CHAPTER 2
Airway and Ventilatory Management

OBJECTIVES:

Upon completion of this chapter, the student will be able to identify actual or impending airway obstruction, explain the techniques of establishing and maintaining a patent airway, and confirm the adequacy of ventilation. Specifically, the doctor will be able to:

A. Identify the clinical settings in which airway compromise is likely to occur.

B. Recognize the signs and symptoms of acute airway obstruction.

C. Describe the techniques to establish and maintain a patent airway and confirm the adequacy of ventilation and oxygenation, including pulse oximetry and carbon dioxide (CO₂) colorimetric monitoring.

D. Define the term “definitive airway” and outline the steps needed to maintain oxygenation before, during, and after establishing a definitive airway.
CHAPTER 2

AIRWAY AND VENTILATORY MANAGEMENT

I. INTRODUCTION

Inadequate delivery of oxygenated blood to the brain and other vital structures is the quickest killer of the injured. Prevention of hypoxemia requires a protected, unobstructed airway and adequate ventilation that must take priority over all other conditions. An airway must be secured, oxygen delivered and ventilatory support provided. Supplemental oxygen must be administered to all trauma patients.

Early preventable deaths from airway problems after trauma often result from:

1. Failure to recognize the need for an airway.
2. Inability to establish an airway.
3. Failure to recognize an incorrectly placed airway.
4. Displacement of a previously established airway.
5. Failure to recognize the need for ventilation.
6. Aspiration of gastric contents.

Remember: Airway and ventilation are the first priorities.

II. AIRWAY

A. Problem Recognition

Airway compromise may be sudden and complete, insidious and partial, and progressive and/or recurrent. Although often related to pain and/or anxiety, tachypnea may be a subtle but early sign of airway or ventilatory compromise. Therefore, assessment and frequent reassessment of airway patency and adequacy of ventilation are important. The patient with an altered level of consciousness is at particular risk for airway compromise and often requires provision of a definitive airway. The unconscious head-injured patient, the patient obtunded from alcohol and/or other drugs, and the patient with thoracic injuries may have compromised ventilatory effort. In these patients, endotracheal intubation is intended to (1) provide an airway, (2) deliver supplementary oxygen, (3) support ventilation, and (4) prevent aspiration. Maintaining oxygenation and preventing hypercarbia are critical in managing the trauma patient, especially if the patient has sustained a head injury.

The doctor should anticipate vomiting in all injured patients and be prepared. The presence of gastric contents in the oropharynx confirms a significant risk of aspiration with the patient’s very next breath. Immediate suctioning and rotation of the entire patient to the lateral position are indicated.

1. Maxillofacial trauma

Trauma to the face demands aggressive airway management. The mechanism for this injury is exemplified by the unbelted passenger/driver who is thrown into the windshield and dashboard. Trauma to the midface may produce fractures/dislocations with compromise to the nasopharynx and oropharynx. Facial fractures may be associated with hemorrhage, increased secretions, and dislodged teeth, causing additional problems in maintaining a patent airway. Fractures of the mandible, especially bilateral body fractures, may cause loss of normal support. Airway obstruction results if the patient is in a supine position. Patients who refuse to lie down may be indicating difficulty in maintaining their airway or handling secretions.

2. Neck trauma

Penetrating injury to the neck may result in vascular injury with significant hemorrhage. This may result in displacement and obstruction of the airway. An urgent surgical airway may be necessary if this displacement and obstruction make endotracheal intubation impossible. Hemorrhage from adjacent vascular injury may be massive and operative control may be required.

Blunt or penetrating injury to the neck may cause disruption of the larynx or trachea, resulting in airway obstruction or severe bleeding into the tracheobronchial tree. A definitive airway is urgently required.

Neck injuries may cause partial airway obstruction by disruption of the larynx and trachea or by compression of the airway from hemorrhage into the soft tissues of the neck. Initially, a patient with this type of serious airway injury may be able to maintain airway patency and ventilation. However, if airway compromise is suspected, a definitive airway must be established. To prevent extending an existing airway injury, an endotracheal tube must be inserted cautiously. When the patient loses airway patency, it may be
precipitous, and an early surgical airway usually is indicated.

3. Laryngeal trauma

Although fracture of the larynx is a rare injury, it can present with acute airway obstruction. It is indicated by the following triad:

a. Hoarseness
b. Subcutaneous emphysema
c. Palpable fracture

If the patient's airway is totally obstructed or the patient is in severe respiratory distress, an attempt at intubation is warranted. Flexible endoscopic-guided intubation may be helpful in this situation, but only if it can be performed promptly. If intubation is unsuccessful, an emergency tracheostomy is indicated, followed by operative repair. However, a tracheostomy, when done under emergency conditions, is difficult to perform, may be associated with profuse bleeding, and may be time-consuming. Surgical cricothyroidotomy, although not preferred for this situation, may be a lifesaving option.

Penetrating trauma to the larynx or trachea is overt and requires immediate attention. Complete tracheal transection or occlusion of the airway with blood or soft tissue can cause acute airway compromise that requires immediate correction. These injuries are often associated with esophageal, carotid artery, or jugular vein trauma, as well as extensive tissue destruction surrounding the area due to blast effect.

Noisy breathing indicates partial airway obstruction that suddenly may become complete. Absence of breathing suggests that complete obstruction already exists. When the level of consciousness is depressed, detection of significant airway obstruction is more subtle. Labored respiratory effort may be the only clue to airway obstruction and tracheobronchial injury.

If a fracture of the larynx is suspected, based on the mechanism of injury and subtle physical findings, computed tomography (CT) may help to identify this injury.

During initial assessment of the airway, the “talking patient” provides reassurance (at least for the moment) that the airway is patent and not compromised. Therefore, the most important early measure is to talk to the patient and stimulate a verbal response. A positive, appropriate verbal response indicates that the airway is patent, ventilation is intact, and brain perfusion is adequate. Failure to respond or an inappropriate response suggests an altered level of consciousness or airway/ventilatory compromise.

B. Objective Signs—Airway Obstruction

1. Look to see if the patient is agitated or obtunded. Agitation suggests hypoxia, and obtundation suggests hypercarbia. Cyanosis indicates hypoxemia due to inadequate oxygenation and should be sought by inspection of the nail beds and circumoral skin. Look for retractions and the use of accessory muscles of ventilation that, when present, provide additional evidence of airway compromise.

2. Listen for abnormal sounds. Noisy breathing is obstructed breathing. Snoring, gurgling, and crowing sounds (stridor) may be associated with partial occlusion of the pharynx or larynx. Hoarseness (dysphonia) implies functional, laryngeal obstruction. The abusive or belligerent patient may be hypoxic and should not be presumed to be intoxicated.

3. Feel for location of the trachea and quickly determine if the trachea is midline.

III. VENTILATION

A. Problem Recognition

Assuring a patent airway is an important first step in providing oxygen to the patient but it is only a first step. An unobstructed airway is not likely to benefit the patient unless the patient also is ventilating adequately. Ventilation may be compromised by airway obstruction but also by altered ventilatory mechanics or central nervous system (CNS) depression. If breathing is not improved by clearing the airway, other etiologies must be sought. Direct trauma to the chest, especially with rib fractures, causes pain with breathing and leads to rapid, shallow ventilation and hypoxemia. Elderly patients and those with preexisting pulmonary dysfunction are at significant risk for ventilatory failure under these circumstances. Intracranial injury may cause abnormal patterns of breathing and compromise
adequacy of ventilation. Cervical spinal cord injury may result in diaphragmatic breathing and interfere with the ability to meet increased oxygen demands. Complete cervical cord transection, which spares the phrenic nerves (C-3, 4), results in abdominal breathing and paralysis of the intercostal muscles. Assisted ventilation may be required.

B. Objective Signs—Inadequate Ventilation

1. Look for symmetrical rise and fall of the chest and adequate chest wall excursion. Asymmetry suggests splinting or a flail chest and any labored breathing should be regarded as an imminent threat to the patient’s oxygenation.

2. Listen for movement of air on both sides of the chest. Decreased or absent breath sounds over one or both hemithoraces should alert the examiner to the presence of thoracic injury. (See Chapter 4, Thoracic Trauma.) Beware of a rapid respiratory rate—tachypnea may indicate air hunger.

3. Use a pulse oximeter. This device gives information regarding the patient’s oxygen saturation and peripheral perfusion, but does not assure adequate ventilation.

IV. MANAGEMENT

The assessment of airway patency and adequacy of ventilation must be done quickly and accurately. Pulse oximetry is essential. If problems are identified or suspected, measures should be instituted immediately to improve oxygenation and reduce the risk of further ventilatory compromise. These include airway maintenance techniques, definitive airway measures (including surgical airway), and methods to provide supplemental ventilation. Because all of these may require some neck motion, protection of the cervical spine must be provided in all patients, especially if the patient has a known, unstable cervical spine injury or is incompletely evaluated and at risk. The spinal cord must be protected until the possibility of a spinal injury has been excluded by clinical assessment and appropriate x-ray studies.

Patients wearing a helmet and requiring airway management should have the head and neck held in a neutral position while the helmet is removed. This is a 2-person procedure. One person provides in-line manual immobilization from below while the second person expands the helmet laterally and removes it from above. In-line manual immobilization is reestablished from above and the patient’s head and neck are secured during airway management. Removal of the helmet using a cast cutter while stabilizing the head and neck minimizes cervical spine motion in the patient with a known cervical spine injury.

Supplemental oxygen should be provided before and immediately after airway management measures are instituted. A rigid suction device is essential and should be readily available. Patients with facial injuries may have associated cribiform plate fractures and the use of soft suction catheters (or nasogastric tube) inserted through the nose may result in passage of the tube into the cranial vault.

A. Airway Maintenance Techniques

The tongue may fall backward and obstruct the hypopharynx if the patient has a decreased level of consciousness. This form of obstruction can be corrected readily by the chin-lift or jaw-thrust maneuver. The airway can then be maintained with an oropharyngeal or nasopharyngeal airway. Maneuvers employed to establish an airway might produce or aggravate cervical spine injury. Therefore, in-line immobilization of the cervical spine is essential during these procedures.

1. Chin lift

The fingers of 1 hand are placed under the mandible, which is gently lifted upward to bring the chin anterior. The thumb of the same hand lightly depresses the lower lip to open the mouth. The thumb also may be placed behind the lower incisors and, simultaneously, the chin gently lifted. The chin-lift maneuver should not hyperextend the neck. This maneuver is useful for the trauma victim because it does not risk compromising a possible cervical spine fracture or converting a fracture without cord injury into one with cord injury.

2. Jaw thrust

The jaw-thrust maneuver is performed by grasping the angles of the lower jaw, one hand on each side, and displacing the mandible forward. When this method is used with the face mask of a bag-valve device, a good seal and adequate ventilation are achieved.
3. Oropharyngeal airway

The oral airway is inserted into the mouth behind the tongue. The preferred technique is to use a tongue blade to depress the tongue and then insert the airway posteriorly. The airway must not push the tongue backward and block, rather than clear, the airway. This device must not be used in the conscious patient because it may induce gagging, vomiting, and aspiration.

An alternative technique is to insert the oral airway upside down, so its concavity is directed upward, until the soft palate is encountered. At this point, with the device rotated 180°, the concavity is directed caudal and the device is slipped into place over the tongue. This method should not be used for children, because the rotation of the device may damage the mouth and pharynx.

4. Nasopharyngeal airway

The nasopharyngeal airway is inserted in 1 nostril and passed gently into the posterior oropharynx. The nasopharyngeal airway is preferred to the oropharyngeal airway in the responsive patient because it is better tolerated and less likely to induce vomiting. It should be well lubricated, then inserted into the nostril that appears to be unobstructed. If obstruction is encountered during introduction of the airway, stop and try the other nostril. If the tip of the nasopharyngeal tube is visible in the posterior oropharynx, it may provide safe passage of a nasogastric tube in the patient with facial fractures.

5. Multilumen esophageal airway device

The multilumen esophageal airway device is used by some prehospital personnel to achieve an airway when a definitive airway is not feasible. One of the ports communicates with the esophagus and one with the airway. The personnel who use these tubes are trained to observe which one is occluding the esophagus and which will provide air to the trachea. The esophageal port is occluded by a balloon and the other port ventilated. A CO₂ detector improves the accuracy with this apparatus. The multilumen esophageal airway device must be removed and/or a definitive airway provided by the doctor after appropriate assessment of the needs of the patient.

6. Laryngeal mask airway (LMA)

The LMA does not provide a definitive airway. Proper placement of this device is difficult without appropriate training. Its role in the resuscitation of the injured patient has not been defined. When a patient has an LMA in place on arrival in the emergency department, the doctor must decide after immediate assessment whether removal or replacement with an endotracheal tube is necessary.

B. Definitive Airway

A definitive airway requires a tube present in the trachea with the cuff inflated, the tube connected to some form of oxygen-enriched assisted ventilation, and the airway secured in place with tape. Definitive airways are of 3 varieties: orotracheal tube, nasotracheal tube, and surgical airway (cricothyroidotomy or tracheostomy). The decision to provide a definitive airway is based on clinical findings and includes (1) presence of apnea; (2) inability to maintain a patent airway by other means; (3) need to protect the lower airway from aspiration of blood or vomitus; (4) impending or potential compromise of the airway, e.g., following inhalation injury, facial fractures, retropharyngeal hematoma, or sustained seizure activity; (5) presence of a closed head injury requiring assisted ventilation (CCS Score <8); and (6) inability to maintain adequate oxygenation by face-mask oxygen supplementation. (See Table 1, Indication for Definitive Airway, page 46.)

The urgency of the situation and circumstances determining the need for airway intervention dictate the specific route and method to be used. Continued assisted ventilation is aided by supplemental sedation, analgesics, or muscle relaxants, as indicated. The use of a pulse oximeter may be helpful in determining the need for a definitive airway, the urgency of the need, and, by inference, the effectiveness of airway placement. Orotracheal and nasotracheal intubations are the methods used most frequently. The potential for concomitant c-spine injury is of major concern in the patient requiring an airway. Figure 1, Airway Algorithm, page 47, provides a scheme by which decisions for the appropriate route of airway management can be made.

C. Definitive Airway—Endotracheal Intubation

It is important to establish the presence or absence of a cervical spine fracture. However, obtaining c-spine
Table 1—Indications for Definitive Airway

<table>
<thead>
<tr>
<th>NEED FOR AIRWAY PROTECTION</th>
<th>NEED FOR VENTILATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconscious</td>
<td>Apnea</td>
</tr>
<tr>
<td></td>
<td>• Neuromuscular paralysis</td>
</tr>
<tr>
<td></td>
<td>• Unconscious</td>
</tr>
<tr>
<td>Severe maxillofacial fractures</td>
<td>Inadequate respiratory efforts</td>
</tr>
<tr>
<td></td>
<td>• Tachypnea</td>
</tr>
<tr>
<td></td>
<td>• Hypoxia</td>
</tr>
<tr>
<td></td>
<td>• Hypercarbia</td>
</tr>
<tr>
<td></td>
<td>• Cyanosis</td>
</tr>
<tr>
<td>Risk for aspiration</td>
<td>Severe, closed head injury with need for brief hyperventilation if acute neurologic deterioration occurs</td>
</tr>
<tr>
<td>• Bleeding</td>
<td></td>
</tr>
<tr>
<td>• Vomiting</td>
<td></td>
</tr>
<tr>
<td>Risk for obstruction</td>
<td></td>
</tr>
<tr>
<td>• Neck hematoma</td>
<td></td>
</tr>
<tr>
<td>• Laryngeal, tracheal injury</td>
<td></td>
</tr>
<tr>
<td>• Stridor</td>
<td></td>
</tr>
</tbody>
</table>

x-rays should not impede or delay establishing a definitive airway when one is clearly indicated. The patient who has a GCS Score of 8 or less requires prompt intubation. If there is no immediate need for intubation, x-ray of the cervical spine may be obtained. However, a normal lateral cervical spine film does not exclude a c-spine injury.

Note: The most important determinant of whether to proceed with orotracheal or nasotracheal intubation is the experience of the doctor. Both techniques are safe and effective when performed properly. Esophageal occlusion by cricoid pressure is useful in preventing aspiration and providing better visualization of the airway.

If the decision is made that orotracheal intubation is indicated, the 2-person technique with in-line cervical spine immobilization should be used. If the patient is apneic, orotracheal intubation is indicated.

Following insertion of the orotracheal tube, the cuff should be inflated and assisted ventilation should be instituted. Proper placement of the tube is suggested but not confirmed by hearing equal breath sounds bilaterally and detecting no borborygmi in the epigastrium. The presence of gurgling noises in the epigastrium with inspiration suggests esophageal intubation and warrants repositioning of the tube. A carbon dioxide (CO₂) detector (colorimetric CO₂ monitoring device) is indicated to help confirm proper intubation of the airway. The presence of CO₂ in exhaled air is an indication that the airway has been successfully intubated, but does not assure the correct position of the endotracheal tube. If CO₂ is not detected, esophageal intubation has occurred. Proper position of the tube is best confirmed by chest x-ray, once the possibility of esophageal intubation is excluded. Colorimetric CO₂ indicators are not useful for physiologic monitoring or assessing the adequacy of ventilation. When the proper position of the tube is determined, it should be secured in place. If the patient is moved, tube placement should be reassessed by auscultation of both lateral lung fields for equality of breath sounds and by re-assessing for exhaled CO₂.

Nasotracheal intubation is a useful technique when urgency of airway management precludes a cervical spine x-ray. Blind nasotracheal intubation requires spontaneous breathing. It is contraindicated in the apneic patient. The deeper the patient breathes, the easier it is to follow the airflow through the larynx. Facial, frontal sinus, basilar skull, and cribriform plate fractures are relative contraindications to nasotracheal intubation. Evidence of nasal fracture, raccoon eyes, Battle sign, and possible cerebrospinal fluid leaks (rhinorrhea or otorrhea) identify patients with these injuries. Precautions regarding cervical spine immobilization should be followed as with orotracheal intubation.
Patients who arrive at the hospital with an endotracheal tube in place must have the proper position of the tube confirmed. This is important because the tube may have been inserted into the esophagus, a mainstem bronchus, or dislodged during patient transport from the field or another hospital. A chest x-ray, CO₂ monitoring, and physical examination are essential to assess the position of the tube. Carbon dioxide in the exhaled air will confirm that the tube is in the airway.

Patients with a cervical spine injury, severe arthritis of the cervical spine, a short muscular neck, or maxillofacial/mandibular injury may be technically difficult to intubate. The use of a flexible fiberoptic endoscope may facilitate these difficult intubations.

The use of anesthetic, sedative, and neuromuscular-blocking drugs for endotracheal intubation in the trauma patient is risky. In certain cases the need for an airway justifies the risk of these drugs. The doctor who uses these drugs must understand their pharmacology, be skilled in the techniques of endotracheal intubation, and be able to obtain a surgical airway if necessary. In many cases where an airway is acutely needed during the primary survey, the use of paralyzing or sedating drugs is not necessary.

The technique for rapid-sequence intubation is as follows:

1. Be prepared to perform a surgical airway in the event that airway control is lost.

Advanced Trauma Life Support
2. Preoxygenate the patient with 100% oxygen.

3. Apply pressure over the cricoid cartilage.

4. Administer a sedative (eg, etomidate, 0.3 mg/kg or 30 mg, or midazolam 2 to 5 mg intravenously)

5. Administer 1 to 2 mg/kg succinylcholine intravenously (usual dose, 100 mg).

6. After the patient relaxes, intubate the patient orotracheally.

7. Inflate the cuff and confirm tube placement (auscultate the patient’s chest and determine presence of CO₂ in exhaled air).

8. Release cricoid pressure.

9. Ventilate the patient.

Etomidate does not have a significant effect on the blood or intracranial pressure. This drug does provide adequate sedation, which is advantageous in these patients. Etomidate or other sedatives must be used with great care to avoid loss of the airway as the patient becomes sedated. Then, succinylcholine, which is a short-acting drug, should be administered. It has a rapid onset of paralysis of less than 1 minute and duration of about 5 minutes or less. The most dangerous complication of using sedation and neuromuscular blocking agents is the inability to establish an airway. If endotracheal intubation is unsuccessful, the patient must be ventilated with a bag-valve-mask device until the paralysis resolves. Long-acting drugs are not used for this reason. Succinylcholine should not be used because of the potential for severe hyperkalemia in the patient with preexisting chronic renal failure, chronic paralysis, or chronic neuromuscular disease.

Induction agents, such as thiopental and sedatives, are dangerous to use in the hypovolemic trauma patient. Small doses of diazepam or midazolam are appropriate to reduce anxiety in the paralyzed patient. Flumazenil must be available to reverse the sedative effects after benzodiazepines have been administered. Practice patterns, drug preferences, and specific procedures for airway management vary between institutions. The principle that the individual utilizing these techniques be skilled in their use, knowledgeable of the inherent pitfalls associated with rapid sequence intubation, and capable of managing the potential complications cannot be overstated.

D. Definitive Airway—Surgical Airway

Inability to intubate the trachea is a clear indication for creating a surgical airway. A surgical airway is performed when edema of the glottis, fracture of the larynx, or severe oropharyngeal hemorrhage obstructs the airway and an endotracheal tube cannot be placed through the cords. A surgical cricothyroidotomy is preferable to a tracheostomy for most patients requiring an emergency surgical airway. A surgical cricothyroidotomy is easier to perform, is associated with less bleeding, and requires less time to perform than an emergency tracheostomy.

1. Jet insufflation of the airway (See Skills Station III, Cricothyroidotomy)

Insertion of a needle through the cricothyroid membrane or into the trachea is a useful technique in emergency situations that provides oxygen on a short-term basis until a definitive airway can be placed. Jet insufflation can provide temporary, supplemental oxygenation so that intubation can be accomplished on an urgent rather than an emergent basis. The jet insufflation technique is performed by placing a large-caliber plastic cannula, #12- to #14-gauge (#16- to #18-gauge in children), through the cricothyroid membrane into the trachea below the level of the obstruction. The cannula is then connected to wall oxygen at 15 L/minute (40 to 50 psi) with either a Y-connector or a side hole cut in the tubing attached between the oxygen source and the plastic cannula. Intermittent insufflation, 1 second on and 4 seconds off, can then be achieved by placing the thumb over the open end of the Y-connector or the side hole. The patient can be adequately oxygenated for only 30 to 45 minutes using this technique. However, only patients with normal pulmonary function who do not have a significant chest injury can be ventilated in this manner. During the 4 seconds that the oxygen is not being delivered under pressure, some exhalation occurs. Because of the inadequate exhalation, CO₂ slowly accumulates and limits the use of this technique, especially in head-injured patients.

Jet insufflation must be used with caution when complete foreign body obstruction of the glottic area is suspected. Although high pressure may expel the impacted material into the hypopharynx where it can be readily removed, significant barotrauma may occur, including pulmonary
rupture with tension pneumothorax. Low flow rates (5 to 7 L/minute) should be used when persistent glottic obstruction is present.

2. Surgical cricothyroidotomy (See Skills Station III, Cricothyroidotomy)

Surgical cricothyroidotomy is performed by making a skin incision that extends through the cricothyroid membrane. A curved hemostat may be inserted to dilate the opening, and a small endotracheal tube or tracheostomy tube (preferably 5 to 7 mm OD) can be inserted. When the endotracheal tube is used, the cervical collar can be reapplied. One must be alert to the possibility that the endotracheal tube can become malpositioned and is easily advanced into a bronchus. Care must be taken, especially with children, to avoid damage to the cricoid cartilage, which is the only circumferential support to the upper trachea. Therefore, surgical cricothyroidotomy is not recommended for children under 12 years of age. (See Chapter 10, Extremes of Age: A. Pediatric Trauma.)

In recent years percutaneous tracheostomy has been reported as an alternative to open tracheostomy. This is not a safe procedure in the acute trauma situation, because the patient’s neck must be hyperextended to properly position the head to perform the procedure safely. Percutaneous tracheostomy requires the use of a heavy guidewire and sharp dilator, or a guidewire and multiple dilators. This may be dangerous and/or time-consuming, depending on the type of equipment used.

E. Airway Decision Scheme

The airway decision scheme (Figure 1, Airway Algorithm, page 47) applies only to the patient who is in acute respiratory distress (or apneic) and in need of an immediate airway, and in whom a cervical spine injury is suspected by mechanism of injury or physical examination. The first priority is to assure continued oxygenation with maintenance of cervical spine immobilization. This is accomplished initially by position (ie, chin lift or jaw thrust) and preliminary airway techniques (ie, oropharyngeal airway or nasopharyngeal airway) already discussed.

In the patient who is still showing some respiratory effort, a nasotracheal tube may be passed if the doctor is skilled in this technique. Otherwise, an orotracheal tube should be passed while a second person provides in-line immobilization. If neither a nasotracheal nor an orotracheal tube can be inserted and the patient's respiratory status is in jeopardy, a cricothyroidotomy should be performed.

In the apneic patient, in-line immobilization should be maintained by 1 person and orotracheal intubation should be performed by another. If severe maxillofacial injury precludes nasotracheal intubation and orotracheal intubation cannot be achieved for any reason, a cricothyroidotomy is indicated.

Oxygenation and ventilation must be maintained before, during, and immediately upon completion of insertion of the definitive airway. Prolonged periods of inadequate or absent ventilation and oxygenation should be avoided.

F. Oxygenation

Oxygenated inspired air is best provided via a tight-fitting oxygen reservoir face mask with a flow rate of 11 L/minute. Other methods (eg, nasal catheter, nasal cannula, notebreather mask) can improve inspired oxygen concentration.

Because changes in oxygenation occur rapidly and are impossible to detect clinically, pulse oximetry should be used when difficulties are anticipated in intubation or ventilation. This includes the transport of the critically injured patient. Pulse oximetry is a noninvasive method to continuously measure oxygen saturation (O₂ sat) of arterial blood. It does not measure the partial pressure of oxygen (Pao₂) and, depending on the position of the oxyhemoglobin dissociation curve, the Pao₂ may vary widely. (See Table 2, Approximate Pao₂ Versus O₂ Hemoglobin Saturation Levels, page 50.) However, a measured saturation of 95% or greater by pulse oximetry is strong corroborating evidence of adequate, peripheral arterial oxygenation (Pao₂ >70 mm Hg or 9.3 kPa). Pulse oximetry requires intact peripheral perfusion and cannot distinguish oxyhemoglobin from carboxyhemoglobin or methemoglobin, which limits its usefulness in the severely vasoconstricted patient and in the patient with carbon monoxide poisoning. Profound anemia (hemoglobin <5 g/dL) and hypothermia (<30°C or 86°F) decrease the reliability of the technique. However, in most trauma patients pulse oximetry is not only useful, but also continuous monitoring of oxygen saturation provides an immediate assessment of therapeutic interventions.
G. Ventilation

Effective ventilation can be achieved by bag-valve-mask techniques. However, 1-person ventilation techniques, using a bag-valve mask, are less effective than 2-person techniques in which both hands can be used to assure a good seal. Bag-valve-mask ventilation should be performed by 2 people whenever possible.

Intubation of the hypoventilated and/or apneic patient may not be successful initially and may require multiple attempts. The patient must be ventilated periodically during prolonged efforts to intubate. The doctor should practice taking a deep breath when intubation is first attempted. When the doctor must breathe, the attempted intubation should be aborted and the patient ventilated.

With intubation of the trachea accomplished, assisted ventilation should follow using positive-pressure breathing techniques. A volume- or pressure-regulated respirator can be used, depending on availability of the equipment. The doctor should be alert to the complications secondary to changes in intrathoracic pressure, which can convert a simple pneumothorax to a tension pneumothorax, or even create a pneumothorax secondary to barotrauma.

H. Pitfalls

1. The inability to intubate the patient expeditiously or to provide a surgical airway results in hypoxia and patient deterioration. Remember that performing a needle cricothyroidotomy with jet insufflation may provide the time necessary to establish a definitive airway.

2. Trauma patients may vomit and aspirate. Functional suction equipment must be immediately available, and the doctor should ensure a secure, patent airway in all trauma patients.

3. Gastric distention may occur when ventilating the patient with a bag-valve-mask device, which may result in the patient vomiting and aspirating. It also may cause distention of the stomach against the vena cava, resulting in hypotension and bradycardia.

4. Equipment failure may occur at the most inopportune time and cannot always be anticipated, eg, the light on the laryngoscope burns out, the laryngoscope batteries are weak, the endotracheal tube cuff leaks, or the pulse oximeter does not function properly.

V. SUMMARY

A. Actual or impending airway obstruction should be suspected in all injured patients.

B. With all airway maneuvers, the cervical spine must be protected by in-line immobilization.

C. Clinical signs suggesting airway compromise should be managed by securing a patent airway and providing adequate oxygen-enriched ventilation.

---

Table 2—Approximate \( P_{aO_2} \) Versus \( O_2 \) Hemoglobin Saturation Levels

<table>
<thead>
<tr>
<th>( P_{aO_2} ) LEVELS</th>
<th>( O_2 ) HEMOGLOBIN SATURATION LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 mm Hg</td>
<td>100%</td>
</tr>
<tr>
<td>60 mm Hg</td>
<td>90%</td>
</tr>
<tr>
<td>30 mm Hg</td>
<td>60%</td>
</tr>
<tr>
<td>27 mm Hg</td>
<td>50%</td>
</tr>
</tbody>
</table>
D. A definitive airway should be inserted if there is any doubt on the part of the doctor as to the integrity of the patient’s airway.

E. A definitive airway should be placed early after the patient has been ventilated with oxygen-enriched air, and prolonged periods of apnea must be avoided.

F. Airway management requires assessment and reassessment of airway patency, tube position, and ventilatory effectiveness.

G. The selection of orotracheal or nasotracheal routes for intubation is based on the experience and skill level of the doctor.

H. Surgical airway is indicated whenever an airway is needed and intubation is unsuccessful.

■ BIBLIOGRAPHY


