14. AIRWAY MANAGEMENT IN THE TRAUMA PATIENT

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Ensuring adequate oxygenation, ventilation, and protection from aspiration are the cornerstones of airway management and the first priority when treating trauma patients. Appropriate airway management depends on the combination of good judgment, the right equipment, and appropriate skills to perform all necessary procedures. Although airway discussions often focus on the mechanics of intubation, many patients can be treated with basic interventions.

I. **Airway equipment and skills**. A diverse array of equipment and skills are necessary for optimal airway management. These include:
   A. **Basic**
      1. Airway positioning, including chin-lift and jaw-thrust maneuvers, to relieve obstruction caused by the tongue or soft tissues.
      2. Application of supplemental oxygen (100% oxygen by partial or nonrebreather mask).
      3. Use of large-bore suction and oral and nasal airways to maintain or restore patency of the upper airway (each is discussed in Chapter 8).
   B. **Advanced (nonsurgical)**
      1. Bag-valve devices with masks
      2. Availability and knowledge of esophagotracheal airway (Combitube, Sheridan, Argyle, NY) (see Chapter 8)
      3. Direct glottic visualization and oral intubation
      4. Alternatives to direct glottic visualization and oral intubation, including nasal, transillumination (or "lighted stylet"), and tactile (or "digital") intubation and laryngeal mask airway placement
      5. **Cricoid pressure** (or "Sellick's maneuver") to lessen the risk of gastric distention during mask ventilation and aspiration during intubation (see Chapter 8)
   C. **Surgical airway**
      1. **Cricothyroidotomy** (open or percutaneous with dilators)
      2. **Translaryngeal jet insufflation**
      3. **Tracheostomy** (in select cases, e.g., laryngeal fracture)

II. **Indications for intubation**. In spontaneously breathing patients, simple skills (e.g., removal of foreign bodies, airway suctioning, chin-lift or jaw-thrust maneuvers) can establish airway patency and restore adequate respiration. Intubation is reserved for those patients who continue to show signs of inadequate respiration after basic interventions, or patients in whom these interventions alone are not likely to sustain adequate respiration.
   A. **Absolute indications for immediate emergency intubation**
      1. Airway obstruction unrelieved with basic interventions
      2. Apnea or near apnea
      3. Respiratory distress (air hunger, severe tachypnea, cyanosis, hypoxemia, or hypercarbia)
      4. Severe neurologic deficits or depressed consciousness (i.e., focal deficit or Glasgow Coma Scale [GCS] score of ≤ 8) from head trauma or any other cause
   B. **Urgent (within minutes) indications for intubation**
      1. Penetrating neck injury (with any sign of airway compromise or enlarging hematoma)
      2. Persistent or refractory hypotension, especially if caused by active hemorrhage
      3. Chest wall injury or dysfunction

4. Less severe but prominent altered consciousness, especially after head injury, including both combative and mildly obtunded patients (**Caveat**: reversible causes, including hypoglycemia and opioid or benzodiazepine overdose, should be considered and treated).

C. **Relative indications for nonemergent intubation**
1. Oromaxillofacial injury.
2. Pulmonary contusion or impending respiratory failure.
3. Need for diagnostic or therapeutic procedures in patients at risk for deterioration (e.g., computed tomography or arteriography).
4. Potential respiratory failure because of intensive systemic analgesic or sedative use.

D. The patient with significant maxillofacial or soft tissue neck injury who is spontaneously breathing, but with some difficulty, is best treated with early intubation, usually orally with direct glottic visualization. This should be performed by the most experienced provider with either topical anesthetics and judicious sedative or analgesic administration. The use of neuromuscular blocking drugs or induction agents to abolish all reflexes and ventilatory drive in these patients can result in an apnea and an inability to intubate or mask ventilate; **this situation can be rapidly fatal**. Other methods to secure the airway, including a surgical airway, must be immediately available in the trauma resuscitation room in this situation. A surgical airway under local anesthesia is another alternative in these situations, and is best performed early (before hypoxemia, hypercarbia, apnea, or extensive tissue deformity occurs).

II. Approach to intubation

A. **Oral intubation**. If the patient requires intubation, this is usually performed using direct visualization of the glottis through the mouth while maintaining in-line stabilization of the cervical spine. **No other procedures should be done while intubation is being attempted**; other activities can interfere with this primary intervention. Of all advanced airway-securing techniques, oral intubation is generally associated with the highest success rates (because of familiarity) and a lowest frequency of complications. **Oral intubation requires three people** (Fig. 14.1): one experienced provider to perform laryngoscopy and intubate, another to provide cervical immobilization, and a third to apply cricoid pressure. Large-bore suction must be readily available before any intubation attempt. Pharmacologic agents can be given as part of a systematic approach to those patients who require analgesia, sedation, or muscular relaxation to safely intubate.

To best visualize the glottis, the intubator attempts to align the oropharyngeal and laryngotracheal axes. The "sniffing position" used for nontrauma patients employs neck flexion and head extension to ease alignment. However, this maneuver is **absolutely contraindicated** in the trauma patient suspected of having cervical spine injuries. Aside from those with clear evidence of isolated extremity injuries, all trauma patients are intubated with the head maintained in a midline, neutral position. Care must be taken to ensure that **no** directional forces (distraction or traction) are applied to the cervical spine.

B. **Nasal intubation**, an alternative to oral intubation, is usually performed in a "blind" fashion in patients who are spontaneously breathing (see Chapter 8). **Nasal intubation is contraindicated in apneic patients or those with midface, nasal, or basilar skull fractures**. Nasal intubation is limited by operator inexperience, higher failure rates compared with oral intubation, and frequent development of sinusitis after >48 hours duration. Although possible in many trauma patients, nasal intubation offers little advantage over oral intubation and can be technically more difficult.

C. **Alternatives**. In select cases when oral and nasal intubation are unsuccessful, another intubation method can be an option before a surgical airway is performed. **Tactile, transillumination, and combination** approaches are well described; each requires practice but can establish an airway

D. **Other confirmatory devices**
   1. **Bulb and syringe devices** are available to confirm intratracheal tube location; these devices are simple to use and inexpensive, but offer no other information. Rapid and complete reinflation of the deflated bulb (within 5–10 seconds) when attached to the endotracheal tube or unimpeded aspiration of a 30–60 mL syringe similarly attached to the endotracheal tube strongly suggests correct placement.

VI. **General intubating procedure**
   A. **Ensure all equipment**—tubes, stylet, blades, handles, suction, bag-valve devices, oxygen, drugs, pulse oximeter, and surgical kits—are available and functioning **before patient arrival**.
   B. **Oxygenate** with 100% O_2 and assist ventilation for 3 to 4 minutes (if possible) to decrease alveolar nitrogen and arterial CO_2 while maximizing O_2 reserves. This is also the time to asses the ease of intubation and mask ventilation and confirm that a **functioning i.v. catheter is present** for drug administration.
   C. **Remove cervical collar** and **begin in-line stabilization** by assistant.
   D. Apply **cricoid pressure**.
   E. **Optional in nonemergent cases**: defasciculate with vecuronium (0.01 mg/kg i.v.) or an equipotent dose of another nondepolarizing agent 2 to 3 minutes before step 5.
   F. **Sedation/induction plus relaxation**: administer etomidate (0.2–0.3 mg/kg i.v.) or fentanyl (2–4 μg/kg) followed by succinylcholine (1–2 mg/kg) or vecuronium (0.28 mg/kg as a single dose or 0.01 mg/kg followed by 0.1 mg/kg in 2 minutes).
   G. **Perform intubation** procedure when relaxation optimal (usually 60–90 seconds after last drug dose).
   H. **Confirm tube placement and gas exchange** using at least three of the following: visualization, physical examination, capnography, oximetry, or bulb or syringe devices.
   I. **Release cricoid pressure**.
   J. **Replace cervical immobilization devices**.
   K. **Place a nasogastric tube** (oral if facial trauma is present) unless contraindicated.

VII. **Failed intubation**
   A. **A clear plan must exist for failed intubation attempts**. To ensure preparation, assume all attempts at intubation will fail. The plan must be agreed on between the team leader and airway physician and is best decided in advance. We offer a basic approach, understanding local expertise can alter this plan at each institution.
      1. Reassess, oxygenate, and ventilate followed by second attempt by same or different operator.
      2. If still unsuccessful, an alternative operator can attempt intubation, or skip to step 3 or 4.
      3. If adequate ventilation and oxygenation, attempt alternative technique (e.g., tactile, transillumination, laryngeal mask airway).
      4. If still failed or inadequate gas exchange, immediate surgical airway.
   B. **Communication helps avert conflict**; however, **the ultimate decision to intubate rests with the trauma team leader**. Each institution should use a multidisciplinary approach to create and practice airway protocols that are clear and well understood by all participants. This include job and task assignments, drug regimens, equipment, and alternatives for each.

Axioms

- All equipment, including oxygen, suction, tubes, stylets, laryngoscopes, and blades, prepared; cricothyroidotomy and jet insufflation trays must be ready before patient arrival.
- A clear plan, agreed on in advance by all physicians involved, detailing the actions and pharmacologic agents to be used must be developed and used in managing the airway of trauma patients.

with a contraindication to succinylcholine, **vecuronium (0.28 mg/kg i.v. as a single dose or 0.1 mg/kg in a 'priming sequence' where 1/10 of the total dose is given first followed in 2 minutes by the remainder)** is used, understanding that a more prolonged effect will occur. If paralysis is needed after intubation, either vecuronium or pancuronium (0.05 mg/kg i.v. increments as needed) with further sedation is recommended.

V. **Monitoring during and confirmation after intubation**. Before and during intubation, patients must be monitored to ensure adequate gas exchange is occurring and problems are recognized and treated. In addition, after establishment of an airway, the location of the tube must be confirmed. **No singular method of monitoring or tube confirmation is infallible**; clinicians must use a combination of directed physical examination and adjunct devices to ensure patient safety. Although chest radiography can be used to help confirm tube placement, this is to be avoided. The following methods are easier to perform at the bedside.

A. Hemodynamic monitoring

1. Observe for signs of poor gas exchange: hypertension and tachycardia (early and sensitive), followed by hypotension and bradycardia (late but specific).

B. Directed physical examination

1. After intubation, the tube should be examined for condensation and fogging; the epigastrium should be auscultated and quiet; the apices and bases of both lungs should be auscultated and show symmetric breath sounds; and the chest should rise normally. If any uncertainty exists, laryngoscopy should be performed to see the tube passing through the vocal cords. Each of these findings can be misleading or difficult to appreciate.
2. Although often unrecognized, a declining mental status should prompt an immediate reevaluation of the airway.

C. Oxygen saturation and exhaled carbon dioxide measurements

1. **Oxygen saturation** is best estimated continuously by pulse oximetry. To maximize O_2 delivery, a saturation of >95% should be sought in all trauma patients. Shock, dyshemoglobinemias (e.g., carbon monoxide related or other substances that bind hemoglobin), dark nail polish, and other physical conditions can limit the accuracy or acquisition of a signal. If pulse oximetry is not possible and any signs of poor oxygen delivery are present, an arterial blood gas analysis should be obtained. **Although arterial oxygen desaturation can indicate incorrect tube placement, this is a late finding**.
2. **Capnography** is the measurement of expired CO_2 concentrations, with qualitative (waveform), quantitative and semiquantitative (usually colorimetric, with a yellow color indicating CO_2 presence) devices available. In nonintubated patients, capnography accuracy is variable because of mixing with ambient air. However, in intubated patients end-tidal capnography shows excellent correlation with alveolar and arterial CO_2 concentrations.

Outside of low or no flow states (e.g., massive pulmonary embolus or cardiac arrest), **capnography is the current standard to confirm intratracheal tube placement** and very useful in guiding minute ventilation. In low or no flow states, detectable expired CO_2 for more than four to six breaths confirms that the tube is an upper airway structure, usually the trachea.

In the rare case where the tracheal tube tip is in the hypopharynx, expired CO_2 will be detected, creating a "false-positive." A capnograph will display an abnormal waveform to help identify this, whereas the commonly used qualitative or semiquantitative (colorimetric) devices will not distinguish this from true tracheal location. The absence of expired CO_2 means either incorrect placement (i.e., esophageal) or little delivery of blood to the pulmonary vascular bed.

of the narrow and contained diameter of the cricoid area. **Relative contraindications** include laryngeal trauma or patient age <10 to 12 years.

c. **Percutaneous dilator-based** kits are available that allow for a large-bore cannula to be placed through the cricothyroid membrane. The patient is then ventilated using noncompressed sources (usually a bag-valve device). These kits offer little advantage to formal cricothyroidotomy.

IV. Pharmacologic assistance during intubation

A. Some patients can be intubated without drugs (e.g., those deeply comatose or in cardiac arrest), whereas others can be treated with topical or local anesthetics to allow for successful intubation or surgical airway placement. However, most patients must receive systemic sedation, analgesia, and a muscular relaxant to ensure that intubation occurs safely and rapidly. A **never** or **always** approach to the use of pharmacologic adjuncts is strongly discouraged because each approach exposes patients to suboptimal care. For example, mildly obtunded or combative patients can be at greater risk of vomiting and aspiration, prolonged hypoxemia and hypercarbia, and laryngoscopic complications if not given appropriate pharmacologic assistance.

B. Before attenuating or ablating any patient's physiologic responses, the physician must assess the likelihood of ease of intubation and ability to mask ventilate. If laryngoscopy is unlikely to be successful even with systemic induction or muscle relaxant drugs (e.g., severe anatomic distortion or impediments), these agents should not be used to facilitate "a look." In addition, **a plan to deal with failure to intubate and mask ventilate must be discussed**. This includes limiting the number of attempts and providing for rapid surgical airway placement.

C. Choosing agents

1. Providers must choose from a variety of sedative, analgesic, hypnotic, and neuromuscular blocking drugs. In the trauma patient, it is best to assume both hypovolemia and a primary central nervous system (CNS) injury exist when choosing a drug regimen. Although these conditions are often not present, this approach allows for a greater margin of safety because either condition can be difficult to exclude in the first minutes after patient arrival.
2. Aside from patients with sedative overdoses, use of a short-acting inductive agent and a neuromuscular blocking agent is preferred. This will optimize intubating conditions, allow for rapid recovery if failure occurs, and limit hemodynamic and intracranial responses, discomfort, and recall.
3. Based on the aforementioned principles, a simple regimen is recommended that meets both effectiveness and safety needs in most trauma patients, recognizing that other regimens, based on local expertise and resources, are possible. We prefer intravenous (i.v.) **etomidate (0.2–0.3 mg/kg) or fentanyl (2–4 μg/kg)** as sedative or inductive agents because of their minimal clinically important side effects at these doses. Hypotension can occur with either of these agents, particularly if severe hypovolemia is present, but is usually less frequent and profound when compared with other regimens. Although barbiturates (especially for isolated head injured patients) and benzodiazepines are used as sedative or inductive agents, their use is to be discouraged because of the more profound and frequent hemodynamic side effects that can occur with their use.

   Succinylcholine (1–2 mg/kg i.v.) is our preferred neuromuscular blocking agent because of its long-standing history of rapid reliability and short duration. Pretreatment with a nondepolarizing neuromuscular blocking agent before succinylcholine administration to prevent fasciculations offers little pragmatic benefit and some risk; for these reasons, we do not employ this routinely in emergent situations. For patients

b. Complications of jet ventilation include barotrauma, local hemorrhage, hypotension from overventilation and decreased venous return, inadvertent placement with resulting subcutaneous or mediastinal emphysema, hypoxia, hypercarbia, and dysrhythmias from prolonged attempts. The frequency of these complications varies from 5% to 50%, depending on operator skill and preparedness and is similar to that seen with cricothyroidotomy when done by experienced providers.

2. **Cricothyroidotomy** is preferred to jet insufflation because of familiarity and the ability to provide optimal protection from aspiration and place a large-bore airway for suctioning.

a. **Technique**. (Fig. 14.3) The operator **palpates** the thyroid cartilage and the caudad, depressed cricothyroid membrane. A 3-cm midline, longitudinal (if anatomic landmarks are not clearly apparent) or transverse **skin** incision (in the thin neck, with clear landmarks) is performed over the membrane. The skin is spread, and landmarks (thyroid cartilage, cricothyroid membrane) reestablished by palpation. A transverse incision (1.5–2 cm) is made through the **membrane**. The procedure is essentially performed using tactile input; if the membrane cannot be seen, incise where the soft membrane is palpated. A tracheostomy tube or endotracheal tube (at least 5-mm internal diameter, but one size smaller than what would be chosen for oral intubation in an adult) is introduced into the airway and cuff inflated. Adequate oxygenation and ventilation are assured by standard techniques.

b. **Complications** include hemorrhage (usually controlled with local pressure and avoided by limiting the size of all incisions), misplacement, hypoxia secondary to prolonged procedure time, esophageal perforation, laryngeal fracture, and subcutaneous emphysema. Stenosis is often a problem if left in place for extended periods because

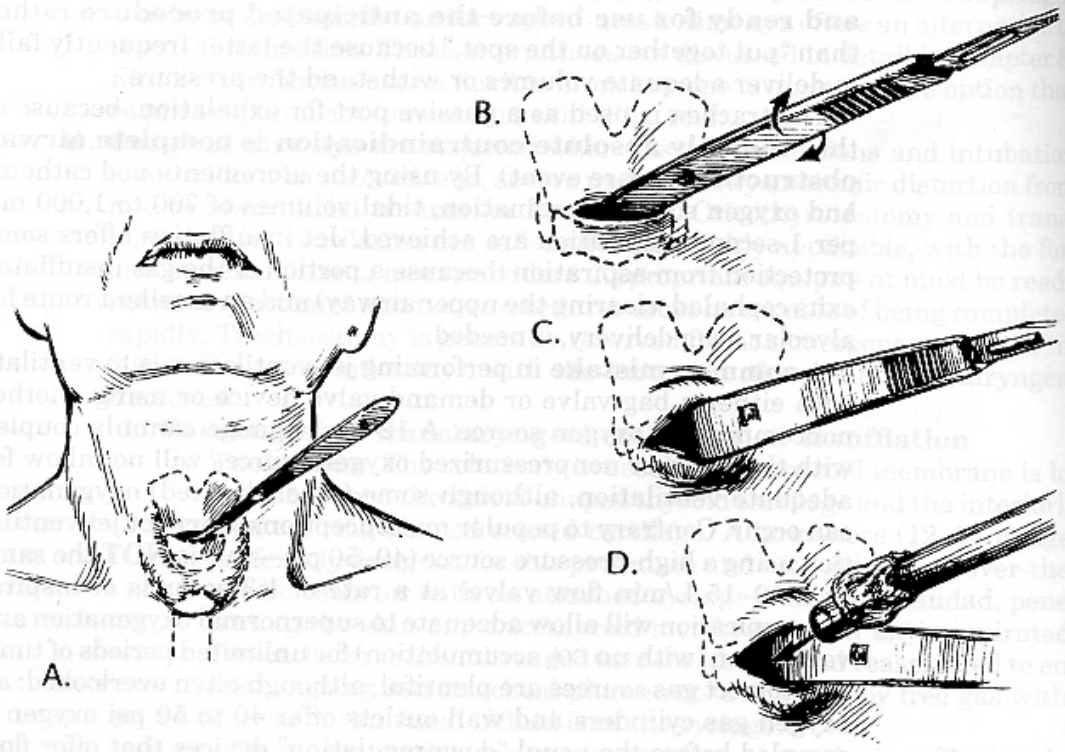

FIG. 14.3. Cricothyroidotomy technique. (From Trunkey DD, Guernsey JM. Cervicothoracic trauma. In: Blaisdell FM, Trunkey DD, eds. *Surgical procedures in trauma management*. New York: Thieme Inc. 1986:303, with permission.)

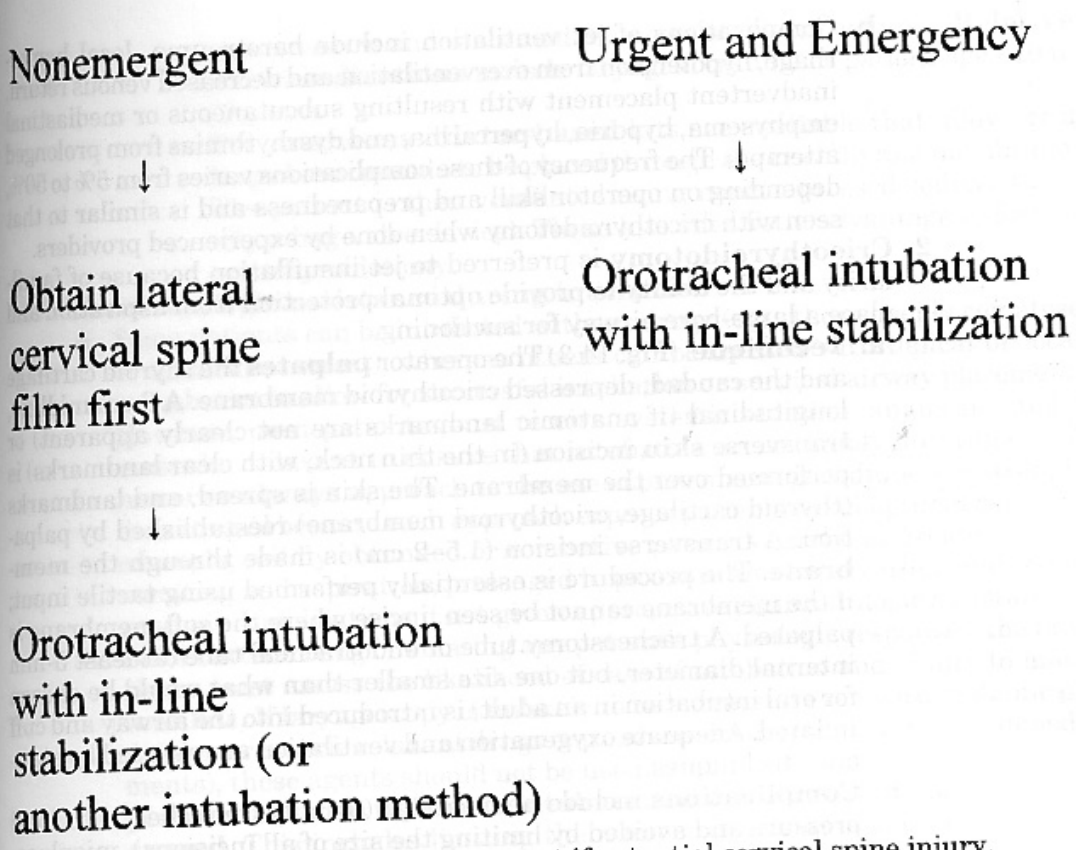

FIG. 14.2. Approach to airway management if potential cervical spine injury.

triggering) or a more elaborate ventilator (with multiple control settings).* The key point is that **the device must be identified and ready for use before the anticipated procedure** rather than "put together on the spot," because the latter frequently fails to deliver adequate volumes or withstand the pressure.

The trachea is used as a passive port for exhalation; because of this, **the only absolute contraindication is complete airway obstruction** (a rare event). By using the aforementioned catheter and oxygen source combination, tidal volumes of 700 to 1,000 mL per 1-second inspiration are achieved. Jet insufflation offers some protection from aspiration (because a portion of the gas insufflated exits cephalad, clearing the upper airway) and an excellent route for alveolar drug delivery, if needed.

A **common mistake** in performing jet ventilation is to ventilate with either a bag-valve or demand-valve device or using another noncompressed oxygen source. A 12- to 14-gauge cannula coupled with these low or nonpressurized oxygen sources will not allow for adequate ventilation, although some (albeit limited) oxygenation can occur. Contrary to popular misconceptions, **correct** jet ventilation using a high-pressure source (40–50 psi—this is **NOT** the same as a 10–15 L/min flow valve) at a rate of 1:3 seconds of inspiration:expiration will allow adequate to supernormal oxygenation and ventilation (with **no** CO_2 accumulation) for unlimited periods of time. The correct gas sources are plentiful, although often overlooked: all oxygen gas cylinders and wall outlets offer 40 to 50 psi oxygen if sampled before the usual "downregulating" devices that offer flow at 1 to 15 L/min.

* See first citation at chapter end for a listing of the many options possible.

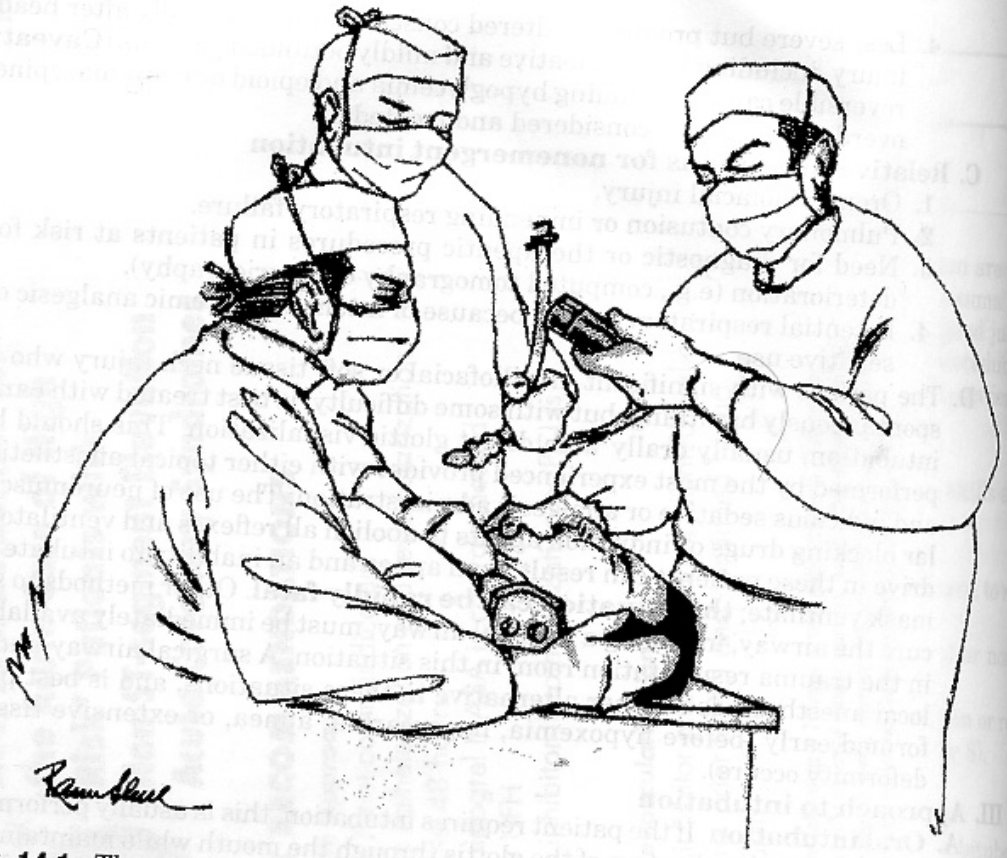

FIG. 14.1. Three-person technique for intubation.

without the need to directly visualize the glottis. Also, use of the **esophagotracheal Combitube or laryngeal-mask airways** offers an alternative to tracheal intubation. These alternatives are discussed in detail in Chapter 8. Finally, intubation over a flexible bronchoscope is an attractive option that requires special equipment and skill (Fig. 14.2).

D. Surgical airways are required when basic interventions and intubation are not likely to succeed (e.g., severe upper airway anatomic distortion from mid or lower facial trauma) or have failed. Cricothyroidotomy and translaryngeal jet ventilation are safe and more readily applicable, with the former more familiar to most providers. Appropriate equipment must be ready before any attempt and both procedures must be capable of being completed rapidly. Tracheostomy is generally reserved for nonemergent situations (in favor of cricothyroidotomy), with the exception of patients with laryngeal fractures.

1. Percutaneous translaryngeal catheter (jet) insufflation

a. Technique. The relatively avascular cricothyroid membrane is located between the shield-shaped thyroid cartilage and the interiorly located, ring-shaped cricoid cartilage. A large-bore (12–14 gauge, preferably designed for this procedure and with side holes) over-the-needle catheter with an attached syringe is directed caudad, penetrating the skin and cricothyroid membrane until air is aspirated. The catheter is then threaded into the airway and reaspirated to ensure ongoing intratracheal placement (evidenced by free gas withdrawal or "bubbles" if fluid is in the syringe).

Then, ventilation occurs via attachment to a jet insufflating device delivering high-flow oxygen at approximately 40 to 50 pounds/square inch (psi) (1 psi = 70 cm H_2O). This device can be a simple high-pressure, one-way valve (to insufflate gas with each manual