Preface

From the first days of our residency training as oral and maxillofacial surgeons, we are taught the paramount importance of maintaining the airway, whether we are doing office sedation, trauma surgery, oncological surgery, or major reconstruction. Failure to obtain and maintain a patent and secure airway for adequate oxygenation and ventilation can quickly lead to the patient's untimely demise.

The objectives of this *Atlas of the Oral and Maxillofacial Clinics of North America* are to discuss the challenges we face in managing the airway and to review common solutions. In this *Atlas*, various techniques of airway management are discussed by distinguished clinicians in the fields of oral and maxillofacial surgery and otolaryngology/head and neck surgery. It is our hope that clinicians will find this Atlas a useful tool in airway management both for learning about unfamiliar techniques and for refreshing knowledge about well-practiced techniques.

There are many alternatives to managing the difficult airway. Even with the common use of the glidescope and fiber-optic intubation techniques, there remain many reliable alternatives to obtaining a secure airway. It is our hope that oral and maxillofacial surgery practitioners and residents alike will find this Atlas informative, clinically relevant, and a substantive guide for airway management.

The editors wish to extend their gratitude to the many clinicians who have taken the time to contribute to this *Atlas of the Oral and Maxillofacial Surgery Clinics of North America*. We would also like to thank Richard H. Haug, DDS, for including this very pertinent topic in the *Atlas series*. We extend a special thanks to John Vassallo, editor of the *Atlas of the Oral and Maxillofacial Surgery Clinics of North America*, for his strong encouragement and support of this project. Finally, we would like to thank our medical illustrators who turn our words into meaningful pictures. The co-guest editors would like to dedicate this edition of the *Atlas of Oral and Maxillofacial Surgery Clinics of North America* to the men and women of the United States Armed Forces, whose every day sacrifices make our freedom possible. We would like to thank our families for supporting us throughout our careers as surgery residents, teachers, and military...
officers. Without their support, none of our dreams would ever become reality. To our past, current, and future residents who continue to challenge us, we thank you for your trust in us, and your tireless efforts in promoting and advancing our surgical specialty.

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Surgical Tracheotomy

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Tracheotomy history

The term tracheotomy, from the Greek root words trachea arteria (rough artery) and tom (to cut), refers to the surgical procedure in which a tracheocutaneous airway is created in the patient's neck. The term tracheostomy, from the Greek root stom (mouth), refers to the making of a semipermanent or permanent opening in the airway. Although the 2 terms have been used interchangeably, tracheotomy actually refers to the surgical procedure and tracheostomy, to the opening created by this surgical procedure.

Tracheotomy was first portrayed on Egyptian tablets in 3600 BC. Asclepiades of Persia was the first person to perform a tracheotomy in 100 BC. Antonio Musa Brasavola, an Italian physician, is the first person credited with documenting this surgical procedure in 1546 for a patient suffering from a laryngeal abscess.

In today's world, tracheotomy is a time-honored procedure, used for the management of the airway in acute settings, such as maxillofacial and laryngeal trauma, and establishment of a secure airway in the management of head and neck infections. Tracheotomy is routinely performed in the intensive care unit for patients on prolonged mechanical ventilation and in management of head and neck oncological surgeries and reconstruction. The oral and maxillofacial surgeon is routinely involved with surgical procedures requiring a secure airway, acutely, or in the setting of long-term management of the airway.

Indications

The decision to perform a tracheotomy should be adapted to each patient and predisposing pathology. The patient's and legal guardian's wishes must be considered, with an informed consent based on understanding the risks of prolonged translaryngeal intubation and the complications of the surgical procedure. Indications for tracheotomy are outlined.

1. Upper airway obstruction due to oncological pathology
2. Expected prolonged intubation
3. Inability to intubate
4. Panfacial maxillofacial trauma
5. Laryngeal and significant neck trauma

The opinions expressed in this article are those of the authors and do not reflect the views of the United States Army.

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1061-3315/10/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.cxom.2009.11.003
oralmaxsurgeryatlas.theclinics.com
6. Adjunct to head and neck surgery:
   a. Ablative tumor surgery
   b. Reconstruction of mandible and maxillary complex

7. Obstructive sleep apnea.

Although there are no absolute contraindications to a tracheotomy procedure, relative contraindications have been reported to include significant burn injury or infection of the trachea.

**Relevant surgical anatomy**

The lower respiratory tract begins at the level of the vocal cords. Inferior to the vocal cords, the rigid cricoid cartilage extends about 1.5 to 2 cm vertically in an area called the subglottic region. The surgical cricothyrotomy enters the cricothyroid membrane in the subglottic region. Inferior to the cricoid cartilage is the trachea. The trachea is made up of 18 to 22 C-shaped rings, with rigidity and flexibility provided by rigid cartilaginous portions anteriorly and laterally and a soft membranous portion posteriorly. In the average adult, the distance from the cricoid cartilage to the carina is approximately 10 to 13 cm. On average, the trachea is 2.3 cm wide and 1.8 cm deep in the anterior-posterior direction. The trachea is generally wider in men than in women (Fig. 1).

The sternohyoid and sternothyroid muscles meet at the midline of the neck and are fused together by an avascular fascia that must be incised and retracted laterally to reach the trachea. Motor nerves run deep and inferior to the sternohyoid and sternothyroid muscles, and if additional retraction is needed, it should be done superiorly to avoid damage to these nerves.

The thyroid gland is encased in the middle layer of the deep cervical fascia and is suspended in the anterior neck by a suspensory ligament from the cricoid cartilage. The posterior portion of the gland is attached to the side of the cricoid cartilage and first and second tracheal ring by the posterior suspensory ligament. This firm attachment allows movement of the thyroid gland during swallowing. The thyroid gland is found anterior to the trachea, with an isthmus crossing the trachea at the level of second or third tracheal rings. This tissue is vascular and should be divided and ligated for adequate hemostasis during this surgical procedure.

The blood supply relevant to surgical tracheotomy is the associated minor arterial and venous supply to the thyroid gland and the brachiocephalic trunk (innominate artery) in the superior outlet of the mediastinum. The superior thyroid artery is the first branch of the external

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**Fig. 1.** (A, B) Relevant surgical anatomy of the neck for operative tracheotomy.
carotid artery, and it descends laterally to the larynx and sternohyoid. It becomes superficial on the anterior part of the gland, supplying the isthmus and anastomoses with the contralateral superior thyroid artery. The inferior thyroid artery arises from the thyrocervical trunk, a branch of the subclavian artery. It is normally found in the tracheoesophageal groove and enters the larynx near the inferior part of the cricoid cartilage.

The great vessels (ie, carotid arteries and internal jugular veins) may be damaged if the dissection is carried too far laterally. The innominate artery or brachiocephalic trunk crosses from left to right in the anterior superior portion of the thoracic inlet, anterior to the trachea, and it is found under the sternum. This vessel can create significant life-threatening hemorrhage if it is damaged during surgical tracheotomy. Occasionally, a single vessel called the thyroid ima artery originates from the arch of the aorta or the innominate artery and enters the thyroid gland near the isthmus.

Venous drainage of the area is provided by the superior thyroid and middle thyroid veins, which drain into the internal jugular veins bilaterally. The inferior thyroid veins follow a different pathway on each side. On the right, the vein passes anterior to the innominate artery to the right brachiocephalic vein or anterior to the trachea to the left brachiocephalic vein. On the left, the vein drains into the left brachiocephalic vein. If bilateral inferior thyroid veins anastomose in the middle, they form the thyroid ima vein, which also drains into the left brachiocephalic vein. The anterior jugular vein begins just below the chin through the union of several small veins. It is found superficially and close to the midline of the neck as it descends over the isthmus of the thyroid. It may be encountered during the surgical approach in the midline of the neck.

The superior laryngeal nerve is found along the superior thyroid artery, and inadvertent damage to this nerve creates dysphonia by altering the pitch regulation. The recurrent laryngeal nerves travel in the tracheoesophageal grooves and may be damaged if dissection strays too far laterally. Damage to recurrent laryngeal nerves may result in hoarseness, aphonia, and an increased risk of aspiration.

Armamentarium

The armamentarium of the tracheotomy procedure is composed of basic surgical instruments and is really tailored to the surgeon's preference and institutional capabilities. The authors present a basic tracheotomy surgical setup and tubes (Fig. 2).

Tracheostomy tubes

Tracheostomy tubes are used to provide a surgical airway and ventilation for the patient, prevent aspiration of secretions, and assist in lower respiratory suctioning and clearance. They are available in multiple varieties of shapes, styles, and sizes made by numerous manufacturers. The basic components of a tracheostomy tube are illustrated in Fig. 3. The dimension of the tubes are specified by inner diameter (ID) and outer diameter (OD).

The ID of the cannula is the functional diameter of the tube. If an inner cannula is part of the tube component for ventilator attachment, the ID designation on the tracheostomy tube is the diameter of the inner cannula. The OD is the largest diameter of the outer cannula. The surgeon must consider the ID and OD when selecting a tracheostomy tube. If the ID is too small, it increases the resistance through the tube making airway clearance difficult and increases the cuff airway pressure to create a seal within the tracheal lumen. A tracheostomy tube with a large OD is difficult to pass into the surgical stoma and also has the potential to cause necrosis of the tracheal wall. Typically, the size of the tracheostomy tube should be three-fourths the tracheal diameter. Most often, a number 6 Shiley cuffed tracheostomy (SCT) is appropriate for the female patient and a number 8 SCT, for the male.

Standard length and extra long tracheostomy tubes are available. The extra length aids in tracheostomy tube placement in obese patients with a large neck.

The tracheostomy tubes can also be fenestrated, with an opening in the tube shaft above the cuff. The inner cannula has a fenestration matching the opening in the tracheostomy tube. There is a plastic plug supplied to cover the tracheostomy tube. The fenestrated tracheostomy tube
Fig. 2. Basic armamentarium used in tracheotomy procedure: (Top-Bottom, Left-Right): Hupp retractors, tracheotomy hook, army-navy retractors, Weitlander; #12 Frazier suction, metal tracheotomy tubes, short Allis, Metz scissors, straight Mayo scissors, curved mosquito clamp, curved Kelly clamp, smooth Adson pickup, #3 blade handle, needle holders, tissue forceps, and towel clips.

allows the patient to breathe through the fenestration and around the cuff once it has been deflated. This feature also allows the patient to force air into the vocal cords and phonate. It is recommended that the cuff be completely deflated before the tube is capped (Fig. 4).

Tracheostomy tubes can be constructed from metal or plastic. Metal tubes are not commonly used because of their rigidity and the lack of a connector to attach a ventilator. Plastic tubes are made from polyvinyl chloride or silicone. These tubes better conform to the anatomy of the trachea.

Fig. 3. Basic components of a standard tracheostomy tube.
Tracheostomy tubes are cuffed or uncuffed. Cuffed tubes protect the patient against aspiration of fluids, allow positive pressure ventilation, and aid in airway clearance. The uncuffed tubes provide no aspiration protection but can also be used for positive pressure ventilation. The authors prefer using a cuffed tracheostomy tube whenever possible. The tracheostomy tubes have high-volume low-pressure cuffs. This is an important feature developed to ensure tracheal capillary perfusion pressure. This pressure is normally around 25 to 35 mmHg, and higher pressures induced by the tube cuff can create mucosal injury and bleeding. If the pressure in the cuff is too low, it allows for aspiration of secretions and air leak. If the clinician finds it necessary to overinflate the cuff to create an air leak seal, this suggests that the diameter of the tracheostomy tube is too small for that patient. The maximum pressure in the cuff should not exceed 25 mmHg, and it can be checked periodically by the respiratory technician or the clinician using a pressure gauge.

Surgical procedure

The patient is positioned supine under general anesthesia, a shoulder roll providing extension at the neck level. Overextension of the neck should be avoided, because it can reduce the airway diameter and cause placement of the tracheostomy too low, risking damage to the innominate artery.

The surgeon should palpate and mark the important landmarks to include the thyroid notch, sternal notch, and the cricoid cartilage. A 1.5-cm horizontal line is marked half way between the cricoid cartilage and the suprasternal notch. This area is then infiltrated with 2% lidocaine with 1:100,000 parts epinephrine. The incision is then made just long enough to allow for placement of the tracheostomy tube. Dissection is carried through skin, subcutaneous layers, and fat, exposing the platysma muscle at the midline in some cases. The platysma muscle is then incised to identify the midline raphae between the strap muscles. The surgeon should periodically feel for the trachea deep within the surgical field to stay midline and avoid lateral dissection. The strap muscles are separated and retracted laterally to expose the thyroid isthmus and pretracheal fascia (Fig. 5).

The thyroid isthmus is normally found over the second and third tracheal rings. Some surgeons retract and elevate the thyroid gland superiorly and do not divide the isthmus. A retracted thyroid isthmus may rub against the tracheostomy tube and irritate it, leading to potential bleeding postoperatively. Furthermore, it can cause difficulty with swallowing as the thyroid gland moves up and down against the tracheostomy tube. The authors prefer to sharply incise the thyroid isthmus at the midline and suture the stump ends with 3-0 silk suture. There is potential for encountering some bleeding during this part of the surgery, and the use of electrocautery controls most bleeding in this area. Next, the tracheal fascia is cleaned off the trachea by using blunt dissection with small mosquito hemostats. A tracheal hook is then used to retract the trachea upward and superiorly (Fig. 6).
Fig. 5. (A, B) Initial horizontal incision made halfway between the cricoid cartilage and the sternal notch. The incision is then carried through skin, subcutaneous layers, and platysma muscle. After identifying the strap muscles, lateral retraction is placed on both sides of the trachea and a vertical incision is made to expose the thyroid isthmus and tracheal fascia.

Once informed of the planned entrance into the airway, the anesthesiologist may elect to reduce the Fio2 (fraction of inspired oxygen) to room air and discontinue the use of halogenated flammable gases. The surgeon should avoid using electrocautery, a potential fire hazard, once the trachea is opened to prevent serious burn injury to the patient. The authors recommend placing two 3-0 silk stay sutures as far laterally as possible on either side of the trachea and taping them to the skin outside of the incision. Postoperatively, if the tracheostomy tube becomes dislodged, these sutures can be used to lift the trachea and aid in replacement of the tube (Fig. 7).

Next, the surgeon prepares to make an incision into the airway for placement of the tube. The authors prefer to create a Björk flap, an inverted U-shaped flap into the trachea through rings 2, 3, and often 4. The inferiorly hinged flap of the anterior tracheal wall is sutured to the fascia or skin of the chest wall using 4-0 Vicryl (Johnson & Johnson, Ethicon Inc, Somerville, NJ, USA) or silk suture. If the inflated endotracheal tube-cuff is accidentally damaged and an air leak is created during these steps, the surgeon must work quickly to finish the surgical procedure and insert the tracheostomy tube to avoid oxygen desaturation. Once the Björk flap has been created, the operator should use the tracheal dilator to increase the circumference of the surgical stoma. This is a crucial step, which facilitates the insertion of the airway device (Figs. 8-16).

Fig. 6. (A, B) Use of electrocautery to incise the isthmus of thyroid gland. Tracheal hook used to retract the trachea superiorly.
Fig. 7. (A, B) Placement of stay-sutures lateral to the midline of the trachea. Entrance into the trachea achieved by creating an inverted U-shaped flap.

Before inserting the tracheostomy tube, the integrity of the tube cuff must be checked by inflating and deflating it. The authors coat the end of the tracheostomy tube with surgical lubricant to help insertion. The surgeon should next ask the anesthesiologist to slowly retract the endotracheal tube above the level of the entry into the airway. The endotracheal tube should not be completely withdrawn until the placement of the tracheostomy tube into the trachea has been confirmed. With the aid of the obturator placed and locked into the tracheostomy tube, the operator gently moves the tube into the trachea, turning it inferiorly to follow the normal anatomical curvature of the trachea. Next, the obturator is removed, the inner cannula is placed, and the anesthesia circuit is connected to the tracheostomy tube; ventilation is confirmed by positive evidence of end-tidal CO\textsubscript{2} and bilateral breath sounds by auscultation. Using interrupted 4-0 Prolene sutures (Johnson & Johnson, Ethicon Inc, Sommerville, NJ, USA), the tracheostomy tube flange is secured to the outer edge of the neck incision. A tracheostomy neck collar-tie is used to additionally secure the flange to the neck, taking care not to fasten the device too tightly. This allows some air leak from the periphery of the incision and does not create any pressure sores on the patient’s neck. To avoid the risk of subcutaneous emphysema and pneumomediastinum, the skin incision is not closed. A 4 x 4 inch sponge around the flange of the tube helps absorb minor oozing in the first 24 hours postoperatively. A portable chest radiograph is obtained in the postanesthetic care unit to confirm position of the tracheostomy tube and to evaluate the lung fields for presence of pneumothorax.

Fig. 8. (A, B) The Björk flap sutured to the anterior chest wall. The standard tracheal dilator is used to increase tracheal circumference before insertion of the tracheostomy tube.
Fig. 9. Surgical landmarks: Thyroid cartilage, cricoid cartilage, tracheal rings, and sternal notch.

Fig. 10. Horizontal incision made halfway between cricoid cartilage and sternal notch over tracheal rings.

Fig. 11. Vertical dissection in the midline thyroid isthmus, separated to expose the tracheal fascia.
Fig. 12. Tracheal fascia cleaned off the tracheal rings.

Fig. 13. Tracheal hook placed into the cricoid cartilage and retracted superiorly. Blade is placed over the tracheal rings to enter the airway.

Fig. 14. Björk flap developed in an inverted U-shape and sutured to the chest wall.
Complications

Complications can occur during the operative and early and late postoperative phases following tracheotomy.

Early Complications

A. Hemorrhage

This is usually minor and can be controlled by packing gauze or Surgicel (Johnson & Johnson, Ethicon Inc, Sommerville, NJ, USA) around the skin incision. The cuff of the tracheostomy tube should also be inflated to 25 mmHg, which helps control minor oozing. Major bleeding from the surgical site may require surgical exploration in the operating room. The most common sites for bleeding include the anterior jugular vein, the thyroid isthmus, and the innominate artery.

B. Subcutaneous emphysema

This can result from positive pressure ventilation, especially with a dislodged tracheostomy tube. It can also occur with forceful coughing against a tightly packed or occluded neck dressing. The neck incision should not be sutured around the tracheostomy tube to allow escape of air.

C. Obstruction

The tracheostomy tube can be occluded by mucous plugs, blood clots, or displacement into the adjacent subcutaneous layers. The distal tip of the tube may also occlude by lying against the tracheal wall. The tracheostomy tube should be suctioned frequently to prevent
common reasons for tube obstruction. If ventilation is not reestablished by suctioning, then the inner cannula must be inserted or the tube replaced.

D. False passage/dislodgement of tube

This can create an airway emergency. The surgeon should rely on the stay sutures to pull the trachea up, which will assist in replacing the tracheostomy tube. Oral intubation equipment and trained personnel in endotracheal intubation must be available if replacement of the tracheostomy tube is unsuccessful.

Late Complications

A. Tracheal stenosis

This occurs from ischemia of the trachea usually because of high pressure cuffs, forced angulation of tubes, or overinflated cuffs that damage the trachea. As discussed earlier, the pressure within the cuff should not exceed 25 mmHg and should be checked by trained personnel at least once per shift.

B. Swallowing problems

The patient may complain of a foreign body sensation on swallowing. Hyperinflation of the cuff can compress the esophagus resulting in dysphagia.

C. Tracheo-innominate artery fistula

This is directly linked to the tracheostomy tube or the cuff placing pressure on the major vessel. Low placement of the tracheostomy and excessive tube and head movement have also been linked to this potentially lethal complication. The overall survival rate is 25%. Correct placement of the tube between the second and third tracheal rings and avoidance of prolonged hyperextension of the neck can prevent this complication. The hemorrhage is evident from severe bleeding through and around the tracheotomy stoma. If erosion occurs, the tracheostomy tube should be overinflated and suprasternal pressure applied through the stoma to achieve tamponade of the vessel. An emergency median sternotomy and innominate artery ligation are then required.

D. Tracheoesophageal fistula

Due to erosion of the tracheostomy tube through the posterior wall of the trachea, surgical repair of the fistula through a cervical approach is required.

E. Granuloma formation

This results from foreign body reaction to the tracheostomy tube. The superficial granulomas can easily be treated with application of silver nitrate sticks. The deeper granulomas may require bronchoscopic removal by trained personnel.

F. Persistent stoma

This is usually due to a tracheostomy tube that has been left in place for a prolonged period or to poor wound healing. Although most stomas spontaneously close with time, surgical closure can be used to close a persistent stoma.

Nursing care of the tracheotomy patient

Much has been written in the literature on the postoperative care of the tracheotomy patient. The authors suggest some general guidelines:

A. The tracheostomy tube must be secured and left undisturbed to heal for 5 to 7 days to allow tracheocutaneous tract formation. Ideally, the first dressing change around the tube should be done by the surgeon on the first postoperative day.
B. The tracheostomy should be kept dry, and frequent change of wound dressing prevents postsurgical infection.

C. Frequent suctioning by the nursing staff, especially in the early phases of the postoperative period, will help pulmonary clearance of secretions and ventilation. The inner cannula must also be changed frequently to aid in keeping a patent tube for adequate ventilation. Deep suctioning beyond the distal tip of the tracheostomy tube should be minimized, because this can increase the risk of mucosal damage.

D. The cuff pressure must be monitored to maintain a pressure of 25 mmHg.

E. Speech, the authors recommend the use of a fenestrated tracheostomy tube to assist in ventilation. This requires changing the standard tracheostomy tube to a fenestrated tube and should be done at least 5 to 7 days after the initial insertion.

Criteria for tracheostomy decannulation

Multiple criteria and protocols are available for tracheostomy tube decannulation and there are practical measures to prevent failure. The clinician should only consider decannulation if the upper airway obstruction is resolved and mechanical ventilation is no longer needed. A time-tested bedside maneuver called the cuff-leak test is a practical check for the presence of upper airway obstruction. The patient should be on appropriate monitors to include pulse oximetry. Following full deflation of the tracheostomy tube cuff, a finger is placed over the tracheostomy tube opening and the clinician notes if breathing through the mouth and nose is present. The presence of stridor, labored breathing, retraction of intercostal muscles, and diaphoresis are signs of upper airway obstruction. The patient should return to the original mode of respiratory support. An endoscopic examination of the airway may reveal the site of obstruction. Decannulation of patients with prolonged tracheotomy is not as straightforward and may require downsizing of the tubes to facilitate it. The following are generalized criteria for patients on prolonged mechanical ventilation.

A. Stable arterial blood gases
B. Absence of distress
C. Hemodynamic stability
D. Absence of fever or active infection
E. PaCO₂ less than 60 mmHg
F. Absence of acute psychiatric disorder
G. Adequate swallowing
H. Ability to expectorate.

Summary

Tracheotomy is a surgical procedure that dates back to early history and medical advancement. The oral and maxillofacial surgeon routinely operates around the airway and should be able to master this procedure by adhering to the surgical principles outlined in this article.

Further readings