Airway Management

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Critical Points

- Perform an airway examination that includes a history of any difficulty and a physical examination.
- Decide on the following: awake versus asleep, spontaneously breathing or paralyzed, direct or video (including flexible fiberoptic) laryngoscopy.
- Have the appropriate basic and advanced airway equipment available.
- Have a sedative, a muscle relaxant, and a vasopressor medication available.
- Develop an initial plan and backup plans before proceeding.
- Take a timeout prior to the procedure to ensure everyone understands the procedure.
- The primary goal is to maintain oxygenation. Putting a tube in the trachea is a secondary goal.

Introduction

Airway management (AM) is one of the most high-risk procedures in medicine. If done poorly, patients suffer significant morbidity and mortality. Patients undergoing emergent AM are at a higher risk and complexity due to the urgent nature and impending threat to life. The incidence of a difficult airway is much higher when AM occurs out of the operating room (OR) [1]. The incidence of adverse events, complications, and surgical airways is higher for out of OR AM [2–4]. For these reasons, it is crucial to be skilled in all facets of AM. It is not acceptable to begin managing a patient's airway, only to come to a point at which the patient is not being oxygenated and the clinician is beyond his or her capabilities. For the purposes of this chapter, AM will be discussed in terms of urgent or emergent airway manipulation in critically ill patients in the ED or ICU.

Whenever dealing with AM, it is important to try to identify a potentially difficult airway. A difficult airway has no one specific identifying feature. In the American Society of Anesthesiologists (ASA) Practice Guidelines, a difficult airway is defined "as the clinical situation in which a conventionally trained anesthesiologist experiences difficulty with facemask ventilation of the upper airway, difficulty with tracheal intubation, or both" [5]. In clinical practice, a difficult airway may be classified as one in which there is

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difficulty with the bag valve mask (BVM), laryngoscopy (either direct (DL) or video (VL)), placing a supraglottic airway device (SGA), or obtaining a surgical airway.

Airway Management Plan

Indications

The three main indications for taking over a patient's airway are: (1) The patient is not able to oxygenate. (2) The patient is not able to ventilate. (3) The patient is not able to protect his or her airway. While these indications are most often cited as the need for AM, there are other indications for securing a patient's airway specifically in emergent situations.

If the patient is unable to tolerate or cooperate for a necessary medical evaluation and treatment, then AM may be indicated. Emergency physicians are familiar with this indication, as a significant number of patients present with an altered mental status due to intoxicants. It may be quite difficult to properly evaluate and treat these patients without using sedating medicines. If these medicines do not work or the patient is a danger to himself or herself or staff members, the only other option may be to heavily sedate the patient and secure the patient's airway.

The anticipated clinical course is another indication for taking over a patient's airway. This indication is more subjective and has more to do with the clinician's gestalt. If a patient is critically ill and his or her condition is likely to deteriorate, then it is advisable to secure the patient's airway. Similar to this indication, AM is indicated whenever a clinician feels that the patient's condition warrants it. If the clinician feels that AM is indicated and is in the patient's best interest, then there should not be any second guessing from other clinicians who are not providing bedside patient's care at that time.

Algorithms

The Anesthesiology Society of America had produced guidelines and an algorithm for difficult airway management for the better part of the last 20 years. The latest version of the guidelines was written by a group of 10 anesthesiologists and 2 methodologists. As the authors state, the guidelines are not meant to be the gold standard. The guidelines do not represent requirements or standards and should be modified or rejected according to the bedside clinician's needs [5].

When approaching AM, it is important for the clinician to develop a treatment algorithm that includes every step along the way until a definitive airway is placed. While there are several algorithms that have been developed by different groups with an interest in airways [5, 6], the bedside clinician should develop an algorithm specific to each patient.

There are several questions that the clinician must answer prior to performing AM on a patient. Each question is a potential branch point in a personalized AM algorithm. Should the patient be awake or asleep? Should the patient be given a muscle relaxant or remain breathing spontaneously? What should be done if there is difficulty with mask ventilation? What should be done if there is difficulty with laryngoscopy? Should DL or VL be the primary mode of laryngoscopy? Should fiberoptic intubation be utilized?

The answer to each of these questions depends on the individual patient and the circumstances for which the patient is being intubated. When the clinician has answered all of these questions, he or she can confidently manage a patient's airway.

Predictors of Difficult Airways

The incidence of a difficult airway in the ED or ICU is not truly known because the incidence of difficulty with mask ventilation or with intubation or both is not truly known. There are several findings associated with a difficult airway, but the discriminatory power of these findings is moderate at best [7]. Because the vast majority of patients are critically ill, the need to place an airway is usually urgent or emergent, which increases the risk and difficulty [8]. There are many different mnemonics that have been devel-

oped in an effort to help simplify ways to predict a difficult airway. Evidence is lacking as to whether or not these mnemonics improve outcome [9]. Despite this lack of evidence, it is important to review the different markers of a potentially difficult airway. See Tables 2.1, 2.2, and 2.3 for different findings associated with a difficult airway. Since any AM procedure has the potential to be difficult, it is better to be overcautious than under cautious.

Table 2.1 Conditions associated with difficult intubations due to distortion of neck anatomy

Conditions associated with distortions of neck anatomy	
Cervical collar	Obstructive sleep apnea
Congenital abnormalities	Previous radiation
Foreign bodies	Previous surgery
Infections	Scoliosis
Halo cervical immobilization device	Short neck
Hematoma	Thick neck
Kyphosis	Trauma, including burns
Obesity	Tumors

Table 2.2 Physical findings associated with difficult intubations

Physical attributes associated with difficult airways	
Age 40–60	Mallampati class 3 or 4
Cervical collar or limited neck mobility	Mouth opening (<4 cm)
Facial fractures	Prominent upper incisors
Halo traction device	Receding jaw
Kyphosis	Short neck
Large tongue	Thick neck
Angioedema of lips, tongue, pharynx	Thyromental distance <6 cm

Table 2.3 Medical conditions that are commonly directly associated with difficult intubations

Medical conditions directly associated with difficult airways	
Anaphylaxis	Facial trauma
Ankylosing spondylitis	Foreign body
Angioedema	Obesity
Bleeding abnormalities	Obstructive sleep apnea or snoring
Cerebrovascular accident	Pregnancy
Congenital abnormalities	Radiation therapy
Croup	Rheumatoid arthritis
Diabetes	Actively having a seizure
Down syndrome	Tetanus
Epiglottitis	Previous oral or neck surgery

Awake Versus Asleep

Most intensivists and EM physicians are more comfortable sedating a patient completely for AM. A total sedative is not indicated in all patients. Recall that it is possible to completely anesthetize the airway and keep the patient awake. Awake AM may be indicated in patients who have multiple findings of a potential difficult airway. The ability to maintain oxygenation while setting up for an awake intubation may pose a challenge, but this challenge can often be overcome with noninvasive positive-pressure ventilation (NIPPV) and a mild sedative [10].

Use of Muscle Relaxants

The use of a total sedating medication in addition to a muscle relaxant will often permit the best chances for success [11]. That being said, if a clinician is going to paralyze a patient as part of his or her AM plan, then the clinician must be willing and able to perform a surgical airway. Giving a patient a paralytic medication to facilitate AM is not always indicated. If the risk of giving a paralytic to a patient is greater than the benefit of having the patient paralyzed, then a paralytic should not be used. This point is specifically for the patient that has multiple findings of a predicted difficult airway and limited resources for the bedside clinician. If the clinician does not feel that the patient could be adequately oxygenated with mask ventilation or SGA, then a paralytic should not be used.

The process of rapid sequence intubation (RSI) is commonly used in the ED because of the concern for patients being nonfasted. In RSI, the patient is given a dose of a sedative medication, which is immediately followed by a paralytic agent. Oxygen is maintained on the patient, but no attempts are made to provide mask ventilation. When the patient has become apneic, the patient is intubated. RSI is useful in the ED for several reasons [12]. By paralyzing the patient, optimal intubating conditions are achieved. The patient's gag reflex and ability to cough are taken away. The vocal cords are also paralyzed, which makes placing an endotracheal tube (ETT) into the trachea much easier.

There are times in which paralyzing a patient may be contraindicated. In these situations, the provider may elect to only sedate the patient, also known as facilitated intubation. In these cases, it has been demonstrated that providers have more difficulty, worse visualization of the glottic structures, and lower rates of successfully placing an ETT into the trachea [13].

Delayed sequence intubation (DSI) is another process by which patients may be intubated with the use of paralytics. DSI is a method of improving preoxygenation in agitated patients suffering from hypoxia-induced delirium. Patients who are uncooperative and not able to be adequately preoxygenated are good candidates for DSI. These patients are first given a sedative that will not affect spontaneous breathing or impair the airway reflexes. The patients are then oxygenated with 100% FiO_2 via non-rebreather mask or NIPPV. After a period of appropriate preoxygenation, a paralytic agent is administered [14]. After muscle relaxation, the patient is intubated.

Direct or Video Laryngoscopy

Direct laryngoscopy has been the main method of AM for decades. Drs. Miller and MacIntosh developed their respective blades in the 1940s, and the designs have changed little over the years. DL is the standard method for placing an ETT. That being said, many clinicians are moving to using VL for all AM. Each method has its drawbacks. It is important to realize that one method will not work for every situation, and clinicians should be proficient at both methods. DL specifically is a learned skill that must be continuously practiced or the skill will vanish.

Patient Preparation

Patient preparation is integral to any AM procedure. With adequate preparation, one is able to maximize the chances for success and minimize the risk to the patient. There are several steps that go into fully preparing for taking over a patient's airway, and each step should be completed whenever time allows.

The patient needs to have all appropriate monitors in place and be properly positioned. Depending on the airway examination, positioning the patient may be as easy as pulling him or her toward the head of the bed. Positioning the patient may mean using multiple blankets, pillows, and wedges to align the oral, pharyngeal, and laryngeal axes.

Appropriate medications should be at the bedside. Rescue medications (eg. a vasopressor) should always be immediately available. Depending on the situation, other medication may also be needed. These may include a sedating agent, a muscle relaxant, or medicines to provide topical anesthesia.

Initial and Backup Plan(s)

The primary goal of any AM plan is to maximize oxygenation. For every patient, the clinician should develop an initial AM plan. The clinician should also develop at least one backup plan. These plans need to be patient specific, based on the clinical scenario, the patient examination, any predictors of a difficult airway, and the clinician's experience and gestalt. Not every clinician will develop the same primary plan for the same patient in the same clinical situation. The bedside clinician's judgment is being used for the specific clinical scenario.

Every AM plan should have at least one backup plan. Things do not always go as predicted, so it is important to know what to do if the primary plan fails. It may be necessary to have multiple backup plans. The final common plan for all AM is to place a surgical airway.

Timeout

If time allows, an airway timeout should be taken. The only reason not to take an airway timeout is if there is an emergent situation where it is not possible to oxygenate the patient. An airway timeout is a chance to make sure that the patient is as safe as possible [15]. A timeout allows all personnel involved to

Table 2.4 Complications associated with airway management

Complications of airway management	
Aspiration	Lung barotrauma
Bradycardia	Mainstem bronchus intubation
Cerebral ischemia	Myocardial ischemia
Death	Oral soft-tissue trauma
Dental trauma	Pharyngitis
Dysrhythmias	Pneumonia
Esophageal intubation	Tachycardia
Granuloma formation	Tracheitis
Hypertension	Tracheal ischemia
Hypotension	Tracheal perforation
Hypoxia	Tracheal stenosis
Laryngitis	Vocal cord paralysis
Laryngospasm	

make sure that they are on the same page. The timeout should consist of every person stating his or her name and what job he or she will be performing. The AM team leader should be the person actually manipulating the patient's airway. The leader needs to review with the team the resources needed and make sure that those resources are available. The leader should state the primary and the backup plan(s). Most importantly, if a team member has a question or is uncertain about something, he or she must speak up.

Complications

The most feared complication of AM is patient death. Thankfully, this rarely occurs. Most complications are much less serious. Some common complications are dysrhythmias, mild airway trauma, and pharyngitis. Less common complications include laryngospasm, tracheal stenosis, and dental trauma. For a more complete list, see Table 2.4.

Assessment

Clinical Situation

As in any patient encounter, it is necessary to assess the situation. For AM, the clinician should be able to assess the situation within a matter of seconds. Depending on the clinical scenario, action may need to be taken within seconds to prevent patient morbidity or mortality or there may be time to fully investigate, examine the patient, and prepare for placing an airway.

In emergent conditions, there is little, if any, time to do more than focus on getting an airway into the patient. Since it is rare that these truly emergent conditions exist, it is important to develop a plan ahead of time. These truly emergent conditions are predominantly those in which the patient has no airway and is already severely hypoxic or in cardiac arrest. Other personnel may have already tried multiple interventions. A common example is the patient brought to the ED by EMS where the paramedics have not been able to obtain an airway despite multiple attempts with different techniques and equipment, and the patient is in cardiac arrest because of not having an airway. A surgical airway may be indicated and must be performed emergently in an effort to save the patient's life.

Under ideal conditions, the clinician has time to prepare appropriately. It would be possible to develop an AM plan, including backup plans. There would be plenty of assistance, which may include other people who are knowledgeable about airway management. There is time to adequately position the patient and equipment necessary. Ideally, the patient has an empty stomach. The anatomy would be such that the mouth could be opened wide without difficulty. The airway itself would be widely patent and without obstruction. The neck would have a full range of motion. He or she would be able to be preoxygenated and would have a normal and intact respiratory drive. The patient would have a normal body mass index. The hemodynamics would be normal. The patient coagulation would be normal and intact.

Most cases requiring AM in the ED or ICU are somewhere between emergent and ideal conditions. These urgent situations require expedited action, but there is time to properly evaluate the patient and develop a strategy that will maximize the potential for positive results.

Airway Examination

An airway examination should be performed on any patient to be given conscious sedation or undergo intubation. Even due to the emergent nature of airways in the ED and ICU, it is imperative to still perform an airway examination on patients. The intent of the examination is to uncover any potential findings that may predict difficulty in any of the steps of AM. Any airway has the potential to be a difficult airway. A percentage of difficult airways may proceed to become a failed airway. A failed airway is one in which the clinician is not able to place an airway of any type. In emergent AM, a failed airway often equates to a patient death. In an effort to prevent patient deaths, it is important to prepare and plan and have a broad knowledge of different AM techniques.

From mask ventilation to surgical airways, a correctly performed airway exam will give the provider information about how best to take over control of the patient's airway. The provider should use the findings from the airway exam to develop an AM plan that has the lowest risk to the patient. There is no evidence that performing an airway exam will change the intubation experience or outcome. There is no single finding that has been shown to reliably predict a difficult airway [7]. For this reason, it is important for the clinician to look for any of the findings that have been associated with a difficult airway. It is advised to develop a system so that one performs the examination the same way each time, so that nothing is missed.

One way to start the airway exam is by looking at the patient's overall body habitus. Pay particular attention to the head and neck. Begin at the base of the neck and move cephalad. There is a higher risk of difficulty associated with obese patients or those with short or thick necks. Limited neck mobility is another predictor of difficulty. If the patient has a cervical collar or Halo brace in place, it is important to know if there are actual injuries to the cervical spine or spinal cord or is the collar just for precaution. Patients with scoliosis or kyphosis are often difficult to position, which may lead to difficulty with AM. Tumors, trauma, foreign bodies, or any other abnormal anatomy findings are associated with a difficult airway. See Table 2.1 for further. One feature of the neck examination that is often overlooked is the cricothyroid membrane (CTM). It is important to locate and evaluate the patient's CTM in case there is a need for a nerve block or a surgical airway.

A small chin may be a concerning finding. The thyromental (also known as the hyomental) distance is measured from the thyroid notch to the tip of the mandible with the head extended, the neck in a neutral position, and the mouth closed. A length of 6 cm or greater is a favorable finding for direct laryngoscopy. Another acceptable measurement is three of the patient's finger breadths. The thyrohyoid distance is measured from the thyroid notch to the hyoid bone (or base of mouth if unable to palpate) with the neck extended. A distance of more than two of the patient's finger breadths is favorable.

An upper lip bite test (ULBT), also termed a mandibular protrusion test (MPT), examines the amount of protrusion of the patient's mandible or amount of jaw thrust. Have the patient attempt to bite as much of his or her upper lip as possible with the lower incisors. In class I, the lower incisors can bite the upper lip above the vermillion border, making the mucosa of the upper lip invisible. In class II, the lower incisors can bite the upper lip below the vermillion border. In class III, the patient is not able to bite his or her upper lip with the lower incisors. Class II or III has been demonstrated to predict difficulty with mask ventilation [16]. A class III ULBT is associated with difficult intubation [17].

After the chin, move to the face and mouth. Facial hair may decrease the ability to mask ventilate a patient. It may be necessary to shave the patient. When examining the mouth, the length of the central incisors should be noted as large or protruding incisors or an overbite may indicate a difficult airway. Look for loose teeth, as these may come out during manipulation of the airway and become an obstruction or aspiration risk. Dentures may be beneficial for mask ventilation but may make intubation more

difficult. Small interincisor distance and a large or protruding tongue are also concerning findings. A high arched palate is also associated with difficult intubations. See Table 2.2 for further information.

Look specifically at the uvula to ascertain the patient's modified Mallampati classification [18]. With the observer at eye level, the patient holds the head in a neutral position, opens the mouth maximally, and protrudes the tongue without phonating. The airway is classified according to the visible structures. In a class I, 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 the uvula are visible. In class IV (added by Samsoon and Young [19]), the soft palate is not visible. Mallampati considered those patients with class IV and possibly class III to be difficult to intubate [18, 20]. See Table 2.5 and Fig. 2.1 for further information.

Even in emergent situations, a provider is able to perform an airway exam. The examination does not take long to perform and provides useful information so that an AM plan may be developed that minimizes patient risk.

Table 2.5 The modified Mallampati score which evaluates the ability to view structures in the posterior pharynx

Modified Mallampati classification	
Class I	The soft palate, fauces, uvula, and tonsillar pillars are visible
Class II	The soft palate, fauces, and uvula are visible
Class III	The soft palate and base of the uvula are visible
Class IV	The soft palate is not visible

Anesthetic History

In addition to an airway exam, reviewing a patient's anesthetic and surgical history will provide information regarding previous AM experiences. With the increased use of electronic medical records (EMR), this information has become easier to obtain. If deemed to be a difficult airway, anesthesiology providers will make notation so that future providers will have the ability to prepare ahead of time. Information about any difficulty with mask ventilation or intubation should be in the anesthetic records. In addition to information about the airway, these records may have information about other problems encountered, such as hypotension with induction or information about the doses of medications used.

There is no evidence that the current AM plan must be the same as plans done on the same patient in the past. The clinical scenario and the patient may be significantly different than previous AM encounters. The plan must be developed by the bedside clinician based on the clinical scenario and his or her judgment.

Physical Examination

The purpose of the patient evaluation is to identify any risk factor that is associated with a diffi-

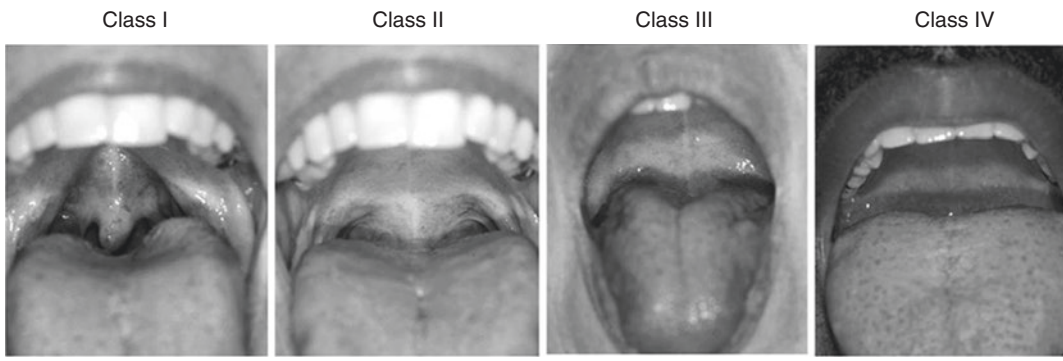

Fig. 2.1 The modified Mallampati classification

cult intubation, so that the provider can prepare his or her intubation plan accordingly. Under ideal circumstances, one would be able to interview the patient to obtain medical history, perform a full physical examination, and then review the patient's medical record for other information, such as electrocardiograms, X-rays, or echocardiograms. When there is ample time, the provider should discuss the details of the intubation procedure and any backup plans with the patient.

In the ICU or the ED, time is limited due to the urgent or emergent patient condition. In these circumstances, the clinician should perform a directed physical examination. The directed physical examination should include an evaluation of the patient's cardiovascular and pulmonary system. It is important to note any abnormal findings. The clinician should develop the AM plan that aims to avoid exacerbating any of these abnormal exam findings. It is also important to perform a directed neurologic exam looking at mental status. It may be necessary to limit sedation in patients with a primary neurologic deficit. Similarly, if there is concern for or a known cervical spine injury, it may be necessary to maintain cervical spine immobilization throughout the AM plan.

In addition to the directed physical examination, it is imperative to review the patient's current vital signs. Hemodynamic instability is commonly seen in patients that require urgent or emergent AM. Many of the medications used will affect the patient's hemodynamics. Laryngoscopy can elevate a patient's intracranial pressure (ICP) significantly. An endotracheal tube that contacts the carina can induce profound bradycardia. When a patient switches from negative-pressure to positive-pressure ventilation, there are significant changes in intrathoracic pressure that will affect hemodynamics. The patient's risk of injury is lower if the provider incorporates the current and predicted vital signs into the AM plan.

Labs and Ancillary Tests

Depending on the patient's condition, there may be time to review potentially pertinent labs or other tests that have been performed. The purpose of reviewing labs and tests is to give the provider more information to formulate an AM plan. Although there is no one lab or ancillary test that must be reviewed, the following studies are often reviewed in an effort to learn more about a patient's clinical status.

An arterial blood gas (ABG) will show the degree of hypoxemia and acidemia. An elevated lactic acid is associated with anaerobic metabolism and may indicate that the patient is in some type of shock. A complete blood count (CBC) would show anemia, which would affect oxygen delivery to the tissues, or thrombocytopenia, which may be, depending on the severity, a risk factor for bleeding. Coagulation studies also provide information about the risk of bleeding during AM. A comprehensive metabolic profile will provide information about the patient's liver function, renal function, and electrolytes, especially the potassium. It is also useful to review cardiac markers to know if the patient has had any cardiac ischemia. All of this information may be helpful in deciding what, if any, medications should be used in the AM plan.

A chest X-ray (CXR) will often provide information about the condition of the patient's lungs. If significant abnormalities are found on the CXR, it will be much more difficult to preoxygenate the patient and maintain high levels of oxygenation during the manipulation of the airway. An electrocardiogram (EKG) may provide information about any conduction abnormalities or active cardiac ischemia. An echocardiogram should provide information about the patient's ejection fraction, right ventricular function, and any valvular abnormalities. All of these tests provide information that is helpful in formulating an appropriate AM plan, so that there is minimal risk for the patient and maximum potential for successful AM without complications.

Medical and Surgical History

As with any other intervention or medical procedure, it is beneficial to know the patient's medical and surgical history. While time may

not allow the provider to obtain a full history, it is advantageous to know the immediate history and events leading to why a patient needs AM. In addition to this basic knowledge, the provider should attempt to ascertain if the patient has any medical condition that is commonly associated with a difficult airway. Any medical or surgical condition that distorts the normal anatomy has the potential to make it difficult to place a definitive airway.

There are several medical conditions that are associated with difficult intubations. Obesity is one of the most common medical conditions that is also commonly associated with difficult mask ventilation and difficult laryngoscopy. As the obesity epidemic continues to worsen, the percentage of patients with a difficult airway will increase. See Table 2.3 for a list of medical conditions that are commonly associated directly with a difficult airway. In addition to medical conditions that are directly associated with a difficult airway, it is possible for essentially any severe medical condition to be indirectly related in some way to a difficult AM. The provider's AM plan is limited due to these severe medical conditions because of the significant morbidity and mortality, which is increased when dealing with urgent or emergent AM.

Equipment

There are many different pieces of equipment needed to provide AM. These pieces range from fairly basic to highly advanced, as well as other ancillary items that are equally important but are not specifically for AM. While there is no evidence to support that having every piece of equipment at the bedside will make an airway easier, most clinicians prefer to have all equipment needed for the initial and backup plans readily available. Depending on the situation, this may include an assistant that is also familiar with airway management. The basic equipment used in AM is often what will save a patient's life. The clinician will use any and all of this equipment in preparation for maximum patient oxygenation prior to moving to the advanced equipment that is used for a definitive airway. A list of airway equipment needed for urgent or emergent AM is found in Table 2.6.

Basic

Basic airway equipment is able to provide oxygen to a patient, but it does not provide the patient with a definitive airway. Any person providing patient care should have knowledge in how to use this equipment. Basic airway equipment includes a continuous oxygen source, a bag valve mask (BVM), oral and nasal airways, a positive end-expiratory pressure (PEEP) valve, and suction capabilities. While labeled as basic, this equipment is anything but basic. This equipment is a fall back for any time when it is difficult or impossible to get oxygen into a patient.

A continuous oxygen source allows the provider to maximize a patient's oxygenation status in an effort to prevent desaturation during AM. The patient should be oxygenated with 100% FiO_2 for 3 minutes to achieve maximum oxygenation [21]. This amount of time will also cause nitrogen washout, also known as denitrogenation. During emergent AM, the patient should also be maintained on 100% FiO_2 to fur-

Table 2.6 Airway equipment that may be needed at bedside or readily available for urgent or emergent airway management

Airway equipment for urgent or emergent airway management	
Basic	Advanced
Bag valve mask, self-inflating, with reservoir	Bougie
Facemasks (multiple sizes)	Endotracheal tubes (multiple sizes)
Oral airways (multiple sizes)	Laryngoscope handles
Oxygen source	Laryngoscope curved blades (multiple sizes)
Nasopharyngeal airways (multiple sizes)	Laryngoscope straight blades (multiple sizes)
PEEP valve	Rescue devices
Suction source with Yankauer suction tip	Supraglottic airway devices (multiple sizes)
	Surgical airway kit
	Video laryngoscopy

ther prevent desaturation [22]. The easiest way to do this is by providing 15 lpm 0_2 through a nasal cannula or using a high-flow nasal cannula (HFNC), which can provide up to 60 lpm O_2. Noninvasive positive-pressure ventilation (NIPPV) is another way to maintain continuous oxygenation during AM, but the logistics of using NIPPV make this option less appealing.

An adult BVM (Fig. 2.2) is usually a 1-L bag with a 15-mm standard adapter that allows ventilation via a mask, an SGA, or endotracheal tube. In the ED and ICU, BVMs are usually self-inflating and disposable and have an oxygen reservoir to insure that the BVM delivers the highest oxygen concentration possible. There are different types of the BVMs and not all are self-inflating. Non self-inflating BVMs usually do not have a reservoir and must be connected to an oxygen source to insure that the bag fills up with oxygen. It is important to make sure to have access to smaller BVMs if the patient is significantly smaller than an average adult. Most disposable BVMs come with a mask. Multiple mask sizes should be immediately available to make sure that the mask is adequate for the size of the patient's face.

An oral airway (OPA) (Fig. 2.3) is used to keep the airway open when using a BVM by preventing the tongue from occluding the hypopharynx. There are many different designs that are currently used throughout the world. The OPA should only be used on patients with a depressed gag reflex; otherwise, the patient may vomit and aspirate gastric contents. The correct size of the OPA is determined by measuring from the corner of the mouth to the tragus of the ear. Common sizes for adults are 80, 90, and 100 mm. The OPA is properly positioned when the proximal flange is resting on the patient's lips.

A nasal airway (NPA) (Fig. 2.4) is placed into the nasal passage(s) in an effort to improve the patient's airway and oxygenation. An NPA may be placed in a patient with an intact gag reflex. The correct size of an NPA is determined by mea-

Fig. 2.2 Bag valve mask with facemask and oxygen reservoir

Fig. 2.3 Oropharyngeal airway

Fig. 2.4 Nasopharyngeal airway

suring from the nasal ala to the corner of the mandible and the size of the largest nare. It is important to use the correct size because if an NPA that is too large is used, it is possible to insert the NPA to the point of stimulating the gag reflex. Common sizes for adults are 5.5–8.5 mm.

A PEEP valve (Fig. 2.5) is beneficial to have immediately available, especially if the patient is severely hypoxic. Similar to PEEP on a ventilator, a PEEP valve attempts to provide end-expiratory pressure in an effort to maintain alveoli open at the end of expiration. By keeping alveoli open, less effort is needed to overcome the resistance of opening a closed alveolus. The end result is an increase in mean airway pressure which equates to improved oxygenation. The provider must be cautious, as a PEEP valve may cause a significant decrease in venous return to the heart, which will be seen clinically as hypotension.

Fig. 2.5 PEEP valve

Finally, suction capabilities are always necessary. It is impossible to accurately predict the amount of secretions or blood in the posterior larynx. Having suction immediately available has the potential to reduce aspiration of contents into the lungs. In clinical situations in which there is copious material in the patient's pharynx, it may be advisable to have more than one suction setup available.

Advanced

A definitive airway is an artificial tube in the trachea. Advanced airway equipment is that which is needed to place a definitive airway. This equipment requires that the provider has advanced training in AM. Advanced equipment includes items for direct and video laryngoscopy, endotracheal tubes, stylets, SGAs, surgical airway placement, and other rescue devices. Equipment options will differ depending on the institution, but the minimal requirement readily available should be equipment for DL, SGAs, rescue stylets, and equipment to obtain a surgical airway.

Laryngoscope handles and blades are needed for direct laryngoscopy. There are many types of straight blades available, including Miller, Wisconsin, and Wis-Hipple (Fig. 2.6). These

Fig. 2.6 Straight laryngoscope blades. (**a**) Profile view of Miller laryngoscope blade. (**b**) Wis-Hipple laryngoscope blades and handle

blades differ in the size or degree of curvature of the spatula on the end of the blade. The most commonly used curved blades are MacIntosh blades (Fig. 2.7). There are other curved blades available that are modifications of Dr. MacIntosh's original design. All laryngoscope blades come in a variety of sizes. For Miller blades, the smallest size is 00, and the largest size is 4. For MacIntosh blades, the smallest size is 0, and the largest size is 4.

Endotracheal tubes (ETT) also come in a variety of sizes and shapes. For the majority of intubations in the ED or ICU, providers will use ETTs with a gentle curve. In the OR, there are many other designs that may be used depending on the type of surgery (most often otolaryngologic cases). ETT sizes range from 2.5 to 10.0 mm. There is no hard and fast rule about what size ETT to place in adults. Most clinicians prefer to place a 7.5-mm tube so that a bronchoscope may be passed, if the need arises. The ETT size required for a specific patient may be determined from the size of the patient's largest nare or the diameter of his or her fifth digit. There are other factors that must be considered when selecting a size. For example, if the patient is presenting with an inhalation injury or has a history of tracheal stenosis, then smaller ETTs should be prepared. If there is the potential for bronchoscopy, then it may be advantageous to place a larger tube. Although each scenario is different, a good rule of thumb is to use a 7.0–7.5 mm ETT on an adult female and a 7.5–8.0 mm ETT on an adult male.

Stylets are another piece of advanced equipment that should be immediately available for any AM procedure. Malleable stylets are commonly used used to make the ETT into a particular shape. The most common shape used is described as a "J" or a hockey stick. Some VL systems recommend the use of their proprietary rigid stylets. A gum elastic bougie, also known as an Eschmann Stylet, is a rubber or plastic stylet (Fig. 2.8) that is designed to be placed directly into the trachea. The ETT is then positioned into the trachea by using a Seldinger technique over the bougie.

There are many different available SGAs. The first SGA developed for AM is the Combi-Tube. The laryngeal mask airway (LMA) is another

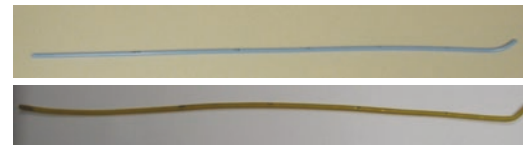

Fig. 2.8 Bougie. (**a**) Disposable plastic stylet. (**b**) Eschmann stylet – Gum elastic bougie

Fig. 2.7 Curved laryngoscope blades. (**a**) MacIntosh laryngoscope blades and handle. (**b**) Profile view of MacIntosh laryngoscope blade

common SGA. The LMA was developed by Dr. Archie Brain. It was first used in 1983 and first available commercially in 1987 [23]. There are now several different versions of LMA available. i-gel, LMA-Fastrach, King Laryngeal Tube, and air-Q are other commonly used SGAs. All SGAs are intended to deliver oxygen to the trachea although no part of the device passes through the vocal cords into the trachea. Some of the devices have supraglottic and infraglottic parts. An ETT may be placed directly into the trachea through some SGAs (known as 2nd generation SGAs).

Medications

Medications will be needed to facilitate AM in the vast majority of cases. The minimum medications that should be immediately available are an induction agent to sedate the patient, a muscle relaxant to take away patient movement and breathing, and a vasopressor to maintain hemodynamics if the patient becomes unstable. Common induction agents include etomidate, fentanyl, ketamine, midazolam, and propofol. These may be used individually or in combination with other medications. Rocuronium and succinylcholine are the most commonly used paralytic medications in the ED or ICU. In a Cochrane Review, rocuronium was found to be "slightly less effective than succinylcholine for creating excellent and acceptable intubating conditions" [24]. Vasopressors that are commonly used as bolus agents include epinephrine, neosynephrine, and vasopressin. These agents plus dopamine and levophed are potential options for a vasopressor administered as a continuous drip. See Table 2.7.

Table 2.7 Medications that are commonly used in urgent or emergent airway management

Medications commonly used in airway management		
Sedation	Paralytic	Vasopressor
Etomidate	Rocuronium	Epinephrine
Fentanyl	Succinylcholine	Ephedrine
Ketamine		Neosynephrine
Midazolam		Vasopressin
Propofol		

If possible, it is important to stabilize a patient's hemodynamics prior to AM. Unstable patients that undergo emergent AM have a high frequency of cardiac arrest in the immediate time period after AM [25]. Even in awake patients, most providers will give an anxiolytic or mild sedative to facilitate ETT placement. There are many different medicines that may be used for different scenarios.

Airway Anesthesia via Topicalization

Most emergency medicine (EM) physicians sedate the vast majority of patients undergoing AM. Having a patient remain awake (or minimally sedated) for AM is not a concept with which most EM physicians are comfortable or have experience [26]. It is unknown how many EM residencies teach how to perform airway nerve blocks or awake intubations. The ability to achieve total airway anesthesia through topicalization and perform an awake intubation is an important skill set for an EM physician to possess. There are many high-risk patients that would benefit from being awake for the AM. Keeping a high-risk patient awake helps reduce the risk of morbidity or mortality.

The nerve blocks commonly performed to achieve total anesthesia of the larynx are the lingual and pharyngeal branches of the glossopharyngeal nerve (GPN), the superior laryngeal nerve (SLN), and the recurrent laryngeal nerve (RLN). The GPN provides innervation to the posterior one third of the tongue and the superior portion of the pharynx. The SLN provides innervation to the inferior portion of the pharynx above the vocal cords. The RLN provides innervation below the vocal cords. To achieve total airway anesthesia, it is necessary to anesthestize all three nerves. Some experts advocate the use of blocks whenever possible, while others advocate that blocks are rarely necessary and that there are alternatives to nerve blocks [27]. The evidence is not clear as to whether one method is better than the other [28–30]. The time to achieve anesthesia by performing the airway blocks is approximately the same as needed to nebulize lidocaine.

To block the GLN, open the patient's mouth and identify the palatopharyngeal fold. A tongue blade or straight laryngoscope blade is inserted and used to move and hold the tongue anteriorly. A small bore, long diameter needle is inserted into the mucosa, and several milliliters (ml) of local anesthetic are injected. A 25-gauge spinal needle and 3 ml of 2% lidocaine is recommended. Take care to aspirate prior to injection so that accidental injection into a vessel does not occur.

To block the SLN, identify the greater cornu of the hyoid bone. After appropriately cleaning the skin, inject a small bore needle just inferior to the greater cornu. Aim the needle medially and anteriorly and inject 3 ml of 2% lidocaine, making sure to aspirate prior to injection.

To block the RLN, a transtracheal block is performed. This is probably the easiest of the blocks. Identify and appropriately clean the CTM. Insert a small bore needle through the membrane into the trachea. Test the location of the needle by aspirating. When air is aspirated, the needle is in the trachea. At this point, inject several milliliters of local anesthetic. Four milliliters of 4% lidocaine is commonly used. The patient will begin coughing, which will disperse the local anesthetic to achieve a greater area of anesthesia.

To anesthetize the larynx without using nerve blocks, nebulized lidocaine has been used for topicalization for many years. Higher concentrations of lidocaine provide anesthesia in a timelier manner. Place 5 ml of 2–4% lidocaine in a nebulizer and have the patient breathe through his or her mouth for approximately 10 minutes or until the nebulizer chamber is empty. This technique is easier than performing the nerve blocks, but the degree of anesthesia is variable. In an effort to improve the degree of anesthesia, the provider may place lidocaine gel or jelly on a tongue blade or OPA and slowly advance it (over several minutes) to the posterior pharynx. The lidocaine gel or jelly will achieve topical anesthesia on the structures with which it comes into contact. Benzocaine is not recommended due to the relative ease of inducing methemoglobinemia.

Nebulized lidocaine may also be used to anesthetize the nasal passages. Lidocaine gel or jelly may be used instead of or in conjunction with nebulized lidocaine. Identify the largest nare and squirt 2–3 ml into it. The solution will slowly make its way down to the posterior pharynx. An alternative to this strategy is to coat an NPA with lidocaine and insert it into the largest nare. After several minutes, the passage should be anesthetized. If planning to nasally intubate a patient, the topical vasoconstrictor, Oxymetazoline, is recommended in an effort to minimize bleeding.

Other Equipment

In addition to the equipment above, there are several pieces of equipment that should be used or be readily available during any AM. Table 2.8 lists the minimum equipment needed. The patient should be connected to a continuous pulse oximeter, a blood pressure cuff that measures every 1–3 minutes, and EKG telemetry. These items should be placed reflexively on any patient who is critically ill. At least one and preferably two working IVs are recommended so that medications and fluid boluses may be given easily. If the patient does not have an IV, intraosseous (IO) access may be an alternative. Some medicines may be given intramuscularly, but the absorption rate is variable and thus not recommended unless there is no other option.

An end-tidal carbon dioxide ($ETCO_2$) device is recommended to help confirm placement of the airway. There are different options available. It is important to give six artificial breaths before a determination about airway placement can be definitively made. $ETCO_2$ devices may not work if a patient has been in cardiac arrest for a prolonged period of time.

Table 2.8 Non-airway equipment that is commonly used during airway management

Non-airway equipment	
Bite block	Magill forceps
Blood pressure cuff	Pulse oximeter
CO_2 detector	Sterile suction catheters
EKG telemetry	Tube securing device
Intravenous or intraosseous access	

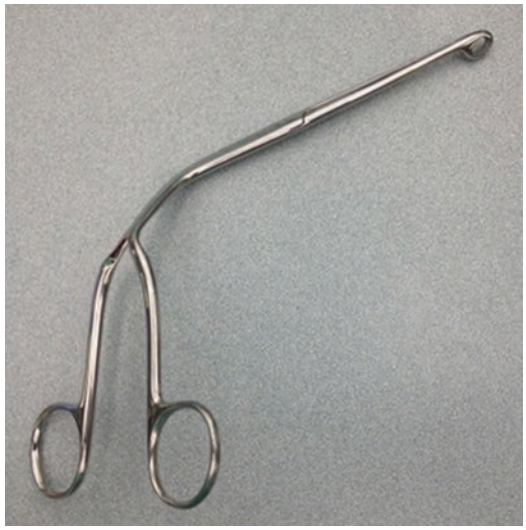

Fig. 2.9 Magill forceps

After an ETT has been placed, it needs to be secured so that the tube does not become accidentally dislodged. Tape may be used to secure the device. Tape is stronger and may prevent inadvertent extubation [31], but a commercially available tube securing device is a better option to prevent skin breakdown [32, 33]. These devices are designed in an effort to minimize tissue necrosis on the face and in the mouth.

Magill forceps (Fig. 2.9) may be needed to retrieve foreign bodies in the airway. Foreign body removal is not common, but when it occurs, it is advantageous to have this piece of equipment. Magill forceps may also be used to help facilitate tube placement into the trachea. These should only be used by providers that have been trained in using Magill forceps, as it is possible to cause trauma to the airway.

Techniques

Mask Ventilation

Mask ventilation is an essential airway skill. Mask ventilation is the initial step used to provide oxygen to a patient requiring AM. Mask ventilation is also the fall back mechanism for providing oxygen to a patient at any point in the AM plan if the patient is hypoxic. If a provider is unable to mask ventilate a patient who is hypoxic and has a poor or nonexistent respiratory drive, then the patient will not likely survive. There are several predictors of difficulty with mask ventilation. See Table 2.9 for further information.

Table 2.9 Predictors of difficult mask ventilation

Predictors of difficult mask ventilation	
Age >57 years old	Edentulous
Beard	Mallampati class III or IV
BMI >30	Snoring history

After the decision has been made to mask ventilate a patient, several steps should occur simultaneously. Adequate resources and personnel should be available. The BVM should be connected to an oxygen source that provides 100% FiO_2 at high flow ~15 L/min. The patient should be properly positioned so that the airway axes are aligned. See Fig. 2.10. The sniffing position or the head-tilt, chin-lift position will allow the best alignment of airway axes. If unable to manipulate the cervical spine due to concern for injury, a jaw thrust maneuver is recommended. In this maneuver, the mandible is elevated by pulling both angles of the mandible anteriorly while maintaining inline stabilization of the cervical spine.

The airway should be opened and a mask placed onto the patient's face such that it completely covers the nose and mouth. The mask cuff should rest between the base of the alveolar ridge and the chin inferiorly, above the bridge of the nose superiorly, and lateral to the nasolabial folds on each side. The provider then pulls the patient's face up into the mask so that the seal is improved. The mask should never be pushed down onto the patient's face, as this may lead to occlusion of the airway or poor oxygenation.

It is possible for a single provider to mask a patient. The provider's nondominant hand is placed on the mask with the thumb and index finger partially encircling the mask connector, similar to an "OK" sign or the letters E and C. The other three fingers are placed under the patient's mandible. It is important to place the fingers on the boney portion of the mandible in an effort to minimize potential injury to the soft tissues. The middle finger is placed beneath the chin. The long

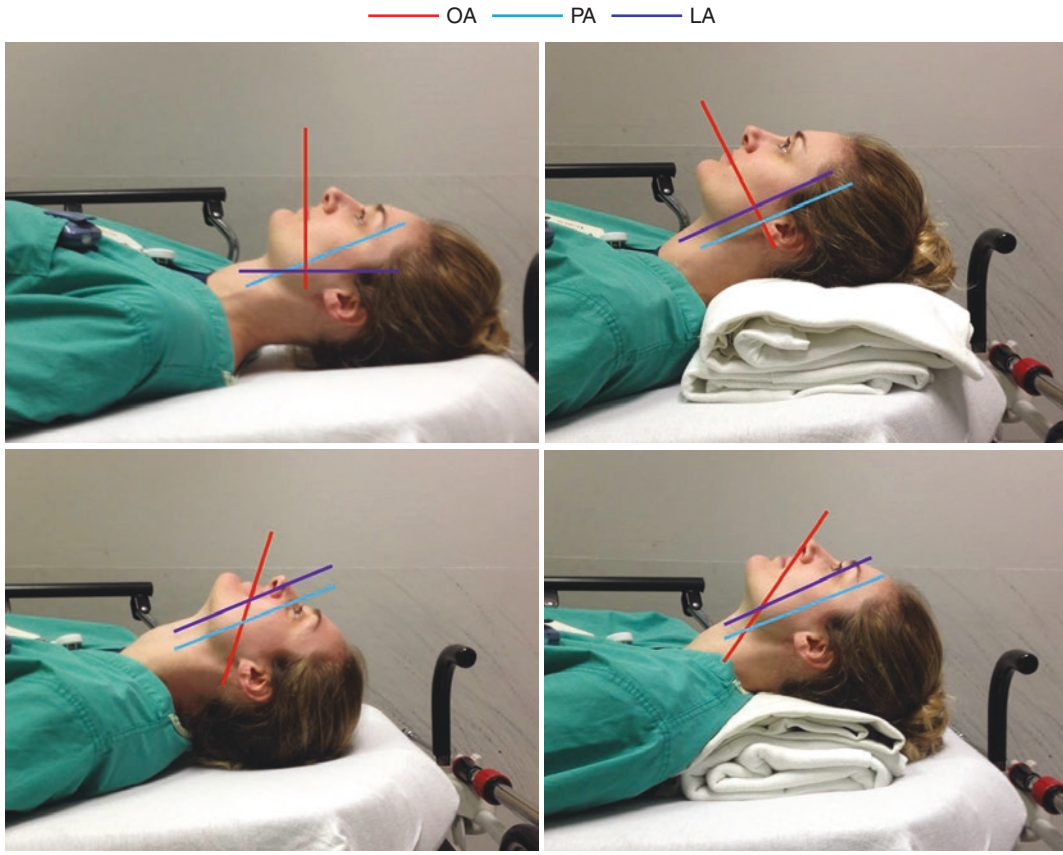

Fig. 2.10 Alignment of the oral axis (OA), pharyngeal axis (PA), and laryngeal axis (LA). (**a**) Head in neutral position. (**b**) Head elevated and neck flexed. (**c**) Head tilted and chin lifted. (**d**) Sniffing position

finger is placed midway between the chin and the angle of the mandible. The little finger is placed under the angle of the mandible. These fingers pull the mandible into the mask in an effort to make a tight seal between the face and the mask. The provider's dominant hand is then used to squeeze the bag to provide positive pressure and oxygen will be forced into the patient's oropharynx, with the goal of proceeding to the lungs.

Whenever possible, a two person, two-handed technique should be utilized. In this technique, it is possible to provide greater air movement [34]. One person's task is to squeeze the bag. The other person's job is to use both hands to achieve an adequate mask seal. There are two options that are commonly used. In the first option, the provider uses both hands to make the "OK" sign or the E and C as described previously. Both hands are used to lift the mandible into the mask. In the second option, the provider places both thumbs on the lateral aspects of the mask and the other fingers under the mandible on the boney portion. The fingers are then used to lift the mandible into the mask.

Cricoid pressure, also known as the Sellick maneuver, may help improve airflow into the trachea. It may also help prevent regurgitation of gastric contents. An assistant applies pressure to the cricoid cartilage in an effort to occlude to esophagus. Dr. Sellick originally recommended 30 Newtons (N) of pressure [35]. Subsequent study has shown that the force needed is between 30 and 40 N (which is the equivalent of 3–4 kg) [36].

When the ability to mask ventilate the patient has been obtained, it is recommended to provide 3 minutes of mask ventilation with 100% FiO_2 for nitrogen washout and fill up oxygen stores

[21]. This denitrogenation will allow the patient to stay on the high portion of the oxygen–hemoglobin dissociation curve longer. How long this effect lasts is unknown, especially in critically ill patients undergoing urgent or emergent AM.

Oropharyngeal Airway

To properly place an OPA, there are two options. Either method is acceptable. The first option is to insert the device with the distal end pointing cephalad and advance the OPA into the mouth. It is important to avoid pushing the tongue into the hypopharynx. Once passed the base of the tongue, rotate the OPA 180° so that the distal end is now pointing caudad. The second option is to use a tongue blade to depress the posterior portion of the tongue and insert the OPA with the distal end already pointing caudad.

Nasopharyngeal Airway

To properly place the NPA, identify the patient's largest nare. Lubricate the tip and shaft of the NPA with lidocaine or a water soluble jelly. Capillary bleeding from the nasal passages is a common complication of NPA insertion. Bleeding is minimized with the use of a lubricating jelly or oxymetazoline, but use caution in patients with severe thrombocytopenia. Insert the NPA into the nare and advance it horizontally along the inferior nasal turbinate. Stop advancing when the flange of the NPA contacts the nare.

Direct Laryngoscopy

Direct laryngoscopy is the hallmark of placing a definitive airway into the trachea. The first recorded successful attempt at DL was done by Alfred Kirstein in Berlin on April 23, 1895 [37]. Since then, there have been many modifications. Today the most commonly used blades are the Miller or the MacIntosh. Robert Miller introduced his design of a straight blade in 1941 [38], and Robert MacIntosh introduced his design in of a curved blade in 1943 [39]. Under emergent conditions, DL has a first pass success rate of 87.4% [40].

Each of the blade designs has a light source at the end of the blade that is powered by batteries in the handle. Most new types of blades are modifications of the design of the original Miller and MacIntosh blades. Fiberoptic versions of the blades are also available. These have the light source in the handle and illumination occurs via the fiberoptic channel on the blade.

To determine the correct size of the blade (either straight or curved), measure from the corner of the mouth to the tragus of the ear and use the blade that most approximates this length. Apply the blade to the handle. There are a variety of different handles available. If time allows, choose the handle that is most comfortable. Once the blade and handle are connected, place the laryngoscope in the left hand.

The patient should be properly positioned and sedate enough so that the gag reflex has been abolished. Taking care to avoid the patient's teeth, the blade is inserted on the right side of the patient's mouth and advanced to the posterior oropharynx. Use the blade to sweep the tongue to the left and then lift up on the blade. It is important for the clinician to avoid using his or her wrist as a fulcrum; otherwise, dental trauma may occur. With the wrist and forearm straight, the laryngoscope is lifted along the handle axis. If unable to visualize the epiglottis, the blade may need to be advanced further and lifted again. Throughout the process, take care to avoid trauma to the structures in the mouth, including the lips.

Once the epiglottis is seen, it is at this point that the two different blades are used differently to obtain a view of the vocal cords. AM clinicians should be equally skilled with either blade. The straight blade tip is used to directly elevate the epiglottis. The curved blade tip is placed in the vallecula at the base of the tongue and then elevates the epiglottis indirectly via the hyoepiglottic ligament. Note that some clinicians advocate using the curved blade to elevate the epiglottis directly. This is an improper use of the blade and may cause harm to the patient.

Instead of a method of slowly advancing the blade while searching for the epiglottis, there is another option for intubation with the straight blade. The straight blade is inserted into the mouth as above and then advanced deep past the oropharynx to the proximal esophagus. The blade is then lifted and slowly withdrawn until the glottis drops into view. The epiglottis may also drop and occlude the view of the glottis. If this occurs, advance the blade so that the tip will be able to directly elevate the glottis.

With the epiglottis lifted out of the way, the glottis should come into view. It is at this point that the Cormack–Lehane view [41] is ascertained. Grade 1 indicates that most of the glottis is seen. Grade 2 indicates that only the base of the vocal cords is seen. More of the glottis may be seen with light pressure on the larynx. A Grade 3 view indicates that only the epiglottis is visualized and no part of the glottis is seen. Grade 4 indicates that no part of the epiglottis is seen, and alternative intubation techniques or equipment may be needed. See Fig. 2.11 for the different Cormack–Lehane views.

If there is difficulty visualizing the vocal cords, it may be necessary to use laryngeal manipulation. A BURP maneuver is commonly attempted. This maneuver involves manipulating the trachea with the provider's right hand by applying a backward, upward, and rightward pressure. Once the best view of the vocal cords is obtained, an assistant takes over holding the trachea in the optimal position.

When the best glottic view has been obtained, the clinician inserts an ETT into the trachea and advances it approximately 1–2 cm beyond the vocal cords. The corresponding ETT depth at the teeth should approximate three times the internal diameter of the ETT. A more correct determination of depth can be obtained by the formula: (body height in cm/5) – 13 [42]. The ETT is held in position manually, and the laryngoscope is withdrawn, taking care not to cause any trauma. The cuff on the ETT is then inflated to a pressure of 20–25 mmHg. Commercial manometers are available to measure the pressure. It is not possible to tell how much pressure is in the cuff by squeezing the pilot balloon manually or by inflating the pilot balloon with a specific amount of air [43].

When the ETT is in place, it is important to confirm the presence of gas exchange. An end-tidal CO_2 detector is attached to the proximal end of the ETT, and breaths are delivered by a BV device. It is important to confirm bilateral breath sounds and the absence of sound over the stomach. The ETT is secured once confirmation of correct placement is obtained. A CXR should then be obtained to confirm the depth of the ETT.

Bougie Stylet

A bougie may be needed with either DL or VL. If the clinician is only able to get a CL view of Grade 3 or 4, a bougie may need to be employed. When the best CL has been obtained, a bougie is placed into the clinician's right hand. The clinician advances the angled end of the bougie into the larynx and watches as the bougie is advanced just under the epiglottis. With further advancement, the clinician should be able to "feel" the bougie bouncing on the tracheal rings through the vibrations of the stylet. If the clinician is

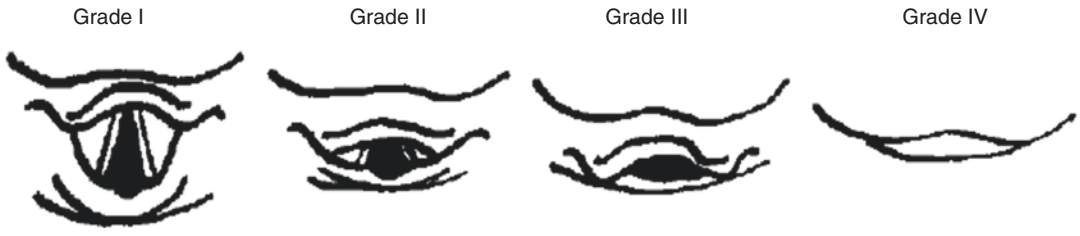

Fig. 2.11 Cormack–Lehane views of laryngoscopy. (Adapted from Samsoon and Young [19])

unable to sense this bouncing, then the bougie is most likely in the esophagus, which has no cartilaginous rings. The bougie is advanced until resistance is met.

At this point, when using DL, some clinicians elect to remove the laryngoscope, but maintaining the laryngoscope in place aids in easing the ETT placement by keeping the oral, pharyngeal, and laryngeal axes aligned. When using VL, most clinicians elect to keep the laryngoscope in place.

Regardless of whether or not the laryngoscope is used, the next step is to load a properly sized, leak-tested, and lubricated ETT onto the bougie. The ETT is advanced over the bougie using a Seldinger technique. When the ETT is unable to be advanced further, the bougie and laryngoscope (if being used) are withdrawn, while maintaining the ETT in place. Attach a BV device and confirm the presence of gas exchange by using the $ETCO_2$ and other clinical means. Assess the adequacy of bilateral breath sounds and oxygenation. If there are no left-sided breath sounds, then the ETT is likely too deep and will probably need to be withdrawn a few centimeters. When appropriate position of the ETT is confirmed, secure it in place.

Video Laryngoscopy

Dr. John Pacey introduced the Glidescope in 2001. The first academic paper was published in 2003 [44]. Since then, the use of VL for AM has skyrocketed, and its use is growing faster than other medical technologies [45]. From the ASA Practice Guidelines, over half of the clinicians surveyed strongly favor using VL on the first intubation attempt [5]. It is potential that DL will become a lost art form, similar to how automatics have largely replaced manual transmissions in cars. More than half (59%) of critical care fellowships in the United States offer specific training with VL and little training in DL [46].

VL was initially developed for difficult airways, but many clinicians are using VL for all intubations. In the OR, VL has a high frequency of success and a higher success on first pass attempts compared to DL [47]. When comparing successful intubation in emergent AM, VL was shown to be no better than DL [48].

VL does not decrease the amount of cervical spine movement compared to DL [49, 50]. In the 10th edition of the Advanced Trauma Life Support student manual, VL is an option for use by experienced providers in specific circumstances [51]. Despite a lack of evidence for improved outcome [52], many providers consider VL to be the primary AM tool for patients in a cervical collar.

Glidescope

The Glidescope (GS) is a video laryngoscope in which the hyperangulated blade design is an anatomically shaped curved blade with a 60° angle on the distal portion of the blade. There is a small camera at the tip that has an antifog feature. The blade is connected via a cable to a video screen. The GS does not use direct line of sight. The GVL is the original model, but there are several versions currently available (Fig. 2.12). There are several sizes of blades available for adult use. Size 3 is recommended to be used in a 10-kg patient to an average-sized adult. Size 4 is recommended for an average adult to morbidly obese patient. Size 5 is recommended for a large adult to morbidly obese patient, specifically "designed to accommodate anatomic anomalies sometimes associated with bariatric patients" [53].

To use the GS, carefully insert the blade into the mouth, either on the right side or more commonly in the midline. The mouth must open to at least 16 mm to accommodate the GVL. Advance the blade to the posterior oropharynx, taking care to avoid trauma to the oral structures. When the blade is in the posterior oropharynx, the operator then turns his or her attention to the video monitor. The blade is manipulated to obtain the best possible view of the glottis. Secretions, foreign bodies, or blood may obscure the view. Withdrawal of the GS and suctioning of the oropharynx may be necessary.

Once the best view of the vocal cords is obtained, the ETT is advanced into the mouth and through the vocal cords while watching the video monitor. Due to 60° angle of the distal tip of the hyperangulated blade, the stylet may need to be manipulated more than when using DL. For this

Fig. 2.12 Glidescope video laryngoscope. (**a**) AVL single-use model. (**b**) Disposable blade. (**c**) AVL with disposable blade

reason, Verathon recommends the use of their proprietary GlideRite rigid stylet (Fig. 2.13). There is some evidence that using the rigid stylet is more efficacious than using a malleable stylet in emergent AM settings [54]. Removing a rigid stylet may be difficult, so it may be necessary to have an assistant perform this part of the procedure.

After the ETT has been placed, withdraw the GS and confirm the presence of gas exchange by using the $ETCO_2$ and other clinical means. Secure the ETT once placement is confirmed.

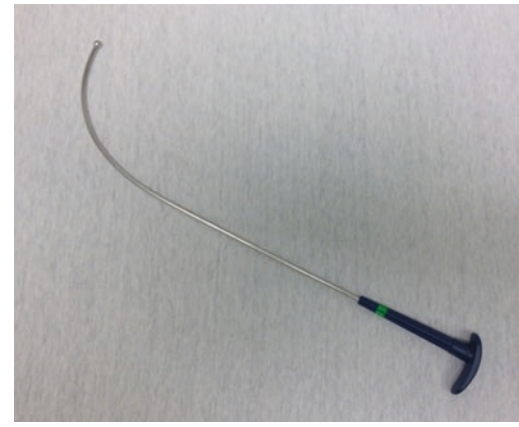

Fig. 2.13 Glidescope proprietary stylet

McGrath

The McGrath MAC enhanced direct laryngoscope (McGrath) merges the ability to perform DL or VL

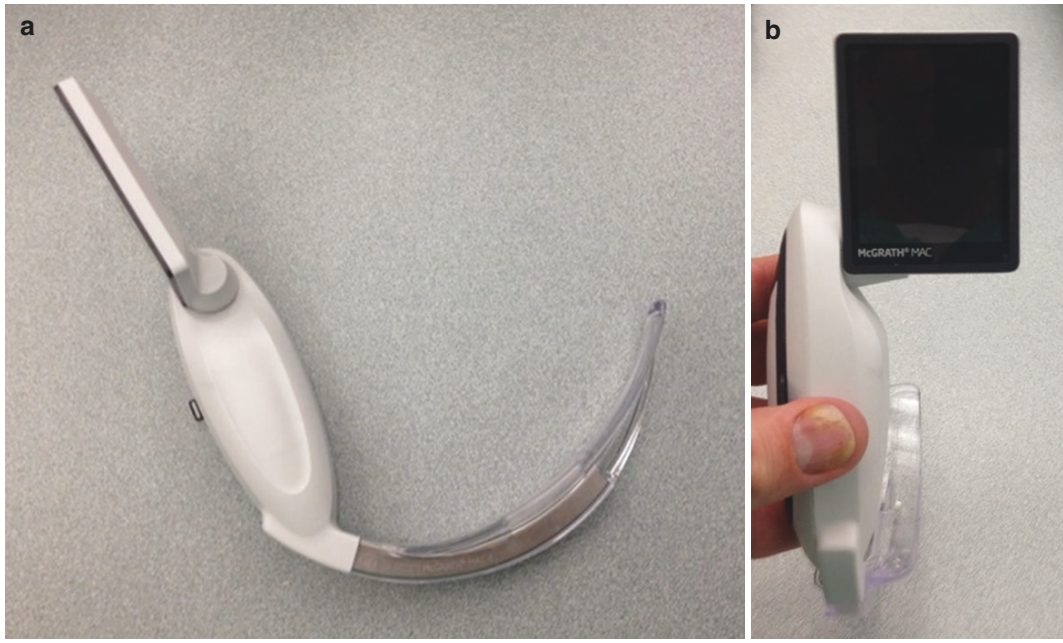

Fig. 2.14 (**a**, **b**) McGrath MAC enhanced direct laryngoscope

in one device. The device is handheld with a 2.5-inch video monitor on top of the handle (Fig. 2.14). A disposable curved blade (similar to a MacIntosh blade but more angulated) is connected such that the camera is inside the blade near the distal tip. There is only one size blade. An antifog material may need to be applied to the camera to enhance the graphics on the video monitor.

The technique for using the McGrath is the same as a curved blade for DL or as a GS for VL. After the ETT has been placed, withdraw the McGrath and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Secure the ETT once placement is confirmed.

C-MAC

The C-MAC is a complete video laryngoscopy system, which has grown from the original device to include disposable, handheld, and fiberoptic devices. The original C-MAC is described further here. The C-MAC has the potential to be used for DL or VL. A curved blade (again, similar to a MacIntosh blade but more angulated) is attached to a handle that is connected by a cable to a video monitor. The antifog camera is inserted into the C-MAC handle. The C-MAC is available in multiple traditional blade sizes for adults. Currently, the C-MAC straight blades are only available in pediatric sizes.

The C-MAC is inserted and used just like a regular curved. After the ETT has been placed, withdraw the C-MAC and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Secure the ETT once placement is confirmed.

There is a potential training benefit of using the C-MAC. Due to the size of the video monitor, a trainee can use the C-MAC for DL and a supervisor is able to see what the trainee sees and offer guidance to improve technique. In a retrospective study of ED intubations, the C-MAC was shown to have better first-pass success compared to DL [55].

Fiberoptic Intubation

A flexible fiberoptic bronchoscope (FOB) is another method of VL that has a role in emergent AM. One of the biggest benefits of FOB for intubation is its use in an awake patient who poses an increased risk of a difficult airway if put to sleep

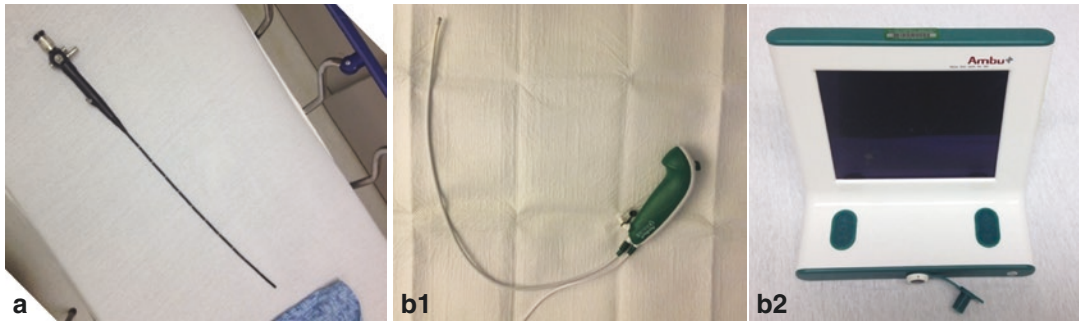

Fig. 2.15 (**a**) Fiberoptic scope with eyepiece. (**b**) 1–2. Fiberoptic scope with video monitor

for AM. FOB can also be used in patients who have unstable neck trauma. In patients with significant angioedema, nasal FOB is a good alternative to a surgical airway.

There are different FOB sizes and types (Fig. 2.15). Some have suction capabilities, while others do not. Some FOBs use an eyepiece, while others are attached to or only have a video monitor. It is important to use a FOB that will allow the use of an appropriately sized ETT. Depending on the manufacturer, a water-soluble lubricant may be placed on the FOB to help with passing the ETT off the FOB into the trachea.

The use of FOB in the ED is often restricted due to either a presumed emergent airway or familiarity with the equipment. Most AM situations in the ED or ICU are urgent, not emergent. Learning how to use a FOB is not complicated, but the process takes finesse and should not be rushed. FOB should be practiced on patients who are not predicted to have difficult airways. The skill requires experience and once mastered is an excellent resource for difficult AM.

To maximize the chances of success with FOB, it is important to prepare the patient properly. The patient may either be in a supine or an upright position. If supine, the FOB operator stands either at the head or to the side of the bed. If upright, the FOB operator stands to the side of the patient. An antisialogogue is recommended in an effort to minimize secretions. An ovassapian airway (Fig. 2.16) is a type of OPA that displaces the tongue and provides a channel through which the FOB and ETT may be passed. A Berman airway or a Williams airway are two other OPAs through which a fiberoptic scope can be passed. If none of these specialized airways are available, have an assistant grasp the tongue with gauze and pull it forward. A jaw thrust maneuver will also facilitate intubation.

To operate the scope, place one hand approximately 8–10 cm from the tip at the distal end of the FOB and the other hand on the control end. The control end will have a lever that flexes and retroflexes the distal end of the scope. The FOB will only move up and down. To move the FOB sideways, the clinician must rotate his or her wrist and shoulder as one unit. Perhaps the most important step to take to maximize success with FOB is to remember to always keep the scope taught. If the FOB is not mildly taught, whenever the operator twists his or her hand to twist the distal end, the distal end will not twist. Laxity in the FOB leads to the scope being twisted on itself like a snake or wet spaghetti.

For oral FOB, insert the scope into the mouth. Once the tip is beyond the back of the tongue, use the control end to bend the tip to follow the natural curvature of the airway. The tip will either be flexed if standing at the head of the bed or retroflexed if standing to the side of the patient. Continue advancing the scope in the midline until the operator's distal hand contacts the patient's mouth. At this point, the operator should focus attention on the eyepiece or video screen. The vocal cords should be in view. Avoid the temptation to "look around" to try to find the vocal cords unless the operator is confident that he or she is in the larynx. Too often, if the cords are not in view, the scope is in the esophagus. Withdraw the scope and try again. It may be necessary to place the distal hand closer to the tip of the FOB.

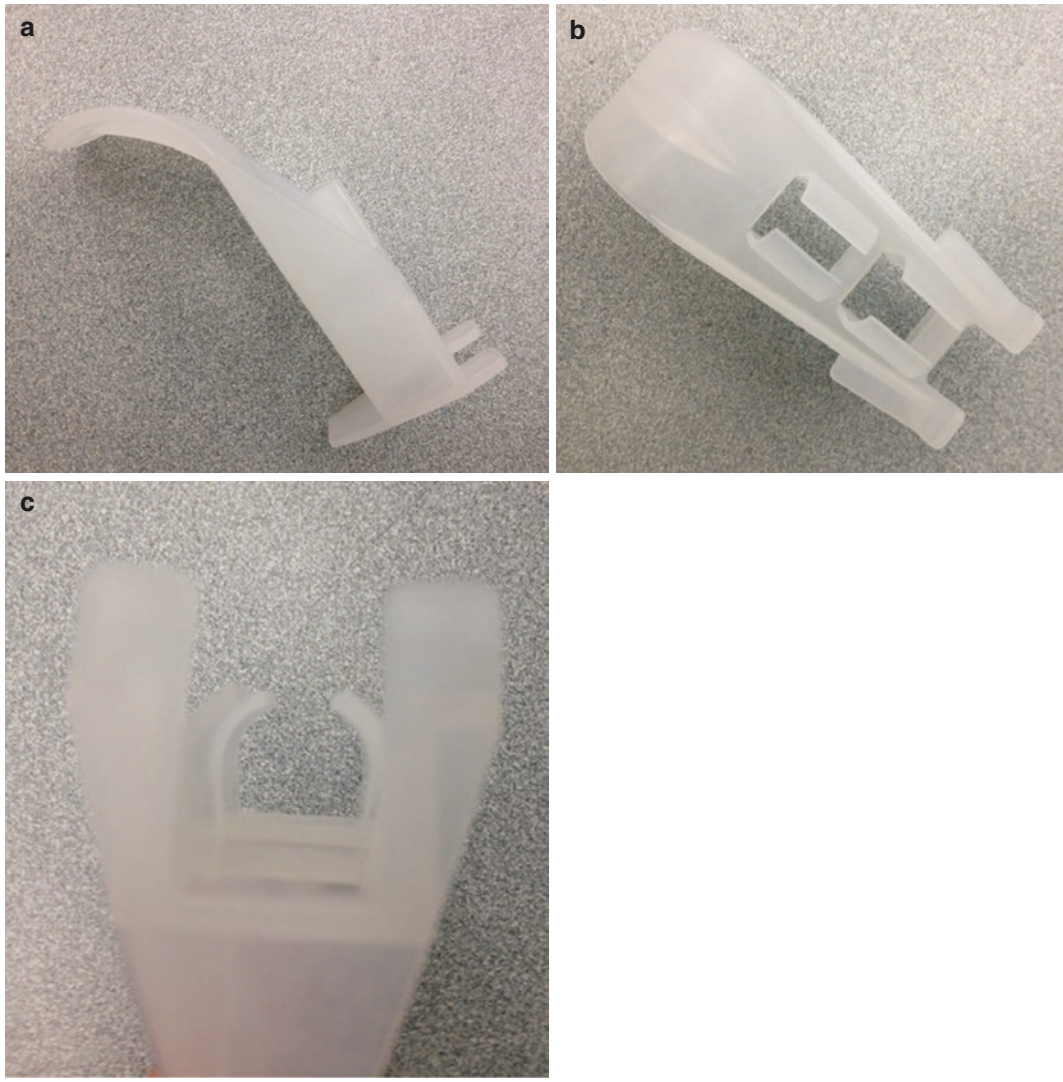

Fig. 2.16 (**a**–**c**) Ovassapian airway

For nasal FOB, insert the scope into the largest nare. Advance the FOB into the nasal passages. Once the operator's hand comes into contact with the patient's nose, look through the eyepiece or video screen. The tip should be in the posterior pharynx a few centimeters above the vocal cords. It may be necessary to flex (or retroflex depending on the operator's position relative to the patient) mildly to see the vocal cords.

With either technique, once the vocal cords are identified, advance the FOB by pulling the scope into the airway with the hand on the distal end, instead of pushing the FOB with the hand on the control end. Advancement of the scope should be done with deliberate action instead of slowly. If done slowly, there is a significant chance that the scope will contact the vocal cords and induce coughing, especially in a spontaneously breathing patient who is not fully anesthetized.

Once the FOB tip has been pulled into the trachea, advance the scope to the mid trachea or until the carina is visualized. At this point, hold the FOB in place and slide the ETT off the scope and slowly into position. Occasionally, the ETT will get caught up on redundant tissue in the larynx (especially if the patient is heavily sedated) or the vocal cords. If this occurs,

gently rotate the ETT 90° and try to advance the ETT again. If this does not correct the situation, the ETT may be too big and a smaller size needs to be used.

When the ETT is in the trachea, use the FOB to confirm placement. Withdraw the FOB while an assistant holds the ETT in place. When the FOB has been removed, confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means and then secure the ETT.

Supraglottic Airway Devices

In the ED and ICU, supraglottic airway devices are mainly used as a backup when the clinician is unable to place the ETT. SGAs are beneficial in situations in which the provider is not able to mask ventilate or oxygenate a patient [56]. Many prehospital emergency medical services place an SGA instead of an ETT. An SGA is not considered a definitive airway, so it is necessary to exchange an SGA for a tube in the trachea.

When performing an airway examination, it is important to identify conditions that may be associated with difficulty placing an SGA. The most prominent finding is a restricted mouth opening. If the SGA cannot fit into the oropharynx, then it cannot be placed appropriately. If there is an obstruction of the airway, then the obstruction must be removed before an SGA will function properly. Along those lines, SGA placement may be difficult in morbidly obese patients due to the amount of redundant tissue in the hypopharynx.

There are many different types of SGAs on the market. Some are disposable. Second generation SGAs allow an ETT to be passed through the SGA into the trachea. Some have two potential ventilation tubes. When inflated, SGAs form a seal around the hypopharynx. All SGAs function by forcing air into the trachea without actually having a tube in the trachea. Not all SGAs occlude the esophagus, so the clinician must always be aware of the potential for reflux and aspiration of gastric contents.

Laryngeal Mask Airway

The first version of the LMA marketed commercially is the LMA Classic. There are other versions now available. See Fig. 2.17, for example. These have slight modifications to the design. All LMAs are inserted in a similar fashion. An appropriate size LMA should be selected depending on the patient's weight. Adult sizes are #3 for patients 30–50 kg, #4 for patients 50–70 kg, and #5 for patients 70–100 kg. An LMA Classic is available for patients weighing >100 kg. If unsure about the patient's weight, it is advised to select the larger size.

Similar to an ETT, it is necessary to inflate the mask to ensure that there are no leaks. Next, remove all air from the mask and make sure that the tip is not folded over. Placing the LMA on a flat surface and applying a mild downward pressure as air is removed from the mask may help prevent the tip from folding over. This action will also help minimize wrinkles in the cuff.

Apply a water-soluble lubricant to both sides of the mask. Open the patient's airway and lift the

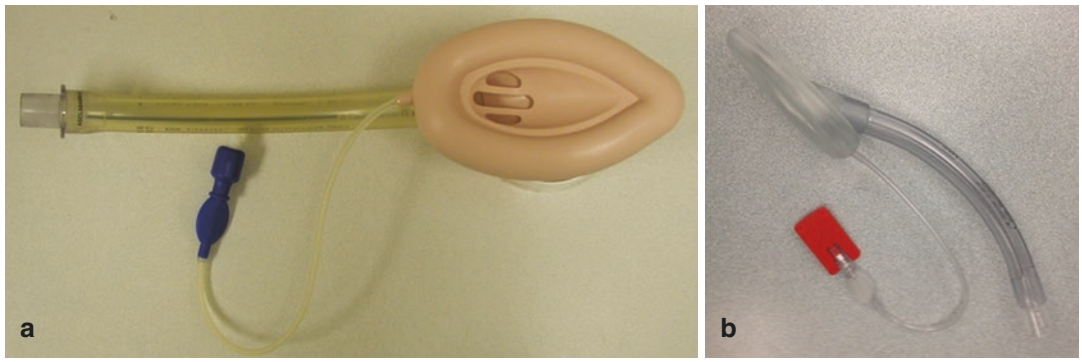

Fig. 2.17 Laryngeal mask airway (LMA): (**a**) Classic. (**b**) Unique

patient's jaw. With the tube side of the mask superiorly position, insert the LMA into the midline of the mouth and advance the mask along the hard palate and to the hypopharynx as far as possible. Cricoid pressure may make placement more difficult. When it is not possible to advance any more, inflate the LMA with air: 20 ml for a #3, 30 ml for a #4, and 40 ml for a #5. As the mask inflates, the LMA will seat itself into position over the larynx.

To minimize cuff leak, make sure that the tube portion of the LMA is in the midline of the mouth and that the head and neck are in a neutral position. If a cuff leak persists, it may be necessary to deflate the cuff, remove the LMA completely, and reinsert the LMA again. If the second insertion does not correct the problem, move to a different size, with the first choice being one size larger if possible.

Laryngospasm or the epiglottis occluding the trachea may cause obstruction of the LMA. In the case of suspected laryngospasm, the provider should attempt to bag the patient through the problem. Use paralytics with extreme caution, especially if the LMA is being placed as a backup airway device. In the case of an epiglottis obstructing the trachea, it may be necessary to remove the LMA and attempt reinsertion.

Once the LMA is properly positioned, attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Secure the LMA in place with tape once placement is confirmed.

It is possible to place an ETT through newer versions of the LMA. The different versions of LMAs have different maximum regular ETTs that can be used. It is recommended to use a FOB to accomplish ETT placement through a non-LMA-Fastrach.

Laryngeal Mask Airway-Fastrach

The LMA-Fastrach, also known as an intubating LMA (I-LMA) (Fig. 2.18), was also developed by Dr. Brain. The I-LMA has a different shape from the LMA Classic. The basis for the design came from MRI images of 50 normal subjects whose heads were in the neutral position [57]. The version with a metal handle may be reused 40 times. The version with the plastic handle is disposable. The Fastrach is available in sizes 3, 4, and 5, which correspond to the same sizes as a regular LMA.

The I-LMA is placed in a similar fashion to other LMAs. Because of the handle, it is often easier to place an I-LMA. Placement confirmation is also similar to other LMA products. Once the I-LMA has been appropriately positioned and oxygenation has been maximized, it is recommended to place an ETT to obtain a definitive airway. There are a few different options for placing an ETT through the I-LMA.

The first option of placing an ETT is done blindly with the wire reinforced ETT and stabilizing rod designed specifically for I-LMAs. The wire reinforced ETT has a distal cuff that conforms to the tube when deflated. This feature allows for the ETT to more easily pass

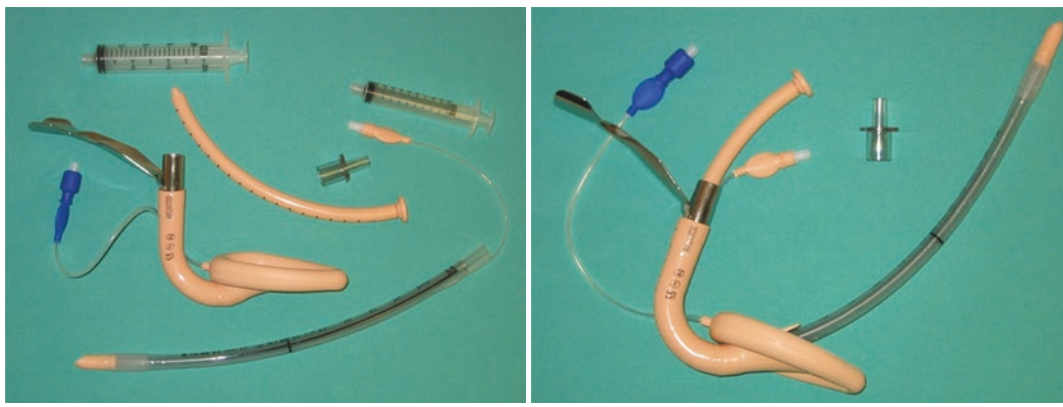

Fig. 2.18 LMA Fastrach. (**a**) LMA Fastrach and syringe, along with wire rimmed ETT, 15mm adapter, syringe, and stabilizing rod. (**b**) Wire rimmed ETT through LMA Fastrach with stabilizing rod in place simulating what the process of ETT placment looks like

through the I-LMA, especially compared to a regular ETT that has a balloon cuff that may get hung up on something as it passes through the I-LMA.

It is important to have the maximum airflow and least amount of resistance possible to ensure easy passage of the tube. There are many different named maneuvers that aim to achieve optimal airflow [58]. The Chandy maneuver, which is probably the most known, has two steps. First, maneuver the I-LMA ever so slightly in a coronal or sagittal plane. When the operator feels that the maximum airflow position has been achieved, the I-LMA is held in that plane and lifted up. This second step lifts the mask off of the posterior pharynx and allows for the ETT to be passed more easily. Use caution with disposable I-LMAs, as the plastic handle has the potential to break since it is not able to lift with as much force as a metal handle.

At this point, the clinician inserts the ETT. To place the wire reinforced ETT, apply a water-soluble lubricant to the ETT and test the cuff for leaks. There may be a bit of resistance as the tube must push through the epiglottic elevating bar, a piece of silicon in the midline of the mask aperture. It may be difficult to tell the depth of the ETT because the centimeter depth markings on the ETT are covered by the metal tube of the I-LMA. This problem does not occur if using the disposable Fastrach. When the tube has been inserted to an adequate depth, inflate the cuff and attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means.

After confirmation that the ETT is in the trachea and the patient is maximally oxygenated, it is necessary to remove the I-LMA. Optimally, the patient would be hemodynamically stable and maximally oxygenated before this step. Removing the I-LMA has inherent risk due to the possibility of dislodging the ETT and losing the patient's airway. It would be advantageous to have an assistant that is familiar with this process at bedside, as there is some level of dexterity required.

To remove the I-LMA, deflate the I-LMA cuff completely. Ensure that the cuff on the ETT is inflated. Remove the 15-mm adapter from the proximal end of the ETT. Place the stabilizing rod into the proximal end of the ETT. The pilot balloon for the ETT should be in the same hand (often the provider's nondominant hand) as that which is holding the stabilizing rod. The provider may choose to continue holding the rod/ETT or have an assistant take over. Slowly withdraw the I-LMA from the mouth over the ETT and stabilizing rod (often done with the provider's dominant hand). As the I-LMA is being withdrawn from the mouth, look for the ETT coming through the epiglottic elevating bar.

When the ETT is visualized, move the hand holding the stabilizing rod/ETT to the mouth and secure the ETT at that position in the mouth. Continue withdrawing the I-LMA until the ETT and stabilizing rod are completely clear of the mask. At this point, remove the stabilizing rod and place the 15-mm adapter back into the proximal end of the ETT. Attach a BV device with an $ETCO_2$ detector and use any other modality to confirm placement into the trachea. Once position is confirmed, the wire rimmed ETT can be either secured and used or exchanged for a regular ETT. If the wire rimmed ETT is used, there is a risk that the patient will bite down and clamp the ETT. If this occurs, the ETT will not go back to its normal shape because the wire will be bent and hold its shape and there is the risk of poor gas exchange.

Instead of blindly inserting the ETT, another option is to place a regular ETT by using a FOB. Lubricate the inside and outside of an appropriately sized ETT (up to 8.0 mm) and then place it onto a FOB. The ETT is placed the same as any other FOB intubation. Once tube position is confirmed, and the FOB has been withdrawn, it is necessary to remove the I-LMA.

When removing the I-LMA over a regular ETT, the stabilizing rod is not specifically designed for this type of ETT, so there is the potential for malposition of the rod. The cuff of a regular ETT will also be larger than the cuff on a wire reinforced ETT specifically designed for I-LMAs, so there is the potential that the ETT may be withdrawn from the airway.

In an effort to minimize the chances of dislodging the ETT from the airway, the FOB itself may be used to guide removal of the I-LMA via a Seldinger technique. Once the ETT position has been confirmed via the FOB and the ETT cuff is inflated, fully deflate the I-LMA cuff. Have an assistant hold the ETT in place. Remove the 15-mm adapter from the proximal end of the ETT and slide it to the proximal end of the FOB. Hold the FOB in place. Slowly withdraw the I-LMA from the mouth. As it is removed, the I-LMA will cover the proximal end of the ETT and slide toward the proximal end of the FOB. When the distal end of the ETT is visualized in the mouth as the mask is removed, the assistant secures the ETT at that position.

Once the I-LMA is completely out of the mouth, use the FOB to confirm that the ETT is still in the trachea. When ETT position has been confirmed, remove the FOB completely from the ETT. Remove the I-LMA and 15-mm adapter from the FOB and place the 15-mm adapter onto the proximal end of the ETT. Attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Secure the ETT once placement is confirmed.

i-gel

The i-gel is an SGA that does not use an inflatable cuff. Instead, the i-gel uses a noninflated cuff made of a gel-like material that rests on the laryngeal structures. Like any other component of AM, it is important to use the proper size. The i-gel comes in pediatric and adult sizes. Adult sizes are #3 for patients 30–60 kg, #4 for patients 50–90 kg, and #5 for patients >90 kg. If unsure about the patient's weight, it is advised to select the larger size.

The patient should be in a sniffing position or with the head tilted and chin lifted. Apply lubricant to all sides of the i-gel. The company recommends gentle pressure on the chin as the i-gel is inserted in the midline along the hard palate [59]. Continue advancing until continuous resistance is encountered. The patient's teeth should be at the black horizontal line, which is the bite block portion on the i-gel. At this point, the i-gel should be in its proper position and care must be taken to avoid dislodging it. Once the i-gel is properly positioned, attach a BV device and confirm the presence of gas exchange by using the $ETCO_2$ and other clinical means. Secure the i-gel in place with tape once placement is confirmed.

It is possible to place an ETT through an i-gel. A #3 i-gel will accommodate up to a 6.0-mm ETT, a #4 i-gel up to a 7.0-mm ETT, and a #5 i-gel up to an 8.0-mm ETT. To place an ETT through an i-gel, use a FOB and the same technique for placement of an ETT through an I-LMA.

Air-Q

The air-Q is another commercially available SGA that is available for AM. air-Q comes in a disposable or reusable (up to 60 times) version. There is a version with a self-pressurizing mask and a version that has an inflatable mask. It is possible to place an ETT through any air-Q. Adult and pediatric sizes are available. Adult sizes are #2.5 for patients 20–50 kg, #3.5 for patients 50–70 kg, and #4.5 for patients 70–100 kg. If unsure about the patient's weight, it is advised to select the larger size. There are minimum mouth apertures for the different sizes: 20 mm for #2.5, 23 mm for #3.5, and 25 mm for #4.5.

To place an air-Q, place the patient in a sniffing position or a head-tilt/chin-lift position. Lubricate the anterior and posterior portions of the mask. Perform a jaw lift or use a tongue blade to maximize ease of insertion. Insert the air-Q in the midline into the pharynx and advance it along the palate to the base of the tongue in an inward and downward motion. Continue advancing until resistance prohibits further advancement. At this point, the air-Q should be in position. Inflate the mask: 2–3 ml for a #2.5, 3–4 ml for a #3.5, and 4–5 ml for a #4.5 [60]. After mask inflation, attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Secure the air-Q in place with tape once placement is confirmed.

To place an ETT through an air-Q, either a FOB or a blind insertion with a bougie may be used. If using a FOB, the technique is similar to

the placement of an ETT through other SGAs previously mentioned. For a blind technique, insert a bougie into the air-Q and advance it slowly. The provider places a hand on the patient's cricoid membrane and "feels" the bougie as it is advanced into the trachea, bouncing on the tracheal rings. With the other hand, the provider should attempt to feel the tracheal rings through the vibrations in the bougie as it is advanced. When the bougie meets resistance, deflate the air-Q and withdraw it from the pharynx and over the bougie, making sure to hold the bougie in place. Place an ETT on the bougie and advance it via Seldinger technique into the trachea. Once the ETT is inserted to an appropriate depth, remove the bougie and secure the ETT manually. Once the bougie has been removed, attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. When appropriate position of the ETT is confirmed, secure it in place.

Combitube

The Combitube is a blind insertion SGA which consists of two tubes that are connected at the distal end and separate at the proximal end. There are two sizes available based on patient height: 37 Fr for patients 48–66″ and 41 Fr for patients >60″. A 15-mm adapter is attached to the proximal end of each tube. One tube is blue and is longer than the other tube which is clear. The blue tube is labeled "1," and the clear tube is labeled "2." Each tube has a balloon with a number that corresponds to the tube number. The balloon on tube 1 holds 85 ml for the 37-Fr size or 100 ml for the 41-Fr size. The balloon on tube 2 is smaller and holds 15 ml of air.

Before insertion, test both balloons to assess for a leak. Lubricate from the distal end of the tube to the base of the larger balloon. Place the patient so that the head is in a neutral position. While lifting the patient's jaw and tongue, grasp the Combitube like a pencil just distal to the two black circumferential lines and insert the Combitube in the midline into the pharynx. Continue advancing until the patient's upper incisors are between the two black circumferential lines. Advancement of the Combitube may take a moderate amount of force, since it usually goes into the esophagus and must traverse the upper esophageal sphincter.

Once the Combitube is in place, inflate the #1 cuff with either 85 or 100 ml of air (depending on the size of the Combitube). If the distal tube is in the esophagus, the large cuff (#1) should seat itself in the oral cavity and prevent air leakage during ventilation. Inflate the #2 cuff with 15 ml of air which will prevent air from leaking out of the trachea (if the tube is there) or from being pushed into the stomach (if the tube is in the esophagus).

After the two cuffs have been properly inflated, connect a BV device to the blue #1 tube and begin ventilation. If the distal tube is in the esophagus (the vast majority of cases), during ventilation, air passes down the #1 tube and out of the tube through several side ports and into the trachea. The distal tip of tube #1 is occluded. Use an $ETCO_2$ detector and any other modality to confirm gas exchange. If unable to confirm oxygenation through the blue #1 tube, attach the BV device to the clear #2 tube and assess for oxygenation through ventilation of that tube.

If adequate oxygenation still cannot be confirmed through either tube, the Combitube is likely too distal in the esophagus. Deflate the distal cuff fully and the proximal large cuff approximately 50% and withdraw the Combitube 1–2 cm. Inflate both cuffs fully. Attach the BV device to the blue #1 tube and begin ventilation and reattempt to confirm gas exchange.

If oxygenation is confirmed through tube #1, the Combitube is in the esophagus. A suction tube can be placed through tube #2 into the stomach to remove gastric contents. If oxygenation is confirmed through tube #2, the Combitube is in the trachea and is functioning like a regular ETT. Regardless of placement location, once the patient has been stabilized, it is recommended to exchange the Combitube for a regular ETT. If the Combitube is already in the trachea, it can be exchanged with a tube exchanger. If the Combitube is in the esophagus, there is no way to exchange it for a definitive airway. The Combitube must be completely removed in order to perform laryngoscopy to place a definitive airway.

King Laryngeal Tube

The King Laryngeal Tube (King) is a blindly inserted SGA with one tube and two balloons. Kings are available from newborn to adult, and each size corresponds to a different colored 15-mm adapter. An appropriately sized King should be selected depending on the patient's height. Adult sizes are #3 for patients 4–5 feet (122–155 cm), #4 for patients 5–6 feet (155–180 cm), and #5 for patients >6 feet (180 cm). If unsure about the patient's height, it is advised to select the larger size. There is a reusable version and a version that allows gastric access.

Prior to placement, inflate the balloons to assess for any leaks. Although there are two balloons, there is only one syringe port. After testing for leaks, lubricate the distal tip. With the patient supine and the head in a neutral position, lift the tongue and jaw and insert the King into the lateral aspect of the mouth. While advancing the King along the hard palate and toward the base of the tongue, move the distal portion of the King toward the midline of the oropharynx. Continue advancing the King until the distal portion of the 15-mm adapter is aligned with the patient's teeth (or gums if edentulous). Inflate the cuff depending on the size of the King: 50 ml for a #3, 70 ml for a #4, and 80 ml for a #5.

Once the balloons are inflated, attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Assess the adequacy of bilateral breath sounds and oxygenation. The King will likely need to be withdrawn 1–3 cm to achieve a position in which ventilation is easy and without much resistance. It may also be necessary to adjust the volume in the cuff to ensure a proper seal in the hypopharynx. Once the King is in its proper position, secure it in place with tape.

After the patient has been stabilized, it is recommended to place an ETT. It is possible to exchange a King directly to an ETT. This may be done with a bougie or a pediatric exchange catheter. Lubricate the catheter and advance it into the King. The catheter should go through the ventilation channel and into the trachea. Once this happens, deflate the King and withdraw it over the catheter. At this point, the process is just like any other ETT exchange. See section "Endotracheal Tube Exchange."

Surgical Airway

A surgical airway is the final option in any AM algorithm. The need for a surgical airway is a rarity, but a surgical airway is associated with high morbidity and mortality. A surgical airway is essentially always an emergency and a high anxiety situation. A cricothyrotomy (crich) is the procedure of choice for an emergent surgical airway. A crich can be performed in less than 30 seconds [61]. A tracheotomy takes too long to perform in an emergency, and there is a higher risk of bleeding, injuries, and long-term complications compared to a crich [62]. Commercial kits are available for either a scalpel incision or a needle crich. Some kits have the necessary equipment to perform either procedure.

The most difficult part of placing a surgical airway is to make the decision to do it. It is possible to limit the amount of anxiety by always being prepared for a surgical airway. It is important to integrate examining the CTM as part of the airway examination. In doing so, the clinician increases his or her familiarity with the CTM location and will know exactly where on the neck to perform the procedure.

There are some findings that may be associated with difficulty performing a crich. If these findings are present, it may be useful to have assistants who are trained in AM available. If the patient has a history of a mass, tumor, or prior radiation or surgery to the neck, the normal anatomy may be distorted and it may be difficult to perform a crich. Similarly, if the patient is obese or there is a significant amount of edema, hematoma, or subcutaneous air in the neck or submental area, a crich may be difficult. It is important to recognize these findings and incorporate them into the AM plan individualized for the patient.

Needle Cricothyrotomy

A needle cricothyrotomy is a temporizing procedure utilized to oxygenate a patient until an alter-

native method is available. A needle crich can be performed on any aged patient. Multiple companies manufacture needle crich kits that have all of the components necessary to perform the procedure. Some of the more common kits are the QuickTrach kit, the Portex kit, and the Pertrach kit.

To perform a needle crich, locate the CTM with the nondominant hand. Clean the area appropriately. Attach a 14- or 16-gauge intravenous catheter to a syringe. An 18-gauge intravenous cannula is recommended if the patient is less than 12 years old. Insert the needle through the CTM. Once the "pop" of the membrane is felt, aspirate air. If air is aspirated, advance the catheter through the membrane and aiming caudad toward the carina. Remove the needle and syringe, while keeping the catheter in place. If air is not aspirated, it is possible that the needle is either too deep, too shallow or off of the midline. Reposition the needle as necessary or withdraw completely and reinsert.

Firmly hold the catheter flange and attach a jet ventilation system. If a jet system is not available, attach a 3-ml syringe to the catheter and remove the plunger. Insert a 15-mm adapter from a 7.0 ETT into the cavity of the syringe. When either a jet or a syringe setup is in place, give the patient short positive-pressure breaths with 100% FiO_2 oxygen. It is important to watch for subcutaneous air or any other sign of barotrauma. It is highly likely that the patient will become hypercarbic due to the limited ability to exhale.

An alternative AM plan should be implemented quickly, as this method of oxygenation is only a temporary solution at best. It is relatively easy for the catheter to become dislodged or obstructed. Once the patient has been appropriately oxygenated and adequate resources are available, it is recommended that a definitive airway be placed.

Surgical Cricothyrotomy

A surgical cricothyrotomy differs from a needle crich in that an incision is made into the neck. The clinician does not have to be a surgeon to perform a surgical crich. Clinicians that perform AM should be proficient in this procedure. Surgical crichs should not be performed on patients less than 12 years old.

To perform a surgical crich, clean the area appropriately. Make a 1- to 2-cm scalpel incision in the skin. Conventionally, a vertical incision is used, but there is no evidence to recommend using a horizontal or vertical cut for the skin incision. Palpate the CTM, which may be obscured by blood or tissue. It may be necessary to use manual skin retractor(s). Once the CTM is identified, make a 1-cm horizontal scalpel incision in the CTM. The CTM incision may then be dilated by the back of the scalpel blade or a Trousseau dilator (Fig. 2.19). A tracheal hook (Fig. 2.20) may be needed to lift the distal portion of the airway.

A 4.0–6.0 Shiley is then placed into the trachea. A trach tube is easier to insert in a surgical

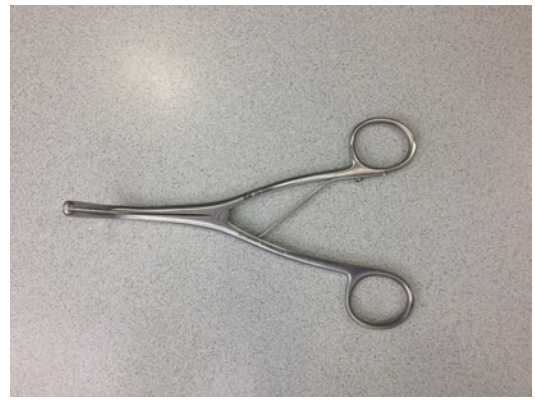

Fig. 2.19 Trousseau dilator

Fig. 2.20 Tracheal hook

airway than an ETT for several reasons. Trach tubes have smaller outer diameters and are more rigid than ETTs. An obturator may be used to facilitate trach tube insertion. Trach tubes are shorter and easier to suction. If a trach tube is not available, a 4.0–6.0 ETT may be used instead. Once a tube is in the trachea, manually hold it in place and inflate the balloon. Attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Secure the trach tube once placement is confirmed.

Regardless of what type of crich is performed, when the patient's oxygenation has been stabilized, the patient will need to have the crich changed to a tracheostomy. The tracheostomy should be performed within 72 hours, yet most clinicians elect to have this done as soon as the patient is stable enough to undergo the procedure.

Melker makes a crich kit (Fig. 2.21), which includes all of the equipment necessary for either a needle or surgical crich. For those clinicians who are more comfortable performing a surgical crich, the kit comes with a scalpel, a Trousseau dilator, and a tracheal hook. For clinicians who are more comfortable with a needle crich, there is the option of using a Seldinger technique to place a 5-mm trach tube instead of an 18-gauge catheter in the airway.

For the needle crich, a skin incision can be made but is not a necessity. If a skin incision is made, then the 18-gauge needle connected to the 12-ml syringe is placed directly into the CTM. If there is no skin incision, the needle is placed percutaneously into the CTM. Once in the airway, the syringe is removed from the needle. The Amplatz 0.38″ wire is placed through the 18-gauge needle advanced into the trachea. Using a Seldinger technique, the needle is removed and the blunt dilator is introduced into the trachea. The blunt dilator is then removed and inserted into the 5-mm trach tube. The dilator/trach tube is then inserted via Seldinger technique into the trachea. The wire and blunt dilator are then removed. At this point, attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Secure the trach tube once placement is confirmed.

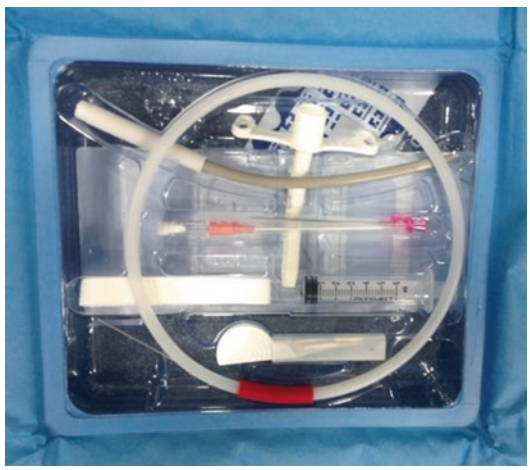

Fig. 2.21 Melker cricothyrotomy kit

Endotracheal Tube Exchange

Endotracheal tube exchange is a high-risk procedure and should be performed with all necessary resources because there is the potential to lose the patient's airway. There are several reasons for which an ETT may need to be exchanged. If the cuff or pilot balloon has a leak, the patient may not receive adequate tidal volumes. If the ETT is too small, the peak inspiratory pressures may be too high. It may not be possible to perform bronchoscopy through a small ETT.

Prior to ETT exchange, make sure that the patient is hemodynamically stable. If the patient has a functioning airway, there is rarely a need to exchange it emergently. Gather resources and personnel necessary to complete the exchange. While there is no evidence to support this practice, it is recommended to sedate and paralyze the patient prior to ETT exchange. With the patient sedated and paralyzed, there is less of a chance of the patient accidently coughing or moving and having the ETT become dislodged.

With the patient adequately sedated, paralyzed, and oxygenated, remove the securing mechanism for the ETT. A laryngoscope may be utilized to facilitate the procedure. Place an airway exchange catheter (AEC) into the ETT. A bougie or Aintree catheter may be used, but a Cook exchange catheter is specifically designed

for ETT exchange and comes in several different sizes, from pediatric to adult. Advance the AEC until continuous resistance is met, which is usually a few centimeters longer than the length of the ETT to the teeth. Withdraw the old ETT from the patient's trachea while holding the AEC in place at the distal end. When the ETT has cleared the mouth, secure the AEC at that location and withdraw the old ETT completely from the AEC. Now, place the new ETT on to the AEC and advance the ETT to the patient's mouth. At this point, grab the distal end of the AEC and advance the ETT completely into the trachea.

When the ETT is in place, attach a BV device and confirm the presence of gas exchange by using an $ETCO_2$ and other clinical means. Assess the adequacy of bilateral breath sounds and oxygenation. The new ETT is likely too deep and will probably need to be withdrawn a few centimeters. When appropriate position of the new ETT is confirmed, secure it in place.

Conclusions

Airway management is more than putting a tube into the trachea. The process of airway management begins with evaluating a patient's clinical status and need for mechanical ventilation. The process continues with a physical examination and more importantly, an airway examination. The next step is to develop an initial and at least one backup plan for airway manipulation. Before beginning the actual procedure, it is important to prepare for all possible scenarios. The most crucial step is the actual placement of a tube into the trachea, but management does not stop there. It ends with conformation of tube placement and a return to pre-management hemodynamics.

This chapter does not cover every potential tool for AM, and a clinician will not become an expert or even proficient in AM just by reading the chapter. AM is a skill that is learned and developed over a significant period of time dealing with multiple different clinical scenarios. The best place to learn the basics of AM is the OR in a controlled atmosphere where there is ample time and the patient is usually not acutely decompensating, not the ED or the ICU where AM is usually urgent or emergent due to the patient's illness severity. Once the basics have been mastered, the clinician can build upon that knowledge in other clinical arenas, such as the ED or ICU. But, the clinician should not stop there. AM is a lifelong learning process that must be practiced and updated continuously.

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