Chapter 3

AIRWAY MANAGEMENT

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INTRODUCTION

Untreated airway obstruction will result in death from cerebral anoxia within several minutes. Fortunately, most causes of airway obstruction can easily be reversed. Although massive exsanguination due to cardiac or aortic injury is not amenable to first-aid measures, the resolution of airway compromise may be lifesaving in the field.

Combat casualties who will require airway interventions can be grouped into four categories:

1. those whose direct trauma to the airway causes obstruction;
2. the severely wounded casualty (eg, with an exsanguinating injury or in a comatose state) who needs a secure airway;
3. those with impending or known respiratory failure due to blast or inhalational injury, exposure to chemical agents, or postinjury or postoperative respiratory insufficiency; and
4. the casualty who needs a controlled airway during the administration of anesthesia for surgery.

In the military, casualties in the last category will certainly constitute the major source of airway interventions, as surgery for most combat injuries will be performed under general anesthesia. Airway management in this setting will be performed by trained anesthesia providers. Most combat casualties arriving at definitive medical facilities will not require immediate operation, and there will be time for a planned approach for airway control.

The number of casualties that comprises the first three categories—those who require emergency airway intervention in the field—is not large. In fact, the data assembled during the Vietnam War by the Wound Data and Munitions Effectiveness Team (WDMET) reveal that only 1.3% of combat casualties who arrived at medical facilities directly from the battlefield required emergency airway management. Only one half of these casualties (0.6% of the total) suffered from a traumatic airway injury.[1] Data collected nearly 30 years later, during the 1991 Persian Gulf War, demonstrated only a 0.4% incidence of airway obstruction due to trauma.[2] On review of the WDMET data, it is impossible to determine the exact number of soldiers who died on the battlefield due to acute airway obstruction prior to medical intervention, although autopsy results suggest that this occurrence was uncommon.[3]

The most gravely wounded casualties—those dying from exsanguination or severe brain injury—will most likely outnumber those seen with direct airway trauma. The major indication for emergency airway management is found in the group with severe head injuries. WDMET data indicate that 0.7% of all casualties who required immediate airway intervention were in this category; these data also show that 10% of casualties treated in medical facilities arrived in a state of hypovolemic shock.[3] Rapid intravenous fluid administration will temporarily reverse shock in most cases, but the treatment of severe hypovolemic shock by rapid fluid resuscitation is facilitated by early airway intubation and mechanical ventilation. These casualties may increase the total percentage of cases in whom immediate airway management is necessary.

Finally, WDMET data indicate that 3.2% of combat casualties arrived alive from the battlefield with difficult breathing due to chest wounds. One half of these casualties had a tension pneumothorax and the remainder had sucking chest wounds.[3] Tension pneumothorax can initially be managed by tube thoracostomy alone, but disruption of the chest wall will usually require tracheal intubation and mechanical ventilation. For the purpose of this discussion, if we exclude (*a*) those casualties who will require ventilatory assistance due to postoperative respiratory insufficiency and (*b*) those suffering from lung damage due to blast overpressure, inhalational injury, or chemical agent exposure, then possibly 5% to 10% of the total combat casualty population entering the military medical system will be candidates for immediate airway management.

In 1980 in the United States alone, 105,000 fatalities and 10 million disabling injuries occurred as a result of accidents.[4–6] In the civilian experience, as in the military, airway management is the *initial* step in resuscitating victims suffering from trauma or sudden cardiac death.[7] Although few data exist regarding the direct impact of appropriate initial airway management on the survival of trauma victims, failure to provide timely emergency airway management in parturient and surgical patients is a leading cause of morbidity and mortality.[8–11] The establishment of trauma centers that foster rapid and appropriate airway management in the prehospital phase of care appears to have a favorable effect on patient outcome.[12,13]

Newcomers to military medicine must appreciate this fundamental fact: the mechanisms of injury are different in civilian and military trauma. Most civilian trauma is caused by blunt injury, while most military battlefield injuries are caused by penetrating missiles. Therefore (owing to the high lethality of penetrating missile wounds of the head, chest, and neck), the percentage of casualties who require lifesaving airway intervention is lower than the percentage seen in civilian accident victims.

FUNDAMENTALS OF AIRWAY MANAGEMENT

The term *airway* is customarily used in two senses: the anatomical (ie, to denote any part of the respiratory tract through which air passes during breathing), and the operational (ie, to denote a device for correcting obstructions to breathing). This semantic imprecision is regrettable because it may confuse the uninitiated, but the usage is well established and we will not attempt to introduce new nomenclature here.

Airway Obstruction

The Medical Service of the Army of the Soviet Union has published data from World War II that help us appreciate the anatomical basis for upper-airway obstruction that is seen in combat casualties (Table 3-1).[14] It appears that almost all classes of injury had a penetrating component as the etiology of the obstruction. Direct airway injury and maxillofacial blunt trauma are also causes. (The nature and detailed management aspects of maxillofacial injury are discussed in Chapter 18, Injuries to the Face and Neck.)

TABLE 3-1

ASPHYXIATION WITH FACIAL AND JAW WOUNDS IN THE RUSSO–GERMAN WAR, 1941–1945

Injury	Frequency (%)
Prolapse of the tongue into the pharynx due to structural damage to the mandible	40
Blockage of upper airway by damaged detached oropharyngeal tissue	29
Compression of the trachea as a result of edema or hematoma in the neck	23
Displacement of the glottis/larynx by surrounding soft tissue	5
Aspiration of blood and vomitus	3

Data source: Rehwald G. *Organization and Tactics of the Medical Service*. Berlin, German Democratic Republic: Military Press, GDR; 1973: Table 3.10.

Many of the battle casualties who require immediate airway intervention will not survive to be evacuated from the site of injury to the field hospital level without first receiving airway control. For these casualties, airway intervention must take place in the first or second echelons of care, where military anesthesia providers are unlikely to be present. Therefore, medics, physician assistants, and physicians providing care at the first and second echelons must be able to provide early airway management. Medical personnel trained in the provision of anesthesia and airway control will be available at the third and fourth echelons of care. The interventions chosen to reverse airway obstruction and to provide definitive airway control will, to some extent, depend on the echelon of care (Table 3-2). Nevertheless, simple maneuvers such as the head tilt and the chin lift, which are discussed later in this chapter, are universally applicable (Figure 3-1). Not only medical officers but also physician assistants within the first and second echelons should be able to use a bag-valve-mask device, place an endotracheal tube, and be familiar with performing an emergency surgical airway intervention such as a cricothyroidotomy. Teaching of these life-saving techniques should be part of any formalized medical training program for these providers.

Goals of Airway Management

The aims of airway management are to (*a*) relieve airway obstruction, (*b*) prevent pulmonary aspiration, and (*c*) serve as an adjunct for therapeutic intervention. The initial and foremost goal of airway management is to ensure relief from obstruction. Obstruction of the upper airway can, in most instances, be dramatically relieved by the simple maneuvers of head tilt and jaw thrust. Cautious sweeping of the oropharynx with the fingers may assist in locating and removing foreign material, teeth, dentures, food, or vomitus. Suctioning of the oropharynx allows for the removal of blood, secretions, and regurgitated gastric contents that may impede spontaneous or assisted ventilation.

TABLE 3-2

AIRWAY MANAGEMENT BY ECHELON

Location	Medical Personnel	Principal Indication for Airway Control
First and second echelons (prehospital levels)	Not anesthesia-trained	Direct upper-airway trauma Exsanguination Comatose state
Third echelon and above (hospital levels)	Anesthesia-trained	Adjunct to general anesthesia and emergency perioperative care

The prevention of pulmonary aspiration of blood, foreign material, or regurgitated gastric contents is the second goal of airway management. The normal protective airway reflexes may be obtunded due to intracranial injury, loss of consciousness, hypoxemia, hypercarbia, or hypovolemia-induced hypotension. Pulmonary aspiration leading to pneumonitis is associated with a very high morbidity, and the mortality rate seen with respiratory insufficiency in these patients may be as high as 50%.[15]

The maintenance of adequate ventilation and gas exchange is the third goal of airway management. Ideally, this is best accomplished by endotracheal intubation. Casualties who present with injury to the central nervous system need not only airway protection but, to maintain a normal acid–base status, may also require mechanical ventilation to assure adequate oxygenation and to eliminate carbon dioxide. Furthermore, control of the airway may allow for hyperventilation to ensure that hypocarbia is used as a temporary therapeutic modality to lower cerebral blood flow and to decrease intracranial pressure in the casualty with acute head injuries. Cervical spine injuries may be associated with spinal cord injury, causing respiratory weakness or paralysis that requires mechanical ventilation. Trauma to the thoracic area, with rib fractures and underlying cardiac or pulmonary contusions, may also require ventilatory assistance. Finally, the pneumonitis resulting from the pulmonary aspiration of gastric contents is best managed by mechanical ventilation and the application of positive end-expiratory pressure (PEEP).

Fig. 3-1. Soft-tissue obstruction (**a**) relieved by head tilt and chin lift (**b**). Reprinted with permission from Cummins RO. *Textbook of Advanced Cardiac Life Support*. Dallas, Tex: American Heart Association; 1994: Chap 2: 2-1.

Patient Evaluation

Assessment of the airway in the combat casualty is an ongoing process. The initial steps in airway management should occur simultaneously with the initial evaluation of the injuries. If supplemental oxygen therapy is available, it should be provided to trauma victims during the initial assessment. Airway patency should be the first priority of the patient evaluation. Signs of airway obstruction include stridor, inability to phonate, nasal flaring, supraclavicular and intercostal muscle retractions, and paradoxical abdominal muscle contractions. If airway obstruction is present, immediate steps must be taken to relieve the obstruction. Once the adequacy of the airway is established, the remainder of the injury evaluation can be completed.

Simple observation and examination of the patient are poor indicators of the adequacy of oxygenation and ventilation. If resources are available, the assessment of arterial or venous oxygen saturation may be helpful in those cases where adequate oxygenation is a concern. A complete physical examination of the patient should be made, in conjunction with other medical personnel, to thoroughly appreciate the extent of the patient's injuries. Examination of the head may reveal scalp lacerations and skull fractures, particularly in the occipital region. These injuries may not be detected during the initial assessment due to their location and may become apparent as the head is manipulated for airway management. If head injuries are found, the technical approach to airway management may have to be altered. Bleeding head wounds may be an unappreciated major cause of hypovolemia. Any casualty who has been unconscious, becomes unconscious, or develops an altered mental status should be assumed to have an intracranial injury and should be treated appropriately. The presence of ocular injuries may also lead to an alteration in airway and anesthetic management.[16]

Although the patency of the airway may have been judged to be adequate during the initial evaluation, continuous and careful patient observation must occur if medical personnel are to recognize changes in mental status or ventilatory ability. These changes can occur in an insidious fashion. All trauma victims who are conscious and complain of cervical pain, those who present with motor or sensory deficits of any extremity, and those who are unconscious must be presumed to have an injury to the cervical spine. These casualties should be treated with cervical immobilization with a rigid collar and back board until radiograph evaluation of the cervical spine, to include visualization of C-7, is performed.[17,18]

Injuries to the airway can be divided anatomically into supraglottic, glottic, and subglottic trauma. Supraglottic injuries (eg, facial fractures) with resultant hemorrhage may be a cause of significant airway obstruction. Glottic injuries may cause stridor and the inability to phonate; casualties with such injuries present with severe respiratory obstruction due to edema or hemorrhage. Subglottic injuries may cause obstruction and can be associated with subcutaneous emphysema that may involve the entire head, thorax, and abdomen, which further complicates airway management. It is paramount that these injuries be detected prior to the insertion of airways, as attempts at endotracheal intubation may be futile, further worsen the airway situation, and delay the establishment of a definitive surgical airway. As most combat casualties have penetrating missile wounds as the mechanism of their injury, an entrance wound in the face or neck will suggest the likelihood for airway compromise that demands surgical intervention.

The presence of a penetrating missile wound to the chest must alert the medical provider to the possibility of lower-airway injury. Lower-airway injury may not be as obvious in the setting of blunt trauma to the chest with possible resultant rib fractures, flail chest, pneumothorax, hemothorax, or pulmonary contusion. The chest should be carefully inspected for asymmetrical motion with ventilation, and for decreased or absent breath sounds. Hypotension seen with distended neck veins is a result of tension pneumothorax compromising venous return to the heart. Needle thoracostomy (with an 18-gauge or larger needle) in the midclavicular second intercostal space can temporarily decompress the tension pneumothorax until a tube thoracostomy can be placed in the T-5 anterior axillary line area. A persistent air leak from a thoracostomy tube may indicate a tracheal or bronchial injury. Chest radiographs should be obtained to detect occult pneumothorax or hemothorax, rib fractures, pulmonary contusion, or to appreciate a widened mediastinum, which suggests injury to the great vessels.

The abdomen, genitourinary system, and extremities must also be examined. Injuries to these areas have only minimal impact on initial airway management. However, it should be appreciated that blood loss in these areas may contribute to profound hypovolemia that necessitates later surgical management requiring airway placement for anesthesia.

BASIC EQUIPMENT FOR AIRWAY MANAGEMENT

The successful approach to airway management requires a thorough understanding of the underlying respiratory pathology, hypoxemia, hypercarbia, or airway obstruction before the selected therapy is applied. To select the correct approach to a particular airway problem, this knowledge must be coordinated with an understanding of the available techniques and airway-management equipment on hand. It is crucial to formulate an individual plan for each casualty and to assemble the proper equipment before attempting to secure an airway. Most importantly, should the original plan prove unsuccessful, all airway-management plans should include several additional approaches.

Standard equipment necessary for emergency airway management is listed in Exhibit 3-1. Depending on the echelon of care that will provide facilities for the management of the airway, addi-

EXHIBIT 3-1

EQUIPMENT NECESSARY FOR EMERGENCY AIRWAY MANAGEMENT

Laryngoscope with blades of various sizes and shapes

Endotracheal tubes of various sizes

Endotracheal tube stylet

Oral and nasal airways

Face masks of various sizes and configurations

Tonsil-tipped suction handle and suction source

Bag-valve-mask device with a self-inflating reservoir and oxygen coupling

Oxygen source and tubing

Nasogastric tubes of various sizes

Emergency drugs

Adapted with permission from Grande CM. Airway management of the trauma patient in the resuscitation area of a trauma center. *Trauma Q*. 1988;5:30-49.

tional equipment and emergency adjuncts may be available.

Oxygen Therapy

The management of hypoxemia is aimed at raising the arterial partial pressure of oxygen (PaO_2). The arterial oxygen content of blood (CaO_2) can be raised by fully saturating hemoglobin and increasing the dissolved oxygen in the blood to maximize its delivery to the tissues. Oxygen therapy allows time for treating the underlying cause of hypoxemia—whether from anemia, hypovolemia, sepsis, pulmonary edema, or cardiac failure. Supplemental oxygen therapy is simple to provide, has minimal short-term risk to the patient, and, because it is so simple, is quite easy for medical personnel to forget to deliver in a crisis.

Oxygen Adjuncts

The simplest method of administering oxygen is via nasal cannulae. The maximal fraction of inspired oxygen (FIO_2) that can be achieved depends on the oxygen flow rate, the patient's minute ventilation, the amount of inspiratory flow, and the volume of the patient's nasopharyngeal anatomical reservoir.[19] The administration of oxygen by this method is effective in mouth breathers because the airflow in the posterior pharynx produces a Bernoulli effect that entrains reservoir oxygen located in the nasopharynx. Each liter of supplemental oxygen that is provided can potentially raise the FIO_2 by 0.03 to 0.04 (3%–4%), although the ceiling flow rate is approximately 6 L. Using nasal prongs, the FIO_2 can therefore be enriched up to 0.45 (45% oxygen).[20] The use of oxygen flow rates greater than 6 L/min wastes resources, serves to be a source of discomfort to the patient, and may dry secretions.

A face mask must be used to achieve further increases in FIO_2. Face masks come in four configurations: simple, partial rebreathing, nonrebreathing, and air-entrainment (eg, Venturi) masks. Simple face masks provide an FIO_2 from 0.35 to 0.60 at a flow rate of 5 to 8 liters of oxygen per minute. In adults, flow rates less than 5 L/min with this type of mask may allow partial rebreathing of exhaled gas. As there is little difference in the maximum FIO_2 that is provided by either nasal cannulae or simple face masks, the choice of using one or the other becomes a matter of patient comfort or preference.[21]

Partial and nonrebreathing masks contain an oxygen reservoir bag and allow for the delivery of an FIO_2 of 0.8 to 1.0, with high flow rates greater than 10 L/min. In the partial rebreathing system, the proper adjustment of oxygen flow allows the oxygen-rich, dead-space portion of the tidal volume to refill the reservoir bag. This constitutes 30% of each tidal-volume breath and, in effect, decreases the required gas flow by one third. Nonrebreathing systems are less efficient but allow for maximum FIO_2 delivery. The rebreathing mask contains one-way valves that prevent rebreathing and entrainment of ambient air into the mask.

Air-entrainment masks employ jet mixing of oxygen with ambient air utilizing the Venturi principle to provide a fixed FIO_2 rate. Oxygen delivery can be specifically selected in an FIO_2 range of 0.24 to 0.50. It is important to appreciate that a specific Venturi setting must be matched to a specific oxygen flow rate to obtain the desired FIO_2. For the application of an FIO_2 in the range of 0.28 to 0.40, a face tent is an alternative to a face mask. In a cooperative patient, a tent is often better tolerated than a mask.

Airway-Management Adjuncts

Casualties suffering from hypoventilation due to airway obstruction may require assistance ranging from simple airway maneuvers to endotracheal intubation and controlled ventilation. The simplest method for airway control entails extending the neck (ie, the head tilt) and elevating the mandible in a forward manner (ie, the chin lift). This maneuver establishes a patent airway by displacing the mass of the tongue away from the posterior pharynx. In the comatose casualty, the loss of muscle tone allows the tongue to fall posteriorly against the pharyngeal tissues and therefore obstruct the airway. This is the most common cause of airway obstruction, and it is easily alleviated. However, cervical extension is contraindicated in patients with known or suspected cervical spine injury, and the chin-lift alone should be attempted with these casualties.

Commonly available airway-management adjuncts may also be used to establish a patent airway. Stiff oropharyngeal airway devices are available in 40- to 100-mm sizes, with the 80- or 90-mm size being acceptable for most adults. The use of these airway devices may cause gagging in awake patients due to stimulation of the pharyngeal structures. Softer nasopharyngeal airway devices are available in French (F) catheter sizes; F28 to F34 are usually placed in adults. They may cause discomfort or epistaxis on insertion, but partially awake patients tolerate them somewhat better than oral airway devices. Nasopharyngeal airway devices can be placed bilaterally if needed (Figures 3-2 and 3-3).

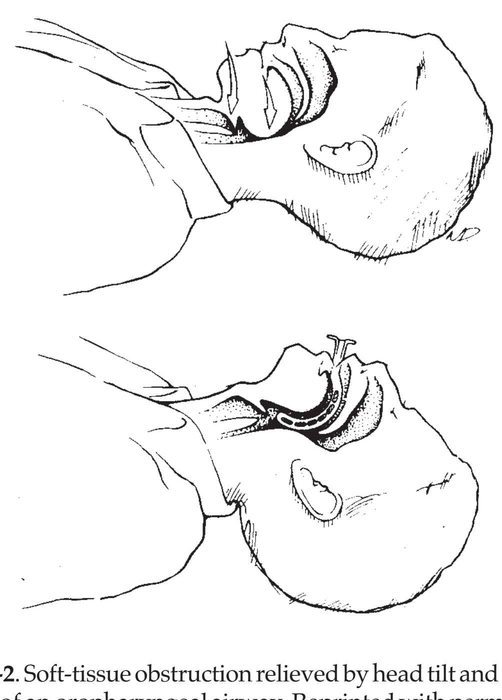

Fig. 3-2. Soft-tissue obstruction relieved by head tilt and placement of an oropharyngeal airway. Reprinted with permission from Cummins RO. *Textbook of Advanced Cardiac Life Support*. Dallas, Tex: American Heart Association; 1994: Chap 2: 2-2.

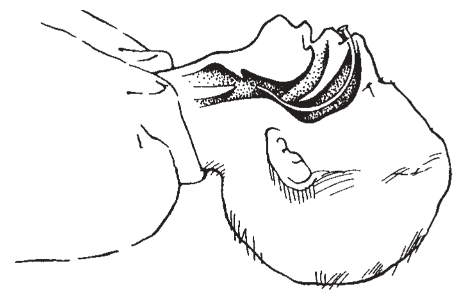

Fig. 3-3. Soft-tissue obstruction relieved by head tilt and the placement of a nasopharyngeal airway. Reprinted with permission from Cummins RO. *Textbook of Advanced Cardiac Life Support*. Dallas, Tex: American Heart Association; 1994: Chap 2: 2-2.

Bag-valve-mask devices may be used to improve oxygenation and ventilation until a more permanent airway can be secured. The face masks that may be fitted to these devices come in a variety of sizes and configurations to better conform to different facial structures. All commercially available bag-valve-mask systems are provided with a standard 22-mm connector that attaches to a standard 15-mm connector fitting, which is found on replaceable masks and endotracheal tubes. The reservoir bags on these devices are either self-inflating or require a flow of oxygen to fill them. The stiffer, self-inflating bag can be used with room air to fill the reservoir, and it comes with an oxygen-inlet port if oxygen supplementation is needed. The use of oxygen allows for an FIO_2 of up to 1.0 with these devices. The bag-valve-mask devices are commonly available in emergency areas and are more easily used by providers who are relatively untrained in airway management. A major disadvantage of this type of device is that little information concerning pulmonary compliance can be obtained by the "feel" of the reservoir bag. These systems have a one-way valve that prevents rebreathing of expired gas. A specialized bag-valve-mask arrangement that is favored by anesthesia-trained personnel is called the Jackson-Rees modification of Ayre's T-Piece, which is essentially a modified Mapleson E circuit.[22,23] This type of bag-valve-mask device has an adjustable exhaust valve that allows for a "feel" of the pulmonary compliance. A disadvantage of this type of device is that a fresh-gas flow is required to inflate the bag, and the exhaust valve must be properly adjusted to prevent the inadvertent application of PEEP. Some degree of rebreathing of exhaled gas may occur at low gas-flow rates.

PLACEMENT OF AIRWAY DEVICES

An appropriate strategy for airway management seeks to accomplish the goals previously described: relief from obstruction, protection from pulmonary aspiration, and treatment of airway injury. The identification of airway injuries in combat casualties requires that immediate attention be instituted to the particular problem. Casualties who are victims of head injury or exposure to chemical agents will need urgent airway control. Casualties with thoracic injuries may need airway control simply to control secretions. Selection of the appropriate airway-management technique requires a knowledge of the injuries received, the availability of airway equipment, and the degree of airway-management skill held by the medical personnel. The goal is to improve the combat casualty's overall status by ensuring safe, effective airway management. It must be understood that there is never a single technique that is most appropriate for a particular patient. Various specialists who will participate in the care of the casualty may have different perceptions regarding the degree to which the injury will influence the problem of airway management. This impression, when combined with another provider's training and experience with airway management, may result in the selection of another technique that is also appropriate for the patient. Suffice it to say that if all providers involved in the care of the battle casualty have a solid understanding of the pathophysiology of injury and select a technique that is compatible with those considerations, then the airway-management plan will be appropriate for that individual patient. Indications for airway and ventilatory management in the postoperative patient are discussed in Chapter 25, Acute Respiratory Failure and Ventilatory Management.

Once the initial airway evaluation has been completed and an adequate airway has been ensured, or at least supported by oxygen therapy and possible airway adjuncts, it is appropriate to complete the assessment of the casualty. It is now possible to consider any anatomical airway limitations and the availability of airway-management equipment to allow for the formulation of primary and alternative plans to formally secure the airway. Suction should be available, and all equipment such as laryngoscopes and endotracheal tubes should be checked. The casualty's level of consciousness will dictate the selection of the technique and the urgency of placing the airway device. It is important to recognize that patients who are alert, oriented to their situation, and who do not demonstrate overt respiratory distress may do well with close observation and supplemental oxygen for a period of time. All too often, these individuals are further traumatized by overly aggressive, hasty attempts to instrument the airway.

Airway Classification

An airway classification system may predict difficult tracheal intubations. The Mallampati airway classification assumes that when the base of the tongue is disproportionately large, the muscular mass of the tongue will encroach upon the larynx and make the laryngoscopic exposure of the glottic opening difficult[24]:

- Class I: Faucial pillars, soft palate, and uvula are visible.
- Class II: Faucial pillars and uvula are visible, but the uvula is masked by the base of the tongue.
- Class III: Only the soft palate is visible; a difficult intubation is predicted.
- Class IV: The soft palate is not visible; a difficult intubation is predicted.

To properly assess the patient according to Mallampati's scheme, the casualty must be able to sit upright with the head in the neutral position, open his mouth as wide as possible, and be able to protrude his tongue. The upper airway is then inspected and graded.[24] Although this classification may not be suitable for all combat casualties due to their inability to sit or perform the required maneuvers, it should be employed on appropriate patients as part of the airway assessment, as Class III and Class IV airways are predicted to be difficult to intubate using standard laryngoscopy (Figure 3-4).[25]

Anesthetizing the Airway

The anatomical areas that will be trespassed during airway management include the nasopharynx, oropharynx, hypopharynx, glottis, and the subglottic areas. The structure that divides the upper and lower airways is the glottis. The upper airway is mainly innervated by the glossopharyngeal (cranial nerve IX) and the superior laryngeal (a branch of cranial nerve X) nerves. The glossopharyngeal nerve supplies the posterior third of the tongue and the oropharynx to its junction with the na-

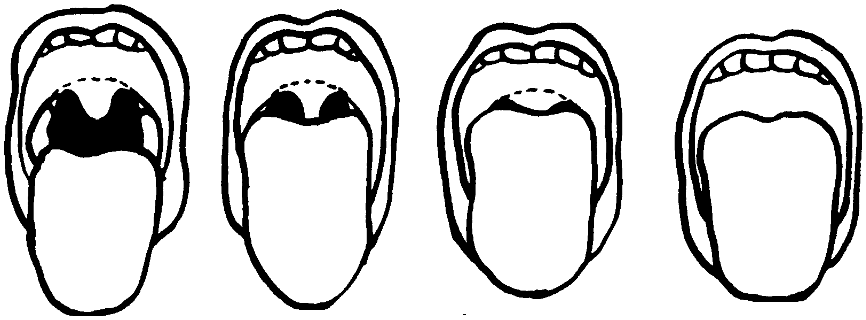

Fig. 3-4. Upper-airway classification is based on visible oral anatomy when the mouth is fully open and the patient is in the sitting position. Class I reveals the soft palate, fauces, uvula, and the anterior and posterior tonsillar pillars. Class II reveals all of the above structures except for the tonsillar pillars. Class III demonstrates that all of the above structures—except the uvula—are obscured. In a class IV airway, all of the pertinent oral structures are obscured by the tongue. Both class III and class IV airways predict a difficult laryngoscopic intubation. Reprinted with permission from Benumof JL. Management of the difficult airway. *Anesthesiology*. 1991;75:1091.

sopharynx. Its distribution includes the pharyngeal surfaces of the soft palate, epiglottis, and the fauces to the junction of the pharynx and esophagus. The superior laryngeal nerve supplies the mucosa from the epiglottis to and including the vocal cords and the motor branch to the cricothyroid muscle. The recurrent laryngeal nerve (a branch of cranial nerve X) supplies the mucosa below the vocal cords and the remainder of the intrinsic muscles of the larynx.

If awake intubation is deemed necessary in a responsive casualty, the application of topical anesthesia to the upper airway and consideration for judicious use of intravenous sedation should be entertained to facilitate airway manipulation. The sensory input for the nasal mucosa is supplied by many named nerve branches that route through the trigeminal (ie, Gasserian) ganglion. Passing a nasotracheal tube can be facilitated by using a local anesthetic agent combined with a topical vasoconstrictor to both anesthetize and shrink the nasal mucosa. Although 4% cocaine can accomplish both purposes, a solution of 1% lidocaine combined with 0.25% neosynephrine or 0.05% oxymetazoline is just as efficacious. Viscous lidocaine or lidocaine, cetacaine, and benzocaine sprays may be used to topically anesthetize the awake patient. Time is required for these agents to penetrate the mucosal tissue to provide adequate anesthesia. Sedation can be accomplished with the judicious use of intravenous benzodiazepines, narcotics, or sedative-hypnotic agents such as sodium thiopental, etomidate, or propofol—in small boluses, if necessary—in arousable patients.

Specific Nerve Blocks

Glossopharyngeal and superior laryngeal nerve blocks augment topical anesthesia applied to the pharynx and upper portion of the larynx. The glossopharyngeal nerve block is performed by injecting 1 to 2 mL of 1% lidocaine behind each tonsillar pillar. Special angled needles and kits are available to perform this block. Caution should be exercised to avoid injecting local anesthetic into the carotid artery: this mishap is associated with seizure activity due to the rapid transport of the anesthetic agent to the brain. The use of a laryngoscope will supply illumination and help to displace the tongue to the side. The superior laryngeal nerve is anesthetized by identifying the superior cornu of the hyoid bone and moving slightly caudally toward the thyrohyoid membrane. The fascia is pierced and 2 to 3 mL of 1% lidocaine is injected bilaterally.

If needed, providing anesthesia to the lower larynx and trachea is best accomplished by the transtracheal instillation of 3 to 4 mL of 4% lidocaine through the cricothyroid membrane to block the recurrent laryngeal branches of the vagus nerve. A note of controversy concerns this maneuver. If we accept the dictum that, by definition, all trauma patients have a "full stomach," then the combat casualty with traumatic wounds is at risk for gastric regurgitation and pulmonary aspiration. Opponents of this practice argue that blocking the recurrent laryngeal nerves removes the last defense the patient has to self-protect against pulmonary aspiration. Proponents argue that the medical provider performs the block to facilitate the process of securing the airway. Regardless of the merits of the argument, however, blocking the recurrent laryngeal nerves allows the anesthesia provider a more rapid and controlled passage of an endotracheal tube whether blindly, under direct vision, or with fiberscope assistance, with less coughing, retching, or vomiting by the casualty.

Nasotracheal Intubation

The awake patient without suspicion of neck injury may tolerate blind nasal endotracheal intubation better than an oral endotracheal tube placed with the use of a laryngoscope. Nasal intubation requires less manipulation of the cervical spine than oral intubation and is not hampered by jaw closing or biting. Slight flexion maneuvers of the neck frequently facilitate blind nasal placement during spontaneous ventilation. The anesthesia provider advances the tube while listening at its end to inspiratory breath sounds. A decrease in sound occurs if the tube passes posterior to the glottic opening. Repositioning and possibly rotating the tube while advancing it toward the open glottis during inspiration is usually successful. Correct placement within the glottis will be associated with an increase in breath sounds heard at the end of the tube, and exhaled vapor that condenses within the tube lumen may be visible during ventilation. Alternatively, the endotracheal tube may be placed nasally and then directly guided into the trachea under laryngoscopic visualization. The tube tip may have to be manipulated into the trachea with Magill forceps. It is important to avoid touching the endotracheal cuff with the Magill forceps, as a tear in the cuff will require that a new endotracheal tube be placed. Nasotracheal intubation is contraindicated in all casualties with midfacial injuries, basilar skull fractures, disorders of hemostasis, foreign bodies in the airway, or airway tumors.

Orotracheal Intubation

Oral intubation is the technique of choice in those casualties who have a contraindication to the nasal route, are obtunded with inadequate ventilation, or are recognized to need the rapid establishment of a secure airway. The goal of laryngoscopy is to align the oral, pharyngeal, and laryngeal axes in such a manner that the glottic opening can be visualized so that an endotracheal tube can be introduced into the trachea (Figure 3-5). The most commonly used blades for laryngoscopy are the straight Miller type and the curved Macintosh type, which are available

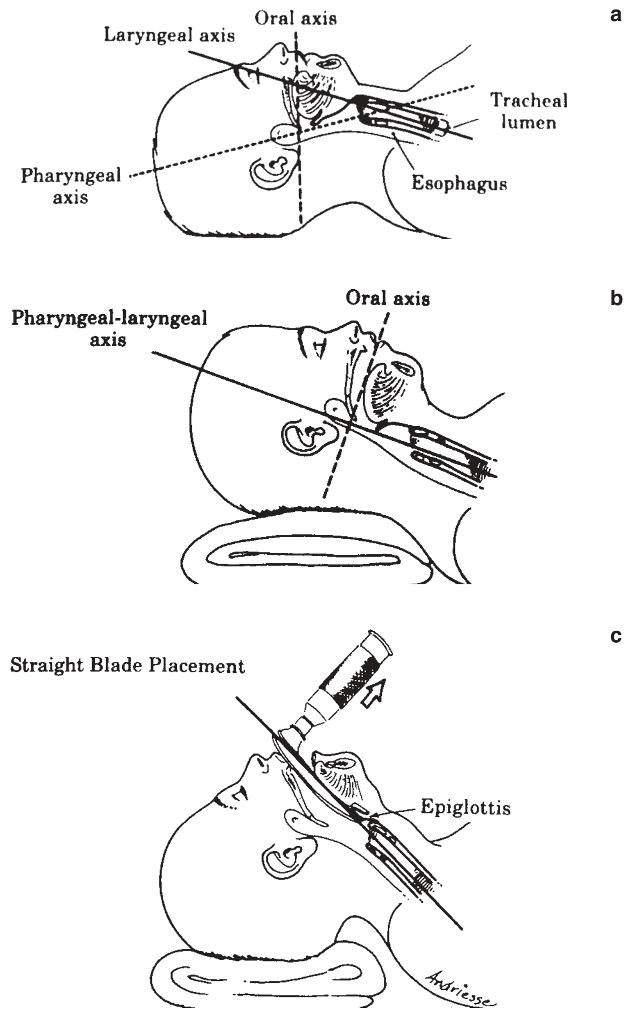

Fig. 3-5. Alignment of the oral–pharyngeal–laryngeal axis to allow for laryngoscopy and endotracheal intubation. (**a**) The long axes of the oral cavity, pharynx, and larynx are not normally aligned when a person is in the supine position. (**b**) Displacing the slightly flexed head forward in relation to the neck aligns the pharyngeal and laryngeal axes. (**c**) Extension of the forward-displaced head will align the oral cavity with the conjoint pharyngeal–laryngeal axis. The blade of the laryngoscope displaces the epiglottis, exposing the glottis. Reprinted with permission from Gaiser R. Airway evaluation and management. In: Davison JK, Eckhardt WF III, Perese DA, eds. *Clinical Anesthesia Procedures of the Massachusetts General Hospital*. 4th ed. Boston, Mass: Little, Brown; 1993: 177.

in various sizes (Figure 3-6).[26] In an obtunded patient, an oral endotracheal intubation can frequently be performed without the use of local anesthetic or supplemental sedative agents.

Since traumatized and obtunded casualties are at risk for pulmonary aspiration, cricoid pressure should be utilized if possible during endotracheal

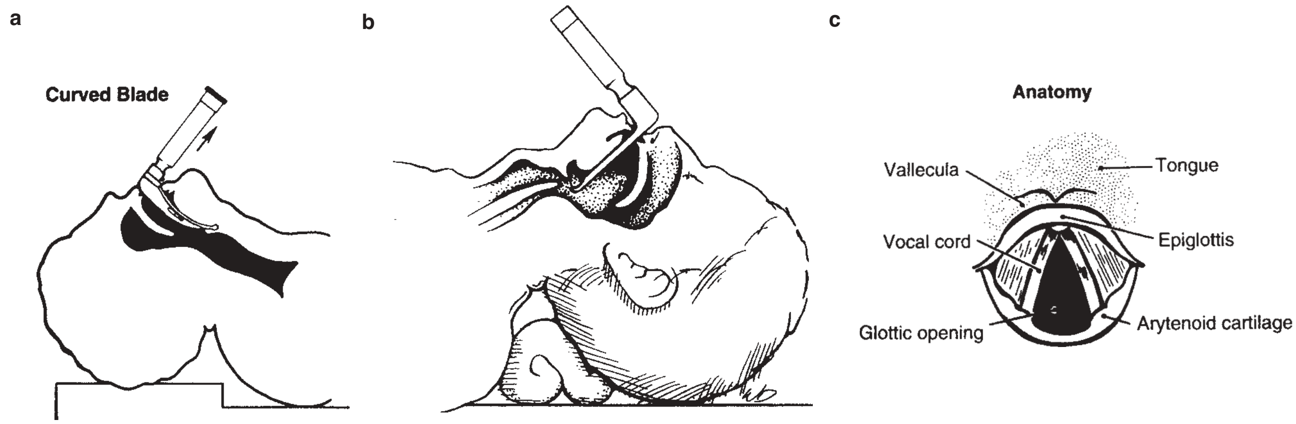

Fig. 3-6. (**a**) The correct placement of the curved blade tip into the vallecula and the use of forward traction allows the epiglottis to be displaced anteriorly to expose the glottic opening. (**b**) The tip of the straight blade is used to lift up the epiglottis to expose the glottic opening. (**c**) The glottic structures visualized during laryngoscopy. Reprinted with permission from Cummins RO. *Textbook of Advanced Cardiac Life Support*. Dallas, Tex: American Heart Association; 1994: 2-4, 2-5.

intubation (Figure 3-7). Firm compression of the cricoid cartilage (*not* the thyroid cartilage) by an assistant is effective in occluding the esophageal lumen and preventing passive gastric regurgitation into the larynx.[27] To avoid esophageal injury, cricoid pressure should be released if the patient retches. The application of cricoid pressure should not displace the cervical spine from the neutral position (the assistant can support the dorsal cervical spine with the other hand).

Cricoid pressure may also facilitate endotracheal intubation by also stabilizing the larynx, thereby helping to guide the tube tip into the glottic opening. The assistant should feel the tube pass through the larynx. Cricoid pressure may be relatively difficult to apply if the casualty is wearing a rigid cervical collar. If the collar can be removed and the cervical spine stabilized in the neutral position during the intubation procedure, the benefits of avoiding pulmonary aspiration will far outweigh the danger of injury to the cervical spinal cord. In many instances, a nasogastric tube will have been placed before the casualty receives endotracheal intubation. The placement of a nasogastric tube relieves increased intragastric pressure and may allow for removal of a portion of the gastric contents. With a nasogastric tube in place, cricoid pressure can be adequately applied without increasing the risk of regurgitation or aspiration.[28] Cricoid pressure should be maintained until successful endotracheal intubation is properly verified.

To complete endotracheal intubation, oxygenation, ventilation if necessary, and oral suctioning are required prior to both induction of general anesthesia and the performance of direct laryngoscopy. Attention to detail regarding laryngoscope and blade selection, patient positioning, and intubating technique is essential, as emergent intubating conditions may be less than optimal. Developing good intubating techniques and adhering to them in these situations are mandatory to provide skillful airway management.

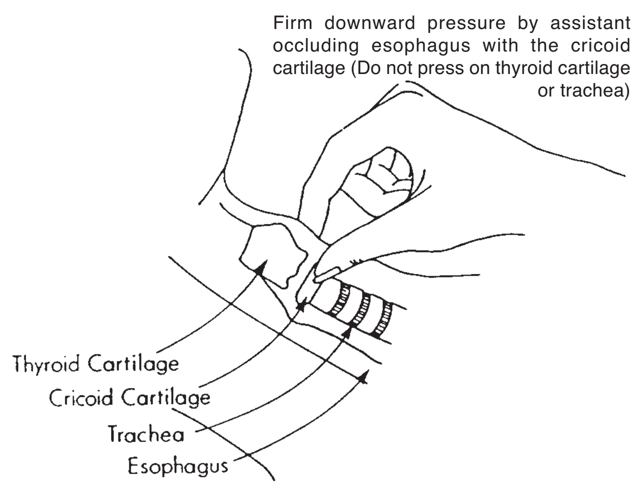

Fig. 3-7. The cricoid cartilage should be firmly compressed with 44 N (10 lb or 4.5 kg) pressure to occlude the esophagus and continue to be held until successful intubation has been verified. Reprinted with permission from Horswell JL, Cobb ML, Owens MD. Anesthetic management of the trauma victim. In: Zuidema GD, Rutherford RB, Ballinger WF, eds. *The Management of Trauma*. 4th ed. Philadelphia, Pa: WB Saunders; 1985: 133.

Rapid-Sequence Induction of Anesthesia

The casualty with a traumatic wound may have neither an airway injury nor difficulty with ventilation yet may require surgical intervention to treat his injury. Again, all casualties are considered to have full stomachs, which puts them at risk for pulmonary aspiration. It is important to realize that it is the time of injury, not the time of last ingestion, that is the most significant. If awake intubation cannot be performed, then a rapid-sequence induction of general anesthesia with cricoid pressure and endotracheal intubation should be performed.

Prior to induction of general anesthesia, it is important to provide an F_{IO_2} of 1.0 for a few minutes through a tight-fitting mask to denitrogenate the lungs and to ensure maximum alveolar and arterial oxygen saturation. If it is impractical to fully denitrogenate prior to induction, an attempt should be made to maximize oxygen saturation by having the casualty take four deep breaths of pure oxygen prior to induction of anesthesia.

The rapid-sequence induction of anesthesia is a technique of quickly administering a sedative-hypnotic agent in conjunction with a muscle relaxant to cause rapid unconsciousness and tracheal muscle relaxation so that the trachea can be intubated as quickly as possible. It is desirable to accomplish this task within less than 90 seconds if possible. No attempt should be made to ventilate the patient by mask after induction of anesthesia until correct placement of the endotracheal tube has been confirmed. The intravenous induction of general anesthesia can be accomplished with ketamine, etomidate, propofol, or sodium thiopental. Thiopental is the most well-known drug for contributing to myocardial depression and hypotension, but all of the induction agents can be associated with these conditions.[29,30]

To allow for endotracheal intubation, succinylcholine, a depolarizing muscle relaxant agent, remains the most reliable agent for producing rapid relaxation of the airway musculature. It has a short duration of action due to its chemical breakdown by plasma cholinesterase. Newer nondepolarizing agents of the aminosteroid and benzylisoquinoline classes that are administered in large doses have been shown to be acceptable alternatives for rapid tracheal intubation.[31–34] The disadvantage to their use is related to their long duration of action following large doses. The nondepolarizing agents generally require that their action be reversed with a cholinesterase-inhibiting agent such as neostigmine combined with an antimuscarinic agent such as atropine. See Chapter 11, Neuromuscular Blocking Agents, for a more complete discussion of this subject.

COMPLICATIONS OF AIRWAY MANAGEMENT

Casualties with respiratory compromise, in whom an effective airway is not promptly established, can die or suffer irreversible neurological injury. Other complications can be divided into (*a*) an acute group, which includes mechanical trauma to the airway or the sequelae of pulmonary aspiration, and (*b*) a chronic group, which comprises the complications associated with prolonged intubation and mechanical ventilation (Exhibit 3-2). The latter complications are addressed in Chapter 25, Acute Respiratory Failure and Ventilatory Management, and are not discussed further in this chapter.

Traumatic complications include injuries to the nasal septum, dental or labial structures, mucosal tissue disruption, and hemorrhage.[35] Mucosal dissection that is complicated by infection may progress to sinusitis, retropharyngeal abscess formation with possible spread to the mediastinal space, and generalized life-threatening sepsis. Vigorous intubation attempts may disrupt or dislocate arytenoid or other laryngeal cartilages.[36] Although damage to the innervation of the larynx is typically a result of trauma or surgery, paralysis of the vocal cords is occasionally related to endotracheal intubation, especially if the patient is intubated for a prolonged time.[37] This injury is typically unilateral, presents clinically with a complaint of hoarseness, does not cause respiratory obstruction, and resolves with time.

Complications associated with prolonged intubation include pressure necrosis of the nasal alae, lips, and tongue. In a patient with a nasal endotracheal tube in place, unrecognized purulent sinusitis may progress to meningitis or sepsis. Vocal cord granuloma, tracheal ulceration, and subglottic stenosis are known complications of prolonged intubation. Although these complications may be unavoidable, attention to technique and early recognition of complications with appropriate consultation may minimize associated morbidity.

Although a given injury may not directly involve the airway, it may be worsened by delayed, improper, or inadequate airway management. Combat casualties frequently have multiple sites of in-

EXHIBIT 3-2

COMPLICATIONS OF INTUBATIONS IN TRAUMA PATIENTS

Oral Intubation
- Trauma from laryngoscopy
- Excessive cervical spine motion
- Esophageal intubation
- Pneumothorax
- Damage to endotracheal tube
- Vomiting or aspiration or both
- Broken teeth
- Inadvertent extubation
- Laryngeal trauma
- Right main bronchus intubation
- Mouth debris forced down the trachea
- Esophageal perforation
- Laryngotracheal disruption
- Blood clots obstructing the tube

Nasal Intubation
- All complications listed above plus:
- False passage in posterior pharynx
- Air entry from paranasal sinuses into subcutaneous tissues
- Nosebleed
- Prolonged intubation:
  - Sinusitis
  - Necrosis of the nose

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jury, which must be prioritized for seriousness of injury and which may require selection of techniques that place one organ system at risk while minimizing damage to another. There are no rigid formulas for selecting a technique for these patients, as each casualty must have an airway-management plan based on individual assessment of the injury and its associated physiological impact. This information, combined with knowledge of the provider skills and the available airway equipment, is used to formulate a prompt, effective approach to airway management.

Regurgitation and Aspiration

All trauma victims and combat casualties are assumed to have gastric atony beginning at the time of their injury and therefore are at risk for gastric regurgitation and pulmonary aspiration due to their having a full stomach. The risk is not minimal, as WDMET autopsy data from soldiers killed on the battlefield confirm that regurgitation and aspiration are common agonal events.[3] Although most endotracheal intubations will be performed by trained anesthesia personnel, an appreciation of the problem must be entertained by all medical personnel who come in contact with the battle casualty.

Manual maneuvers such as the use of cricoid pressure during endotracheal intubation will help to minimize the risk of passive regurgitation and aspiration. A nasogastric tube may help to partially decompress gastric volume and air. If time allows, the intravenous pharmacological manipulation of gastric volume and pH can help to reduce the risk of aspiration. Histamine-2 receptor blocking agents given intravenously (eg, cimetidine 300 mg, ranitidine 50 mg) help both to decrease the rate and volume of acid secretion and to increase the pH of gastric contents.[38–40] Unfortunately, pharmacological treatment for aspiration prophylaxis requires time for the agents to work and may not be helpful in emergency airway-management situations. Metoclopramide 10 mg, administered intravenously, promotes gastric emptying into the small intestine within a few minutes by relaxing the pylorus and increasing peristaltic activity.[41] When time precludes the use of intravenous agents for aspiration prophylaxis, a nonparticulate antacid such as sodium citrate 30 mL, or sodium bicarbonate 8.4% 2.5 to 5.0 mL, administered orally or through a nasogastric tube, will raise the gastric pH for up to 30 minutes.[42] The benefit from the increased gastric pH outweighs any concern over increased volume of stomach contents; in addition, the stomach contents may be less harmful even if aspirated into the airway. Although the acid-buffering power of colloidal antacids is superior to that of nonparticulate solutions, the particulate antacids have been shown to worsen the pneumonitis associated with pulmonary aspiration.[43]

Management of Pulmonary Aspiration

If gastric regurgitation and pulmonary aspiration have occurred, then the oropharynx and trachea should be suctioned immediately, and the pH of the secretions should be determined. The casualty should be intubated if this has not already been accomplished. Bronchoscopy may be indicated if the aspiration of particulate matter has occurred. Casualties with significant aspiration may present with immediate bronchospasm, wheezing on auscultation, and elevated peak airway pressures. A high FIO_2 along with PEEP should be delivered. Serial arterial blood gas measurements will reflect the degree and course of the pulmonary injury. The patient should be observed in an intensive care setting and given supportive therapy. Chest radiography is useful in following the clinical course, but radiographic changes lag behind the clinical course by several hours. Antibiotic therapy is indicated only for proven bacterial infection. Steroids are not indicated for the management of this condition. Pulmonary aspiration progressing to the adult respiratory distress syndrome (ARDS) is associated with mortality as high as 50%.[44]

MANAGEMENT OF THE FAILED INTUBATION

In the general population who present for surgery without evidence of injury to the airway, tracheal intubation or the maintenance of a patent airway will be difficult in an estimated 1% to 3% of patients.[45] The inability to secure a patent airway in a patient who cannot be ventilated is perhaps one of the most serious situations faced in airway management. Consequently, it is imperative that alternative nonsurgical and surgical strategies be considered. Repeated attempts at intubation using the same techniques seldom succeed and increase the potential for iatrogenic airway injury. An algorithmic approach to the difficult airway and failed intubation has been promulgated to help formulate alternative strategies in the management of this problem (Figure 3-8).[25] The key to success is the combination of carefully assessing the airway, formulating and proceeding with a plan that does not limit other options, and having assistance and extra equipment to manage this demanding problem. The decision to place a surgical airway should be considered early if advanced airway equipment or individuals skilled in advanced airway-management techniques are not available.

In the first and second echelons of care, cricothyroidotomy is the accepted approach to securing an emergency surgical airway when it is impossible to ventilate a casualty by nonsurgical means (Figure 3-9). The decision to perform either cricothyroidotomy or tracheostomy at the third or fourth echelons of care will depend on both the availability of surgical personnel trained in tracheostomy and the urgency of airway access. The cricothyroid membrane can be used to gain access to the airway using large-bore catheters, wires, or percutaneous airway devices. If large-bore (12- or 14-gauge) catheters are used, temporary oxygenation and ventilation using a bag-valve-mask or jet-ventilation equipment attached to a high pressure oxygen source can be used. Percutaneous airway devices can be used, if available.[46–49] A guidewire (0.030 in.) or an epidural catheter can be placed through the cricothyroid membrane in a retrograde fashion to pass through the oropharynx or nasopharynx. The guidewire or the catheter can then be retrieved, and an endotracheal tube may then be guided over the device into the laryngeal inlet. The wire or catheter can then be removed and the endotracheal tube advanced into the trachea.[50] Alternatively, at higher echelons of care, if a fiberscope is available, it can be preloaded with an endotracheal tube and then advanced over the retrograde wire and visually directed into the trachea. The wire is then withdrawn and the endotracheal tube is advanced under fiberscope guidance.

Other alternative methods for intubation are available, but these require specialized equipment that may not be available at forward areas of care. These devices, including the laryngeal mask airway (LMA), lightwand, and fiberoptic laryngoscope, all of which may facilitate the management of the difficult or failed intubation, are presently not included in the Department of Defense's Deployable Medical Systems (DEPMEDS) equipment list, although they are available in most fixed hospitals.

The LMA (a new device that is under consideration for the DEPMEDS equipment list) bridges the gap in airway management between a face mask and endotracheal intubation.[45,51] The LMA is designed to be placed blindly into the pharynx, forms a low-pressure seal around the laryngeal inlet, and allows for either spontaneous or low ($\leq$ 20 cm H_2O) positive-pressure ventilation. This device is available in various sizes, is relatively easy to insert, and has a role in the management of the difficult or failed intubation in a casualty who does *not* have trauma to the airway (Figures 3-10 through 3-17). The LMA is not suitable for an awake patient, as it causes as much gagging as an oropharyngeal airway. It is possible to pass a small endotracheal tube through the larger LMAs, either using a fiberscope or blindly through the LMA grate that sits above the glottis.

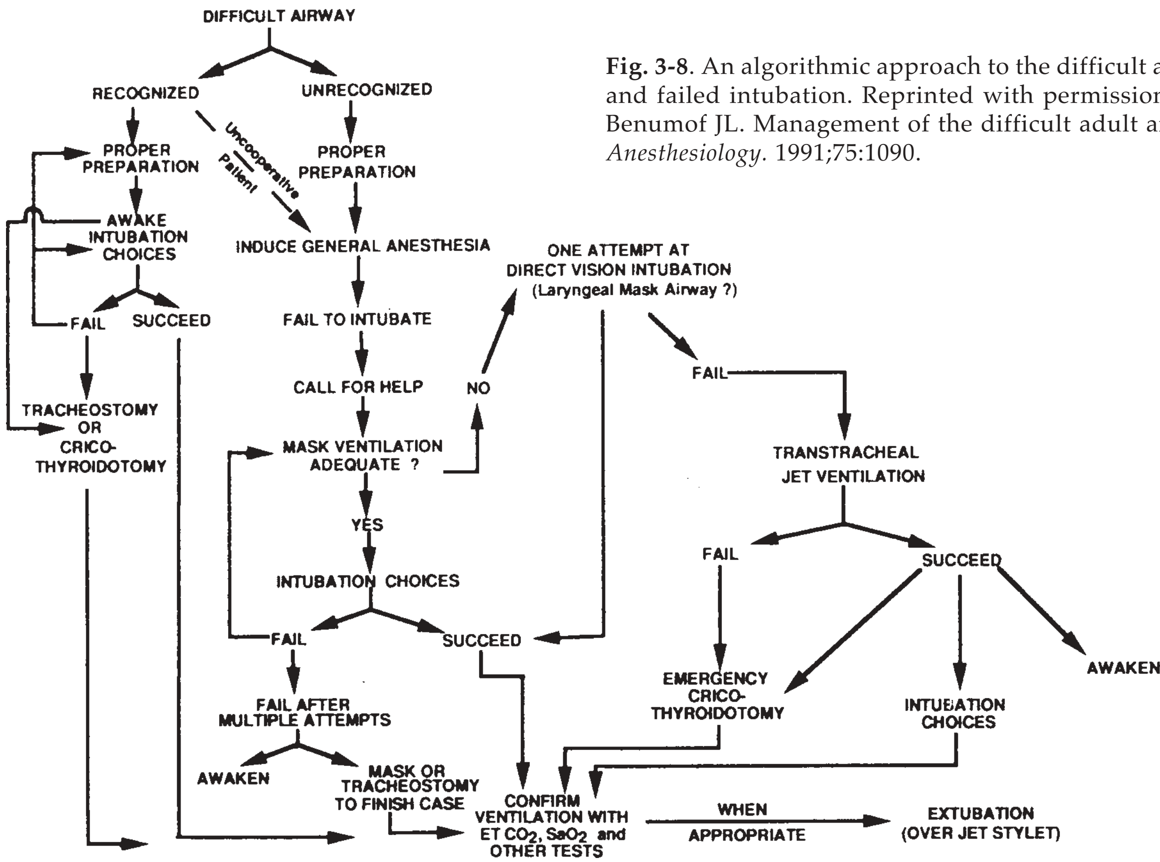

Fig. 3-8. An algorithmic approach to the difficult airway and failed intubation. Reprinted with permission from Benumof JL. Management of the difficult adult airway. *Anesthesiology*. 1991;75:1090.

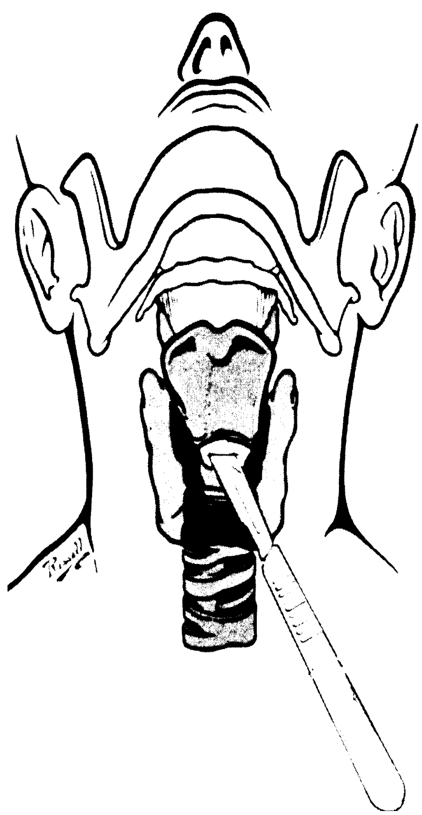

Fig. 3-9. Performance of cricothyroidotomy with a scalpel. Reprinted with permission from Cummins RO. *Textbook of Advanced Cardiac Life Support*. Dallas, Tex: American Heart Association; 1994: Chap 2: 2-13.

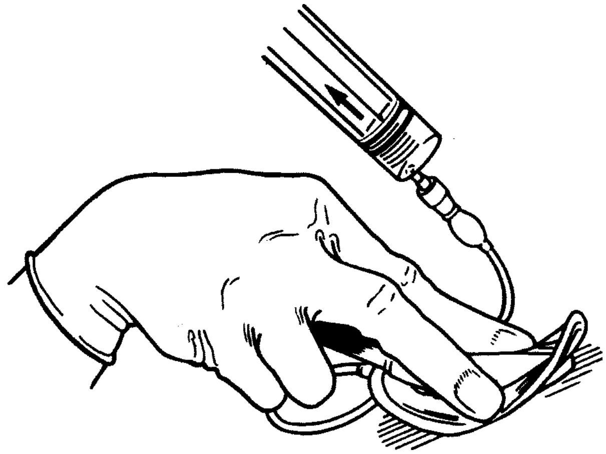

Fig. 3-10. The cuff of the laryngeal mask airway should be tightly deflated to ensure that there are no folds near the tip of the mask. Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 5.

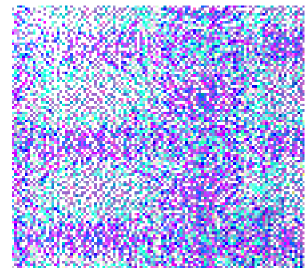

Fig. 3-11. Lubrication should be applied only to the rear of the laryngeal mask airway, *not* to the open bowl of the mask. Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 5.

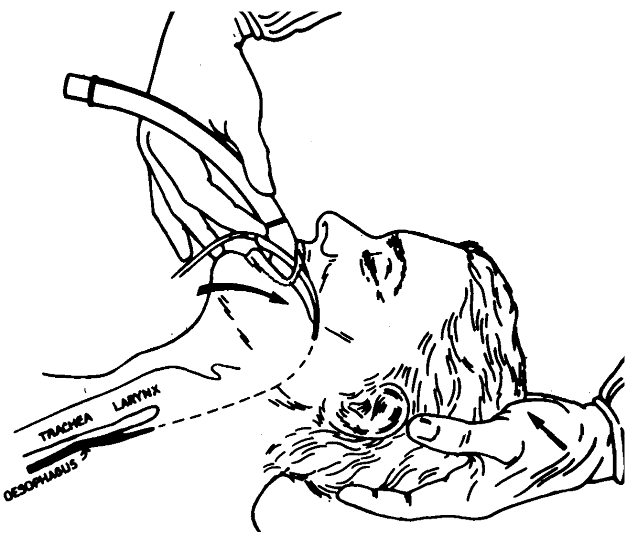

Fig. 3-12. Under direct vision, press the mask tip upward against the inner surface of the patient's upper incisors to flatten the tip. Arrows indicate direction of applied pressure exerted by each hand. Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 7.

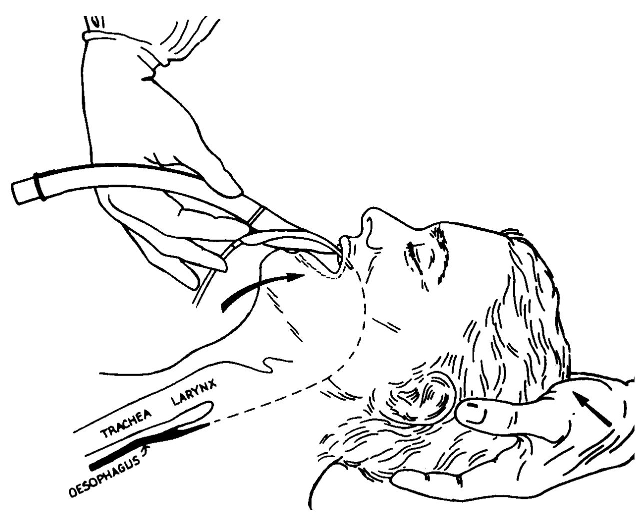

Fig. 3-13. Using the index finger, keep pressing the mask upward as it is advanced into the pharynx, to ensure that the tip of the mask remains flattened and avoids engaging the patient's tongue. Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 8.

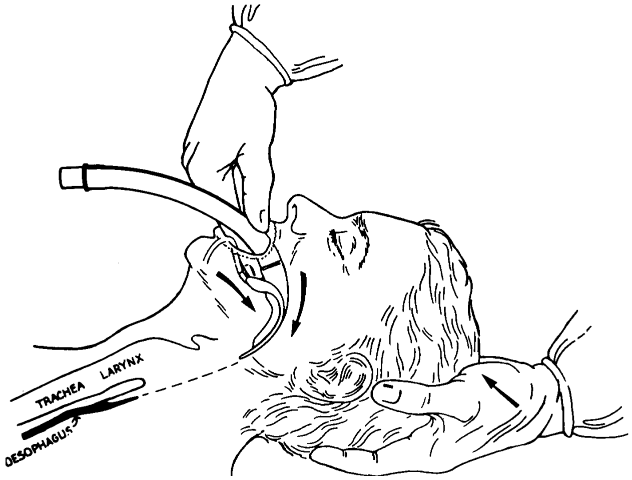

Fig. 3-14. With the patient's neck flexed and head extended, press the mask into the posterior pharyngeal wall using the index finger. The index finger must be directly in line with the mask aperture. Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 8.

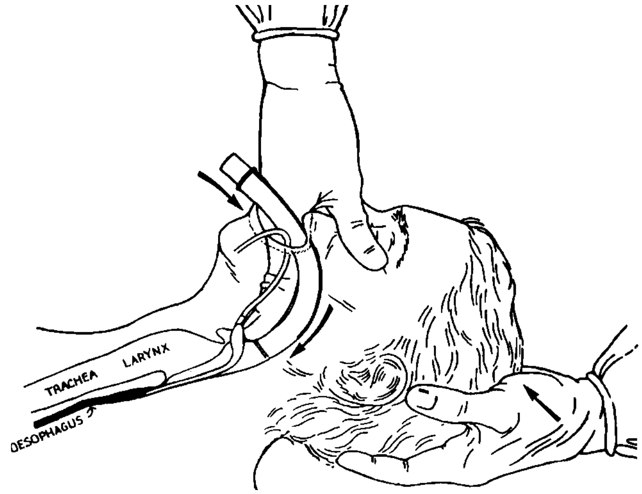

Fig. 3-15. The mask can be seated into position with one fluid motion while the anesthesiologist continues to push the mask with the index finger. Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 9.

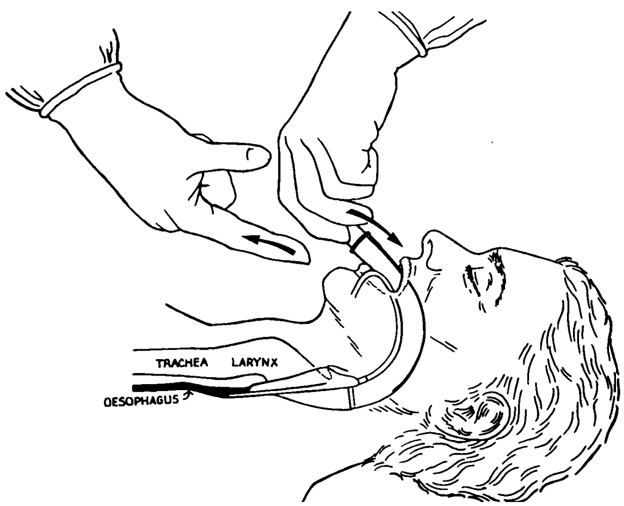

Fig. 3-16. While grasping the tube and continuing to exert downward pressure, remove the index finger from the patient's oral cavity. Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 9.

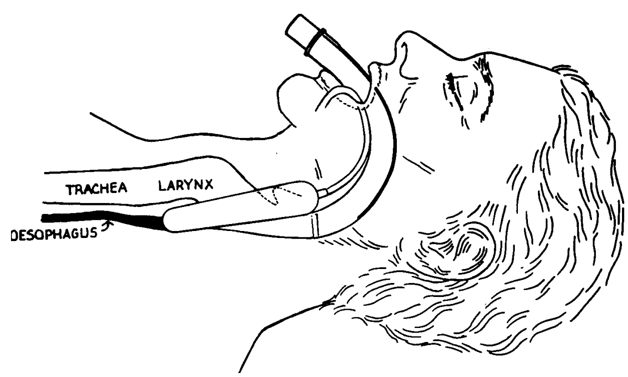

Fig. 3-17. Inflate the mask with the recommended amount of air. The mask should rise slightly as it seats itself in the correct position over the larynx. A slight airleak (< 20 cm H_2O) is acceptable if the chest moves with respiration. Deflate and reseat the mask if there is a large airleak (> 20 cm H_2O). Reprinted with permission from Baskett PJF, Brain AIJ. *The Use of the LMA in Cardiopulmonary Resuscitation Handbook*. 1st ed. Henley-on-Thames, England: Intavent Research Ltd; 1994: 9.

The lightwand is a lighted, flexible stylet over which an anesthesia provider can blindly place an endotracheal tube into the trachea through either the mouth or the nose (Figure 3-18). The lightwand can be positioned easily without manipulating the neck. The instrument should be used in dim ambient light and advanced following the curve of the tongue. A glow seen over the lateral neck indicates that the tip lies in the pyriform fossa. A loss of tip brightness generally indicates that the lightwand has entered the esophagus. A marked glow in the anterior neck with a cone of light pointing caudad indicates its proper position at the glottic opening, and the tube can then be slid off the stylet and passed into the trachea.[52,53]

The fiberoptic laryngoscope is a shortened version of the fiberoptic bronchoscope. It requires a light source and incorporates a suction port (which can also be used to entrain oxygen) and optics into a flexible bundle that fits easily through an endotracheal tube. It allows for direct visualization of the airway structures. These fiberscope devices are expensive, somewhat fragile, and require that anesthesia providers be trained to use them. The devices are likely to be available in only the higher echelons of care. The Patil-Syracuse mask (manufactured by Bay Medical, Clearwater, Fla.) is a face mask modified with an entry port for the introduction of a fiberscope during mask ventilation. Specialized oral airways such as the Williams (manufactured by Bay Medical, Clearwater, Fla.), Berman (manufactured by Sun Medical, Clearwater, Fla.), and Ovassapian (manufactured by Bay Medical, Clearwater, Fla.) intubating airways have been developed to facilitate introduction of the fiberscope tip into the laryngeal orifice.[54–57]

Fig. 3-18. Once the cone of light is seen at the glottic opening, the endotracheal tube is passed from the lighted stylet into the trachea. Photograph: Courtesy of Laerdal California, Inc, Long Beach, Calif.

SPECIAL AIRWAY-MANAGEMENT CONSIDERATIONS

Head Injury

In the civilian setting, where motor-vehicle blunt trauma predominates as the cause for injury,

> a head injury occurs every 15 seconds, and a patient dies of a head injury every 12 minutes, a physician dealing with trauma is confronted with a head-injured patient almost every day. Approximately 50% of all trauma deaths are associated with head injury, and more than 60% of vehicular trauma deaths are due to head injury.[58(p161)]

Both early recognition of intracranial injury and institution of appropriate therapy will minimize secondary neuronal injury and increase the potential for neurological recovery. Airway management for the casualty with head injuries has three goals. The first is to provide adequate ventilation to those whose medullary respiratory centers may have been compromised due to increased intracranial pressure (ICP) from edema or hemorrhage. The second is to reduce the risk for gastric regurgitation and pulmonary aspiration, because a decreased sensorium with possible compromise to cranial nerve function alters the normal protective airway reflexes. The third is to decrease the risk for aspiration and allow for the transient use of hypocapnia (Pa_{CO_2} 25–30 mm Hg) to prevent or manage increased ICP.[59]

An obtunded state, a deterioration in mental status, or a Glasgow coma scale determination of 8 points or less signals the need for immediate airway management (Exhibit 3-3).[60,61] Ideally, endotracheal intubation should be accomplished rapidly and under deep anesthesia so that the untoward hemodynamic effects of laryngoscopy can be blunted. Hypertension in response to laryngoscopy and endotracheal tube placement may exceed the limits of cerebral autoregulation and contribute to further intracranial hemorrhage, edema, and an increase in ICP with compromise of cerebral perfusion pressure (CPP) and cerebral function. Coughing or bucking in response to intubation efforts elevates not only cerebral-inflow pressure but also central venous pressure, with resultant decreases in CPP.

EXHIBIT 3-3

GLASGOW COMA SCALE

Eye Opening	
Spontaneous	_____ 4
To verbal command	_____ 3
To pain	_____ 2
None	_____ 1
Verbal Response	
Oriented and converses	_____ 5
Confused and converses	_____ 4
Inappropriate words	_____ 3
Incomprehensible words	_____ 2
None	_____ 1
Motor Response	
Obeys command	_____ 6
Localizes pain with a purposeful response	_____ 5
Flexion withdrawal	_____ 4
Abnormal flexion	_____ 3
Decerebrate extension	_____ 2
None	_____ 1

A normal individual would score 15, while a patient in profound coma would score 3. A score of 8 or less is considered indicative of a severe head injury, and endotracheal intubation should be performed to protect the airway.

Painful stimuli should be administered by pressure over the supraorbital notch, or by pressure on a nail bed with a pencil. The best performance score at each time of testing should be reported. Some centers record a score before and after resuscitation has been completed.

Cold caloric testing and tonic neck reflexes provide information regarding the integrity of the brainstem in comatose patients.

While hypertension is poorly tolerated in casualties with brain injuries whose blood–brain barrier is disrupted, hypotension is just as dangerous: inadequate cerebral perfusion may occur in areas of brain injury where cerebral autoregulation of blood flow is compromised or nonexistent.

If a barbiturate such as thiopental is available, its use as an induction agent in the dose range of 3 to 5 mg/kg will provide deep anesthesia, decrease the cerebral metabolic rate of oxygen demand ($CMRO_2$), and not interfere with any cerebral autoregulation that remains intact.[62] Barbiturates can depress cardiovascular function and their use may be limited in a casualty who is hypovolemic and hypotensive. Etomidate 0.1 to 0.3 mg/kg or propofol 1 to 2 mg/kg may be acceptable alternatives. Ketamine should be avoided in the casualty with head injuries. Lidocaine 1.5 to 2.0 mg/kg will blunt the tracheal response to laryngoscopy, augment anesthetic depth, and serve as a cerebral vasoconstrictor.[63] The use of muscle relaxants can provide stable intubating conditions, prevent coughing with resultant elevation of ICP, and minimize the risk for gastric regurgitation and pulmonary aspiration. Succinylcholine has been the muscle relaxant of choice due to its reliable rapid onset and short duration of action, but it has the potential to cause muscle fasciculation–induced increases in ICP, although this issue is controversial.[64–66]

Cervical Spine Injury

Cervical spine injuries with cord compromise at or above the C-3 level mandate immediate airway control and mechanical ventilation. Casualties with cervical injuries may also require intubation due to other areas of trauma.[67] If ventilation is adequate, any conscious casualty presenting with neck pain or neurological deficit, or one who is unconscious, will need radiographic examination of the cervical spine to include visualization of C-7 before cervical-fixation devices are removed or the airway is instrumented. If immediate intubation is required prior to radiographic examination, or if bony or ligamentous cervical instability is diagnosed, then cervical stabilization should be accomplished by the senior surgeon while the most skilled endoscopist manages the airway. If not otherwise indicated, a blind nasal intubation may be accomplished with minimal manipulation of the airway. The application of topical anesthesia may help to minimize coughing or gagging. Direct laryngoscopy can be accomplished with cervical stabilization to avoid flexion, and particularly extension, of the cervical spine. The use of anesthetic agents in any casualty with a high cervical cord injury should be approached with caution, as the casualty may have an altered sympathetic nervous system response to these agents.[68]

Eye Injury

Penetrating (ie, open) ocular injuries are commonly seen in combat casualties who have received multiple fragment wounds. The care of casualties with open globe injuries should minimize any coughing or straining to prevent extrusion of intraocular contents.[16] The potential for ocular salvage and preservation of visual function must be assumed until a complete examination can be performed by an ophthalmic surgeon. Airway management will require deep anesthesia with muscle relaxation to avoid further loss of intraocular contents. Succinylcholine has been considered to be relatively contraindicated in open eye injuries because muscle fasciculations have the potential to increase intraocular pressure. Pretreatment with a small dose of a nondepolarizing muscle relaxant has been shown to minimize but not ablate this problem,[69] although one large study[70] has indicated that the increased intraocular pressure seen with the use of succinylcholine is more a theoretical than a clinical concern.[69] Higher-than-usual intubating doses of nondepolarizing muscle relaxant agents are acceptable alternatives to succinylcholine in appropriate patients.[31–34]

DIRECT INJURY TO THE AIRWAY

Maxillofacial Injury

The combat casualty suffering from multiple traumatic injuries, especially head injures, frequently has associated midfacial and mandibular abnormalities. Medical personnel should determine the presence of these injuries before instrumenting the airway. Casualties with facial lacerations often present with copious bleeding that may contribute to airway obstruction. Relief of obstruction can frequently be obtained with gentle suctioning and, if possible, by allowing the casualty to sit forward rather than lie supine. Gentle, forward traction on an unstable, fractured mandible may also relieve simple obstruction. The nasal approach to endotracheal intubation is contraindicated in the casualty with midfacial fractures. Passage of endotracheal, gastric, or suction tubes via the nares may dislodge bone fragments or introduce infection, or the tube may pass upward into the cranial vault if the cribriform plate has been disrupted.

If endotracheal intubation is required, direct visualization of the larynx is usually possible and can often be performed in an awake patient after the topical application of anesthetic agents to the airway. Fiberoptic intubation can be considered, but secretions and bleeding often obscure the view and make this technique very difficult. A blind oral technique such as using a lightwand may be helpful if direct visualization is difficult. If anesthesia of the larynx and trachea is needed, previously discussed approaches to the airway and aspiration-prevention techniques can be utilized.

It is important to make an early determination if airway instrumentation above the larynx would be very difficult or futile. If this is true, or if multiple intubation approaches fail, then arrangements need to be made for an urgent or emergent surgical approach to the airway.

Laryngeal and Tracheal Injury

Direct trauma to the larynx and trachea is relatively rare, based in part on the anatomical relationship of these to bony structures: the mandible provides a bony shelf that overhangs the larynx and hyoid bone, while the sternum offers protection to the trachea. Injuries to the larynx and trachea can be divided into (*a*) blunt and (*b*) penetrating types.

Airway compromise results either from disruption of laryngotracheal structures or from secondary compression due to hemorrhage or subcutaneous emphysema. Blunt trauma to the anterior neck may cause dislocation or fracture of the thyroid, cricoid, or tracheal cartilages. Alternatively, a blow to the chest may cause a concussive injury to the trachea.[71–73]

Penetrating injuries may also damage the superior or recurrent laryngeal nerves, resulting in partial anesthesia and airway obstruction. A neck wound that causes a divided cervical trachea is best managed by directly intubating the distal portion of the tracheal opening with a tracheostomy or endotracheal tube.

The diagnosis of tracheal injury is based on the history of trauma to the area and finding the signs and symptoms of airway obstruction. Stridor may be the only presenting sign, although some victims may have difficulty with phonation. The inability to vocalize the "E" sound may indicate arytenoid dislocation or injury to the recurrent laryngeal nerve with arytenoid weakness or paralysis. Airway obstruction tends to worsen with deep inspiration and coughing. The proper recognition and care of these patients requires that the examiner have a high index of suspicion for airway injury.

Management of the casualty with a potential airway injury should be predicated on the knowledge that such injuries have the potential to be rapidly fatal. The casualty with obvious signs of obstruction such as hoarseness and dyspnea, especially in the presence of subcutaneous air or a pneumothorax, requires immediate airway control. When the larynx has been separated from the trachea or if the trachea is disrupted, orotracheal intubation—although sometimes possible—can be dangerous. A tracheostomy using local anesthesia is the safest approach in such a casualty. Once the airway is secured, laryngoscopy and bronchoscopy are used to establish the diagnosis. Intubation over a flexible bronchoscope is useful in preparation for operative repair during thoracotomy.

In addition to direct injuries to the airway, the aspiration of foreign bodies can be life threatening. Removal of foreign bodies requires the coordination and planning of anesthesia, surgical, and operating room personnel. The circumstances, location, and description of the foreign body can be obtained from history and physical examination, respiratory symptoms, and radiographic studies. The anesthetic plan should allow for removal of the foreign body without worsening the casualty's respiratory status.

The casualty who has airway obstruction from an expanding infectious site or from aspiration of a foreign body may require an anesthetic approach that deviates from the usual rapid-sequence induction technique. These conditions often require that a mask-inhalational induction of anesthesia be performed to (*a*) preserve spontaneous ventilation and (*b*) allow for intubation under deep inhalational anesthesia. The risk of gastric regurgitation and pulmonary aspiration in these casualties is less than the risk of being unable to ventilate or intubate a patient with an abnormal airway who has received a neuromuscular blocking agent.

Thermal Injury

Injuries to the airway caused by changes in temperature may be purely thermal in nature, due to chemical exposure, or a result of both mechanisms. A history of the events surrounding the inhalational injury and physical evidence of facial burns, charred nasal vibrissae, or carbonaceous sputum may provide an indication for immediate airway management. Although a diagnosis may be suspected, a conclusive diagnosis of airway injury cannot be made without examination of the casualty's upper and lower airways, usually by a surgeon skilled in the management of thermal injuries. Airway edema from the original injury and subsequent airway embarrassment occurs insidiously. Subsequent fluid-resuscitation therapy in the burned casualty may worsen airway edema and cause respiratory obstruction at any time. Therefore, a high index of suspicion of both airway injury and the need for airway management is essential in all thermally injured casualties. During the first 12- to 24-hour period after the burn, succinylcholine may be used to facilitate endotracheal intubation during airway management. After the first day, during the intensive-care phase of treatment, succinylcholine should be avoided. The burn victim's muscles rapidly develop extrajunctional receptors that are associated with an exaggerated release of potassium in response to the administration of succinylcholine, which frequently results in a hyperkalemia-induced cardiac arrest.[74]

SUMMARY

Most combat casualties who survive long enough to be admitted to field hospitals for the treatment of their injuries will require some form of airway management during the course of their treatment. Most of these casualties will have been through triage on arrival at the medical facility and will receive semielective resuscitative or reconstructive surgery. Their airway management will be provided by trained anesthesia providers. In a few casualties (< 5%–10% of the total), emergency, lifesaving airway management may need to be carried out by medical personnel before the casualty reaches a field hospital. Combat casualties who require immediate airway control are usually in extremis due to exsanguination, severe head injury, or destructive injuries to the face or neck. Standard techniques to provide endotracheal intubation should be applied to all casualties except for those with direct airway trauma. Patients with direct airway injuries can be best managed by creating a surgical airway. Other patients may benefit from alternative means to secure an adequate airway with such devices as the laryngeal mask airway or lightwand if standard endotracheal intubation is difficult. Once hypoxia has been averted or treated, gastric regurgitation and pulmonary aspiration remain the greatest threats to the combat casualty who requires airway management. At the hospital level, rapid-sequence induction of anesthesia combined with cricoid pressure to facilitate endotracheal intubation will minimize the risk of pulmonary aspiration. Casualties with potential cervical spine injury due to blunt head or neck trauma need to be approached with special caution, as manipulation of the neck has the potential to cause injury to the cervical spinal cord. Finally, thermally injured patients must be evaluated for airway injury, and appropriate airway management must be instituted as expeditiously as possible.

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