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Atlas of the Oral and Maxillofacial Surgery Clinics

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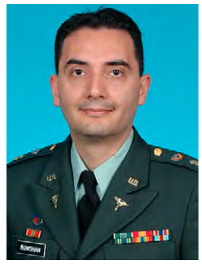
Preface



Henry H. Rowshan, DDS, MAJ, USA   Dale A. Baur, DDS, MD
Guest Editors

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 extent 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

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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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Atlas of the Oral and Maxillofacial Surgery Clinics

Causes of the Difficult Airway

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The American Society of Anesthesiologists (ASA) has stated there is not a standard definition of the difficult airway in the literature. However, they recognize the difficult airway to be one in "which a conventionally trained anesthesiologist experiences difficulty with face mask ventilation of the upper airway, difficulty with tracheal intubation, or both." Furthermore, the ASA Difficult Airway Task Force in 2003 defined the following: difficult face mask ventilation, difficult laryngoscopy, and difficult and failed intubations. A difficult face mask ventilation is a situation in which the clinician is unable to provide adequate tidal volumes due to one or more of the following problems: inadequate mask seal, excessive gas leak, or excessive resistance to the ingress or egress of gas. A difficult laryngoscopy is defined as not being able to see any part of the vocal cords with a direct laryngoscopy. A difficult intubation refers to the situation in which multiple intubation attempts are required in the presence or absence of tracheal pathology. Lastly, a failed intubation is defined by multiple attempts whereby the clinician fails to secure the airway. Any of these difficulties can lead to unfavorable outcomes such as hypoxic brain injuries, airway injuries, and even death.

There are 2 separate scenarios for considering the difficult airway. The first is difficult mask ventilation (DMV) and the second, difficult tracheal intubation (DTI). DMV can be clarified as lacking the ability to maintain oxygen saturation (pulse oximetry $>92\%$), or lacking the ability to reverse signs of inadequate ventilation with positive-pressure mask ventilation under general anesthesia. There are several risk factors associated with DMV. These factors include body mass index (calculated as the weight in kilograms divided by height in meters squared) of more than 26 kg/m^2, the presence of a beard, edentulism, a history of snoring, and an age older than 55 years.

The second category, DTI, remains constant among anesthesia-related patient injuries, and is the third most common respiratory-related episode leading to death and possible brain damage. Many factors are helpful in recognizing a DTI patient, and these predictors include decreased mouth opening, Mallampati classification, restricted head and neck movement, a retrognathic mandible, protrusive maxillary incisors, decreased thyromental distance, decreased sternomental distance, obesity, and a previous history of difficult intubation. The experience of the intubator and the equipment used obviously may play a role in the DTI.

It is worth noting that DMV and DTI can be encountered either together or separately from one another. Rose and Cohen stated that the incidence of DMV is 0.9%, whereas other studies by Asai and colleagues reported 1.4%. One study by Williamson and colleagues showed that the incidence of DMV increased significantly when difficult intubation was encountered, and the incidence rose to 15% in their retrospective study of 2000 reports.

Recognizing a potentially difficult airway is important in avoiding a life-threatening emergency. Therefore, it is critical to preoperatively assess every patient by completing a full history and physical. A thorough history can provide clues in detecting a possible difficult

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airway. Does the patient have any c-spine pathology that limits their neck's range of motion? Does the patient have any temporomandibular dysfunction that limits their maximal incisal opening? Has the patient ever been told that he or she was a difficult intubation after undergoing a general anesthetic? These are just some of the basic, but key elements that could provide valuable details of the patient's history.

A key aspect to the physical examination is the airway assessment, which takes only minutes to complete. This assessment provides crucial information, which could mean the difference between a safe and successful anesthetic and a life-threatening emergency situation. Normal head extension is in the range of 35°. An adult should have a maximal incisal opening of approximately 40 mm, or 2 to 3 fingerbreadths. The patient's thyromental distance should be evaluated. Anything less than 6 cm might suggest a difficult airway. Mallampati's classification of the relationship between the size of the base of the tongue, faucal pillars, soft palate, and base of the uvula provides yet another clue. Classes I and II have adequate hypopharyngeal views and typically are easier intubations, whereas classes III and IV tend to be more difficult intubations. Again, these parameters could mean the difference between life and death for a patient undergoing general anesthesia.

It has been estimated that difficult direct laryngoscopy and difficult intubation present anywhere from 1.5% to 8.5% of all airway cases. The reasons why clinicians encounter difficult airways are numerous. The spectrum of reasons ranges from congenital syndromes to malignancies to odontogenic infections, to name but a few. Regardless of the etiology, clinicians must recognize it and prepare for the worst-case scenario. Airway impairment has been further subdivided into the anatomic regions that affect the airway. These classifications were described by Liess and colleagues as above the larynx, supraglottic, glottic, subglottic, and tracheobronchial. The following sections discuss the factors that can result in a difficult airway.

Tumors

Tumors of the maxillofacial region can present with either a direct or indirect impingement on the airway. A mass may be of significant size and directly make the exchange of oxygen difficult, as it can lead to tracheal deviation, or the tumor itself may be situated on the larynx (Figs. 1–5). As Moorthy and colleagues showed with their clinical experience of 801 cases, patients with laryngeal tumors present an obvious challenge to securing the airway, and therefore it is pertinent that the clinician be extremely prepared and follow a set of guidelines to reduce the number of emergency situations. Second, the impingement can present itself as an adverse outcome from treatment. Following any procedures in the maxillofacial region, a patient is susceptible to developing a hematoma. Whether the hematoma is a result of a resection, fine-needle aspiration, or even placement of a dental implant during the reconstruction phase, a hematoma may lead to a crisis needing immediate intervention (see Fig. 5). Patients who undergo surgery for a head and neck tumor may also

Fig. 1. Patient with a mass compressing the airway. (*Courtesy of* R. Rezaee, MD, Cleveland, OH.)

Fig. 2. Patient with a mass compressing the airway. Deviated placement of the surgical airway. The lateral placement was found to be the shortest distance to the trachea. (*Courtesy of* R. Rezaee, MD, Cleveland, OH.)

undergo radiation treatment that could potentially lead to fibrotic scarring of the tissues in the neck. This fibrosis could lead to a reduced range of motion or a distortion in the tissue of the upper airway, both of which could prevent securing an airway.

Congenital anomalies

Syndromes that affect the development of the craniofacial complex can present the practitioner with a difficult intubation. Such syndromes include, but are not limited to, Pierre Robin sequence, Treacher Collins syndrome, Craniofacial synostosis, Goldenhar syndrome, and laryngeal atresia. For instance, patients with either Pierre Robin sequence or Treacher Collins syndrome will present with severe mandibular retrognathia and chin dysplasia, in which both abnormalities lead to a posteriorly displaced tongue. This condition leads to difficult visualization of the vocal cords during conventional laryngoscopy.

Infections

Odontogenic infections of the deep facial spaces can lead to life-threatening airway compromises. Ludwig angina is of greatest concern. Ludwig angina involves the submandibular, sublingual, and submental spaces bilaterally. In addition to the tracheal deviation (Fig. 6) that these patients can present with, trismus can make direct laryngoscopy a challenge.

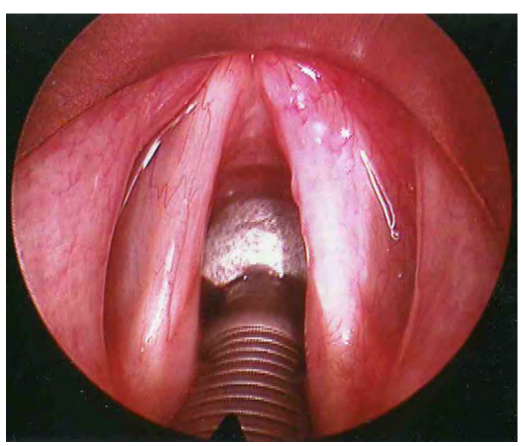

Fig. 3. A normal larynx. (*Courtesy of* R. Rezaee, MD, Cleveland, OH.)

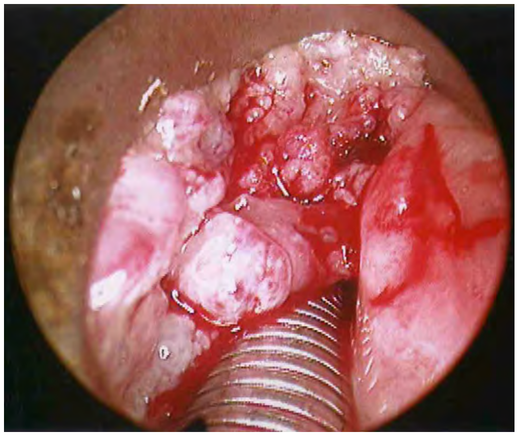

Fig. 4. Larynx with laryngeal mass. (*Courtesy of* R. Rezaee, MD, Cleveland, OH.)

Trauma

Patients who present with maxillofacial trauma can be classified as having a difficult airway for a variety of reasons. Fractures of the maxillomandibular complex can make it difficult to successfully deliver adequate tidal volumes during bag mask ventilation (Fig. 7). If the mandible is avulsed, it may be necessary to pass a suture or towel clip in the midline of the tongue to prevent airway obstruction by the tongue. Trauma patients may have cervical spine injury, which requires them to be placed in a c-collar until the appropriate studies are done and a surgical team clears them. Even though immediate surgery is rarely needed for the maxillofacial trauma patient, these patients often present with multiple other injuries that do require immediate intervention. If an emergency trip to the operating room is inevitable for these patients, the c-collar can make securing the patient's airway more difficult as their neck extension is limited. Thus, maxillofacial trauma may result in a difficult airway, directly or indirectly.

Inadequate range of motion

Limited range of motion of either the temporomandibular joints or the patient's neck can present itself as another challenging scenario. As discussed previously, the optimal position for intubation is with the head extended to 35°. If the patient is unable to reach this position, either due to injury or a previous c-spine fusion, the practitioner might find it more challenging to successfully place an endotracheal tube by conventional methods. Patients who suffer from

Fig. 5. Patient with thyroid carcinoma that led to a hematoma compressing the airway. (*Courtesy of* R. Rezaee, MD, Cleveland, OH.)

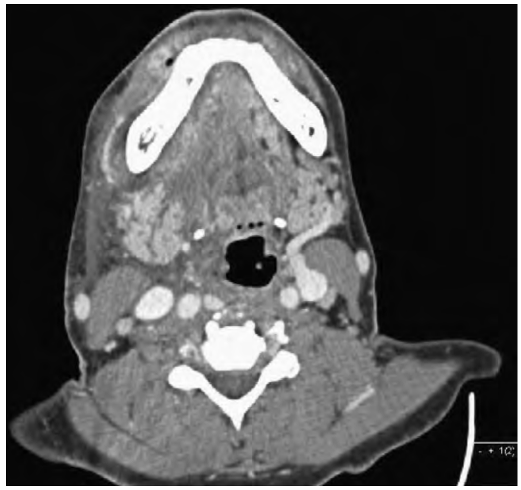

Fig. 6. Tracheal deviation due to infection.

temporomandibular dysfunction may also have a limited interincisal opening for various reasons, two of which are pain and internal derangement. If pain is the limiting factor, the induction of anesthesia could relieve this symptom, allowing the patient to open to the standard 40 mm required for an easier intubation. If internal derangement is the cause, the attempt to intubate the patient will likely result in a difficult airway because the maximal incisal opening could be inadequate to introduce a laryngoscope into the patient's mouth, necessitating an alternative method for intubation.

Temporomandibular joint (TMJ) ankylosis also poses a problem. TMJ ankylosis results from soft tissue or bony ankylosis (Fig. 8). TMJ ankylosis can be congenital or posttraumatic, and may lead to a severe inability to open the mouth.

Other

In this broad category a large number of scenarios can present themselves. Anything from obesity to anatomic anomalies can pose as challenges for a practitioner attempting to secure a patient's airway. An obese patient can present a challenge in one of the most basic principles, proper patient positioning. When placed in a supine position an obese patient will likely not be

Fig. 7. Computed tomography (CT) scan of mandibular fracture. Posterior displacement of the anterior mandible and lack of tongue support led to an airway compromise.

Fig. 8. CT Scan of bilateral temporomandibular joint ankylosis.

in proper sniffing position. The sniffing position allows the intubating clinician the easiest view of the vocal cords. This position allows for the oral, tracheal, and pharyngeal axes to be in a somewhat linear organization. To properly achieve this position the patient may need to be propped up with several pillows or blankets under their upper back. The mere placing of these pillows or blankets can be a difficult task in a nonemergency situation. Therefore, it is important to consider proper patient position when considering an obese patient to undergo a general anesthetic.

There are many anatomic variations to take into consideration when evaluating a patient preoperatively. Some to consider are macroglossia, prominent upper incisors, micrognathia, and a short neck. For these reasons, it is crucial that clinicians complete and document a full history

Fig. 9. Lateral cone-beam CT view of an obstructive sleep apnea patient.

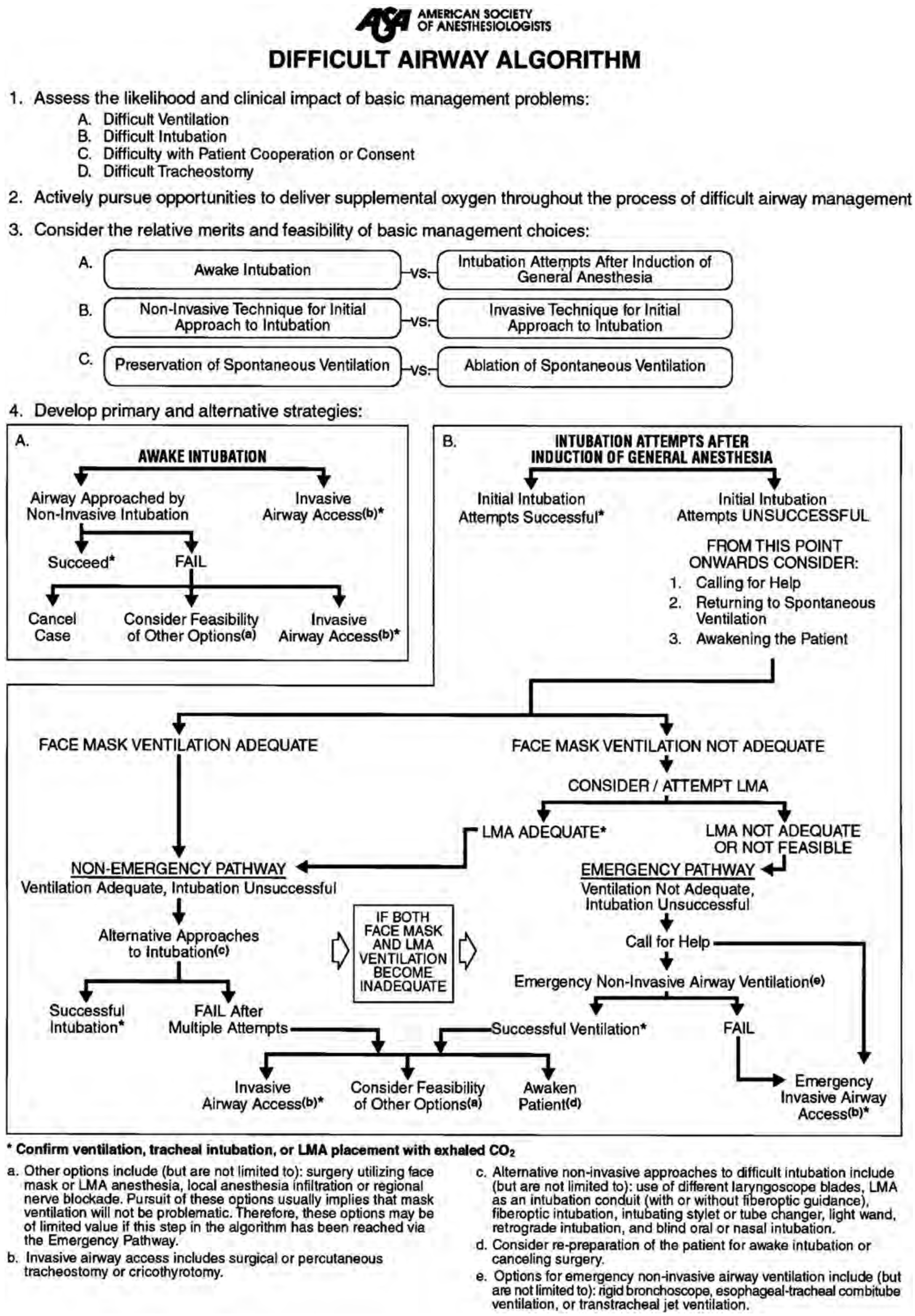

Fig. 10. Difficult airway algorithm. (*From* Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2003;98:1269; with permission.)

and physical. It is important for the clinician to anticipate any difficulty that may be encountered and be prepared for the worst.

Obstructive sleep apnea (OSA) affects more than 10% of the population older than 65 years and affects men more than women. OSA is described as the episodic collapse of the upper airway during sleep, which leads to a blockage despite a continuous attempt to breathe normally. Airflow obstruction may occur at any point along the airway from the soft palate to the hypopharynx posterior to the tongue. This narrow airway in an OSA patient is illustrated in Fig. 9.

Managing the difficult airway

Benjamin Franklin once said ''By failing to prepare you are preparing to fail.'' This adage can be applied to the everyday practice of oral and maxillofacial surgery. The first step in avoiding an emergency situation is proper evaluation of the patient preoperatively. If the patient is deemed a candidate for a general anesthetic, it is of the utmost importance that one is prepared for the worst-case scenario. Whether that may be in the operating room or the office, both should have either an area or cart that is dedicated to managing the difficult airway. This equipment should be checked and maintenance provided on a regular basis in order to avoid a catastrophe. This equipment should allow for the ability to bag mask ventilate a patient, either through a circuit and anesthesia machine or a simple bag mask. The following basic equipment should be available: face masks, oral and nasal airways, laryngeal mask airway (LMA) devices, laryngoscopes in multiple sizes, with both Macintosh and Miller blades, cuffed endotracheal tubes in multiple sizes, malleable stylets, and a cricothyrotomy set.

Each clinical scenario that is encountered will pose different challenges to the clinician. Therefore, it is critical that the clinician is able to recognize an emergency quickly and act accordingly. Just as important as the appropriate equipment being available is the clinician's ability to troubleshoot the difficult airway. In 2003 the ASA developed ''The Difficult Airway Algorithm,'' which can be used as a tool to guide the management of the difficult airway. (Fig. 10).

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Further readings

Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2003;98:1269.

Adnet F, Baillard C, Borron SW, et al. Randomized study comparing the ''sniffing position'' with simple head extension for laryngoscopic view in elective surgery patients. Anesthesiology 2001;95:836.

Asai T, Koga K, Vaughan RS. Respiratory complications associated with tracheal intubation and extubation. Br J Anaesth 1998;80:767.

Benumof JL. Management of the difficult adult airway. With special emphasis on awake tracheal intubation. Anesthesiology 1991;75:1087.

Burkle CM, Walsh MT, Harrison BA, et al. Airway management after failure to intubate by direct laryngoscopy: outcomes in a large teaching hospital. Can J Anaesth 2005;52:634.

Crosby ET, Cooper RM, Douglas MJ, et al. The unanticipated difficult airway with recommendations for management. Can J Anaesth 1998;45:757.

Del Castillo-Pardo de Vera JL, Lopez-Arcas Calleja JM, Burgueno-Garcia M. Hematoma of the floor of the mouth and airway obstruction during mandibular dental implant placement: a case report. Oral Maxillofac Surg 2008;12:223.

Drazen JM. Sleep apnea syndrome. N Engl J Med 2002;346:390.

Frerk CM. Predicting difficult intubation. Anaesthesia 1991;46:1005.

Kraus SL. Physical therapy management of temporomandibular disorders. In: Fonseca RJ, editor. Oral and maxillofacial surgery, vol. 4. Philadelphia: W.B. Saunders; 2000. p. 165.

Langeron O, Amour J, Vivien B, et al. Clinical review: management of difficult airways. Crit Care 2006;10:243.

Lavery GG, McCloskey BV. The difficult airway in adult critical care. Crit Care Med 2008;36:2163.
Liess BD, Scheidt TD, Templer JW. The difficult airway. Otolaryngol Clin North Am 2008;41:567.
Mallampati SR, Gatt SP, Gugino LD, et al. A clinical sign to predict difficult tracheal intubation: a prospective study. Can Anaesth Soc J 1985;32:429.
Gal TJ. Miller's anesthesia: 2-volume set. 6th edition. Philadelphia (PA): Churchill Livingstone; 2009.
Moorthy SS, Gupta S, Laurent B, et al. Management of airway in patients with laryngeal tumors. J Clin Anesth 2005;17:604.
Noordzij JP, Goto MM. Airway compromise caused by hematoma after thyroid fine-needle aspiration. Am J Otolaryngol 2005;26:398.
Oghalai JS, Giannoni C, Donovan DT, et al. Aggressive cervical lymphoma presenting as airway obstruction. Otolaryngol Head Neck Surg 1999;120:610.
Ovassapian A, Tuncbilek M, Weitzel EK, et al. Airway management in adult patients with deep neck infections: a case series and review of the literature. Anesth Analg 2005;100:585.
Pashayan AG, Passannante AN, Rock P. Pathophysiology of obstructive sleep apnea. Anesthesiol Clin North America 2005;23:431.
Posnick JC, Ruiz RL. Treacher Collins syndrome: current evaluation, treatment, and future directions. Cleft Palate Craniofac J 2000;37:434.
Rashkin MC, Davis T. Acute complications of endotracheal intubation. Relationship to reintubation, route, urgency, and duration. Chest 1986;89:165.
Rose DK, Cohen MM. The airway: problems and predictions in 18,500 patients. Can J Anaesth 1994;41:372.
Samsoon GL, Young JR. Difficult tracheal intubation: a retrospective study. Anaesthesia 1987;42:487.
Tintinalli JE. Emergency medicine: a comprehensive study guide. 6th edition. New York (NY): McGraw-Hill Professional; 2003.
Van Elstraete AC, Mamie JC, Mehdaoui H. Nasotracheal intubation in patients with immobilized cervical spine: a comparison of tracheal tube cuff inflation and fiberoptic bronchoscopy. Anesth Analg 1998;87:400.
Walker RW. Management of the difficult airway in children. J R Soc Med 2001;94:341.
Wetmore RF. Pediatric otolaryngology: requisites in pediatrics. 1st edition. Philadelphia (PA): Mosby; 2007.
Williamson JA, Webb RK, Szekely S, et al. The Australian Incident Monitoring Study. Difficult intubation: an analysis of 2000 incident reports. Anaesth Intensive Care 1993;21:602.
Young T, Palta M, Dempsey J, et al. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 1993;328:1230.

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Atlas of the Oral and Maxillofacial Surgery Clinics

Management of the Difficult Airway

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Oral and maxillofacial surgeons use in-office anesthesia techniques on a daily basis more than any other specialty outside anesthesiology. Despite the magnitude of the number of patients who receive deep sedation and general anesthesia in oral and maxillofacial surgeons' offices every year, the mortality is low, attesting to the skill and safety vigilance of the specialty. Nevertheless, complications are inevitable and urgent or emergent issues need to be anticipated. Therefore, competence in airway evaluation and management of the difficult airway are essential skills for the oral and maxillofacial surgeon.

Difficult or failed airway management during untoward events accounts for most anesthesia-related morbidity and mortality, and there is no one test to determine a patient's risk of airway compromise while undergoing general anesthesia [1]. Instead, multiple considerations must be taken into account when evaluating and treating each patient. Because airway compromise can lead to rapid decompensation of the patient, thorough evaluation and competent knowledge of how to approach a difficult airway allow swift action when complications in airway management occur, potentially alleviating a life-threatening situation.

What is a difficult airway?

There is no one accepted definition of a difficult airway, but instead the difficult airway generally comprises a set of factors including inadequacy of ventilation using a facemask, inability to visualize the vocal cords with a laryngoscope, difficulty or inability to intubate with standard endotracheal tubes, or the need to use surgical means to establish an airway. The level of difficulty may be altered by the patient's health status, airway anatomy, or the surgical procedure that is being performed. The goal for the oral and maxillofacial surgeon is to evaluate the difficult airway thoroughly preoperatively and correlate these findings with a potential difficult airway to prevent complications during anesthesia.

Airway evaluation

Because of the number and variety of procedures that are performed in close proximity to the airway, many patients undergoing oral and maxillofacial surgery present special challenges with anesthesia and airway protection. It is imperative, therefore, that any patient undergoing nonemergent anesthesia in an office or operating-room setting should have a complete history and airway physical examination to identify and attempt to prevent any airway compromise. Important questions include difficulties with anesthesia in the past, family history of difficult anesthesia, and a current list of all medications being taken. If there is a history of prior anesthetic problems, the oral and maxillofacial surgeon should request anesthesia records to identify which airway management techniques were used and if the results were optimal for the

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patient's treatment. Other factors that may lead to difficult airway management and are important to include in the preoperative evaluation include a history of sleep apnea, snoring, or head and neck abnormalities [2].

Many preoperative physical examinations have been developed to predict the possibility of a difficult airway. Individually, these tests may not be sensitive or specific enough to use independently, but in combination they may be used to quantify a patient's risk of undergoing anesthetic procedures [1]. These tests include the Mallampati classification, thyromental distance, sternomental distance, and maximum vertical opening (MVO).

Mallampati score

The Mallampati classification system was developed to relate the oropharyngeal space with the ease of direct laryngoscopy by rating the shape of the palate and the displacement of the tongue [1,3]. This test also assesses if the MVO is large enough to permit intubation. To perform the test, the examiner observes the patient at eye level and asks the patient to open the mouth maximally and protrude the tongue without phonating. The examiner then classifies the airway according to the structures that are visible in the pharyngeal area. In a class I airway the soft palate, fauces, uvula, and tonsillar pillars are visible; in class II the soft palate, fauces, and uvula are visible; in class III the soft palate and base of uvula are visible; and in class IV only the hard palate is visible (Fig. 1). A Mallampati score of III or greater indicates the potential for a difficult intubation and mandates additional consideration. Tuzuner-Oncul and Kucukyavuz [4] evaluated difficult intubations in 208 oral and maxillofacial surgery patients and concluded that a Mallampati score of III or IV related to a sensitivity of 59% and a specificity of 83% for the prediction of difficult intubation.

Thyromental distance

The thyromental distance is believed to be an indicator of the ability to displace the tongue during attempted direct visual laryngoscopy (DVL) and is therefore a marker for the amount of mandibular space available [1]. The thyromental distance is measured with the patient lying supine with the head fully extended and the mouth closed. A ruler measures the straight line distance from the thyroid notch to the lower border of the mentum. A distance of 6.5 cm or less is a predictor of a difficult airway as it is usually seen in patients with retrognathia or a short neck [5]. This creates the inability to visualize the larynx during tracheal intubation (Fig. 2). This test can be performed simply at the bedside without a ruler by estimating the number of fingerbreadths between the thyroid and the mentum. Three fingerbreadths or more is usually consistent with the ability to visualize the larynx during DVL (Fig. 3).

Fig. 1. Mallampati classification (class I–IV).

Fig. 2. Thyromental distance. Ruler measurement from thyroid cartilage to menton of mandible.

Sternomental distance

The sternomental distance is classified as an indicator of head and neck mobility. It is measured with the patient's head in full extension from the sternal notch to the bony menton (Fig. 4). During airway evaluation a patient who has less than 12.5 cm sternomental distance may not have the neck flexibility to be placed in the proper position for ventilation or oxygenation [5]. The proper alignment about the atlantooccipital joint when the neck is extended places the axes of the larynx, pharynx, and mouth so they are almost parallel: the so-called sniffing position (Fig. 5). This sniffing position increases the success rate of DVL and the ability to establish a secure airway [6,7].

MVO

Because the oropharyngeal airway is generally the main access point for ventilation in an emergency, an interincisal distance of less than 30 mm is considered to add potential difficulty to airway management. Trismus, infection, tumors, and temporomandibular joint (TMJ) disorders are encountered by the oral and maxillofacial surgeon regularly and can severely limit the MVO. Once general anesthesia has been induced with muscle relaxation, patients who have a condition in which pain limits the ability to open will have an increase in MVO. On the other hand, when a true mechanical obstruction exists, the practitioner must be prepared with alternative airway options, as even paralyzed patients may not open their mouth sufficiently for placement of a laryngoscope.

Fig. 3. Thyromental distance. Finger measurement from top of thyroid cartilage to menton of mandible.

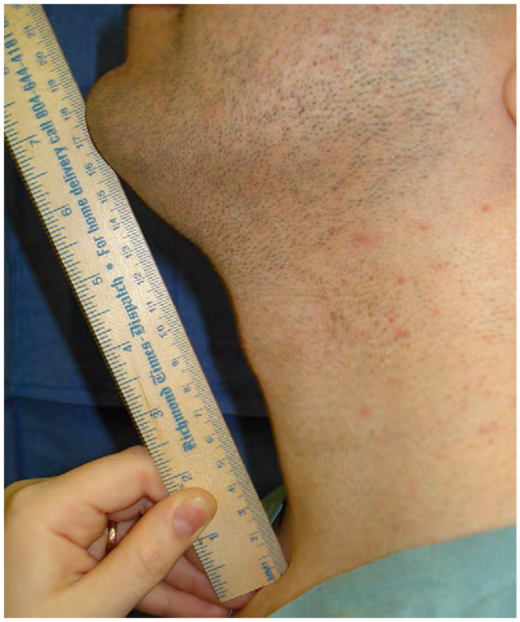

Fig. 4. Sternomental distance. Ruler measurement from top of sternal notch to menton of mandible.

Other factors to consider in anesthesia evaluation

Along with the preoperative tests that objectively evaluate a difficult airway, the oral and maxillofacial surgeon must also consider the overall body habitus of the patient and note any congenital or pathologic conditions that could influence and alter airway management (Tables 1 and 2). The obese patient requires special consideration during airway evaluation; the overweight patient has a decreased functional residual capacity, desaturates oxygen stores rapidly, and may have difficulty with mask ventilation [6]. Obesity is also associated with a decrease in posterior airway space, which increases the risk factors for obstructive sleep apnea [8]. In a clinical review of the management of difficult airways, Langeron and colleagues [8] found that in obese and morbidly obese patients (body mass index [BMI] calculated as weight in kilograms divided by the square of height in meters >30 kg/m^2 and >40 kg/m^2, respectively) the risk of oxygen desaturation during induction of anesthesia and the risk of difficult intubation are increased significantly.

Techniques for management of the difficult airway

Even with thorough preoperative evaluation, the unexpectedly difficult airway may be encountered regularly by the oral and maxillofacial surgeon and can quickly become a life-threatening emergency if not handled properly. More than 600 patients die annually because of inability to intubate, [9] and DVL is impossible in 0.05% to 0.35% of patients who have an apparently normal airway evaluation [4]. Maintaining Spo_2 levels and preventing long apnea periods are goals throughout any anesthetic procedure; as long as a patient can be adequately ventilated complications are less likely to occur. Bag-valve-mask ventilation is a skill that is heavily relied on when securing a definitive airway is difficult or impossible. The most feared situation encountered with the difficult airway is the ‘‘cannot intubate–cannot ventilate patient.’’ Prospective studies have found independent risk factors for increasing the difficulty of bag-mask ventilation, including age greater than 55 years, BMI greater than 26 kg/m^2, edentulism, presence of a beard, and history of snoring [8]. There is a continuum in bag-valve-mask ventilation with many adjunct maneuvers that can make ventilation more successful (Fig. 6). If it is not immediately possible to ventilate a patient with a bag-valve-mask via the natural airway the patient should first be repositioned with a head tilt, chin lift, and jaw thrust [6,7].

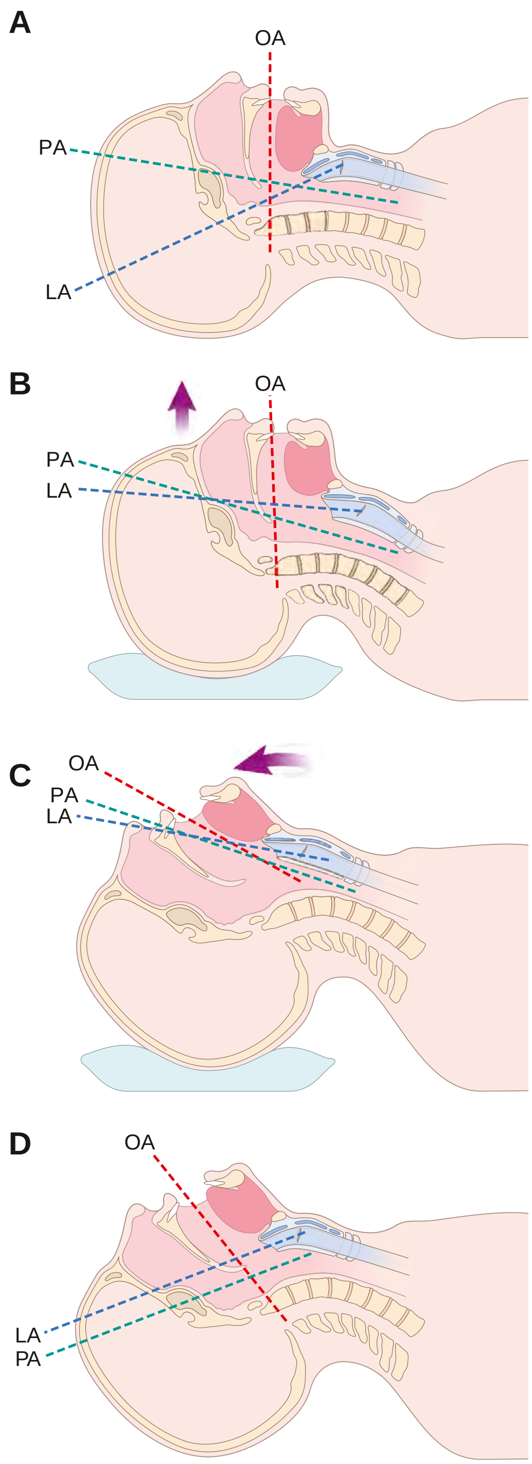

Fig. 5. Sniffing position: correct patient placement (*A–D*). (*From* Stackhouse R, Infosino A. Airway management. In: Stoelting R, Miller R, editors. Basics of anesthesia. 5th edition. Philadelphia: Churchill Livingstone/Elsevier; 2007. p. 214; with permission.)

If this is unsuccessful, 2-hand-mask ventilation with a second operator or insertion of nasal/oral airways or both should be considered. If outpatient anesthesia is being performed in an office setting another trained person should be immediately available in case a second set of hands is needed to assist with bag-valve-mask ventilation. If the second operator is needed, the optimal position is for the primary anesthesia provider to fix the mask to the face with the left hand while

Table 1
Congenital syndromes associated with airway difficulty

Syndrome	Potential complication
Pierre Robin	Mandibular retrognathia, macroglossia, micrognathia
Trisomy 21 (Down)	Macroglossia, microstomia, laryngospasm is common
Goldenhar	Cervical spine abnormalities, mandibular hypoplasia
Treacher Collins	Mandibular hypoplasia, difficult to DVL
Turner	High likelihood of difficult intubation

the right hand remains on the ventilation bag. The second person covers the primary anesthesiologist's left hand with his or her right hand and lifts the jaw into the mask with the left hand (Fig. 7). This technique provides the primary provider with the necessary sense of tactility and compliance for good ventilation. If the second operator does not feel comfortable assisting with the placement of the mask the primary operator may use both hands for jaw thrust and placement of mask while the second operator squeezes the bag for ventilation (Fig. 8).

Adjunct oral and nasal airways work to create a passage for oxygen transmission by preventing the base of the tongue from falling against the wall of the pharynx. Oral and nasal airways come in various sizes (Figs. 9 and 10) and should be chosen so that the tip of the airway is lined up with the angle of the mandible when the proximal end is resting at the lips or the nares (the correct position of adjunct airways is shown in Figs. 11 and 12). Oral airways are better tolerated in the deeply anesthetized patient so as not to provoke laryngospasm and are usually sufficient in the edentulous patient to allow a patent airway and appropriate fit of the bag-mask. Nasal airways are better suited for the more lightly anesthetized patient and may stay in place throughout many oral and maxillofacial surgical procedures to maintain an open air passage. Any combination of oral and nasal airways may be used to increase oxygenation and create a patent airway in the patient who is difficult to ventilate with a bag-valve-mask. If these adjunct techniques are successful and the patient can be adequately ventilated, the practitioner may move on to establishing a secure airway at a nonurgent pace. If ventilation is inadequate, more rapid attempts at securing an airway become necessary; this is discussed in detail elsewhere in this article.

Difficult intubation may be anticipated with thorough preoperative evaluation, but as many as 5.8% of all intubations in seemingly normal patients are eventually classified as difficult [1]. A difficult intubation has been defined as one that requires external laryngeal manipulation, laryngoscopy requiring more than 3 attempts at intubation, intubation requiring nonstandard equipment or approaches, or the inability to intubate at all [2]. Endotracheal intubation through the nose or the mouth is the most common way to maintain a secure airway for a patient. Endotracheal intubation via DVL is the most common first-line maneuver to intubate a patient. To perform DVL the patient is placed in the sniffing position (see Fig. 5), the patient's mouth is gently opened with scissor motion of the right hand, and a laryngoscope is entered into the patient's mouth from the right side, moving the tongue to the left side of the mouth using

Table 2
Pathologic states associated with airway difficulty

Pathologic state	Potential complication
Diabetes	Decreased mobility at atlantooccipital joint
Mandibular abscess	Distortion of airway, mechanical obstruction with limited MVO, difficult to ventilate
Radiation therapy	Fibrosis with limited neck extension, distortion of airway
Ankylosing spondylitis	Fusion of cervical spine, unable to extend neck
Thyromegaly	Goiter may distort/compress airway
Scleroderma	Immobile skin surrounding lower facial third and TMJ restriction limit MVO
Maxillary/mandibular trauma	Difficulty with ventilation, possible airway obstruction
Rheumatoid arthritis	TMJ arthritis, immobile cervical spine, mandibular hypoplasia
Neoplasm (oral, laryngeal)	Airway obstruction/distortion
TMJ disorders	Limited MVO
Hypothyroidism	Large tongue, myxedema, difficult to ventilate and intubate
Sarcoidosis	Airway obstruction with lymphoid tissue
Obesity	Upper airway obstruction once sedated, mask ventilation difficult

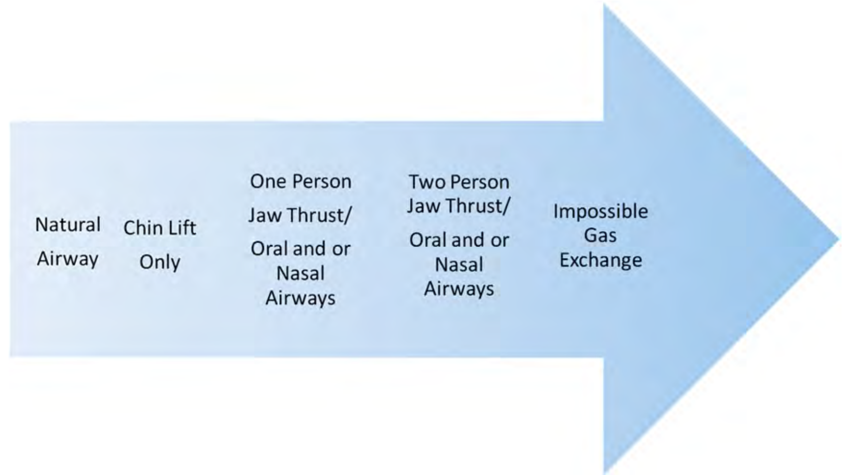

Fig. 6. Continuum on bag-valve-mask ventilation.

the flange on the scope (Fig. 13). Multiple variations of laryngoscope blades exist (Fig. 14), with the most common being the Macintosh (straight) and Miller (curved) blades. No one blade is more successful than any other; the most important aspect is that the practitioner feels comfortable with the laryngoscope. If the laryngeal aperture is not visualized with the laryngoscope after correct placement, external cricoid pressure (Sellick maneuver) is attempted to better visualize the vocal cords. This maneuver is accomplished by using the thumb and first finger to apply downward pressure on the cricoid cartilage; this compresses the esophagus against the cervical spine to prevent gastric aspiration and close the aperture of the esophagus, thus increasing the likelihood of tracheal intubation. After 3 failed attempts with 1 or multiple practitioners, direct laryngoscopy should be stopped in favor of alternative approaches to a secure airway. Repeated unsuccessful laryngoscopy can cause bleeding, edema, and increased secretions, which may make later ventilation impossible [2].

A bougie is a semirigid elastic tube that is a 60-cm, 15-French stylet with a curve 3.5 cm from the distal tip (Fig. 15) [2,6]. The bougie may be inserted under the tip of the epiglottis when the vocal cords cannot be visualized using DVL and cricoid pressure. The curved tip of the bougie

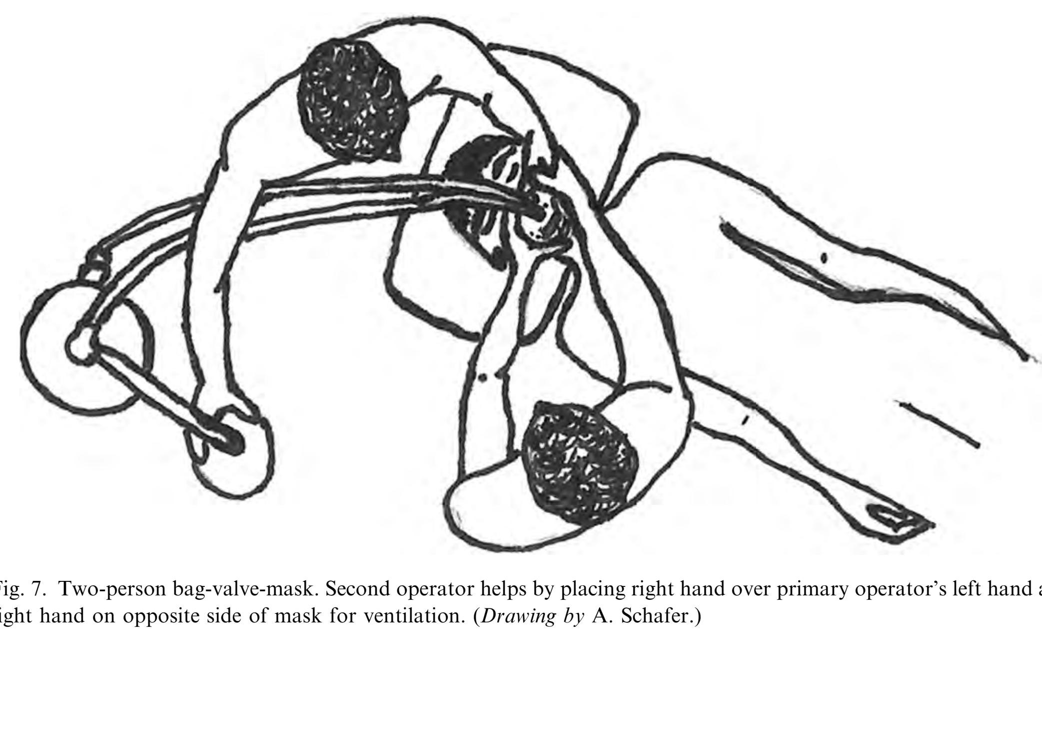

Fig. 7. Two-person bag-valve-mask. Second operator helps by placing right hand over primary operator's left hand and right hand on opposite side of mask for ventilation. (*Drawing by* A. Schafer.)

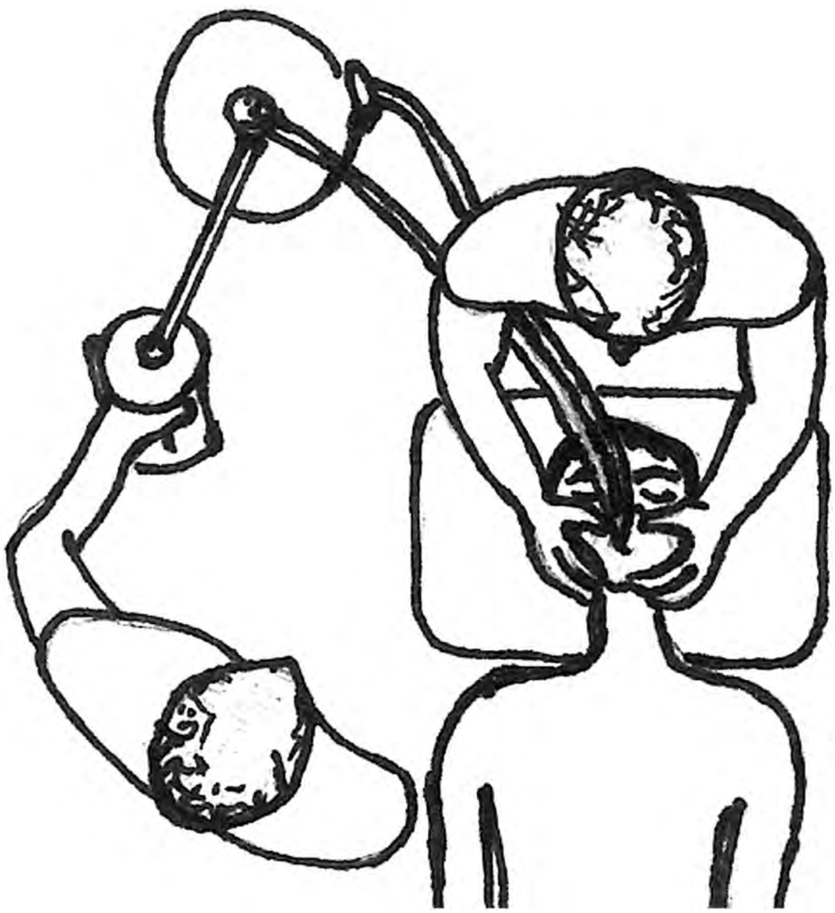

Fig. 8. Two-person bag-valve-mask. Second operator to squeeze bag while primary operator positions patient and creates seal on mask. (*Drawing by* A. Schafer.)

Fig. 9. Various sizes of oral airways.

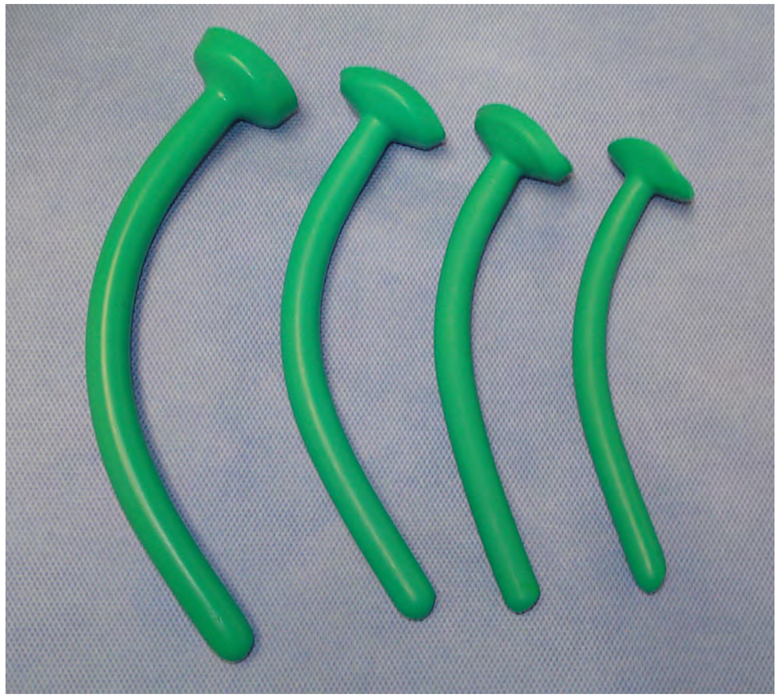

Fig. 10. Various sizes of nasal airways.

should be felt ‘‘bumping’’ down the tracheal rings, at which time an endotracheal tube may be fed over the bougie and into the trachea.

Options for alternative airways

Laryngeal mask airway

An alternative airway in case of difficult intubation is the laryngeal mask airway (LMA). The LMA is a supraglottic airway that is electively used for many oral and maxillofacial surgery procedures but can also be used in an emergency in the ‘‘cannot ventilate–cannot intubate’’ patient. The factors that make intubation difficult rarely make LMA placement difficult, therefore the likelihood of difficulty with both is rare [6]. Although the LMA allows for ventilation and oxygenation, it does not completely prevent aspiration. The LMA is a balloon-rimmed mask that rests on the lateral hypopharyngeal walls, vallecula, retrocricoid area, and piriform sinus (Fig. 16). The LMA comes in many sizes (Fig. 17) and its size is chosen initially based on the ideal body weight of the patient (Table 3). Standard midline placement of the LMA

Fig. 11. Correct placement of oral airway in patient.

Fig. 12. Correct placement of nasal airway in patient.

has a 76% to 96% success rate of proper insertion on the first attempt [10] and is easy with little practice. First, the patient is placed in the sniffing position, the LMA is lubricated on the convex side with water-soluble lubricant, and then placed using the hard palate as a guide. In many patients, placing the device in inverted and then rotating it as it is passed will make insertion easier. The LMA is then passed behind the tongue and into the pharynx. Once resistance is felt, the LMA is at the retrocricoid area and the balloon should be inflated; the LMA normally protrudes slightly. The LMA is then connected to the breathing circuit and checked for any air leaks. Potential complications with the LMA include partial obstruction by folding of the epiglottis, but this is usually easily corrected by moving the deflated LMA in a cephalad or caudad direction and attempting to reinflate the balloon [11]. Because of the potential for

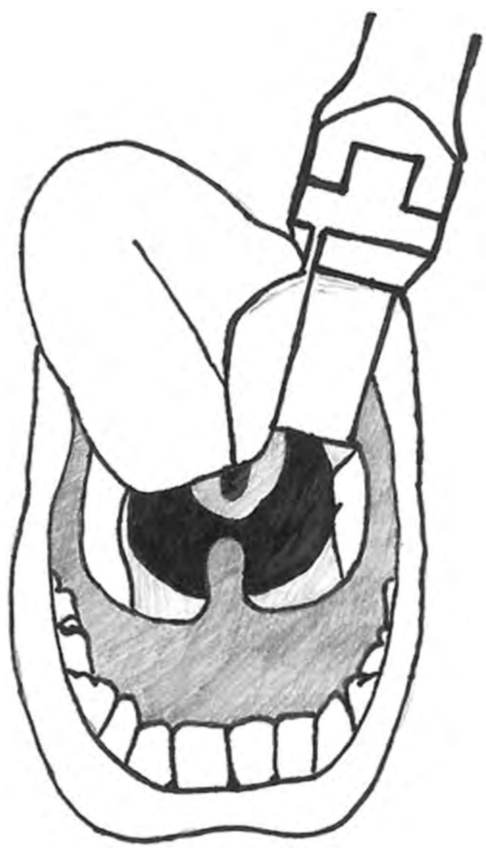

Fig. 13. View of vocal cords during DVL. Moving the tongue to the left side of the mouth allows for visualization of the vocal cords. (*Drawing by* A. Schafer.)

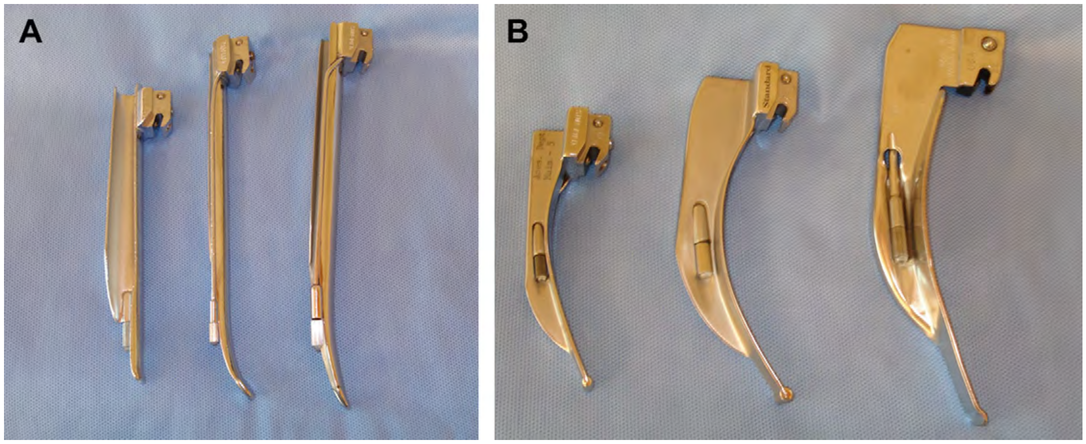

Fig. 14. Laryngoscopy blades. (*A*) Straight Miller blades, which lift with the epiglottis when correctly placed. (*B*) Curved Macintosh blades, which sit in the vallecula when correctly placed.

aspiration the LMA is contraindicated in patients who are not NPO (nil by mouth), who have a hiatial hernia or gastroesophageal reflux, the obese population, and patients who are pregnant.

Multiple variations on the standard LMA have been developed to improve on its characteristics. The ''intubating LMA'' (Fig. 18) has a larger diameter and shorter tube in comparison with the classic LMA, ensuring that an endotracheal tube up to size 8 can pass through it without obstruction and reach an appropriate depth to pass through the vocal cords. The ability to ventilate and oxygenate the patient with a difficult airway by placing the intubating LMA first allows for time to get help from other practitioners, gather any other adjunct means necessary to establish tracheal intubation, and reposition the patient if needed. Once the patient has an appropriate ventilatory pattern with the intubating LMA, anesthesia should be deepened to prevent laryngospasm, and a blind endotracheal intubation may be attempted with a lubricated endotracheal tube through the intubating LMA. The aperture at the base of the intubating LMA is designed to line up with the vocal cords if the correct size is placed, which increases the chance of successful tracheal intubation. In the patient who has glottic or

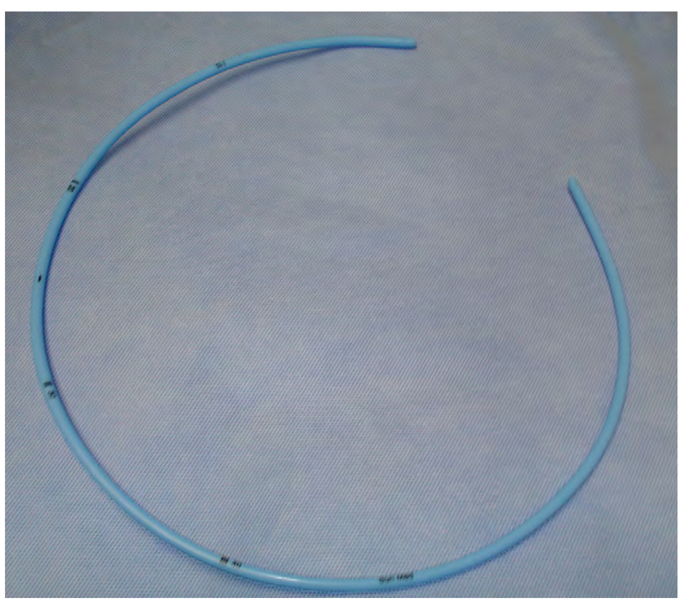

Fig. 15. Bougie. This semirigid stylet can be used when a direct view of the larynx is not possible with DVL.

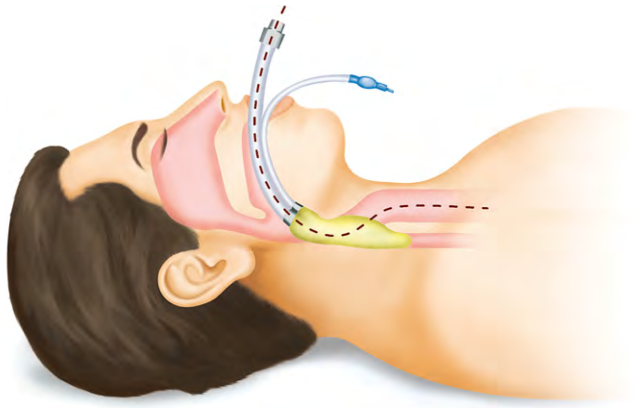

Fig. 16. Correct placement of LMA.

laryngeal edema, or bleeding caused by multiple prior attempts at DVL, a flexible fiberoptic scope with an endotracheal tube premounted may be fed into the intubating LMA. After visualizing the scope passing through the vocal cords, the endotracheal tube may be advanced into place and inflated. The intubating LMA may then be deflated and removed or may be left in place until completion of the surgical case with the endotracheal tube. Tentillier and colleagues [12] found that in 45 prehospital emergency patients in whom intubation was not possible by DVL, successful placement of the intubating LMA was accomplished in 96% of patients and the ability to intubate blindly through the LMA was found in 91%.

The LMA CTrach (LMA Inc, Singapore) is built similarly to the intubating LMA but also features a fiberoptic viewing screen magnetically mounted to the LMA so that the vocal cords may be visualized while the endotracheal tube is being placed (Fig. 19). This technique eliminates the need for a separate fiberoptic scope and increases the chance that blind intubation will be successful.

Combitube

The Combitube (Kendall Sheridan Catheter Corporation, Argyle, NY, USA) is an esophageal/tracheal double-lumen airway that was designed as an alternative to endotracheal

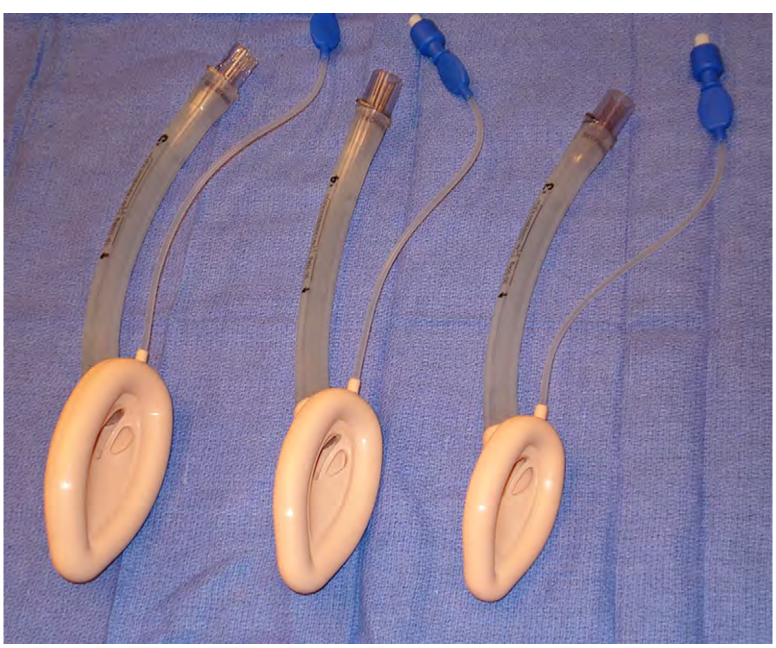

Fig. 17. Various sizes of LMA. This version is reusable and can be sterilized.

Table 3
LMA size choice based on weight

LMA size	Weight range for patient (kg)
1	<5
1.5	5–10
2	10–20
2.5	20–30
3	30–50
4	50–70
5	75–100

intubation in an emergency setting. The Combitube is blindly placed and regardless of whether it enters the trachea or the esophagus the patient should be able to be ventilated (Fig. 20) [13]. The esophageal lumen has an open proximal end and a blocked distal end with perforations at the pharyngeal level, whereas the tracheal lumen has an open distal end. To place a Combitube, the mandible and tongue are lifted with the left hand and the tube is inserted to the premarked depth with the right hand. Next, the oropharyngeal (blue) port is inflated with 100 mL of air with the large syringe provided. The distal tube (white) is then inflated with 10 to 15 mL of air with the small syringe provided. A ventilating device is first attached to the longer blue tube because the Combitube is most likely in the esophagus. The patient is then ventilated through the perforating holes in the tube. If no auscultation is heard with the ventilating device hooked to the blue tube, then tracheal intubation is most likely and the ventilating device should be moved to the white tube port, and the patient can then be ventilated via the distal opening (Fig. 21). Breath sounds must always be confirmed bilaterally to ensure that placement is correct. The Combitube is advantageous because it can be placed blindly by practitioners with minimal training and without extending the neck, and may be used without worry of aspiration of gastric contents with a 95% success rate [14]. Studies have also found that in patients with difficult airways and who have failed DVL, bougie, and an attempt to attain an airway with an LMA, use of the Combitube can be a successful intermediate airway until a definitive airway can be established [15]. Disadvantages include the inability to suction tracheal secretions in the esophageal position and a short time (approximately 2–3 hours) before a more stable airway is necessary to prevent tongue ischemia.

Fiberoptic intubation

Fiberoptic laryngoscopy is an advanced airway technique that is useful for patients who have had a prior experience of a difficult airway, because it may be used in the awake or lightly

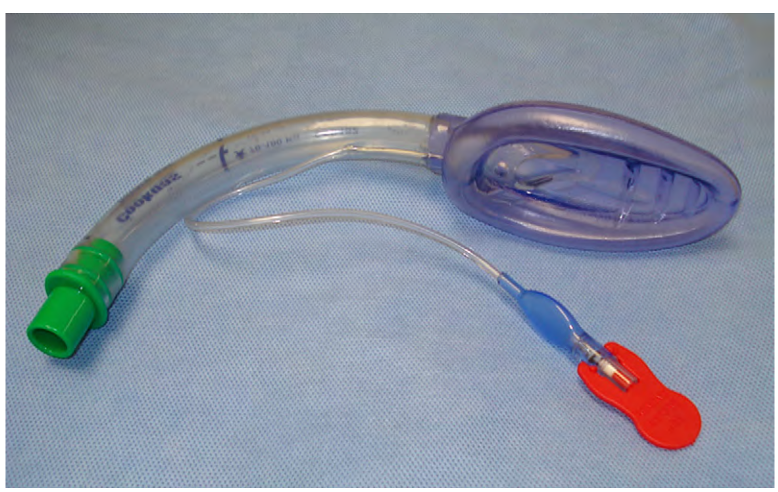

Fig. 18. This disposable intubating LMA allows for conversion to endotracheal intubation via the larger-diameter tube.

Fig. 19. LMA CTrach. Fiberoptic screen allows visualization of endotracheal tube passing through the vocal cords.

anesthetized patient to ensure the ability to intubate the patient before the induction of general anesthesia [6]. Nasal or oral fiberoptic laryngoscopy (Fig. 22) with the endotracheal tube prefed onto the scope can be used in patients with neck movement restriction and with potential airway obstruction. For an awake fiberoptic intubation, the patient should be given a full explanation of what to expect throughout the process and be made as comfortable as possible with topical oral or nasal anesthesia, tracheal and laryngeal local anesthesia, and minimal sedation. An antisialagogue should be administered, and if nasal intubation is used, the nasal mucosa should be anesthetized and vasoconstricted with a lidocaine-phenylephrine combination. Nasal fiberoptic intubation is considered easier by many practitioners because of the angulation in which the scope exits the pharynx (an example of nasal fiberoptic intubation is given in Fig. 23). If oral intubation is used, an oral airway specifically designed to work with the fiberoptic scope should be used to help line the exit of the scope with the laryngeal outlet (Fig. 24). In either case, the fiberoptic scope is advanced until the carina is visualized and then the endotracheal tube is slid over the stationary fiberoptic scope and the scope is then gently removed.

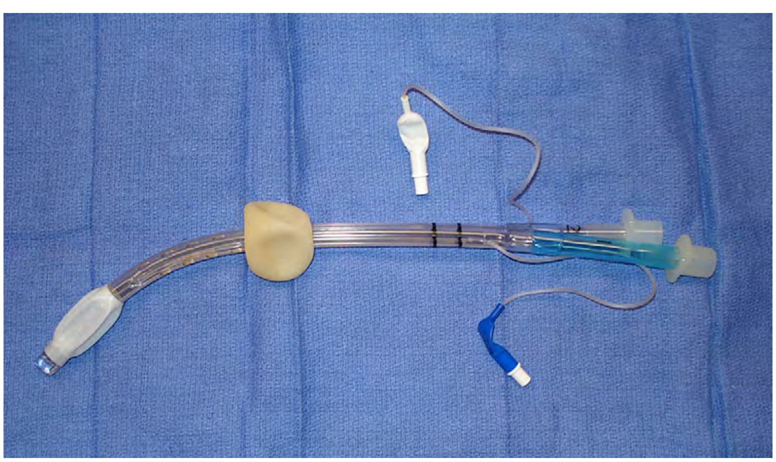

Fig. 20. Combitube. This double-lumen tube allows blind placement and ventilation if the tube is placed in either the esophagus or the trachea.

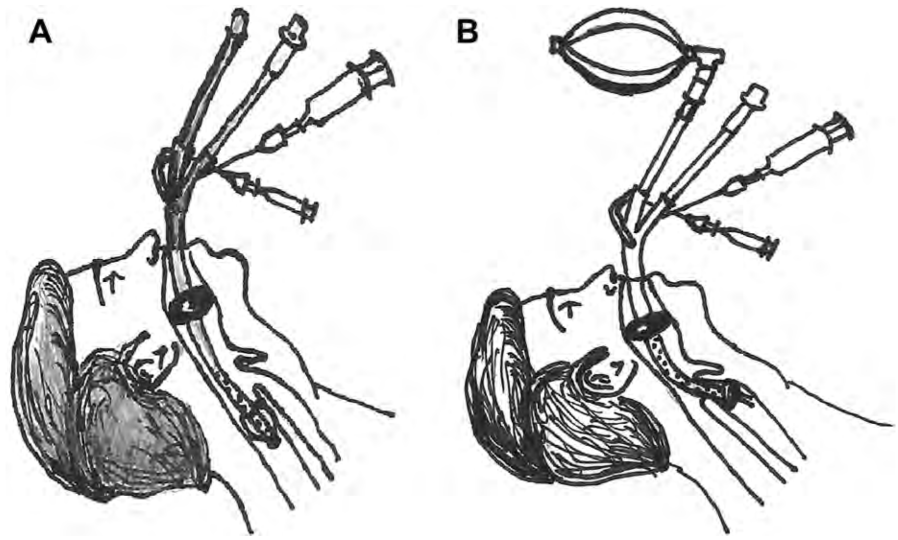

Fig. 21. Placement of Combitube in esophagus. (*A*) Ventilation occurs via perforating holes in tube while esophagus is blocked. (*B*) Placement of Combitube in trachea with ventilation through the distal opening. (*Drawing by* A. Schafer.)

Because of the high level of training necessary for fiberoptic laryngoscopy, it is not recommended for the novice practitioner as a rescue measure for a difficult/failed intubation patient.

Invasive emergent airway techniques

As a worst-case scenario in a patient in which none of the other adjunct airway techniques for ventilation or intubation has been successful, the oral and maxillofacial surgeon must be prepared to perform an emergent/invasive surgical airway. Transtracheal jet ventilation and cricothyrotomy are alternative means to provide oxygen in an emergent situation. These techniques are covered elsewhere in this issue.

Tracheostomy

Generally considered to be the definitive surgical airway, tracheostomy is the clear answer to the long-term compromised airway. Although highly effective, it is not a benign procedure and carries with it several long-term potential complications. In addition, tracheostomy should never be considered as an emergency airway. Because the surgical procedure is associated with many

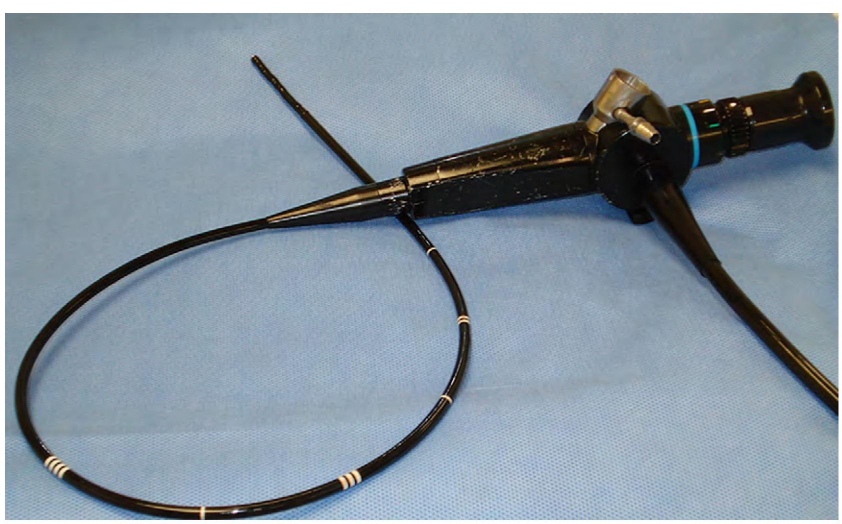

Fig. 22. The fiberoptic scope may be used for either nasal or oral intubation in the awake or asleep patient.

Fig. 23. Fiberoptic scope during nasal intubation. The patient's head is in a neutral position, which allows for potential intubation in the patient with cervical spinal injuries.

hazards (eg, damage to the recurrent laryngeal nerve or several large vessels in the neck and thorax), it should be performed only under ideal conditions (ie, in the operating room) with adequate lighting, suction, and ancillary personnel. In an emergency, those considering tracheostomy in the emergency department or a surgeon's office should instead perform cricothyrotomy, with later conversion to tracheostomy in the operating room.

Difficult airway algorithm

The algorithm in Fig. 25 has been designed with the oral and maxillofacial surgeon providing in-office anesthesia in mind. An algorithm can help a practitioner when the unexpected occurs

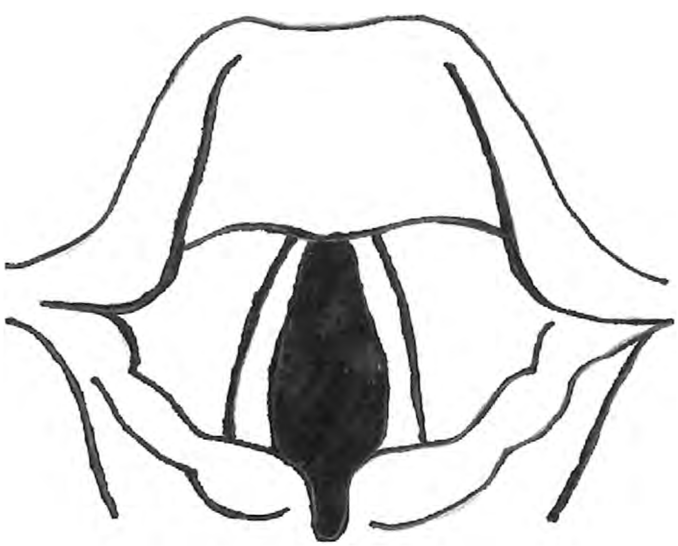

Fig. 24. Larynx. This view of the open vocal cords is perfect for passing the fiberoptic scope in oral or nasal intubation. (*Drawing by* A. Schafer.)

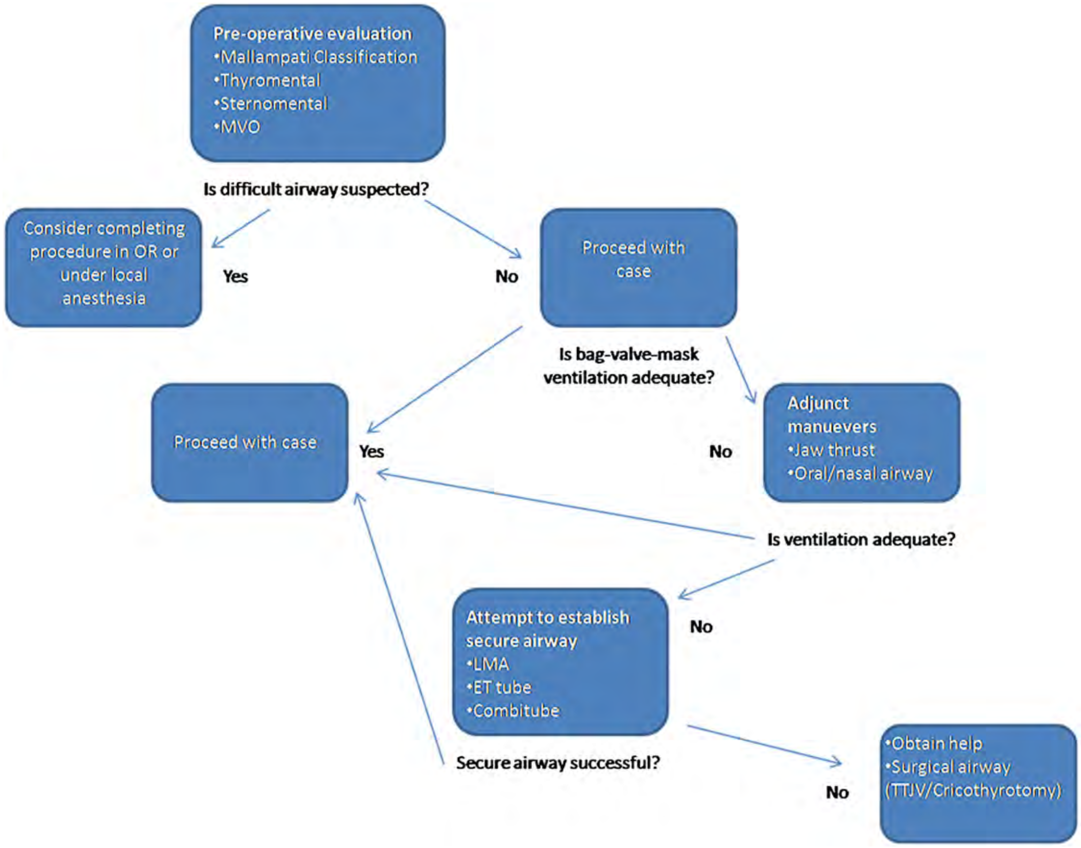

Fig. 25. Difficult airway algorithm for office anesthesia provider.

and provides a systematic approach to the progression of a difficult airway situation. The most important thing to remember in a difficult airway case that is not predicted is to be prepared and stay calm. Make sure your office has developed practice scenarios so that equipment and personnel necessary in emergency situations are available quickly. Also remember that attempting the same maneuver multiple times to establish an airway decreases the success rate; instead find 2 or 3 alternative airway adjuncts that each practitioner is comfortable with and proceed through the algorithm to prevent long-term damage to the patient's health.

Summary

The oral and maxillofacial surgeon frequently encounters and manages difficult airways. Knowledge of and calm progression by practitioner and staff through different means to ventilate and manage a difficult airway are crucial. Practitioners should become comfortable with different types of alternative or rescue airways in order to intervene quickly in case of emergent or unanticipated airway compromise.

References

[1] Shiga T, Wajima Z, Inoue T, et al. Predicting difficult intubation in apparently normal patients. Anesthesiology 2005;103:429–37.
[2] Liess B, Scheidt T, Templer J. The difficult airway. Otolaryngol Clin North Am 2008;41:567–80.
[3] Mallampati S, Gatt S, Gugino L, et al. A clinical sign to predict difficult tracheal intubation: a prospective study. Can Anaesth Soc J 1985;32:429–34.
[4] Tuzuner-Oncul A, Kucukyavuz Z. Prevalence and prediction of difficult intubation in maxillofacial surgery patients. J Oral Maxillofac Surg 2008;66:1652–8.

[5] Iohom G, Ronayne M, Cunningham A. Prediction of difficult tracheal intubation. Eur J Anaesthesiol 2003;20:31–6.
[6] Stackhouse R, Infosino A. Airway management. In: Stoelting R, Miller R, editors. Basics of anesthesia, 5th edition. Philadelphia: Churchill Livingstone Elsevier; 2007. p. 207–39.
[7] Finucane B, Santora A. Airway management. 2nd edition. St. Louis (MO): Mosby; 1996. p. 107–40, 187–225.
[8] Langeron O, Amour J, Vivien B, et al. Clinical review: management of difficult airways. Crit Care 2006;10(6):243.
[9] King T, Adams A. Failed tracheal intubation. Br J Anaesth 1990;65:400.
[10] McCrirrick A. Experience with the LMA in two hundred patients. Anaesth Intensive Care 1991;19:256–60.
[11] Joshi G, Smith I, White P. Laryngeal mask airway. In: Benumof J, editor. Airway management principles and practice. 1st edition. St. Louis (MO): Mosby; 1996. p. 353–63.
[12] Tentillier E, Heydenreich C, Cros A, et al. Use of the intubating laryngeal mask airway in emergency pre-hospital difficult intubation. Resuscitation 2008;77:30–4.
[13] Frass M. The combitube: esophageal/tracheal double lumen airway. In: Benumof J, editor. Airway management principles and practice. 1st edition. St. Louis (MO): Mosby; 1996. p. 444–54.
[14] Krafft P, Schebesta K. Alternative management techniques for the difficult airway: esophageal–tracheal Combitube. Curr Opin Anaesthesiol 2004;17:499–504.
[15] Mort T. Laryngeal mask airway and bougie intubation failures: the combitube as a secondary rescue device for in-hospital emergency airway management. Anesth Analg 2006;103:1264–6.

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Atlas of the Oral and Maxillofacial Surgery Clinics

Emergency Cricothyrotomy

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Establishment of an unobstructed airway and adequate oxygenation is a basic tenet of life support. Mechanical or anatomic airway obstructions can arise secondary to trauma, pathology, foreign bodies, and infection. The oral and maxillofacial surgeon is uniquely trained to provide surgical and anesthetic care and must be prepared to provide emergency airway management. The purpose of this article is to review the indications, contraindications, and techniques of surgical and needle cricothyrotomy.

Indications

Emergency cricothyrotomy is indicated when there is an emergent or urgent need for an airway and the individual cannot be intubated orally or nasally for any reason. Cricothyrotomy is specifically useful when an airway obstruction has occurred at the glottis or supraglottic level. The American Society of Anesthesiologists (ASA) directs that an emergency cricothyrotomy is indicated as the final pathway in their algorithm for treatment of the difficult airway. The ASA defines a difficult airway as a ‘‘clinical situation in which a conventionally trained anesthesiologist experiences difficulty with face mask ventilation of the upper airway, difficulty with tracheal intubation, or both.’’

There are a myriad of events that can lead to a difficult airway and the ‘‘can't intubate, can't ventilate’’ scenario. Loss of the airway may arise unexpectedly, as in cases of acute trauma. For example, approximately 10% of penetrating cervical trauma cases lead to difficulty in establishing an airway. This situation is often a result of injury to major vessels of the neck causing an expanding hematoma at the level of the airway. Also, in cases of blunt facial trauma, the primary cause of death is airway obstruction. Such airway obstruction may occur because of hypopharyngeal obstruction from mandible fractures or aspiration of blood after uncontrolled facial bleeding. Loss of the airway may alternatively occur during planned, elective intubations or sedations. Such situations often are a result of difficult patient anatomy (short, obese neck) or a disease state such as retropharyngeal abscess, vocal cord paralysis, or laryngeal edema. According to one study, of all clinical situations using cricothyrotomy, 32% involved blood or vomitus in the airway, 32% facial fractures, 11% failed intubation in the absence of other specific problems, and 7% involved traumatic airway obstruction. There is no fail-safe method of predicting which patients will be more difficult to intubate or ventilate. However, as part of a preoperative anesthesia assessment, an airway history should be conducted to elicit medical, surgical, and anesthetic risk factors. Furthermore, an airway physical examination should be

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conducted, whenever feasible, before the initiation of anesthetic care and airway management (Table 1).

Cricothyrotomy is generally preferred over tracheotomy for emergency airway access. Anatomic considerations are largely the reason for an up to 5-fold increase in complications with emergency tracheotomy over elective tracheotomy. Access to the trachea is more caudal than with the cricothyroid membrane, and therefore complications such as pneumothorax and mediastinal perforation are more likely to occur when using emergency tracheotomy rather than cricothyrotomy. Also, unlike the laryngeal and cricoid cartilages, the tracheal cartilage is absent posteriorly. Thus, damage to the esophagus and posterior tracheal wall is more likely in an emergent tracheotomy than in a cricothyrotomy.

General contraindications and precautions

There are few absolute contraindications to cricothyrotomy. However, a few notable exceptions exist. For example, the procedure is contraindicated when a complete or partial transection of the airway exists. Also, cricothyrotomy should not be performed in cases of significant injury to the cricoid cartilage or a severely fractured larynx. In all of these cases the airway should be accessed below the injury, and a tracheostomy would be the preferred method to secure the airway.

Emergency cricothyrotomy is generally contraindicated in neonates and younger children. The age cutoff varies in the literature; in practice, multiple factors such as size and weight, anatomic variables, and injury/illness will help determine what technique is utilized. However, a general upper age limit is 10 to 12 years. In the younger pediatric population, cricothyrotomy can damage the cricoid cartilage and lead to subsequent sublgottic stenosis. Because the pediatric airway is funnel shaped, with the narrowest airway diameter located at the cricoid ring, even a minor amount of stenosis can cause significant airflow impairment. Therefore, needle cricothyrotomy should be considered the emergency treatment of choice in the pediatric population.

Surgical anatomy

Knowledge of the anatomy of the anterior neck, larynx, and trachea is necessary to successfully complete any invasive airway procedure. The cricoid cartilage attaches inferiorly to

Table 1
Components of the preoperative airway physical examination

Airway examination component		Nonreassuring findings
1.	Length of upper incisors	Relatively long
2.	Relation of maxillary and mandibular incisors during normal jaw closure	
3.	Relation of maxillary and mandibular incisors during voluntary protrusion	Patient mandibular incisors anterior to maxillary incisors
4.	Interincisor distance	Less than 3 cm
5.	Visibility of uvula	Not visible when tongue is protruded with patient in sitting position (eg, Mallampati class >II)
6.	Shape of palate	Highly arched or very narrow
7.	Compliance of mandibular space	Stiff, indurated, occupied by mass, or nonresilient
8.	Thyromental distance	Less than 3 ordinary fingerwidths Breadths
9.	Length of neck	Short
10.	Thickness of neck	Thick
11.	Range of motion of head and neck	Patient cannot touch tip of chin to chest or cannot extend neck

From Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Anesthesiology 2003;98(5):1269–77; with permission.

the tracheal rings. At the level of this junction is the isthmus of the thyroid gland. Also, in approximately 40% of patients a pyramidal lobe of the thyroid gland may lie in the anterior neck midline over or near the arch of the cricoid cartilage or the cricothyroid membrane. The median cricothyroid ligament (cricothyroid membrane) is immediately surrounded by cricoid cartilage, cricothyroid muscle, and thyroid cartilage (Fig. 1). The cricothyroid ligament is 20 to 30 mm in width and 9 to 10 mm in length. In infants, the membrane is only approximately 3 mm in length. In addition, in children and infants the larynx is more rostrally located, potentially making identification of topical landmarks more difficult. The most identifiable landmarks in the preadolescent population are the hyoid bone and cricoid cartilage. Between the skin of the anterior neck and the cricothyroid ligament lie the adjacent infrahyoid muscles, pretracheal layer of deep cervical fascia, thyroid gland, anterior jugular veins, and associated superior thyroid arteries and veins. These vessels arborize to supply tissues in their course from the external carotid artery-internal jugular vein origin to the superior pole of the thyroid gland. The cricothyroid artery and vein run transversely over the cricothyroid membrane, and may anastomose with the laryngeal artery and vein by penetrating the cricothyroid membrane near the inferior border of the thyroid cartilage. Therefore, to avoid the vessels, an attempt should be made to avoid incising the superior portion of the membrane.

Techniques

Needle Cricothryotomy

The patient is positioned supine with the neck hyperextended (stable cervical spine) to expose the laryngotracheal complex. The cricothyroid membrane is approximately 1.5 to 2.0 cm in

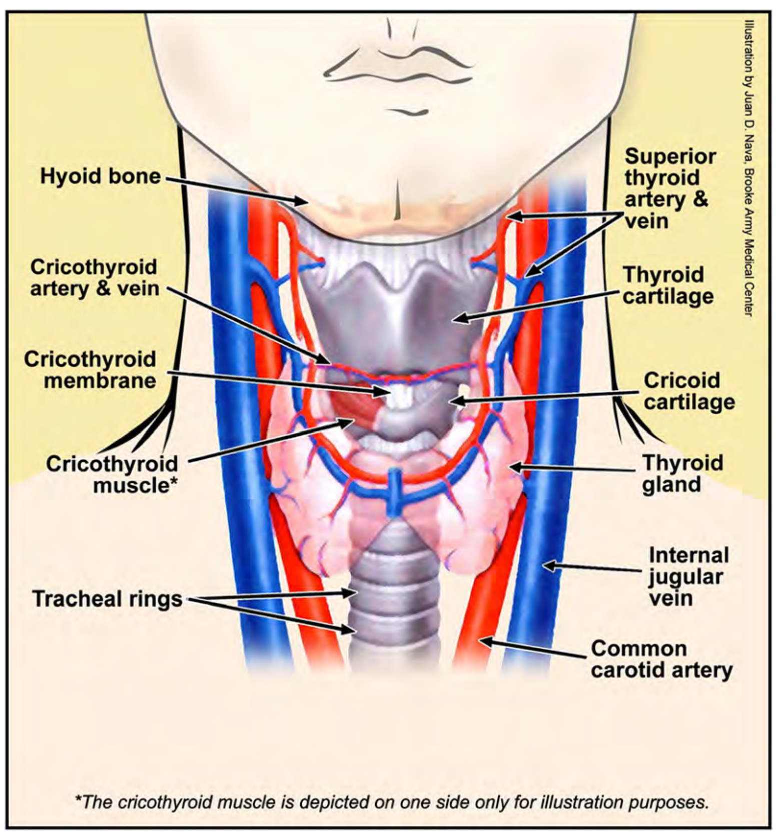

Fig. 1. Anterior neck airway anatomy.

width and 2 to 3 cm below the laryngeal prominence, and is located by palpating the small depression between the laryngeal prominence superiorly and the cricoid cartilage inferiorly.

Next, a 5- or 10-ml syringe is filled with 2 to 3 ml of normal saline. If the patient is awake and it is available, lidocaine with epinephrine should be used and following proper catheter placement, is injected to help suppress unwanted airway reflexes such as coughing and laryngospasm. The laryngotracheal complex should be stabilized with the nondominant hand (Fig. 2) and a 12- or 14-gauge needle (16- or 18-gauge for pediatric use) attached to the syringe is inserted at a 30° to 45° angle caudally toward the sternal notch through the skin, subcutaneous tissue, and cricothyroid membrane. The cricothyroid artery is best avoided by inserting the needle in the inferior aspect of the cricothyroid membrane. As an alternative, an angiocatheter prepackaged as a transtracheal catheter may be used. Commercially available kits are also available that contain the essential equipment.

While advancing the needle the syringe should be aspirated, and bubbles in the fluid will indicate entry into the trachea (Fig. 3). The needle is held in place and the catheter advanced to the hub. Once the catheter is in place, the needle is withdrawn and the syringe emptied of saline. To confirm proper placement, 10 mL of air is withdrawn into the catheter and the air is plunged into the airway. If subcutaneous expansion or resistance is felt, the catheter is likely advanced too far into the posterior trachea, or it is located subcutaneously. The syringe is then removed, and the catheter is secured and connected to a jet ventilation apparatus, which consists of a flow regulator connected to the oxygen source. (Fig. 4) The patient is ventilated by opening and closing the in-line valve device. Breaths should be delivered in a 1:4 second inspiratory-to-expiratory ratio. If airway obstruction is present, a decreased I:E ratio of 1:9 should be used to reduce the risk of barotraumas.

For adults and older adolescents, oxygen should be supplied through a standard 50-psi wall source. Recent studies have shown resuscitation bags do not provide adequate ventilation because of the inability to deliver adequate tidal volume while allowing sufficient time for

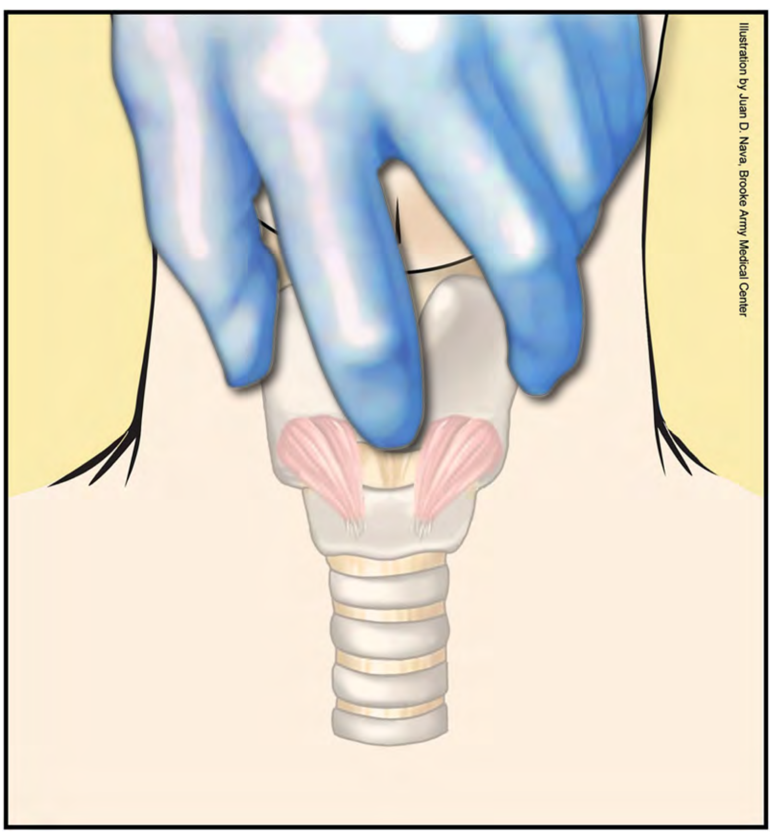

Fig. 2. Stabilization of Larynx is completed with the nondominant hand and the cricothyroid membrane is palpated.

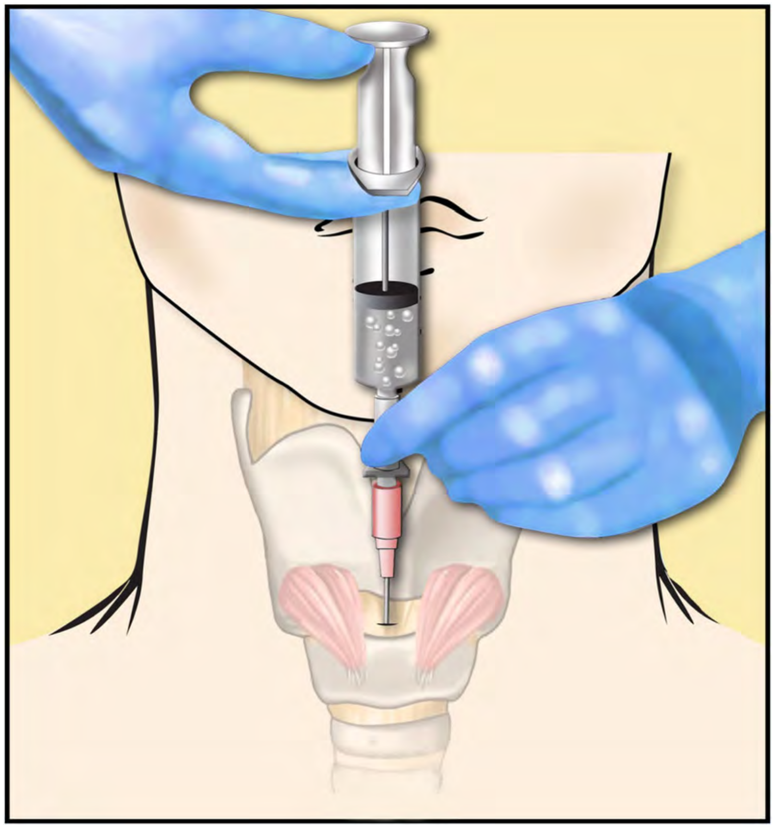

Fig. 3. The needle is angled caudally at a 45° angle. Negative pressure is used to look for bubbles in the fluid, a sign of entry into the trachea.

exhalation. The exception to this is children younger than 5 years, who can be ventilated with a resuscitation bag because of their smaller lung capacities and tidal volumes. If only low-pressure oxygen sources are available, a surgical airway should be performed to provide effective ventilation. Table 2 lists recommended parameters for percutaneous translaryngeal ventilation.

Surgical Cricothyrotomy

Necessary equipment should be readily available if possible, and includes a bag-valve-mask device, oxygen source, no. 15 scalpel, hemostats, tracheal hook, scissors, and Trousseau dilator.

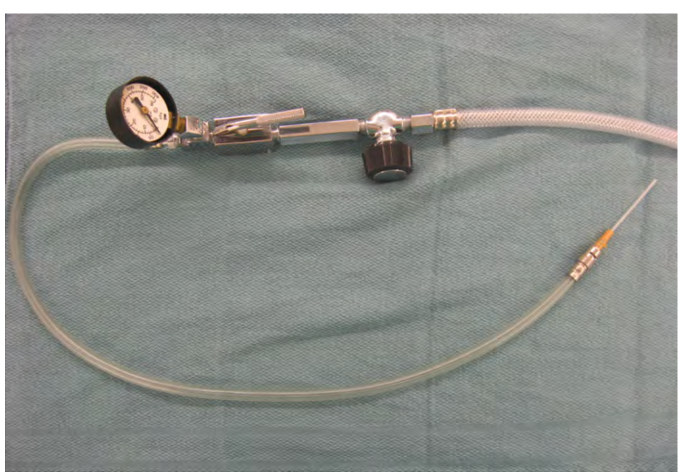

Fig. 4. Jet ventilator connected directly to a 14-gauge catheter.

Table 2
Recommended parameters for percutaneous translaryngeal ventilation

	Pounds per square inch	Tidal volume (cm^3)
Adults	30–50	700–1000
Children 8 years or older	10–25	340–625
Children 5–8 years	5–10	240–340

A small tracheotomy tube (Shiley number 4 or 6) is the preferred airway adjunct. If a tracheotomy tube is unavailable, a 5.0, 5.5, or 6.0 endotracheal tube can be used for an adult. Tubes larger than 7 mm are much more difficult to place through the cricothyroid membrane. When using the endotracheal tube, the uncuffed end of the tube is cut to approximately 6.5 cm in length and adjusted later if necessary.

Patient positioning and identification of the cricothyroid membrane is accomplished as described for the needle cricothyrotomy technique. Antiseptic solution is applied, and local anesthesia with epinephrine can be used to provide both anesthesia and hemostasis. Stabilization of the larynx is completed with the nondominant hand, and is a critical step in maintaining the proper orientation of the laryngeal structures prior to the incision (see Fig. 2). A no. 15 scalpel is used to make a single 3- to 5-cm vertical incision in the midline over the thyroid cartilage extending to a level below the inferior border of the cricoid cartilage (Fig. 5). The vertical incision helps avoid vascular injury, and is safer and more expedient than a horizontal one, particularly in an emergent situation with disturbed or difficult anatomy. The initial incision is only through skin and subcutaneous tissues, taking care to avoid incising deeper, because this may result in damage to the laryngeal cartilages or posterior tracheal perforation. The cricothyroid membrane is then exposed and the blade turned horizontally to perforate the membrane, so that the blade goes in to approximately half its length (Fig. 6). An

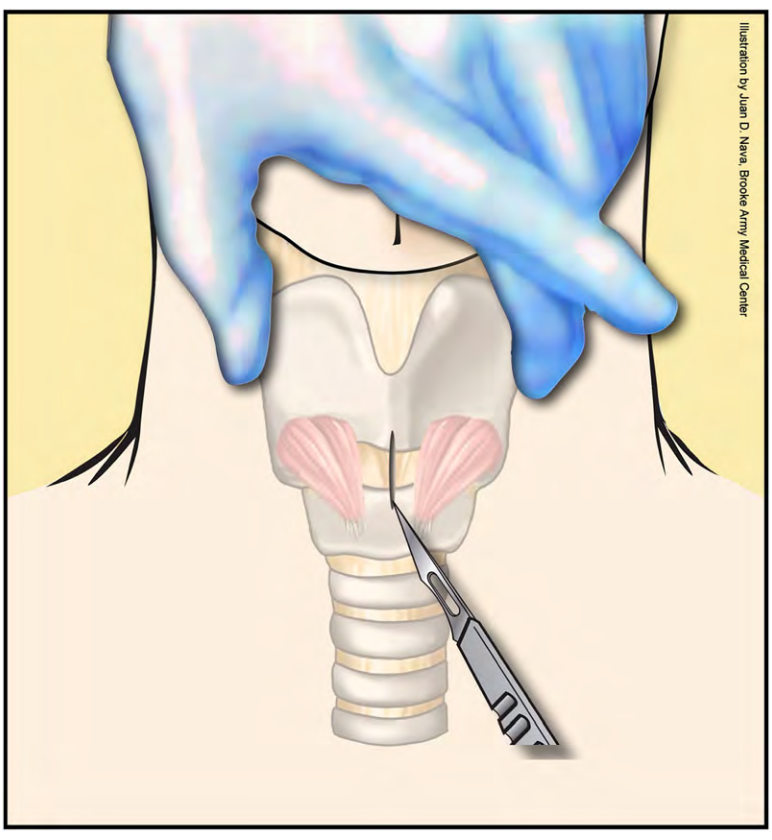

Fig. 5. A single 3- to 5-cm vertical incision is made in the midline over the thyroid cartilage extending to a level below the inferior border of the cricoid cartilage.

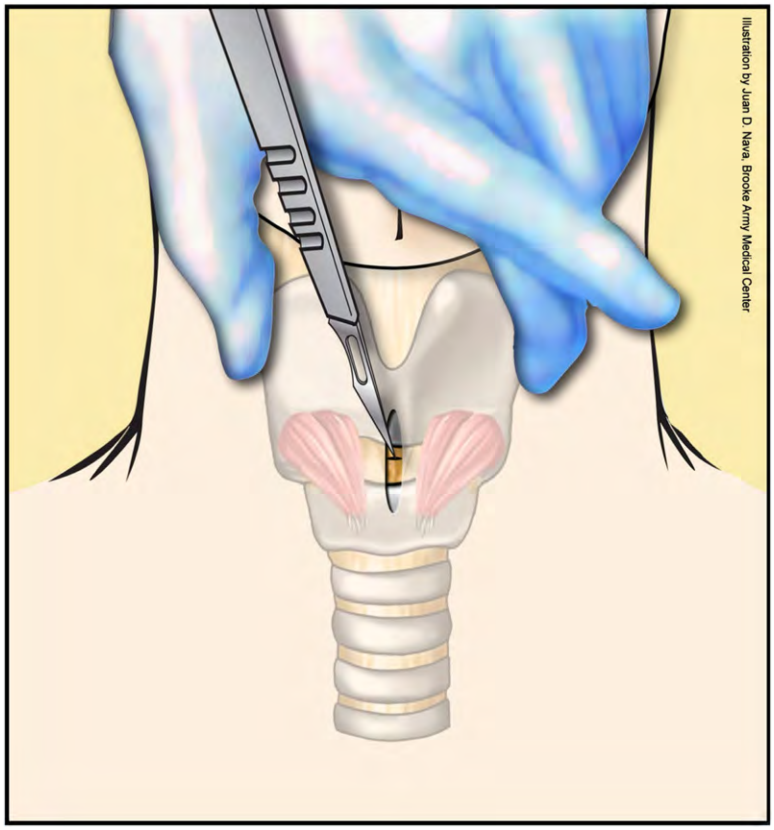

Fig. 6. The cricothyroid membrane is incised transversely.

attempt should be made to make the horizontal stab incision at the inferior half of the membrane, nearer the cricoid cartilage, to reduce the chance of damaging the vocal cords and cricothyroid vessels. A Trousseau dilator is then used to penetrate and widen the membrane entry site (Fig. 7). If such an instrument is unavailable, a Kelly clamp, curved hemostat, right-angle instrument, or the back end of the scalpel handle (turned 90°) can be used to widen the incision and improve access to the airway. If additional access is required, a tracheal hook can be inserted under the thyroid cartilage and controlled upward traction applied. Next, the tracheal or endotracheal tube is inserted (Fig. 8). If using an endotracheal tube, the end should be placed no more than 2 to 3 cm to avoid placement into the right main-stem bronchus. The airway adjunct is then connected to a bag-valve-mask device for ventilation and bilateral breath sounds, confirming placement. The tube is secured with a tracheal tie, suture, or adhesive tape (Fig. 9).

Conversion from Cricothyrotomy to Tracheostomy

A surgical cricothyrotomy should be changed to a tracheostomy if the airway is needed for more than 48 hours. If a needle cricothyrotomy has been completed, the patient should undergo a formal tracheostomy as soon as possible because of the suboptimal ventilation and higher risk of catheter dislodgment.

Complications

Reported complication rates vary from 8.7% to 40%, depending on the location of the procedure, patient population, clinical scenario, and clinician's level of training. The most common complications are bleeding and misplacement of the tracheal tube. Venous bleeding is common and usually stops spontaneously. Sources of arterial bleeding include the cricothyroid

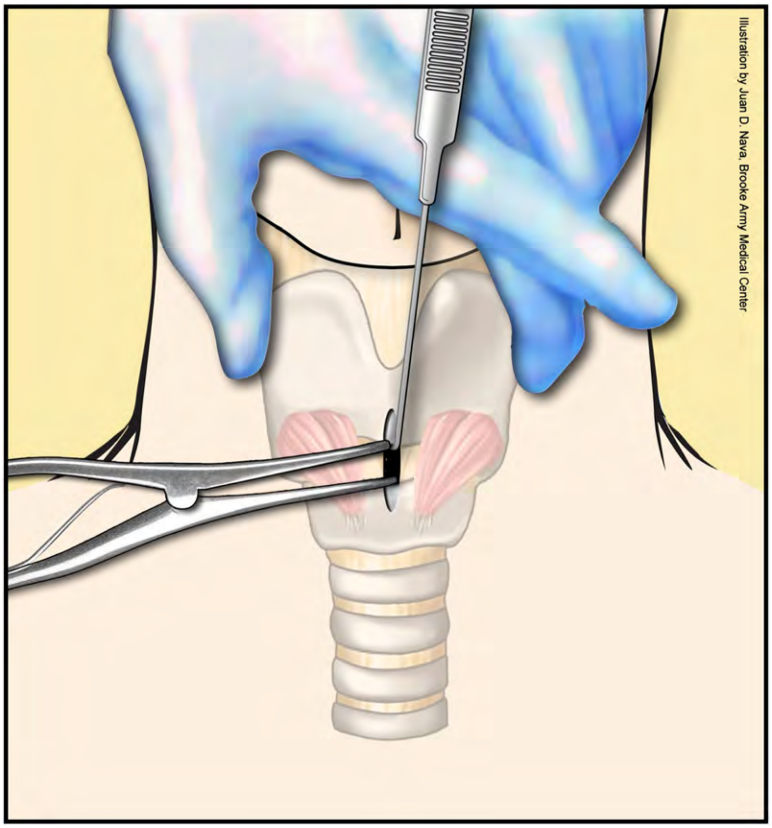

Fig. 7. The Trousseau dilator and tracheal hook are inserted to improve access to the airway.

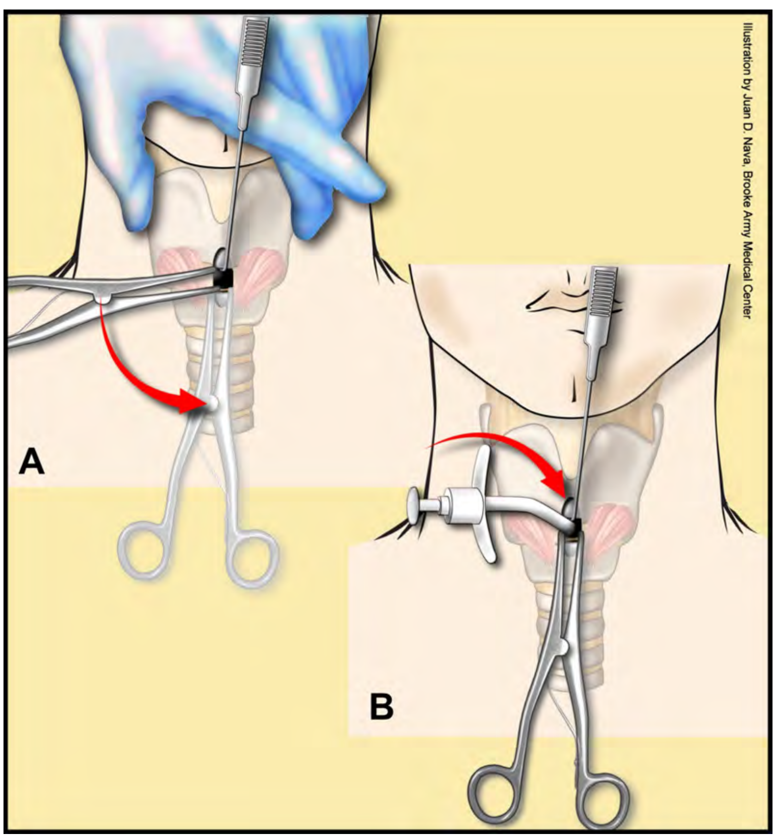

Fig. 8. The dilator, or back end of the scalpel handle, can be rotated 90° (*A*) before insertion of the tube into trachea (*B*).

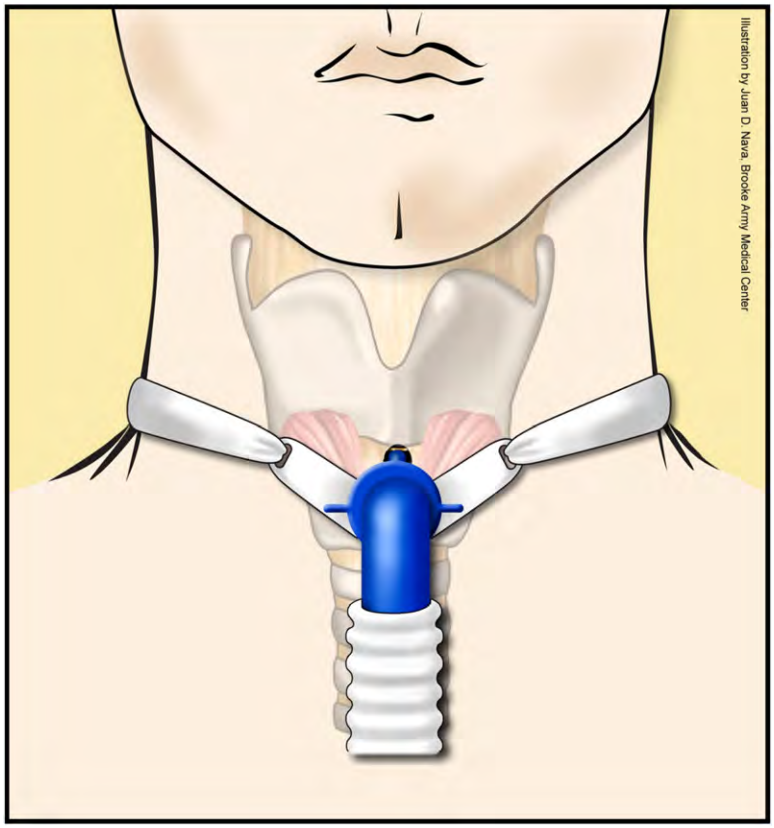

Fig. 9. Ventilator tubing is attached and the tube is secured.

or thyroid ima arteries. Direct pressure should be applied and, if necessary, surgical measures utilized to stop the bleeding after securing the airway. Tube displacement is more likely to occur in an obese patient, with the tube positioned anterior to the larynx and trachea. Signs of displacement include absent breath sounds, high airway pressures, and massive subcutaneous emphysema. If the incision is placed superiorly into the larynx, the tube may be misplaced above the cricothyroid membrane. The airway should be converted to tracheostomy as soon as the misplacement is recognized. Furthermore, an estimated 10% of cricothyrotomies result in tube displacement below the cricothyroid membrane. In this situation, no specific treatment is required except recognition of the position as a high tracheostomy. Barotraumas with pneumothorax/pneumomediastinum may be caused by ventilation initiated immediately after tube placement. Additional acute complications include subcutaneous emphysema, perforation of the posterior trachea, tracheal transection with distal end displacement, fracture of the larynx, recurrent laryngeal nerve injury, injury to the vocal cords, and esophageal perforation. Late airway complications may occur in up to 52% of cases including infection, dysphasia, altered voice, and laryngeal or tracheal stenosis.

Fortunately, with advances in airway techniques and equipment, emergency cricothyrotomy is not a common procedure. However, in the event that a surgeon has no other means of securing an airway, this procedure may avert a catastrophe. If such a situation does occur, quick and decisive action can best be carried out if there is a thorough understanding of the anatomy and techniques involved.

Further readings

Mace SE, Khan N. Needle cricothyrotomy. Emerg Med Clin North Am 2008;26:1085–101.

Katos GM, Goldenberg D. Emergency cricothyrotomy. Operat Tech Otolaryngol Head Neck Surg 2007;18:110–4.

Caplan RA, Benumof JL, Berry FA, et al. Practice guidelines for management of the difficult airway. Anesthesiology 2003;98:1269–77.

Gens DR. Surgical airway management. Emergency medicine manual. 6th edition. New York, Chicago, and San Francisco: McGraw-Hill Professional; 2003. p. 119–23.

Fortune JB, Judins DG, Scanzaroli D, et al. Efficacy of prehospital surgical cricothyrotomy in trauma patients. J Trauma 1997;42(5):832–8.

Li J, Murphy-Lavoie H, Bugas C, et al. Complications of emergency intubation with or without paralysis. Am J Emerg Med 1999;17:141.

Erlandson MJ. Cricothyrotomy in the Emergency Department revisited. J Emerg Med 1989;7:115–8.

Chang RS, Hamilton RJ. Declining rate of cricothyrotomy in trauma patients with an emergency medicine residency: implications for skills training. Acad Emerg Med 1998;5:247–51.

Strange GS, Niederman LG. Surgical cricothyrotomy. Textbook of pediatric emergency procedures. Philadelphia, Baltimore, and New York: Wolters Kluwer/Lippincott Williams and Wilkins; 2008. p. 331.

Hooker EA, Danzl DF, O'Brien DO, et al. Percutaneous transtracheal ventilation: resuscitation bags do not provide adequate ventilation. Prehospital Disaster Med 2006;21:431–5.

Greenfield RH. Percutaneous transtracheal ventilation. Textbook of pediatric emergency procedures. Baltimore and Philadelphia: Lippincott Williams and Wilkins; 1997. p. 239–49.

Gillespie MB, Eisele DW. Outcomes of emergency surgical airway procedures in a hospital-wide setting. Laryngoscope 1999;109(11):1766–9.

Spaite DW, Joseph M. Prehospital cricothyrotomy: an investigation of indications, technique, complications, and patient outcome. Ann Emerg Med 1990;19:279–85.

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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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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

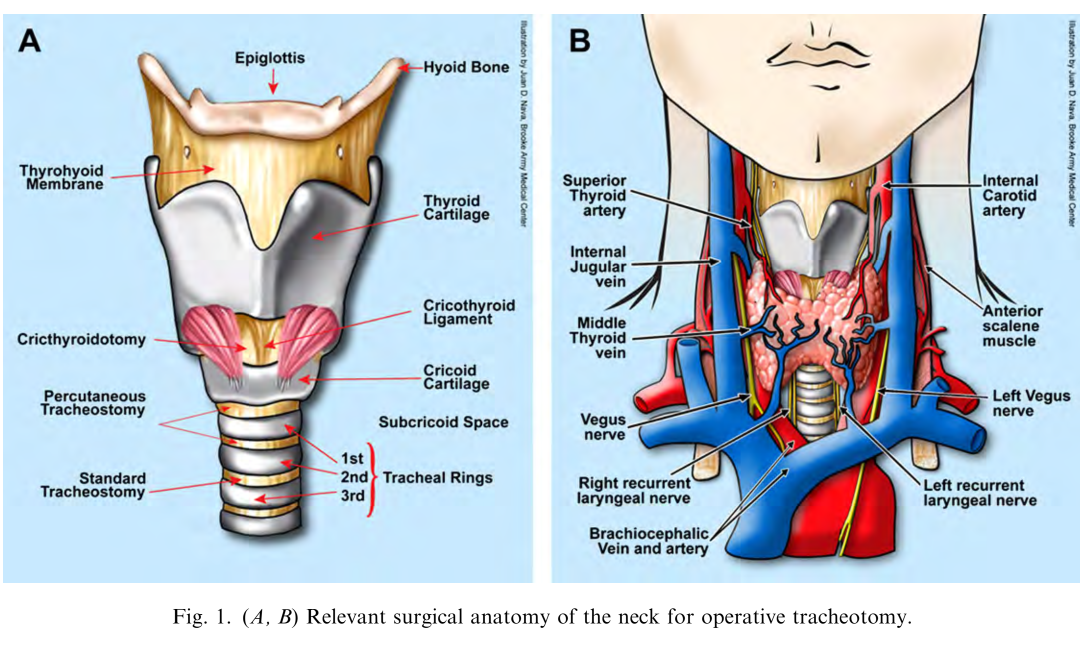

Fig. 1. (*A, B*) Relevant surgical anatomy of the neck for operative tracheotomy.

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 tracheostomy 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 breath 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.

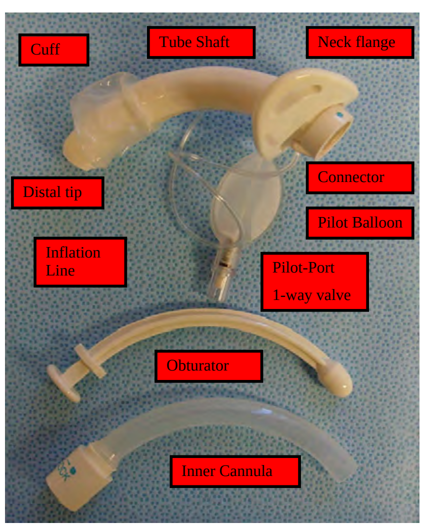

Fig. 3. Basic components of a standard tracheostomy tube.

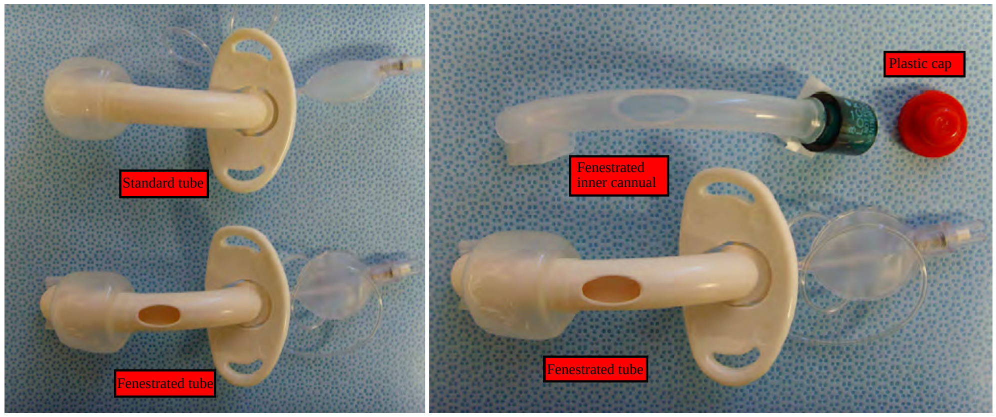

Fig. 4. Fenestrated and Nonfenestrated tracheostomy tubes.

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).

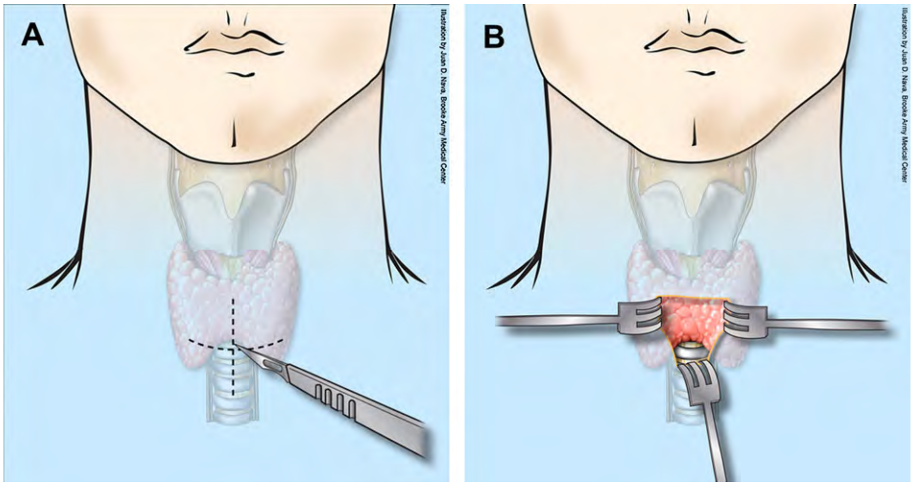

Fig. 5. (*A, B*) Initial horizontal incision made half way between the cricoid cartilage and the sternal notch. The incision is then carried through skin, subcutaneous layers, and platysma muscle. After identifying the strap muscles, lateral retraction is placed on both sides of the trachea and a vertical 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 FIO_2 (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, Sommerville, 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).

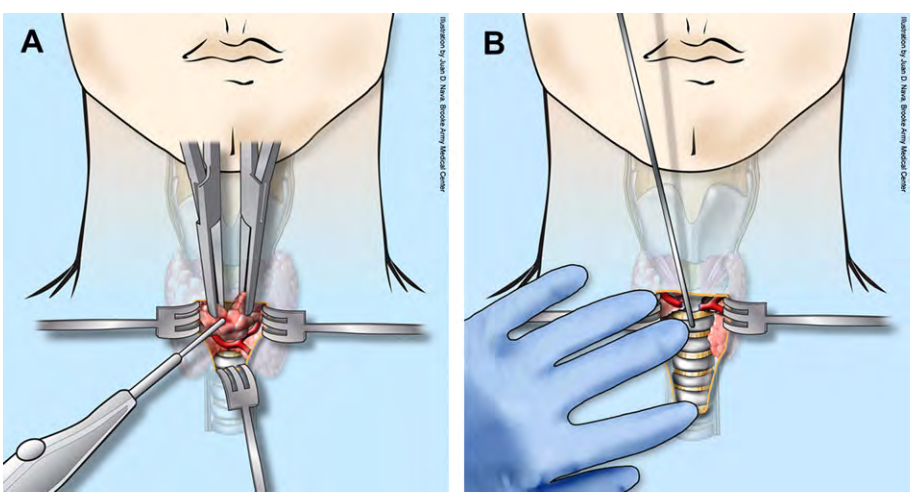

Fig. 6. (*A, B*) Use of electrocautery to incise the isthmus of thyroid gland. Tracheal hook used to retract the trachea superiorly.

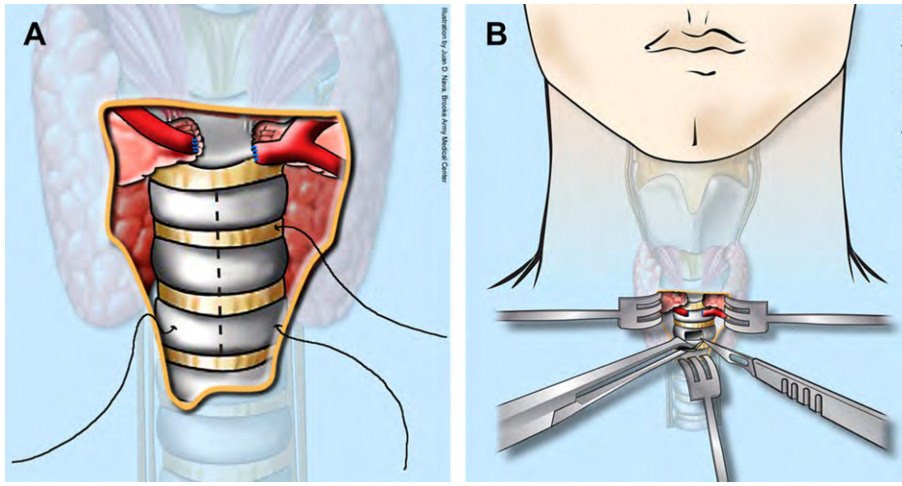

Fig. 7. (*A, B*) Placement of stay-sutures lateral to the midline of the trachea. Entrance into the trachea achieved by creating an inverted U-shaped flap.

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_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 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 $\times$ 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.

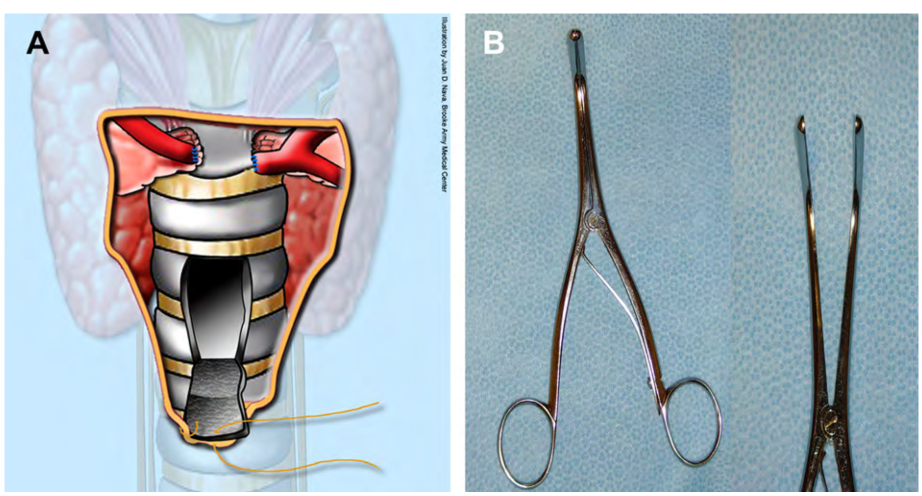

Fig. 8. (*A, B*) The Björk flap sutured to the anterior chest wall. The standard tracheal dilator is used to increase tracheal circumference before insertion of the tracheostomy tube.

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.

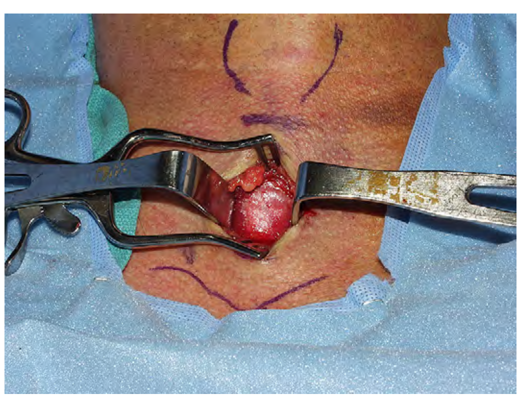

Fig. 11. Vertical dissection in the midline thyroid isthmus, separated to expose the tracheal fascia.

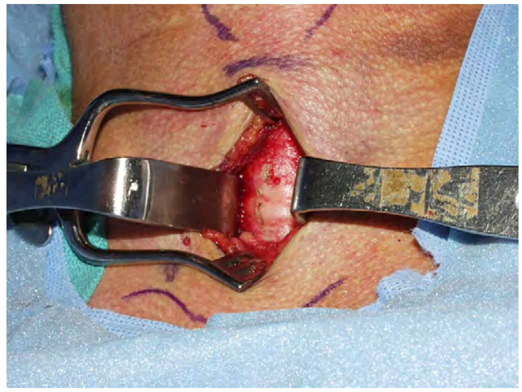

Fig. 12. Tracheal fascia cleaned off the tracheal rings.

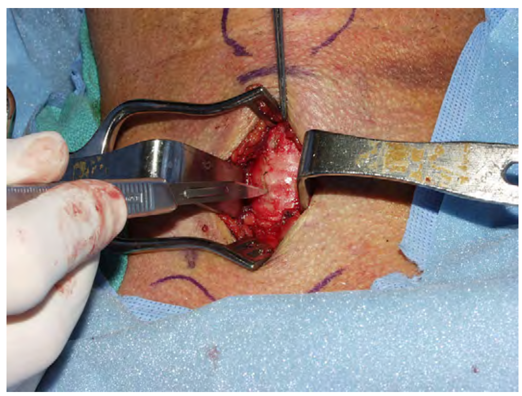

Fig. 13. Tracheal hook placed into the cricoid cartilage and retracted superiorly. Blade is placed over the tracheal rings to enter the airway.

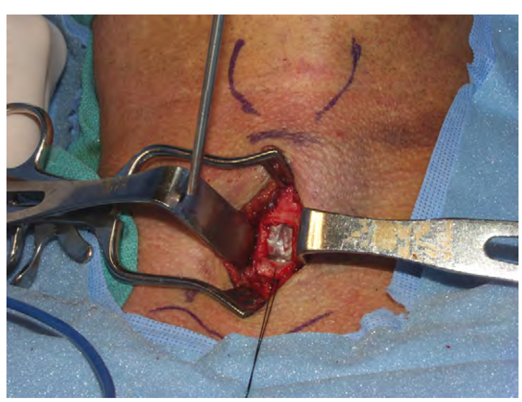

Fig. 14. Björk flap developed in an inverted U-shape and sutured to the chest wall.

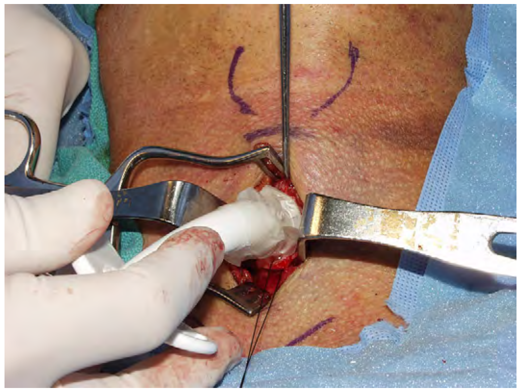

Fig. 15. Tracheostomy tube placed into the trachea as the anesthesia provider retracts the endotracheal tube.

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

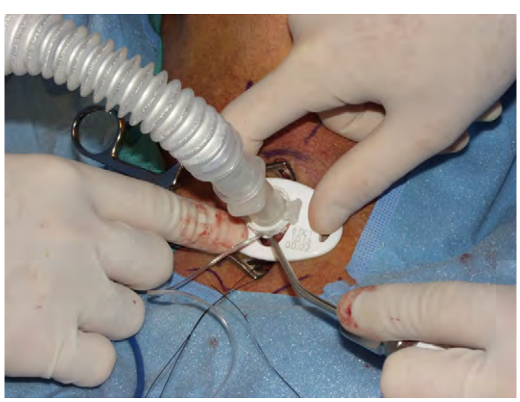

Fig. 16. Tracheostomy tube connected to the anesthesia circuit to provide ventilation.

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. $PaCo_2$ 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

Stock CR. What is past is prologue: a short history of the development of the tracheostomy. Ear Nose Throat J 1987; 66(4):166–9.
Rood S. Anatomy for tracheotomy. In: Myers E, Stool SE, Johnson JT, editors. Tracheotomy. New York: Churchil Livingstone; 1985. p. 89–97.
Heffner JE, Sahn SA. The technique of tracheotomy and cricothyroidotomy. J Crit Illn 1987;2(1):79–87.
Cumming CW. Thyroid Anatomy. In: Otolaryngology-head and neck surgery. 3rd edition. St. Louis (MO): Mosby; 1998. p. 2445–9.
Hess DR. Tracheostomy tubes & related appliances. Respir Care 2005;50(4):497–510.
Leyn PD. Tracheotomy: clinical review and guidelines. Eur J Cardiothorac Surg 2007;32:412–21.
Kent LC. Tracheostomy decanulation. Respir Care 2005;50(4):538–41.

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Percutaneous Tracheotomy

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Airway access via tracheotomy is one of the most commonly performed procedures in critically ill patients. Despite being one of the oldest surgical procedures, first documented approximately 4000 years ago, it was not until the early 20th century that it is was deemed safe and viable when Jackson [1] established clinical guidelines and proper surgical technique. Variations of the standard open tracheotomy have evolved over the last 50 years as technological advances and interest in minimally invasive techniques have grown. Since Ciaglia and colleagues [2] introduced the percutaneous dilatational tracheotomy (PDT) in 1985; percutaneous tracheotomy (PCT) has become increasingly popular. In fact, PCT has gained widespread acceptance in many intensive care units (ICUs) and trauma centers as a viable alternative approach, and in some cases, it is the procedure of choice.

There are various types of PDT techniques available, the majority of which require puncture of the trachea with subsequent guide wire insertion. Three major modifications have occurred in the basic technique since Ciaglia's initial report. First, the tracheal interspace for cannulation has been moved one or two levels caudal to the cricoid cartilage. Second, a single beveled curved dilator has replaced multiple sequential dilators. Third, the routine use of video fiberoptic bronchoscopy has been advocated to improve the safety of the procedure.

History of the procedure

Attempts at PCT began soon after Seldinger [3] first described arterial line placement via catheter insertion over a guide wire. In 1955, Shelden and colleagues [4] reported the first PCT attempt by guiding a cutting trocar into the trachea on a slotted needle. Unfortunately, the trocar used for this method caused multiple complications including fatalities from injury to adjacent vital structures. Since then, percutaneous airway access methods have improved, and various refinements to the technique have been reported.

Toye and Weinsten [5] reported in 1969 on a technique in which they introduced a single tapered dilator with a recessed cutting blade inserted over a guiding catheter. The blade was designed to cut tissues placed under tension as the dilator was advanced into the trachea.

In 1985, Ciaglia and colleagues [2] described the PDT. In their method, a guide wire was introduced into the airway through a needle. This was followed by serial dilations with sequentially larger dilators.

In 1989, Schachner and colleagues [6] reported the Rapitrach method, which employed a dilating forceps device containing a beveled metal cone-shaped tip designed to be advanced with pressure over a wire into the trachea.

Griggs and colleagues [7] in 1990 reported the guide wire dilating forceps method similar to the Rapitrach method with the exception that the tip of the instrument did not have a cutting edge.

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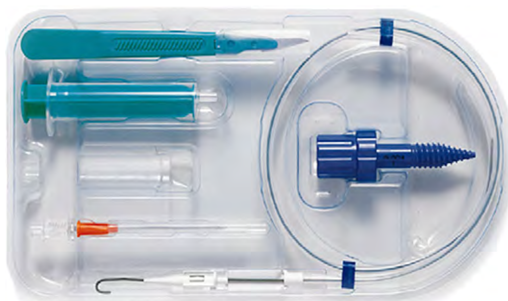
In 1997, Fantoni and Ripamonti [8] described the translaryngeal tracheotomy, which employed a specially designed cannula used to dilate the trachea in a retrograde manner.

Byhahn and colleagues [9] in 2000 introduced the Ciaglia Blue Rhino, which was a modified version of the previously described Ciaglia technique. They modified the dilator so a hydrophilically coated curved dilator, the Blue Rhino, was used to dilate the stoma in a single step rather than multiple steps. They stated that the risk of posterior tracheal wall injury and intraoperative bleeding was reduced. Additionally, the technique minimized the risk of adverse oxygen desaturation during repeated airway obstruction caused by use of multiple dilators. The use of bronchoscopic guidance was advocated for monitoring the procedure [10].

In 2002, Frova and Quintel [11] introduced a new variation on PCT called the PercuTwist technique. This technique features a single-step dilator with a self-tapping screw (PercuTwist, Rusch, Kernen, Germany) used to achieve a controlled rotating dilation of the airway. In their preliminary study, no significant bleeding or other relevant procedure related complications were found.



Percutwist set

In 2008, Gromann and colleagues introduced balloon dilatational tracheotomy [12]. The balloon mainly exerts radial force to widen the tracheotomy site, which theoretically aims to reduce typical complications such as fracture of the tracheal cartilage rings or injuries to the posterior tracheal wall.

Indications

In general terms, indications for percutaneous tracheotomy are the same as those for standard open tracheotomy. The most common indication for the procedure is a need for airway access for prolonged mechanical ventilation. The Council on Critical Care of the American College of Chest Physicians gives recommendations for tracheotomy for those patients expected to require mechanical ventilation for longer than 7 days.

Contraindications

There has been much debate over what constitutes absolute and relative contraindications for the procedure. In their recent review, Al Asari and Hijazi [13] described them. Specifically, contraindications are listed in Box 1.

Most publications consider cervical injury, pediatric age, coagulopathy, and emergency airway access as absolute contraindications, whereas short stature, thick neck, or obesity are relative contraindications. Several reports, however, recently have emerged specifically addressing the safety and feasibility of performing PCT in patients with previously described contraindications for the procedure [14].

For instance, in patients with inability to extend the neck due to lack of cervical spine clearance, the PCT complication rate has been reported to be 7.1% [15]. PCT also has been reported to be a safe method of airway access in patients who have undergone anterior cervical spine fusions [16–18].

Box 1. Contraindications to percutaneous tracheotomy

Absolute contraindications
- Patient age younger than 8
- Necessity of emergency airway access because of acute respiratory compromise
- Gross distortion of the neck anatomy due to:
  - Hematoma
  - Tumor
  - Thyromegaly
  - High innominate artery

Relative contraindications
- Patient obesity resulting in loss of palpable anatomic landmarks
- Refractory bleeding diatheses
  - Prothrombin time or activated prothrombin time greater than 1.5 times normal
  - Platelet count less than 50,000/μL
  - Bleeding time greater than 10 minutes
- Need for positive end–expiratory pressure (PEEP) greater than 20 cm water
- Evidence of soft tissue neck infection involving planned surgical site

Byhahn and colleagues studied the safety of percutaneous tracheotomy in 73 obese patients (body mass index 27.5 kg/m^2) in a cohort of 474 adults. The overall complication rate was 43.8% ($n = 32$) in the obese group compared with 18.2% ($n = 73$) in the control group. Obese patients had a 2.7-fold increased risk for perioperative complications and a 4.9-fold increased risk for serious complications [19].

Bronchoscopically guided PDT in patients with low platelet counts who are platelet transfused before the procedure, or patients who have their heparin therapy temporarily suspended during the procedure, are reported to have low complication rates [20].

The impact of bronchoscopically guided PDT on oxygenation in patients with hypoxic respiratory failure requiring high PEEP was studied recently. The results suggested high PEEP did not jeopardize oxygenation 1 hour and 24 hours after the procedure, and PDT may be performed safely in patients with acute respiratory distress syndrome with high PEEP requirements [21,22].

Although in the earlier reports, most authors considered PCT to be contraindicated in emergency airway management, more recent evidence supports the feasibility and safety of emergency PCT even in these settings [23–25].

Preoperative details

Equipment

Necessary equipment includes

- PDT kit (Cook Critical Care Incorporated, Bloomington, IN, USA): 22-gauge needle and syringe; 11-F short punch dilator; 1.32-mm guide wire; 8-F guiding catheter; 18-F, 21-F, 24-F, 28-F, 32-F, 36-F, and 38-F dilators; Shiley size 8 double-cannula tracheotomy tube; fiberoptic bronchoscope
- GWDF kit (Sims Portex, Hythe, UK): 14-gauge needle and syringe, guide wire (J-tipped Seldinger wire type), scalpel, Howard-Kelly forceps modified to produce a pair of GWDF, Shiley size 8 double-cannula tracheotomy tube with curved obturator, fiberoptic bronchoscope
- Rapitrach kit (Fresenius, Runcorn, Cheshire, UK): 12-gauge needle and syringe, short guide wire, scalpel, Rapitrach PCT dilator, standard Portex 8-mm tracheotomy tube with curved obturator, fiberoptic bronchoscope

Ciaglia Blue Rhino kit (Cook Critical Care Incorporated, Bloomington, IN, USA): 14-gauge catheter introducer needle and syringe, guide wire (J-tipped Seldinger wire type), guiding catheter, introducer dilator, loading dilators, single tapering Blue Rhino dilator, size 8 Shiley tracheotomy tube with curved obturator; fiberoptic bronchoscope.

Preparation

Proper preparation requires

Intravenous sedation and short-acting paralysis
Oxygenation with 100% oxygen before and throughout the procedure (as opposed to the open procedure, where the oxygen is reduced if the electrocautery is used)
Proper positioning of the patient with neck extension if needed, assuming there are no contraindications
Cleaning the endotracheal (ET) tube with suctioning and lavage if needed.

Percutaneous dilatational tracheotomy techniques

The neck is prepared and draped in the usual sterile fashion. Patients with a short neck or low cricoid cartilage are extended with a shoulder roll. The cricoid cartilage is identified. The skin can be injected with 1% lidocaine with 1:100,000 epinephrine. A 1.5- to 2-cm vertical skin incision is made at the level of the second and third tracheal rings. Then, blunt dissection of the midline may be performed. A 16-gauge needle is inserted between the first and second or the second and third tracheal rings. When air is aspirated into the syringe, or when the position of the needle is verified by bronchoscopy, the guide wire is introduced. The needle is removed, and the guide wire is left in place. The dilators are introduced in a sequential manner from small to large diameter. The tracheotomy tube is placed over the appropriate size introducer and the assembly passed over the guide wire. The tracheotomy tube then is introduced, and the cuff is inflated. The guide wire and introducer are removed, and the breathing circuit is connected. The ET tube is removed after proper placement of tracheotomy tube is confirmed by returning end–tidal CO_2 or visual confirmation via transendotracheal tube videobronchoscopy.

In all of the techniques in the following sections, the basic initial and concluding steps of the tracheotomy procedures are similar to the aforementioned technique. Therefore only the differences in techniques will be emphasized.

Guide Wire Dilating Forceps Technique

After initial preparation, a 14-gauge intravenous needle with saline-filled syringe is inserted in the midline of the incision. When proper placement is confirmed by visualization of air bubbles in the syringe, the outer plastic cannula is advanced into the lumen of the trachea, and the needle is removed. A J-tipped Seldinger wire is introduced into the trachea, and the plastic cannula is removed. The tip of the Seldinger wire is passed through the closed locked guide wire dilating forceps (GWDF). The forceps are advanced through the soft tissues of the neck until resistance is felt. The GWDF are released and opened to dilate the soft tissues anterior to the trachea, and the forceps then are closed, locked, and reinserted over the wire into the trachea. A slight loss of resistance occurs as the tracheal membrane is pierced. To prepare the stoma of the tracheotomy, the GWDF are opened to the same diameter as during that done with dilation of the soft tissues. A tracheotomy tube with obturator is inserted over the guide wire and advanced into the trachea. The obturator and guide wire are removed.

Rapitrach Technique

With this technique, the subcutaneous layers are dissected bluntly with a pair of forceps until the tracheal rings can be palpated with a finger. A 12-gauge needle is inserted into the trachea. In this technique, the Rapitrach dilator is introduced into the trachea over a guide wire. The dilator is opened when its tip lies in the trachea. A tracheotomy tube with obturator is inserted through the dilator jaws into the trachea.

Ciaglia Blue Rhino Technique

A 1 cm skin incision is made vertically in the low central neck between the inferior aspect of the cricoid cartilage and the suprasternal notch. A 16-gauge angiocatheter is inserted between the first and second or the second and third tracheal rings. When air is aspirated into the saline-filled syringe or when the position of the needle is verified by bronchoscopy (Fig. 1A), the needle is removed, leaving the plastic catheter in place (see Fig. 1B). The guide wire then is introduced through the catheter (see Fig. 1C). The catheter is removed leaving the guide wire in the distal trachea (see Fig. 1D). Next, a small dilator is advanced over the guide wire to dilate the skin and anterior tracheal wall. This small dilator is removed, thus allowing the insertion of a more rigid plastic sheath that prevents kinking of the guide wire during the final dilation step (see Fig. 1E). Then, the Blue Rhino single tapering dilator (white in color) is introduced over the sheath/sheath combination until the stoma is dilated to the marked diameter (36-F) (see Fig. 1F). Once proper dilation is achieved, a cuffed tracheotomy tube, previously assembled over one of the three appropriately sized introducers, is advanced over the sheath/sheath until the cannula is in place within the tracheal lumen (see Fig. 1G). The introducer and sheath/sheath are removed; the cuff is inflated, and the breathing circuit is connected (see Fig. 1H). Bronchoscopic guidance of the needle and the guide wire insertion is strongly recommended with this technique. Bronchoscopic guidance during PCT appears to be the most significant contributing factor responsible for potential hypercarbia developing during the procedure. Therefore, bronchoscopic guidance should be limited to the initial dilatation steps only. The prepackaged set is shown in Fig. 2.

Serial illustration of how the percutaneous tracheotomy is performed routinely in the authors' institution using Ciaglia Blue Rhino (see Fig. 2) and videobronchoscopy.

Bronchoscopy

Many paratracheal cannula insertions and pneumothoraces can be avoided if endoscopic monitoring is employed, especially for less-experienced operators and patients with short, thick necks [10]. In addition, a bronchoscope may be used to change and upsize the ET tube before start of the procedure. This will allow for better visualization and reduce the chance of hypercapnia and increased intracranial pressure (ICP) associated with use of bronchoscopy performed through a small-sized ET tube. This is an especially important consideration in neurosurgical ICU patients. The use of a bronchoscope will aid with monitoring the site and position of the initial needle entry into the trachea and also with confirmation of the final position of tracheotomy tube in the airway. This will help avoid early retraction of the ET and inadvertent extubation of the patient before proper insertion of tracheotomy tube.

Advantages of percutaneous dilatational tracheotomy techniques

The main advantage of PDT is the ability of this technique to be performed at the bedside, thus eliminating risks associated with patient transportation. In addition, operating room expenses are avoided, including using less equipment and personnel [13,26,27]. Many authors believe that the primary advantages of PDT are avoidance of the operating room and thus its associated costs. PDT has been shown to reduce significantly the cost of tracheotomy compared with surgical tracheotomy (ST) ($1569 plus or minus $157 for PDT vs $3172 plus or minus $114 for ST). This is predominantly due to eliminating operating room charges. The concept of a shorter delay between the time of decision to perform a tracheotomy to the time the procedure is actually done using the PCT method has been confirmed by Friedman and colleagues [27]. The waiting time for a ST has been reported to be up to 1 wk, costing about $1000/wk to $7500/wk for an unnecessary extended ICU stay [13] Therefore, the cost for extra stay in the ICU waiting for the procedure [13,26] can be avoided with a more prompt bedside

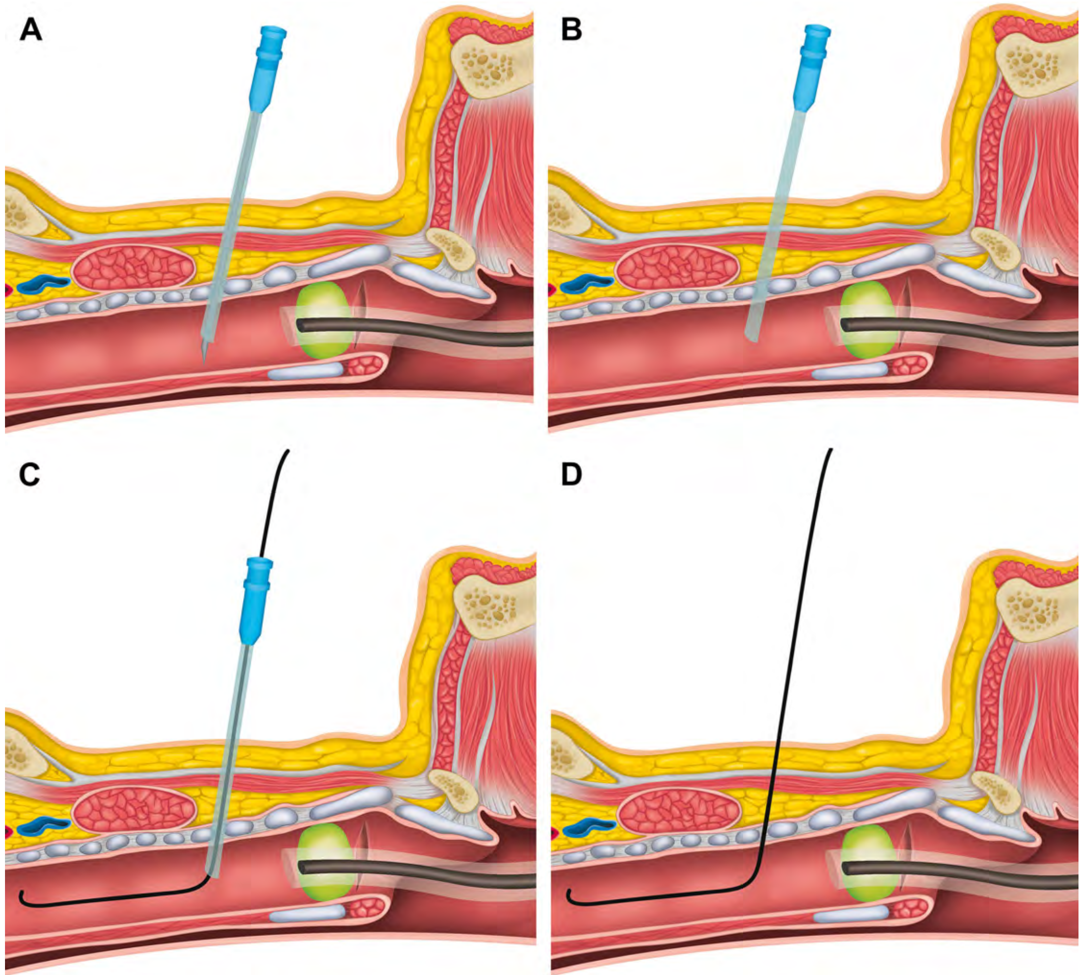


Fig. 1. (*A*) A 1 cm skin incision is made vertically in the low central neck between the inferior aspect of the cricoid cartilage and the suprasternal notch. A 16-gauge angiocatheter is inserted between the first and second or the second and third tracheal rings. (*B*) When air is aspirated into the saline filled syringe or when the position of the needle is verified by bronchoscopy, the needle is removed leaving the plastic catheter in place. (*C*) The guide wire then is introduced through the catheter. (*D*) The catheter is removed leaving the guide wire in the distal trachea. (*E*) A small dilator is advanced over the guide wire to dilate the skin and anterior tracheal wall. This small dilator is removed, thus allowing the insertion of a more rigid plastic sheath that prevents kinking of the guide wire during the final dilation step. (*F*) The Blue Rhino single tapering dilator (white in color) is introduced over the sheath/sheath combination until the stoma is dilated to the marked diameter (36-F). (*G*) Once proper dilation is achieved, a cuffed tracheotomy tube, previously assembled over one of the three appropriately sized introducers, is advanced over the sheath/sheath until the cannula is in place within the tracheal lumen. (*H*) The introducer and sheath/sheath are removed, the cuff is inflated, and the breathing circuit is connected.

percutaneous procedure. Further cost reductions theoretically could be attained by eliminating the routine use of flexible bronchoscopy, although this potentially would increase the risks of the procedure. Other advantages of PDT are a small incision and tight fit of the tube against the stoma, less dissection and tissue damage, reducing wound complications (such as bleeding and infection), in addition to an esthetically more favorable scar [28–30].

Complications of percutaneous dilatational tracheotomy techniques

Over the last 20 years, many studies have compared PCT with open ST. Most studies suggest either lower complications rates with PCT or no statistical significant differences between the methods. Most complications of PDT are minor and with no serious sequelae. Bleeding, infection, and hypoxia are infrequent. A recent report from a single center examined the complications of 827 PDT procedures performed over 8 years. This study revealed a mortality

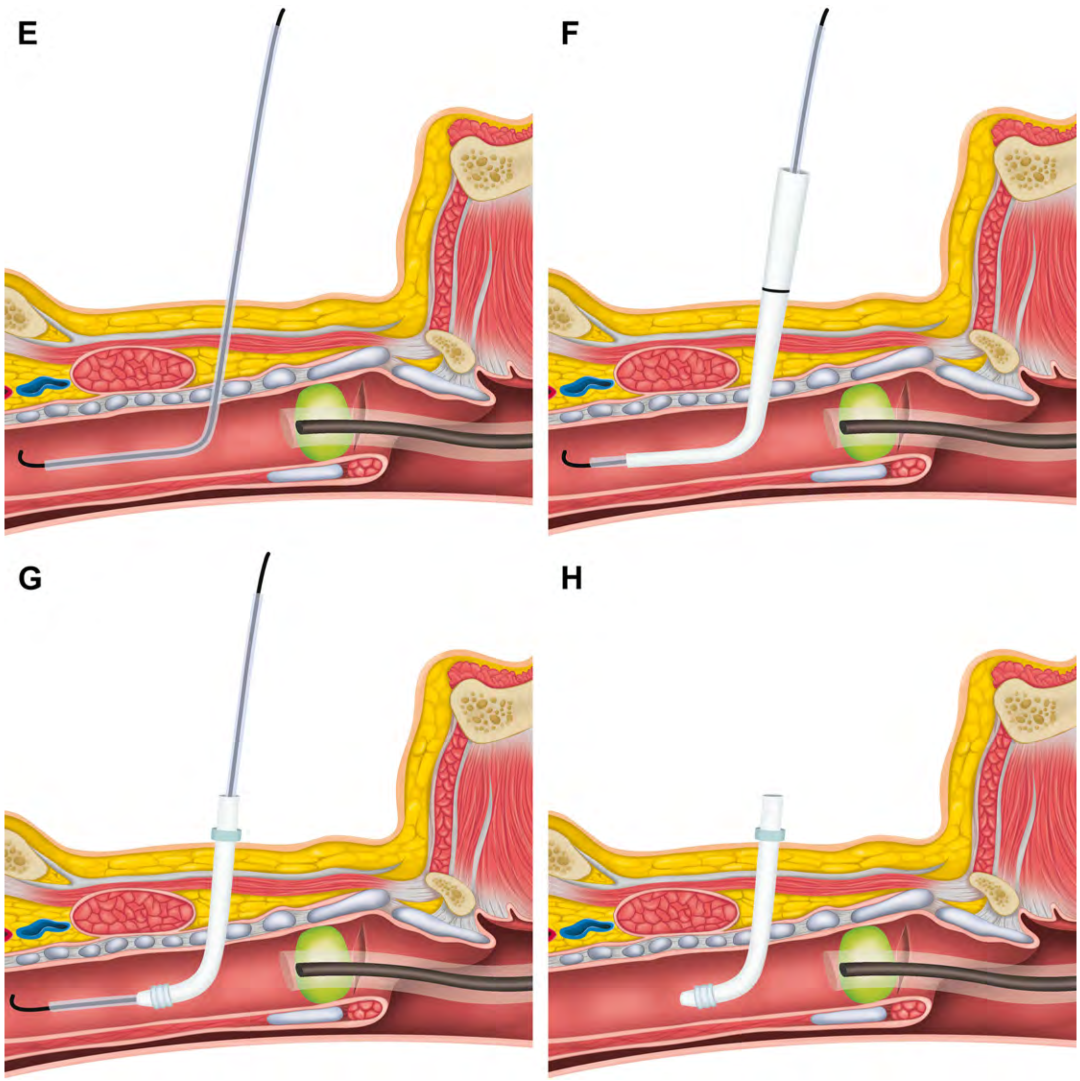


Fig. 1 (*continued*)

rate and perioperative complication rate of 0.6% and 6%, respectively. The most serious and common problem after PCT has been premature extubation. Early postoperative complications occurred in 5% of patients, with bleeding being the most common. Tracheal stenosis was seen in only 1.6% of patients who survived their ICU stay and were subsequently decannulated [31].

In Higgins and Punthakee's meta-analysis [32], the percutaneous method was associated with a higher incidence of decannulation and obstruction.

A prospective and randomized study by Melloni and colleagues [33] concluded that in addition to a lower rate of postoperative complications, PDT is a simpler and quicker technique than ST. There were, however, more prevalent late tracheal complications, although this finding was not statistically significant. The authors evaluated and followed 50 consecutive translaryngeally intubated patients with respiratory failure who were randomized to undergo either ST (25 patients) or endoscopic-guided PDT (25 patients) up to 6 months. ST was performed in 41plus or minus 14 minutes versus 14 plus or minus 6 minutes for PDT ($P<.0001$). In the ST group, there were no intraoperative complications. In the PDT group, two intraoperative complications (minor hemorrhages) were observed. In the ST group, nine early postoperative complications occurred: one minor bleeding, seven stomal infections, and one accidental decannulation. In the PDT group, only one early postoperative complication (minor bleeding) occurred. Early postoperative complication rates were 36% for ST and 4% for PDT. In the ST group, there

Fig. 2. Ciaglia Blue Rhino package containing stets of syringes, needles, catheter, different size dilators and a forceps.

were no late tracheal complications. In the PDT group, two late tracheal complications (one segmental malacia and one stenosis at the level of the stoma) were observed [33].

The incidence of other complications compares favorably with that observed in the standard ST [34]. Some of the complications reported for PCT are unique to this type of procedure and are not encountered with ST, such as paratracheal insertion of the tracheotomy tube and posterolateral tracheal wall laceration [35].

Using the bronchoscope during percutaneous tracheotomy carries the risk of neurologic complications, particularly in patients with intracranial hypertension. Using the fiberoptic bronchoscope (FB) for pulmonary toilet has been thought to produce substantial, but transient, increases in ICP, and herniation may be precipitated in an occasional patient [36]. The authors evaluated 23 patients with Glasgow Coma Scale score less than 8 or management of postcraniotomy trauma that underwent 26 FBs. The patients had ICP monitors or ICP monitors and ventriculostomy drains in place. FB was performed to aid in the diagnosis of nosocomial pneumonia or to aid in resolving lobar atelectasis. The authors reported rapid ICP increases in 21 procedures (81%) after introduction of the bronchoscope, with the mean highest ICP of 38.0 mm Hg. The average time for return of ICP to baseline was 13.9 minutes.

Kocaeli and colleagues [37] confirmed the increase in ICP during PCT and suggested that ICP should be monitored closely. They additionally suggested that preventive strategies should be instituted in an attempt to prevent secondary insult to an already severely injured brain. Imperiale and colleagues [38] studied the effect of PercuTwist tracheotomy as a single-step method that allows for effective ventilation during the procedure, thus reducing the risk of hypercarbia and development of intracranial hypertension. The authors had intraoperative monitoring, including continuous electrocardiogram, Spo2, invasive arterial blood pressure, ICP, cerebral perfusion pressure (CPP) (mean arterial blood pressure-ICP). They reported a transient ICP increase that approached significance ($P = .051$), but no episodes of CPP reduction below 60 mm Hg occurred. They concluded that the technique did not cause secondary pathophysiological insult and could be considered safe in a selected population of brain-injured patients. Nonetheless, the operating surgeon must keep this in consideration when performing the procedure in this patient population.

Hill and colleagues [39], in a retrospective study of 356 patients, reported an overall complication rate of 19%, with a long-term symptomatic tracheal stenosis rate of 3.7%. Norwood and colleagues [40] reported a rate of 31% in tracheal stenosis, and changes after PTC revealed by fiberoptic laryngotracheoscopy (FOL) and tracheal computed tomography (CT). Symptomatic stenosis manifested by subjective respiratory symptoms after decannulation was found in 3 of 48 (6%) of their patients. Tracheal stenosis was defined as more than 10% tracheal narrowing on transaxial sections or coronal and sagittal reconstruction views. Koitschev and colleagues [41] reported the same findings and concluded that dilational tracheotomy is associated with an increased risk of severe suprastomal tracheal stenosis compared with the surgical technique. The authors suggested that a procedure-related mechanism (ie, tracheal ring invagination and the consecutive development of granulation tissue) rather than the length of time the cannula was in place (which normally would produce the stenosis below the stoma in the area of the cuff) may be causing the problem [42]. Hotchkiss and McCaffrey [43] have studied the laryngotracheal injury patterns after percutaneous dilational tracheotomy in cadavers. The authors concluded that laryngotracheal injuries found after percutaneous dilational tracheotomy indicated that severe damage to mucosa and cartilage surrounding the intended stoma site occurs at the time of placement. These injuries may contribute to clinically significant tracheal stenosis, preventing decannulation in patients undergoing percutaneous dilational tracheotomy. Raghuraman and colleagues [44] compared tracheal stenosis types in patients undergoing tracheal resection and reconstruction for treatment of tracheal stenosis following PCT versus ST in a combined prospective and retrospective observational study. The authors concluded that stenosis caused by PCT occurred earlier and was subglottic in nature compared with that by ST. Surgical correction of stenosis was more difficult in the PCT group because of its presentation in the subglottic area.

Summary

In conclusion, PCT has been shown to be a safe and reliable method to perform a tracheotomy. The main advantage of this method is its simplicity. It can be performed easily in a nonoperating room setting, thus reducing transportation risks in critically ill patients and reducing cost. Complication rates have been reported to be similar to open tracheotomy. There are numerous methods and predesigned packages available to perform this procedure. Bronchoscopic guidance is recommended.

References

[1] Jackson C. Indications for tracheotomy. Mod Treat 1965;14:779–91.
[2] Ciaglia P, Firsching R, Syniec C. Elective percutaneous dilatational tracheotomy. A new simple bedside procedure; preliminary report. Chest 1985;87:715–9.
[3] Seldinger SI. Catheter replacement of the needle in percutaneous arteriography; a new technique. Acta Radiol 1953; 39:368–76.
[4] Shelden CH, Pudenz RH, Freshwater DB, et al. A new method for tracheotomy. J Neurosurg 1955;12:428–31.
[5] Toye FJ, Weinsten JD. A percutaneous tracheostomy device. Surgery 1969;30:384–9.
[6] Schachner A, Ovil Y, Sidi J, et al. Percutaneous tracheostomy–a new method. Crit Care Med 1989;17:1052–6.
[7] Griggs WM, Worthley LI, Gilligan JE, et al. A simple percutaneous tracheostomy technique. Surg Gynecol Obstet 1990;170:543–5.
[8] Fantoni A, Ripamonti D. A nonderivative, nonsurgical tracheostomy: the translaryngeal method. Intensive Care Med 1997;23:386–92.
[9] Byhahn C, Wilke HJ, Halbig S, et al. Percutaneous tracheostomy: Ciaglia Blue Rhino versus the basic ciaglia technique of percutaneous dilational tracheostomy. Anesth Analg 2000;91:882–6.
[10] Kost KM. Endoscopic percutaneous dilatational tracheotomy: a prospective evaluation of 500 consecutive cases. Laryngoscope 2005;115:1–30.
[11] Frova G, Quintel M. A new simple method for percutaneous tracheostomy: controlled rotating dilation. A preliminary report. Intensive Care Med 2002;28:299–303.
[12] Gromann TW, Birkelbach O, Hetzer R. Ballon dilatational tracheostomy: technique and first clinical experience with the Ciaglia Blue Dolphin method. Chirurg 2008;80:622–7.
[13] Al-Ansari MA, Hijazi MH. Clinical review: percutaneous dilatational tracheostomy. Crit Care 2006;10:202.
[14] Blankenship DR, Kulbersh BD, Gourin CG, et al. High-risk tracheostomy: exploring the limits of the percutaneous tracheostomy. Laryngoscope 2005;115:987–9.
[15] Mayberry JC, Wu IC, Goldman RK, et al. Cervical spine clearance and neck extension during percutaneous tracheostomy in trauma patients. Crit Care Med 2000;28:3436–40.
[16] Sustic A, Krstulovic B, Eskinja N, et al. Surgical tracheostomy versus percutaneous dilational tracheostomy in patients with anterior cervical spine fixation: preliminary report. Spine 2002;27:1942–5 [discussion: 5].
[17] Ben Nun A, Orlovsky M, Best LA. Percutaneous tracheostomy in patients with cervical spine fractures—feasible and safe. Interact Cardiovasc Thorac Surg 2006;5:427–9.

[18] Tabaee A, Murry T, Zschommler A, et al. Flexible endoscopic evaluation of swallowing with sensory testing in patients with unilateral vocal fold immobility: incidence and pathophysiology of aspiration. Laryngoscope 2005; 115:565–9.
[19] Byhahn C, Lischke V, Meininger D, et al. Perioperative complications during percutaneous tracheostomy in obese patients. Anaesthesia 2005;60:12–5.
[20] Kluge S, Meyer A, Kuhnelt P, et al. Percutaneous tracheostomy is safe in patients with severe thrombocytopenia. Chest 2004;126:547–51.
[21] Beiderlinden M, Groeben H, Peters J. Safety of percutaneous dilational tracheostomy in patients ventilated with high positive end–expiratory pressure (PEEP). Intensive Care Med 2003;29:944–8.
[22] Shah S, Morgan P. Percutaneous dilation tracheostomy during high-frequency oscillatory ventilation. Crit Care Med 2002;30:1762–4.
[23] Klein M, Weksler N, Kaplan DM, et al. Emergency percutaneous tracheostomy is feasable in experienced hands. Eur J Emerg Med 2004;11:108–12.
[24] Clarke J, Jaffery A. How we do it: emergency percutaneous tracheostomy: a case series. Clin Otolaryngol Allied Sci 2004;29:558–61.
[25] Ault MJ, Ault B, Ng PK. Percutaneous dilatational tracheostomy for emergent airway access. J Intensive Care Med 2003;18:222–6.
[26] Freeman BD, Isabella K, Cobb JP, et al. A prospective, randomized study comparing percutaneous with surgical tracheostomy in critically ill patients. Crit Care Med 2001;29:926–30.
[27] Friedman Y, Fildes J, Mizock B, et al. Comparison of percutaneous and surgical tracheostomies. Chest 1996;110: 480–5.
[28] Stoeckli SJ, Breitbach T, Schmid S. A clinical and histologic comparison of percutaneous dilational versus conventional surgical tracheostomy. Laryngoscope 1997;107:1643–6.
[29] Walz MK, Peitgen K, Thurauf N, et al. Percutaneous dilatational tracheostomy—early results and long-term outcome of 326 critically ill patients. Intensive Care Med 1998;24:685–90.
[30] Gysin C, Dulguerov P, Guyot JP, et al. Percutaneous versus surgical tracheostomy: a double-blind randomized trial. Ann Surg 1999;230:708–14.
[31] Kearney PA, Griffen MM, Ochoa JB, et al. A single-center 8-year experience with percutaneous dilational tracheostomy. Ann Surg 2000;231:701–9.
[32] Higgins KM, Punthakee X. Meta-analysis comparison of open versus percutaneous tracheostomy. Laryngoscope 2007;117:447–54.
[33] Melloni G, Muttini S, Gallioli G, et al. Surgical tracheostomy versus percutaneous dilatational tracheostomy. A prospective–randomized study with long-term follow-up. J Cardiovasc Surg (Torino) 2002;43:113–21.
[34] Fernandez L, Norwood S, Roettger R, et al. Bedside percutaneous tracheostomy with bronchoscopic guidance in critically ill patients. Arch Surg 1996;131:129–32.
[35] Lin JC, Maley RH Jr, Landreneau RJ. Extensive posterior–lateral tracheal laceration complicating percutaneous dilational tracheostomy. Ann Thorac Surg 2000;70:1194–6.
[36] Kerwin AJ, Croce MA, Timmons SD, et al. Effects of fiberoptic bronchoscopy on intracranial pressure in patients with brain injury: a prospective clinical study. J Trauma 2000;48:878–82 [discussion: 82–3].
[37] Kocaeli H, Korfali E, Taskapilioglu O, et al. Analysis of intracranial pressure changes during early versus late percutaneous tracheostomy in a neuro–intensive care unit. Acta Neurochir (Wien) 2008;150:1263–7 [discussion: 7].
[38] Imperiale C, Magni G, Favaro R, et al. Intracranial pressure monitoring during percutaneous tracheostomy percutwist in critically ill neurosurgery patients. Anesth Analg 2009;108:588–92.
[39] Hill BB, Zweng TN, Maley RH, et al. Percutaneous dilational tracheostomy: report of 356 cases. J Trauma 1996;41: 238–43 [discussion: 43–4].
[40] Norwood S, Vallina VL, Short K, et al. Incidence of tracheal stenosis and other late complications after percutaneous tracheostomy. Ann Surg 2000;232:233–41.
[41] Koitschev A, Simon C, Blumenstock G, et al. Suprastomal tracheal stenosis after dilational and surgical tracheostomy in critically ill patients. Anaesthesia 2006;61:832–7.
[42] Koitschev A, Graumueller S, Zenner HP, et al. Tracheal stenosis and obliteration above the tracheostoma after percutaneous dilational tracheostomy. Crit Care Med 2003;31:1574–6.
[43] Hotchkiss KS, McCaffrey JC. Laryngotracheal injury after percutaneous dilational tracheostomy in cadaver specimens. Laryngoscope 2003;113:16–20.
[44] Raghuraman G, Rajan S, Marzouk JK, et al. Is tracheal stenosis caused by percutaneous tracheostomy different from that by surgical tracheostomy? Chest 2005;127:879–85.

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Atlas of the Oral and Maxillofacial Surgery Clinics

Retrograde and Submental Intubation

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Retrograde intubation

Retrograde intubation was first described in 1963 by Waters, who used this technique for intubation of a patient with cancrum oris. Direct laryngoscopy remains the technique of choice to place an endotracheal tube (ETT). However, alternative techniques may be needed when the airway is found to be difficult or intubation unsuccessful. The retrograde intubation technique is an option for managing the difficult airway and is discussed in the American Society of Anesthesiology difficult airway algorithm. It may be especially useful when a fiberoptic system is not readily available.

Retrograde intubation is one of many techniques that can be used in those cases where oral or nasal tracheal intubation may be extremely difficult or impossible because of factors already discussed in this atlas. Retrograde intubation is a reliable and easily learned technique that offers an alternative to more invasive surgical solutions for securing the airway.

The advantage of retrograde intubation is that it can be used in adult or pediatric patients who are whether awake, sedated, or obtunded. This technique is indicated in those patients who cannot be intubated in a traditional manner but whose condition is not extreme enough to warrant a surgical airway. This technique may also be used to secure a nasoendotracheal tube, by passing the guidewire through the nose instead of the mouth. Contraindications to retrograde intubation include nonpalpable neck landmarks, pretracheal mass, severe flexion deformities of the neck, tracheal stenosis, coagulopathies, and infections.

Technique

Patients should be supine in the operating theater and be receiving supplemental oxygen through a nasal canula or face mask. The thyroid and cricothyroid cartilages are palpated and, if time permits, marked with a surgical marking pen (Fig. 1). Palpation of the cricothyroid membrane is then performed. Local anesthesia may be administered in the skin overlying the cricothyroid membrane. Airway reflexes can be blunted with 4% lidocaine directly into the trachea, by aerosolization or topical application. After the skin has been prepared, an 18-gauge introducer needle is passed through the skin and cricothyroid membrane and pointed in a cephalad direction at approximately a 45° angle (Fig. 2). Correct placement in the trachea is confirmed by attaching the needle to a 10-mL syringe containing approximately 5 mL of normal saline. Once the needle has been passed through the skin and entered the trachea, the plunger on the syringe is aspirated. If the needle is in the trachea, air bubbles

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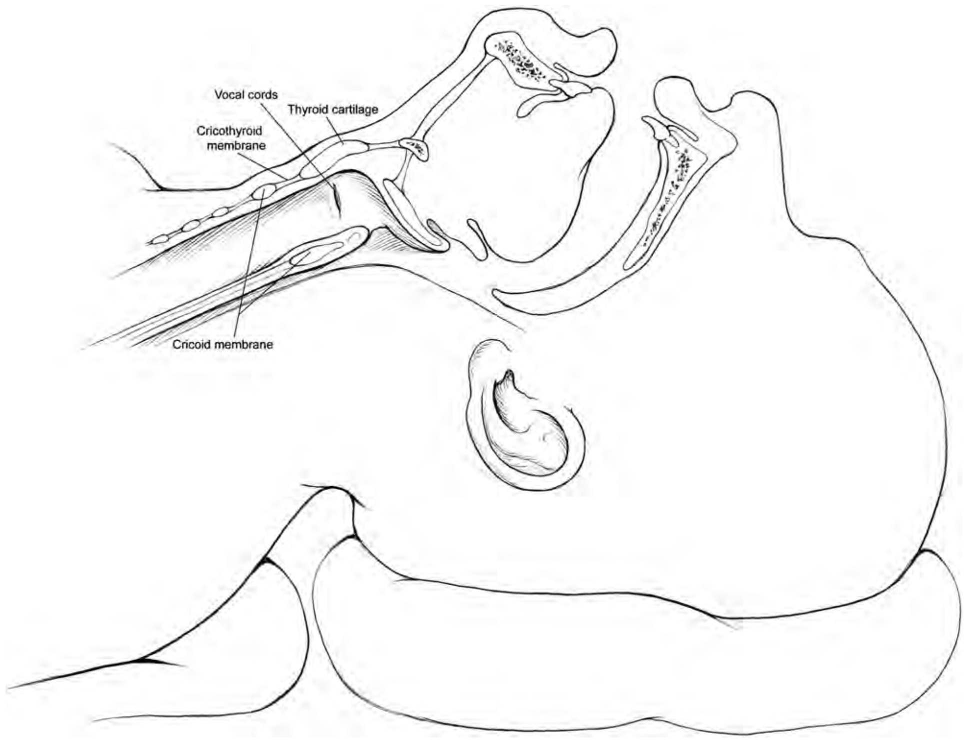

Fig. 1. Patient position. (*Courtesy of* Kathleen I. Jung; with permission.)

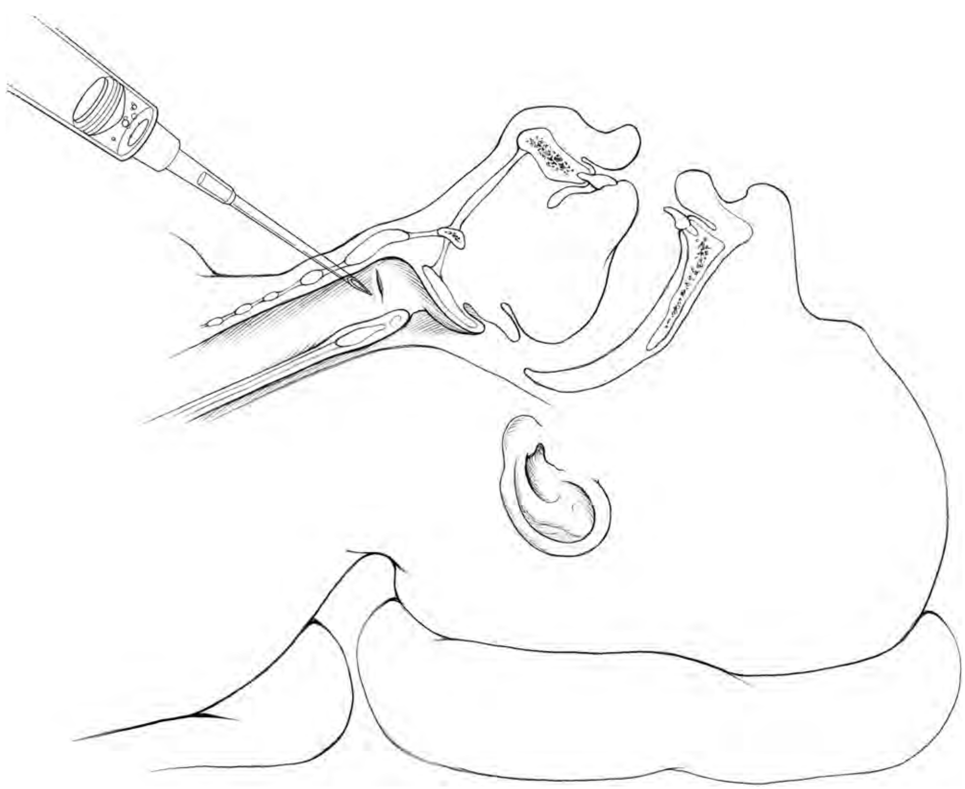

Fig. 2. Needle placed through cricothyroid membrane into trachea. (*Courtesy of* Kathleen I. Jung; with permission.)

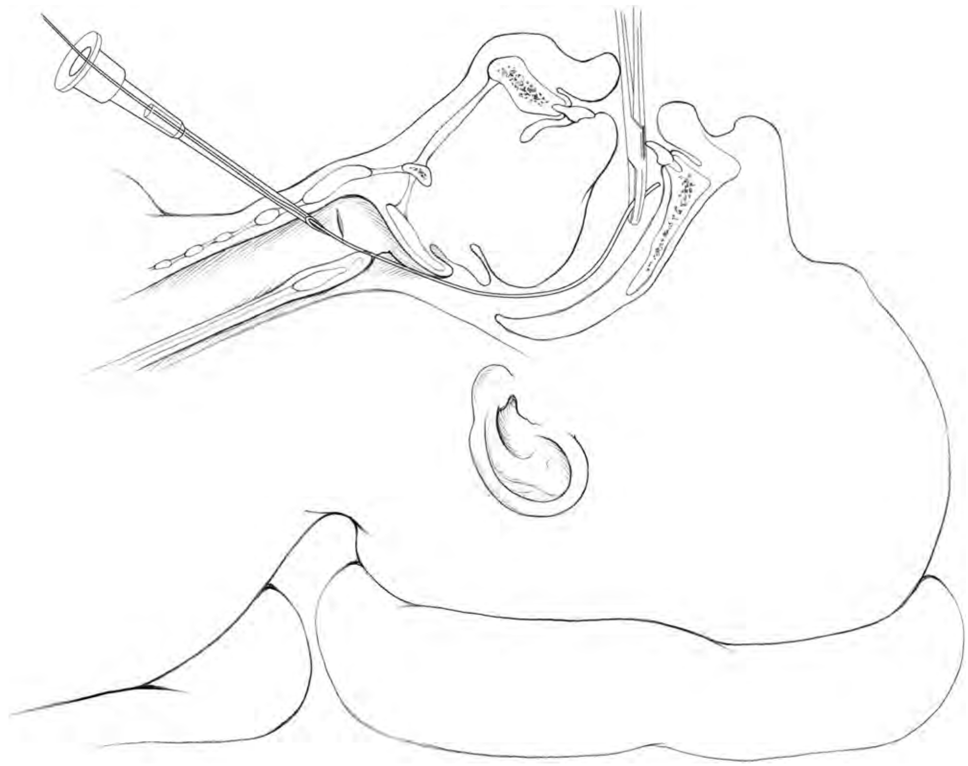

Fig. 3. Wire has been passed through and is visible in mouth. (*Courtesy of* Kathleen I. Jung; with permission.)

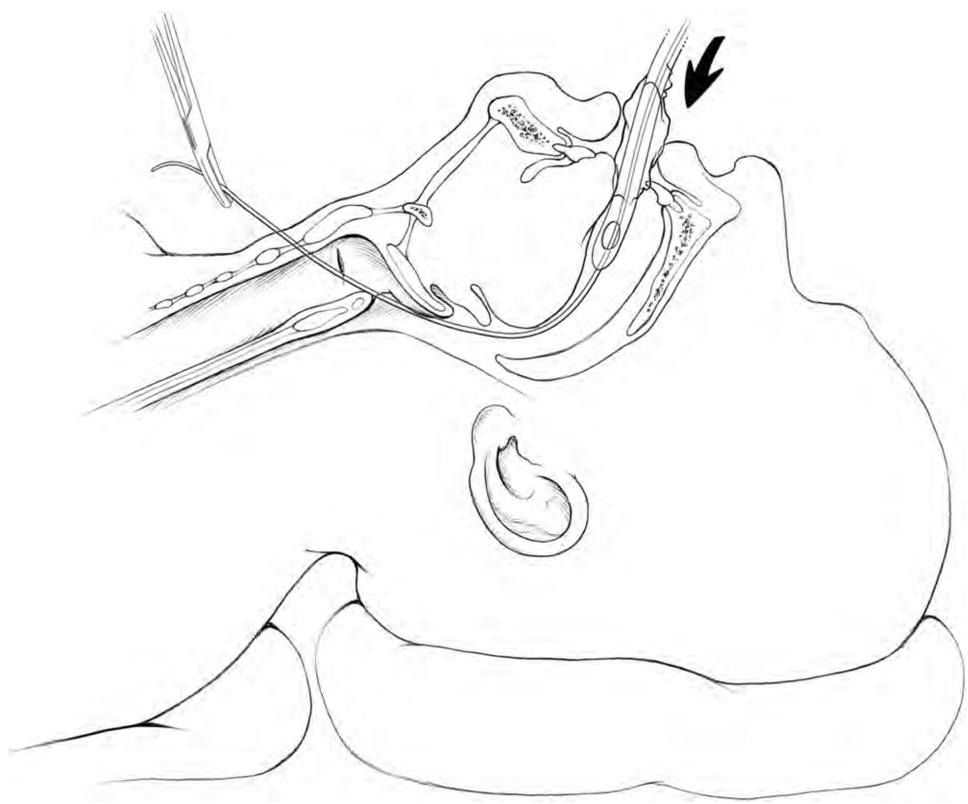

Fig. 4. ET tube passed over wire. (*Courtesy of* Kathleen I. Jung; with permission.)

will be seen in the syringe (see Fig. 2). The syringe is removed, maintaining the needle in the proper position. A 50-cm flexible J-tipped guidewire is then passed through the needle and directed superiorly so that the distal end of the wire can be retrieved from the mouth. Once the guidewire is visible in the mouth, hemostats are used to grasp the tip of the wire and advance it out of the mouth (Fig. 3). Once the guidewire is properly secured, the needle is withdrawn off the wire. An appropriate length of wire must be brought through the mouth so that an endotracheal tube can be passed over the wire while still controlling the end of wire. At this point, the wire should be relatively straight and taut. The endotracheal tube is advanced slowly over the wire and through the mouth (Fig. 4). The endotracheal tube is gradually advanced to the level of the cricothyroid. The wire may be relaxed to allow the tube to enter the trachea. Attempts to advance the endotracheal tube may result in tenting of the skin at the location of the guidewire (Fig. 5), whereupon the skin end of the wire is withdrawn from the cricothyroid membrane and endotracheal tube from the mouth. The endotracheal tube can now be advanced in the normal fashion, and confirmation of the tube's position is performed in the usual manner.

Retrograde intubation is one of many techniques that can be used to secure a difficult airway. Commercial retrograde intubation kits are available. Success in completing this procedure is variable and may depend on the surgeon's skills and experience. Inability to pass the endotracheal tube over the guide wire into the trachea or accidental extubation during removal of the guidewire are potential problems with this technique.

Submental intubation

The 2 most common methods of intubation, orotracheal and nasotracheal, used in the management of the trauma patients are sometimes contraindicated. In patients with the concomitant need for maxillomandibular fixation (MMF) and with fractures involving the nasal pyramid or cranial base, orotracheal and nasotracheal intubation is contraindicated. Naso-tracheal intubation can lead to communication of the nasal cavity with anterior cranial fossa

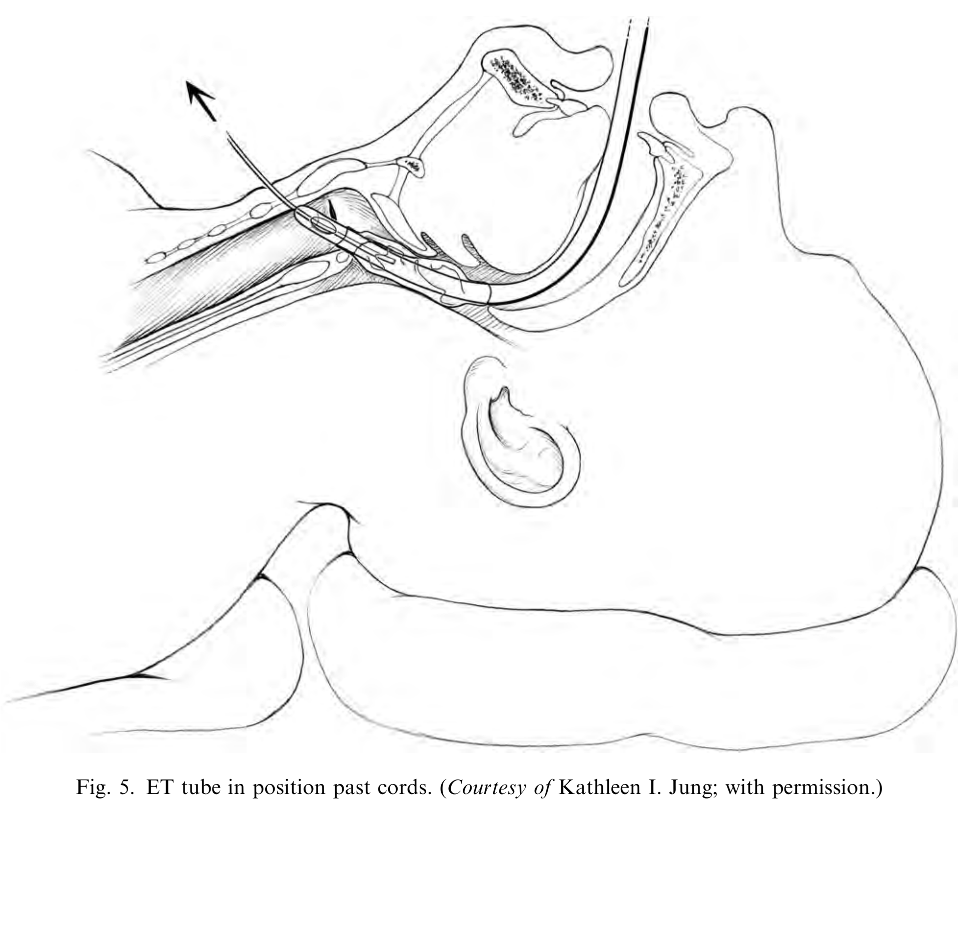

Fig. 5. ET tube in position past cords. (*Courtesy of* Kathleen I. Jung; with permission.)

Fig. 6. Flexible spiral embedded endotracheal tube.

and potentially catastrophic complications. In these situations, the standard solution would be retromolar intubation if space is adequate, or changed tube position during the operation, or tracheostomy to establish a secure airway. Intraoperative changing of tube positions has its associated risks.

Tracheostomy is a viable option for securing a surgical airway; however, it is associated with significant risk of iatrogenic complications. Tracheal stenosis, surgical emphysema, tracheoesophageal fistula, tracheoinnominate fistula, and scarring are among some the iatrogenic risks associated with tracheostomy. Submental intubation can be a viable alternative to a tracheostomy in select cases where prolonged ventilation is not required.

Submental intubation was first proposed by Hernadez Altemir in 1986 as an alternative to classical techniques in airway management. This method involves passing the proximal end of the ETT through the anterior floor of the mouth. This technique allows simultaneous access to the dental occlusion and nasal pyramid without the morbidity associated with tracheostomy.

Indications for submental intubation include maxillofacial fractures involving the nasal pyramid or extending to the cranial base that require control of interdental occlusion. Submental intubation has also been beneficial in establishing a surgical airway in orthognathic

Fig. 7. Inferior border of mandible and skin incision marked.

Fig. 8. Curved artery forceps tips in submental tunnel.

surgery. Contraindications to submental intubation include patients who require long periods of assisted ventilation and a severe traumatic wound on the floor of mouth.

Technique

With the patient placed in the supine position in the operating room and receiving supplemental oxygen, orotracheal intubation is done in the standard fashion using a reinforced (spiral embedded) tracheal tube (Fig. 6). Intravenous prophylactic antibiotics should be infused within 1 hour before the procedure, and coverage should be continued until the submental intubation is reversed. The patient is then ventilated with a fraction of inspired oxygen (FiO_2) of 1.0 throughout the procedure. A 1.5-cm incision through the skin is made in the right anterior submental region parallel to the inferior border of the mandible (Fig. 7). A right-sided incision is preferred because it allows easier direct laryngoscopy to confirm the tube position; however, the incision can be made on either side. Blunt dissection is performed using curved artery forceps. The subcutaneous fat, platysma, superficial layer of the deep cervical fascia, and mylohyoid are dissected bluntly, creating a tunnel along the lingual cortex of the mandible. Once the tips of the forceps are palpated through the lingual mucosa, the mucosa can be incised sharply allowing the forceps to enter the oral cavity (Fig. 8). The circuit is disconnected at the ETT and

Fig. 9. Curved artery forceps inserted into oral cavity through submental tunnel.

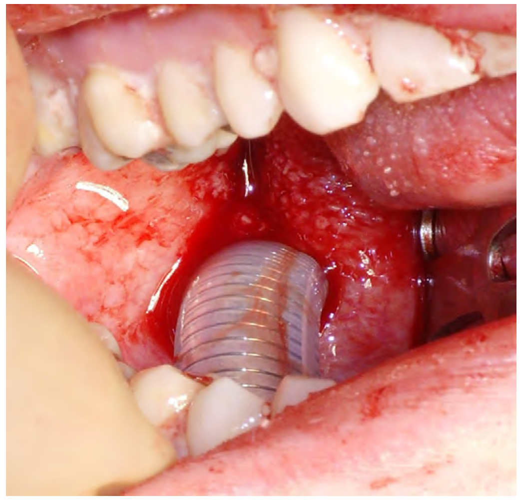

Fig. 10. Endotracheal tube position in right paralingual groove.

the tube connector is removed. The proximal end of the ETT is then grasped with the forceps and pulled carefully through the tunnel (see Fig. 8; Figs. 9 and 10). The pilot balloon is next passed through the tunnel using the forceps. The circuit is reconnected and the distal tube position is confirmed by auscultating the lung fields (Fig. 11). The ETT is then secured to the submental skin using 2-0 silk suture.

Once the operation is completed, MMF is released, the circuit is disconnected from the ETT, and the tube connector is removed. The proximal end of the ETT is then pulled intraorally through the tunnel, the tube connector is replaced, and the ETT is reconnected to the circuit.

The patient can then be extubated when the standard criteria are met. The submental incision can be closed in layers using 4-0 Vicryl (Johnson & Johnson, Ethicon Inc, Sommerville, NJ, USA) to close the platysma and 5-0 Prolene (Johnson & Johnson, Ethicon Inc, Sommerville, NJ, USA) to close the skin. The intraoral mucosal incision can be left to heal secondarily.

Complications associated with submental intubation include localized infection and sepsis, poor wound healing or scarring, and postoperative salivary fistula. Other complications reported in the literature include mucocele formation on the floor of the mouth and paresthesia of the lingual nerve. The operating surgeon needs to be aware of the possibility that the ETT could become dislodged from the trachea. Overall, submental intubation has been shown by many authors to have a high success rate, is easy to perform, and has a low rate of complication.

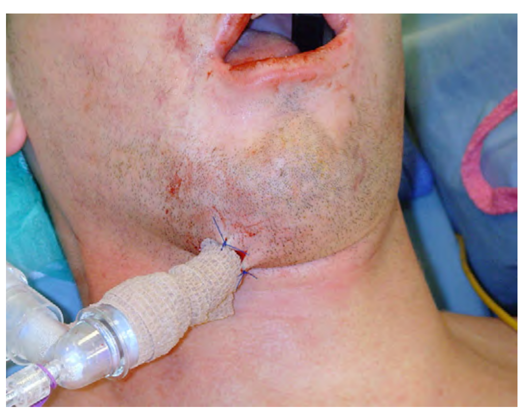

Fig. 11. Submental intubation complete with tube secured to skin.

Further readings

Altemir HF. The submental route for endotracheal intubation. A new technique. J Oral Maxillofac Surg 1986;14:64.
Burbulys D, Kianusch K. Retrograde intubation. Emerg Med Clin North Am 2008;26:1029–41.
Chandu A, Smith AC, Gebert R. Submental intubation: an alternative to short term tracheostomy. Anaesth Intensive Care 2000;28:193.
Chandu A, Witherow H, Stewart A. Submental intubation in orthognathic surgery: initial experience. Br J Oral Maxillofac Surg 2008;46:561.
Dhulkhed V. Retrograde intubation in temporomandibular joint ankylosis - A double guide wire technique. Indian J Anaesth 2008;52:90–2.
Leissner KB. Retrograde intubation with epidural catheter and cook airway exchange catheter. Can J Anesth 2007;54: 400–1.
Lessard MR, Brochard LJ. Weaning from ventilatory support. Clin Chest Med 1996;17:475.
Marlow TJ, Goltra DD, Schabel SI. Intracranial placement of a nasotracheal tube after facial fracture: a rare complication. J Emerg Med 1997;15:187.
Meyer C, Valfrey J, Kjartansdottir T, et al. Indications for and technical refinements of submental intubation in oral and maxillofacial surgery. J Craniomaxillofac Surg 2003;31:383.
Muzzi DA, LOssasso TJ, Cucchiara RF. Complication from a nasopharyngeal airway in a patients with basilar skull fracture. Anesthesiology 1991;74:366.
Stoll P, Galli C, Wachter R, et al. Submandibular endotracheal intubation in panfacial fractures. J Clin Anesth 1994; 6:83.
Taicher S, Givol N, Peleg M, et al. Chainging indications for tracheostomy in maxillofacial trauma. J Oral Maxillofac Surg 1996;54:292.
Waters DJ. Guided blind endotracheal intubation for patients with deformities of the upper airway. Anaesthesia 1963; 18:158–62.