incisions, reduced infection risk, and improved bedside convenience and safety data. For those that wish to continue to learn more about current practical information for tracheostomies, one may consider exploring the United Kingdom's National Tracheostomy Safety Project.

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